SUBARU®

Confidence in Motion

Technician Reference Booklet

Engine Theory and Diagnosis

AUTOMOTIVE Youth Educational Systems PROUD PARTNER

WE SUPPORT PROFESSIONAL CERTIFICATION THROUGH THE National Institute for AUTOMOTIVE SERVICE EXCELLENCE

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This Technical Reference Booklet (TRB) is designed to be used in a classroom environment or as a guide for self study.
The TRB is not intended to be used as a supplement or substitute for the Subaru Service Manual. Always consult the appropriate Service Manual when performing any diagnostics, maintenance or repair to any Subaru vehicle.

Table of Contents

Engine Theory and Diagnosis

Engine Theory and Diagnosis

Introduction

This training course introduces the operational characteristics and components of the engine mechanical system, and identifies how to properly inspect and service the engine mechanical system.

Course Objectives

The student will be able to:

- Apply proper use of Personal Protective Equipment (PPE) and other related safety practices related to engines.
- Explain 4-cycle engine theory, identify basic engine components, and describe basic system functions.
- Identify cylinder block components and describe their basic functions.
- Utilize the Subaru Technician Information System (STIS) to locate component specifications, testing procedures, and determine serviceability
- Manipulate precision measuring tools to accurately measure mechanical component and interpret the results.
- Identify engine sealing methods, describe their basic functions, perform proper liquid sealant removal, surface preparation, and sealant application.
- Identify engine lubrication system components, describe their basic functions, perform dynamic testing and interpret the results.
- Identify engine cooling system components, describe their basic functions, perform dynamic testing and interpret the results.
- Identify traditional engine condition tests, describe their basic premise, and perform dynamic testing and interpret the results.

NOTES:

Safety

Personal Protection Equipment

Personal Protective Equipment

There are many safety precautions that you must observe when working on vehicle systems. Refer to the appropriate service information and observe all safety cautions and warnings.

As a general warning, before attempting to diagnose or service any vehicle system component, always wear appropriate work clothing such as:

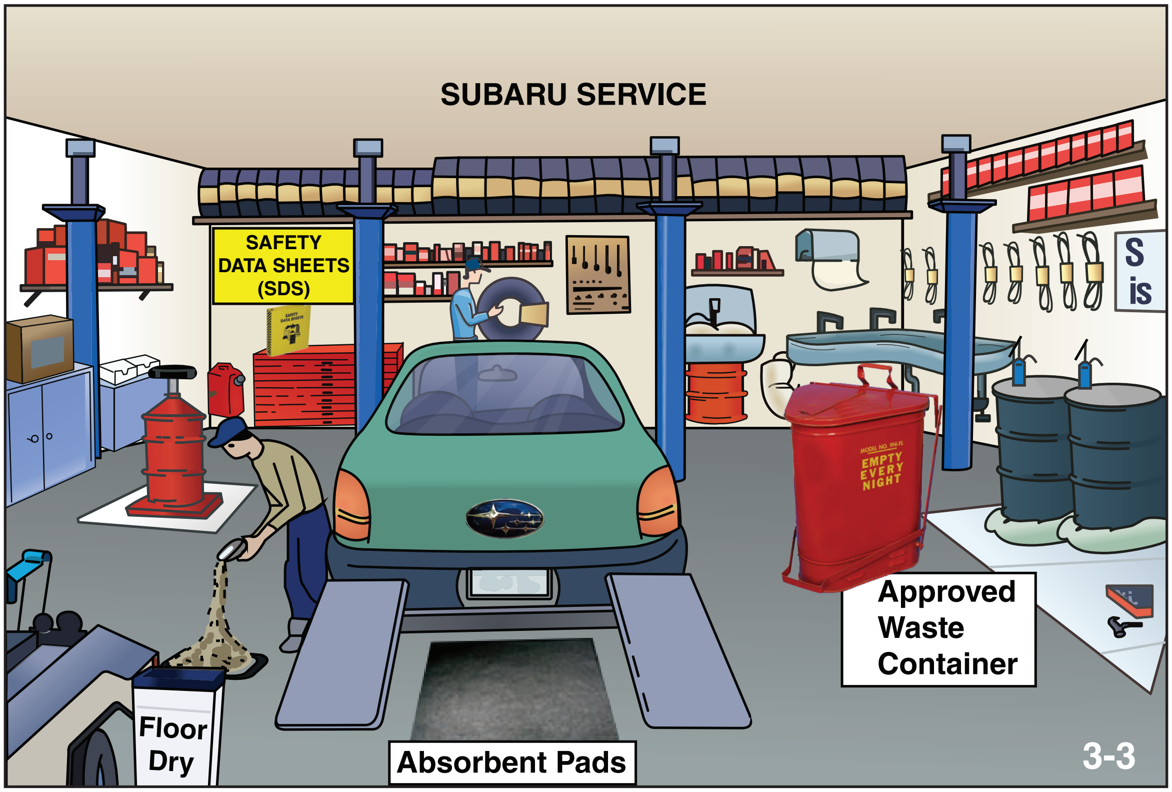
- Safety glasses with side shields
- Gloves (Chemical resistant)
- Approved Subaru uniform
- Protective shoes (steel toe, oil and slip resistant)

To avoid inhaling spray chemicals and dust, a properly ventilated work area is essential.

Refer to the material safety data sheets (SDS) located in the appropriate location in the service department.

CAUTION: Keep hands away from hot exhaust system components. Keep hands and loose clothing away from rotating components. Always wear appropriate clothing and personal protective equipment. Failure to observe these precautions can result in serious injury to you and/or others.

Environmental Impact



Environmental Impact

Do not dispose of automotive fluids, domestically or industrially in drains, waterways, or landfills. These chemicals contain contaminants such as solvents that can leach into soil and waterways, causing environment damage and health hazards.

Contain and collect spillage with non-combustible, absorbent material such as sand, floor dry, or absorbent pads and place the contaminated material in a certified waste container for disposal according to local regulations.

When handling shop chemicals always refer to the Material Safety Data Sheet (SDS) for the particular chemical you are working with.

WARNINGS and CAUTIONS

Gasoline

Only keep gasoline, flammable solvents, and used rags in approved containers.

Battery Acid

If skin comes in contact with battery acid: Rinse the area well with water. If you get acid on your clothing, remove the clothing immediately.

If battery acid is ingested: DO NOT INDUCE VOMITING. Drink large quantities of water or milk. Follow with milk of magnesia, beaten eggs, or vegetable oil. CALL A PHYSICIAN OR POISON CONTROL CENTER IMMEDIATELY.

If battery acid comes in contact with the eyes: Rinse eyes with water for 20 minutes and get prompt medical attention.

If fumes are inhaled: Move victim to a fresh air location and receive medical treatment from a doctor.

Do not mix battery acid with other products that react with acid, such as toilet bowl or drain cleaners, bleach, or ammonia. Dangerous fumes form when mixed with chemicals like these.

Lubricants

Always dispose of oil in proper receptacles.

Refrigerant

Refrigerant boils at approximately – 30°C (– 22°F). When handling it, be sure to wear protective goggles and protective gloves. Direct contact of the refrigerant with skin may cause frostbite.

If the refrigerant gets into your eye, avoid rubbing your eyes with your hands. Wash your eye with plenty of water, and receive medical treatment from an eye doctor.

Provide good ventilation and do not work in a closed area.

Avoid releasing HFC-134a into the atmosphere. Use a refrigerant recovery system to discharge and recycle the gas.

Coolant

Vehicle components are extremely hot immediately after driving. Be wary of receiving burns from heated parts. Do not open the cooling system while it is still hot. The system is under pressure and if opened, could spray you with hot coolant and cause burns.

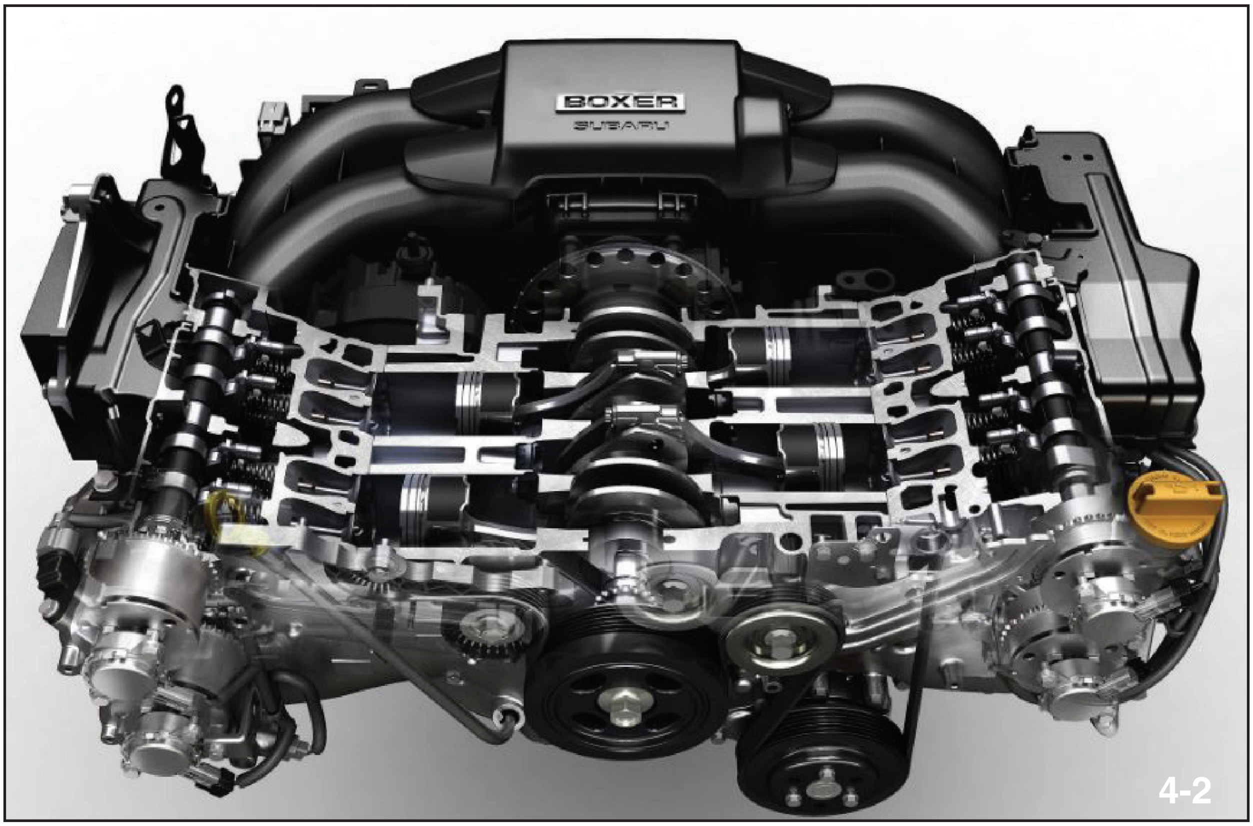
Follow all government and local regulations concerning disposal of refuse when disposing engine coolant.

Sodium

Sodium is used in some exhaust valves to assist in heat dissipation. The sodium contained in the hollow part of the valve stem has a low flash point. Exposure to water will cause sodium to EXPLODE. Always dispose of sodium filled valves properly.

NOTES:

The 4-cycle Engine

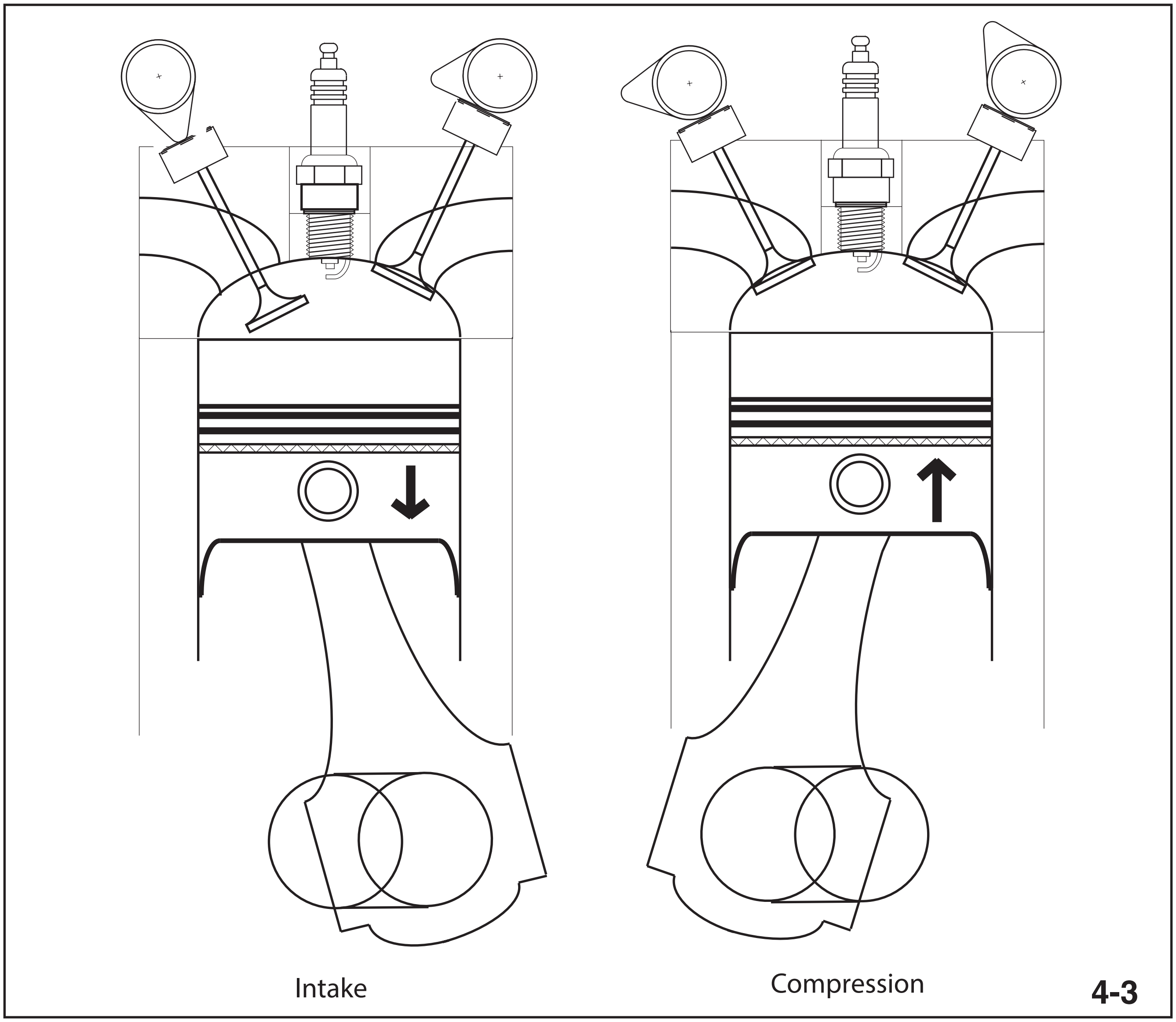


4-Cycle Internal Combustion Engine

Internal combustion engines provide the power to propel the drive wheels of most automotive vehicles. Subaru uses 4- or 6-cylinder, 4-cycle, horizontally opposed engines. These engines are constructed of aluminum and steel components. They are lightweight, durable, and powerful engines. These engines contain:

- Pistons that are fit into a cylinder block and attached to the crankshaft reciprocate in turn providing rotational force.
- Camshafts and valves that are fit into the cylinder heads provide control of the air/fuel mixture that enters the cylinders.
- A timing system keeps the crankshaft and camshafts in time to sequence the four cycles that occur within the engine.
- A pressurized lubrication and cooling system is utilized to keep the engine and its components lubricated and cool.

4-cycle Theory



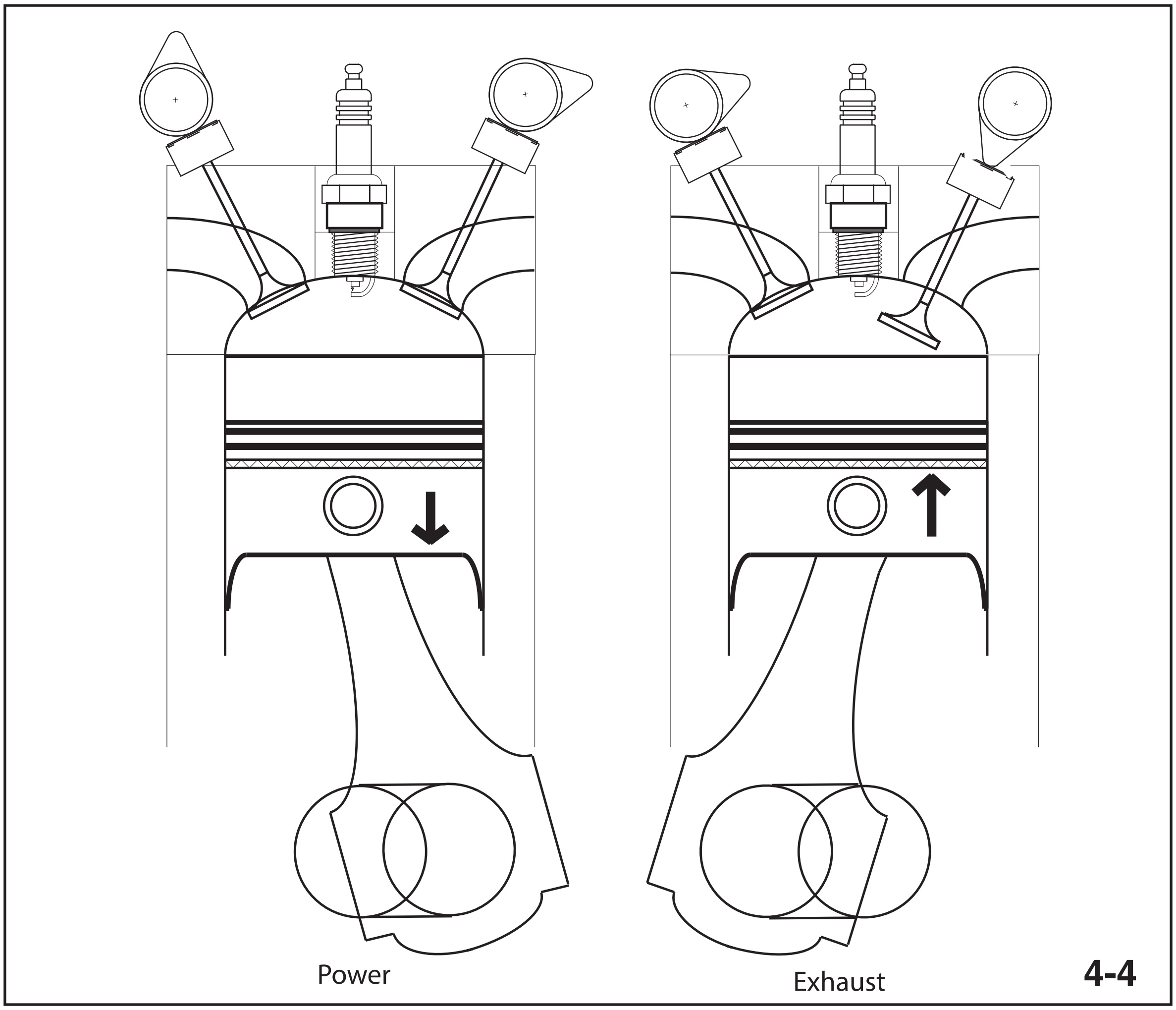
Intake and Compression Cycles

Internal combustion engines in most modern automobile applications are a 4-cycle design. A cycle refers to the full travel of the piston either up or down within the cylinder bore. It takes four cycles to complete one combustion event.

These cycles are:

Intake stroke; the piston is pulled downward with the intake valve open and the exhaust valve closed, drawing in air and fuel.

Compression stroke; the intake and exhaust valves are closed and the piston moves upward, compressing the air and fuel drawn in during the intake cycle.

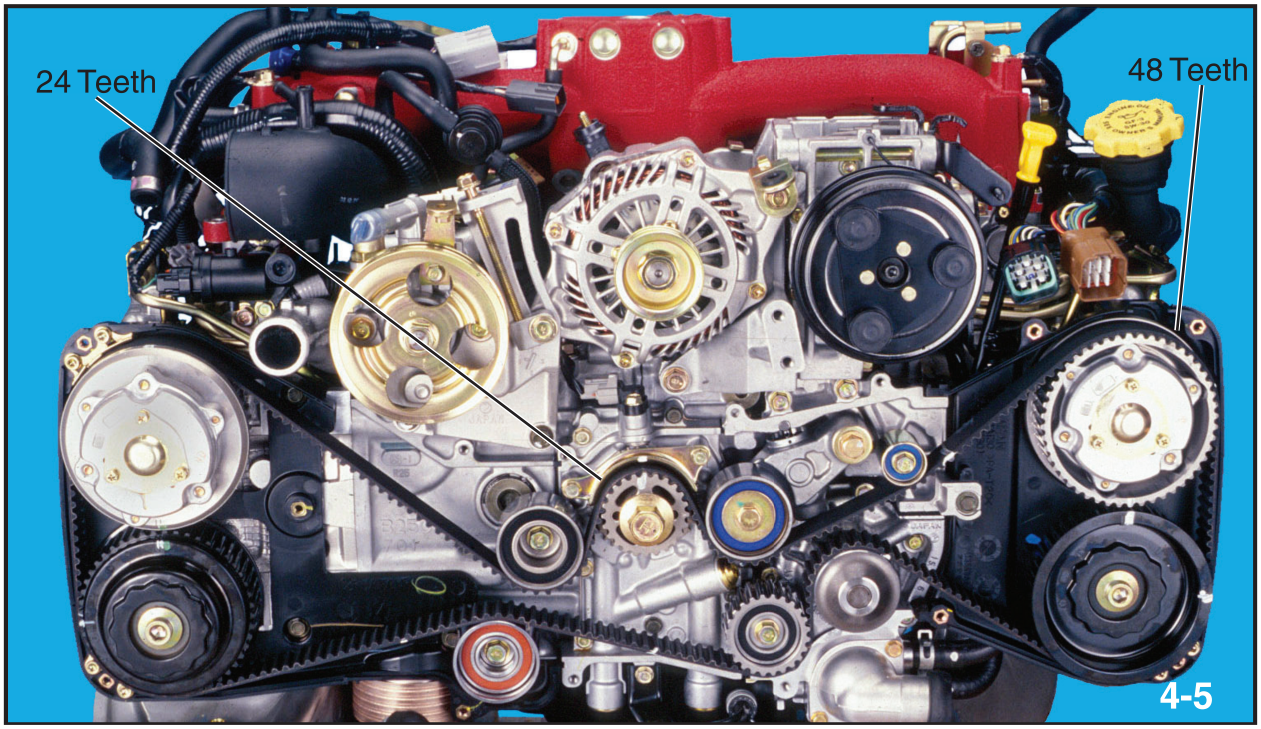


Power and Exhaust Cycles

Power stroke; the compressed air and fuel mixture is ignited, this creates a rapid expansion of gases within the cylinder. This expansion forces the piston down the cylinder and rotates the crankshaft.

Exhaust stroke; the piston moves upward with the exhaust valve open, allowing the burned air and fuel to exit the cylinder.

Crankshaft/Camshaft Relationship



Typical Valve Timing System

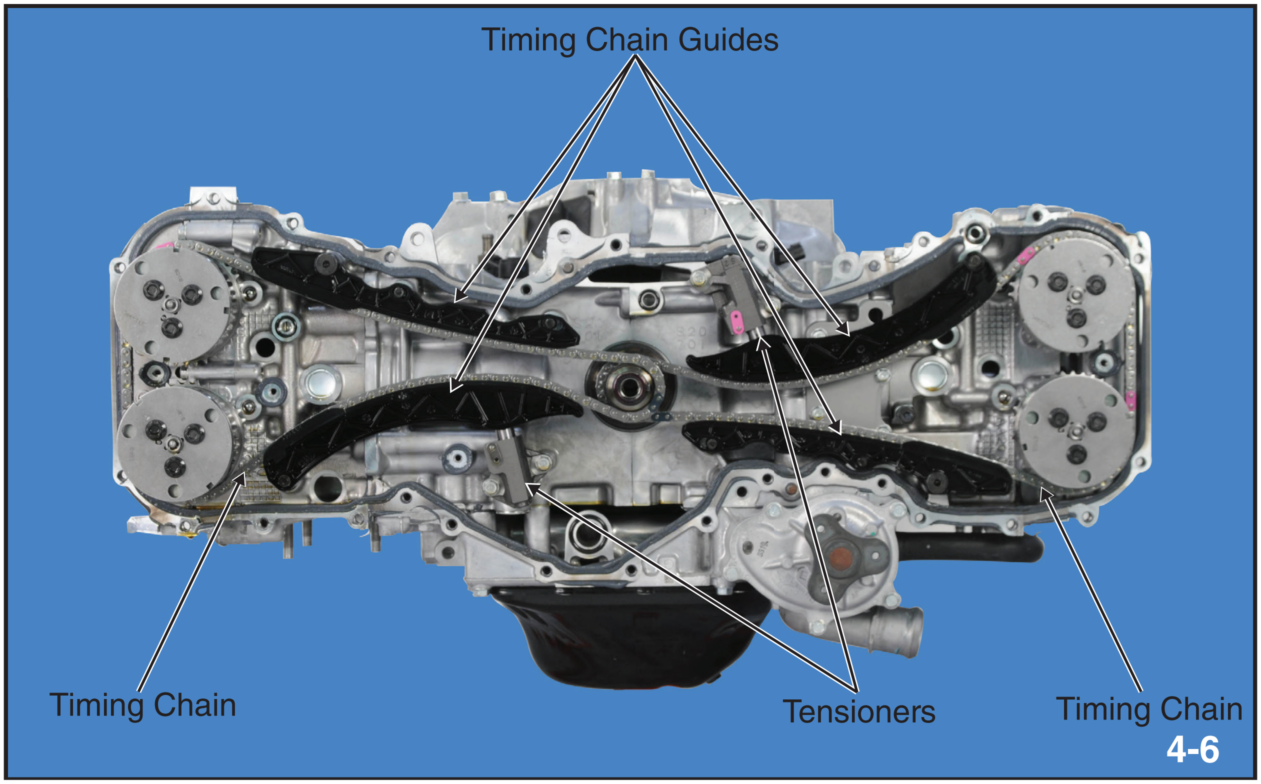
It is necessary to have the valves in the proper position during all four cycles or strokes of the piston. As an example, both valves need to be closed for combustion to occur. To accomplish this, the camshaft is connected to the crankshaft via a timing belt or a timing chain. This component synchronizes the movement of the intake and exhaust valves with every piston stroke. The crankshaft rotates at a 2:1 ratio (two crankshaft revolutions for every one camshaft revolution) allowing the 4 cycles to occur.

An improperly timed engine can result in valve to piston interference that can cause damage to the engine.

Timing Belt or Chain Path

The timing belt or chain(s) can drive multiple components within the timing system, most belts or chains wrap around drive, driven or idler sprockets or pulleys that come into contact with both sides of the timing belt/chain.

Timing Chain



Timing Chain

The timing chain is a flat multi-link type that is located behind the front timing cover. The chain is bathed in engine oil and is a high durability type drive system.

Guides

Guides that contact the back side of the chain provide guidance to clear components within the chain path. Guides typically are made of aluminum and have a nylon insert to help quiet the chain and provide a surface for the chain to slide on with minimal wear. Typically one guide will have a tensioner that applies proper tension to the chain.

Timing Belt

The timing belt is a flat belt made of rubber reinforced with fiberglass strands, one side of the belt has teeth the other is flat. The belt wraps around drive sprockets or driven pulleys and is kept tight via a tensioner.

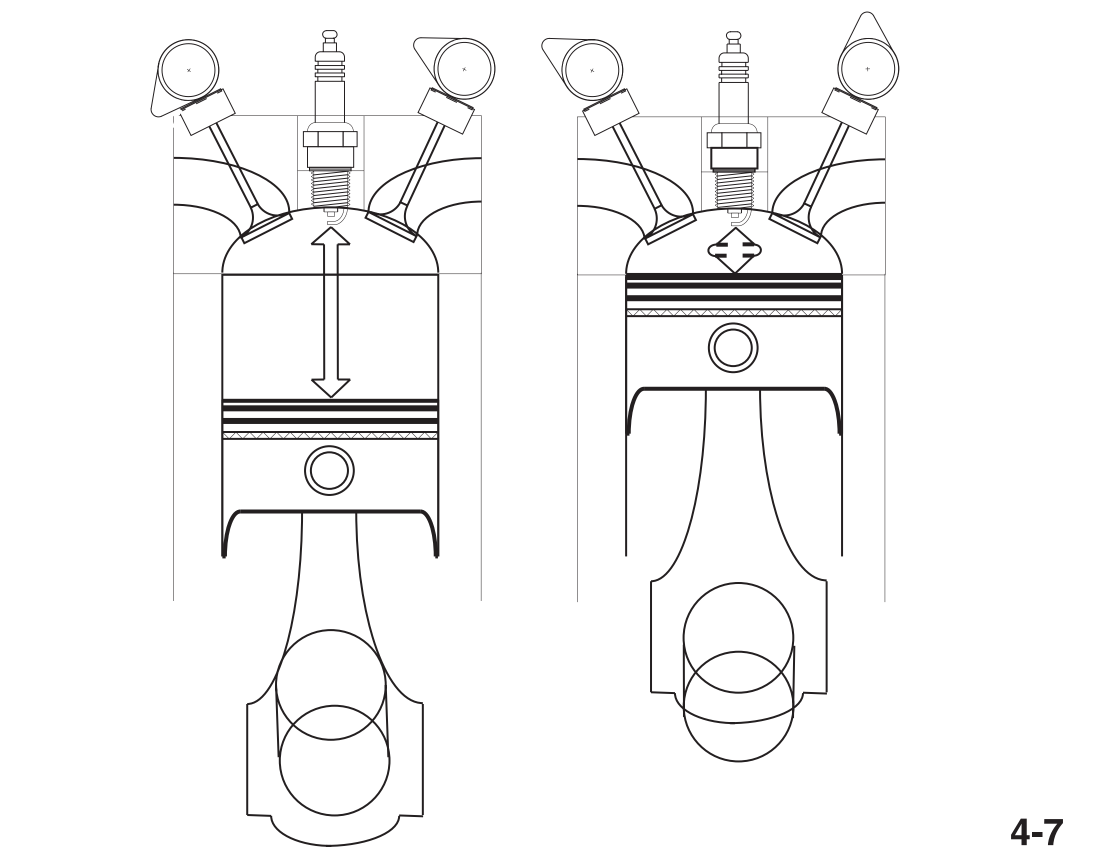
Tensioner

The tensioner is a device that applies a specified amount of pressure to the timing belt or chain to keep it tight against all the sprockets, pulleys, and guides. Typically the tensioner is self-adjusting. The tensioner may be spring loaded, oil system pressurized, or a self contained gas charged type. Tension on the belt or chain prevents slippage and maintains accurate valve timing.

Pulleys

Pulleys are used with timing belt systems, they are used like guides to rout the belt around components of the engine and provide positive traction to the drive or driven sprockets by directing the belt more than half way around the sprocket.

Compression Ratio


4-7

Compression Principle

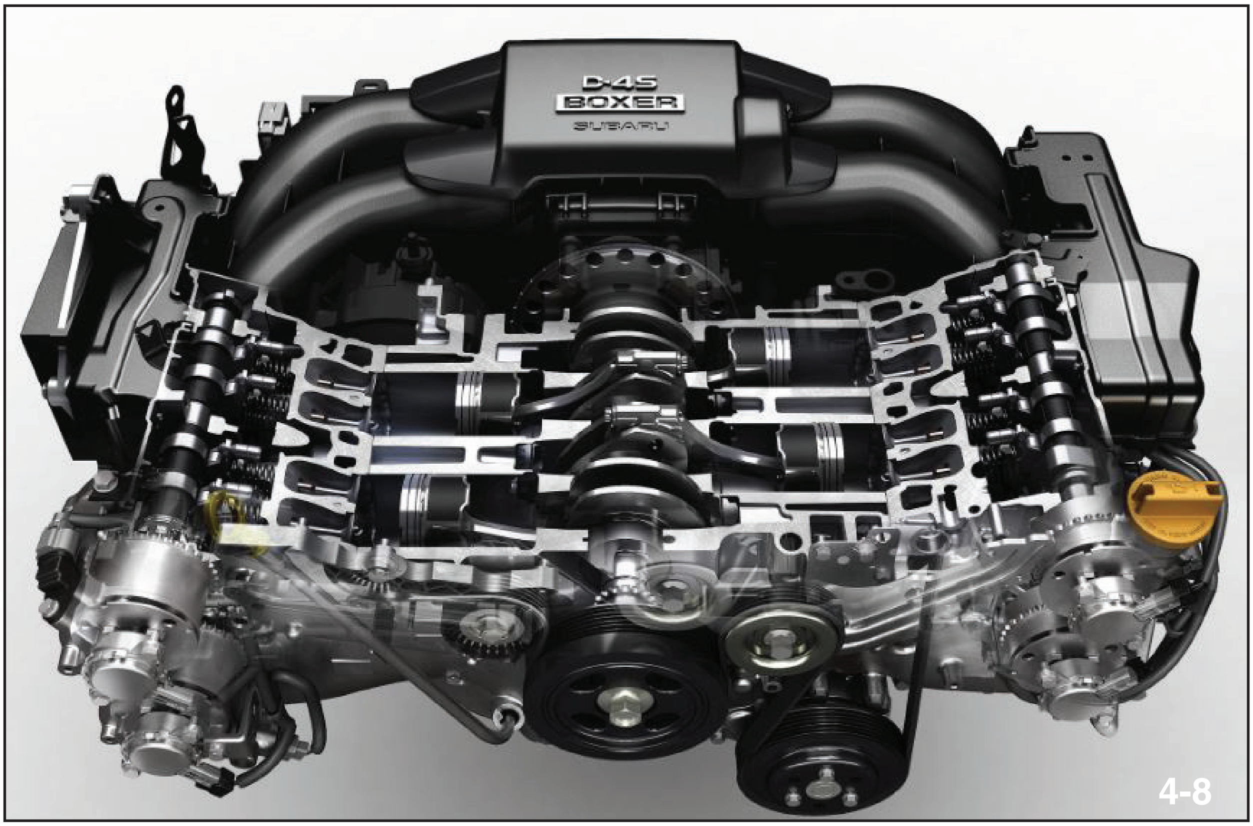
As the piston travels from bottom dead center (BDC) to top dead center (TDC) with the valves closed, pressure is built up as the air/fuel mixture is compressed. This action, called compression also generates heat which contributes to the burning of the fuel when the spark plug ignites it.

The compression ratio is calculated by dividing the volume measurement of the cylinder with the piston at BDC by the volume of the cylinder when the piston is at TDC.

- Calculate the cylinder volume at BDC and TDC.
- Volume = 3.14 x piston bore x piston stroke ($V = \pi r^2 \cdot h$)
- Compression Ratio = Cylinder volume at BDC / volume at TDC
- (Example 1: 100 cc/10 cc = 10 or a 10:1 ratio)
- (Example 2: 100 cc/8 cc = 12.5 or a 12.5:1 ratio)

The higher the compression ratio of the engine, the more power the engine will output. As the compression ratio increases the heat produced by the compression stroke also increases. Lower octane gasoline burns faster with the added heat of higher compression the gasoline/air mixture may explode rather than burn. This is what causes pre-ignition or spark knock, higher compression engines use higher octane fuel (which burns slower) to prevent this from occuring.

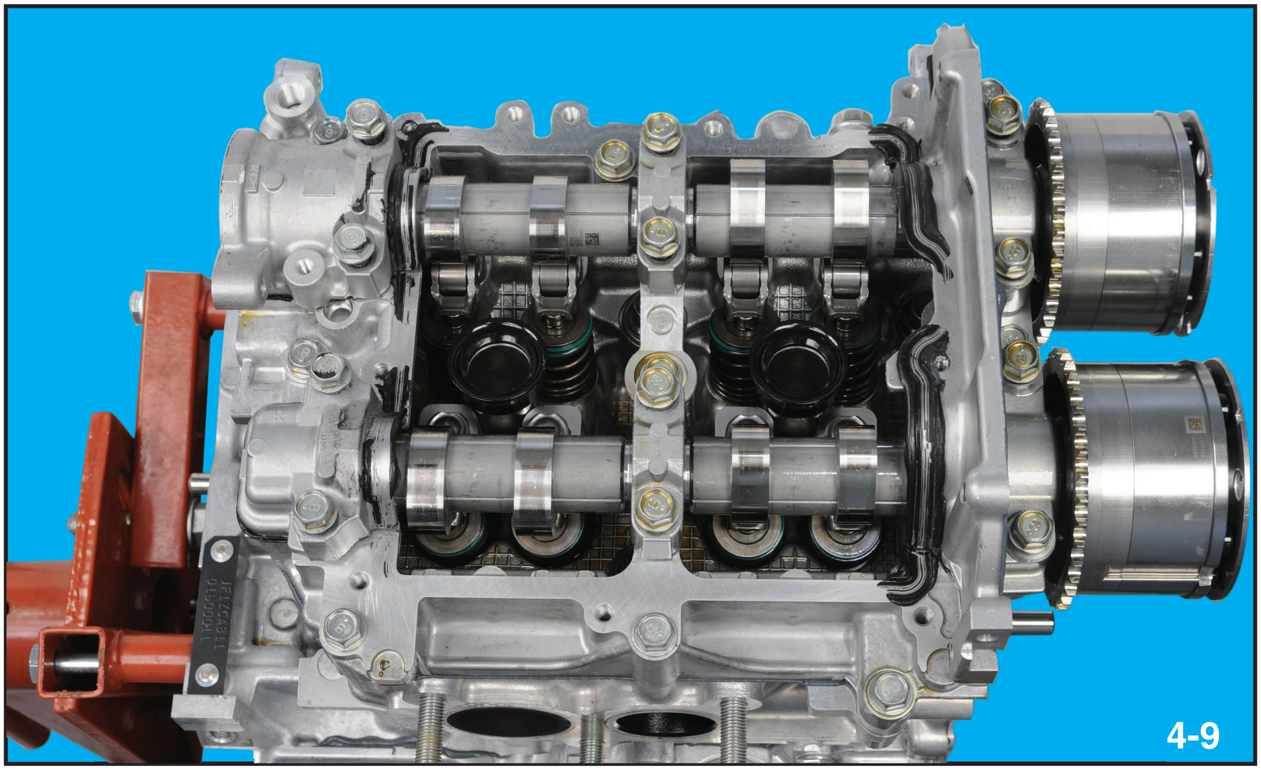
Horizontally Opposed Block Configuration



Block Configuration

In a horizontally opposed engine, the cylinders are positioned 180 degrees apart from each other. The piston rod journals are also positioned 180 degrees apart from each other on the crankshaft. As each piston moves away from the crankshaft centerline, the piston on the opposite side of the block is doing the same, harmonically canceling each other's actions. Unlike inline and V configuration engines, this type of engine design has inherent balancing properties.

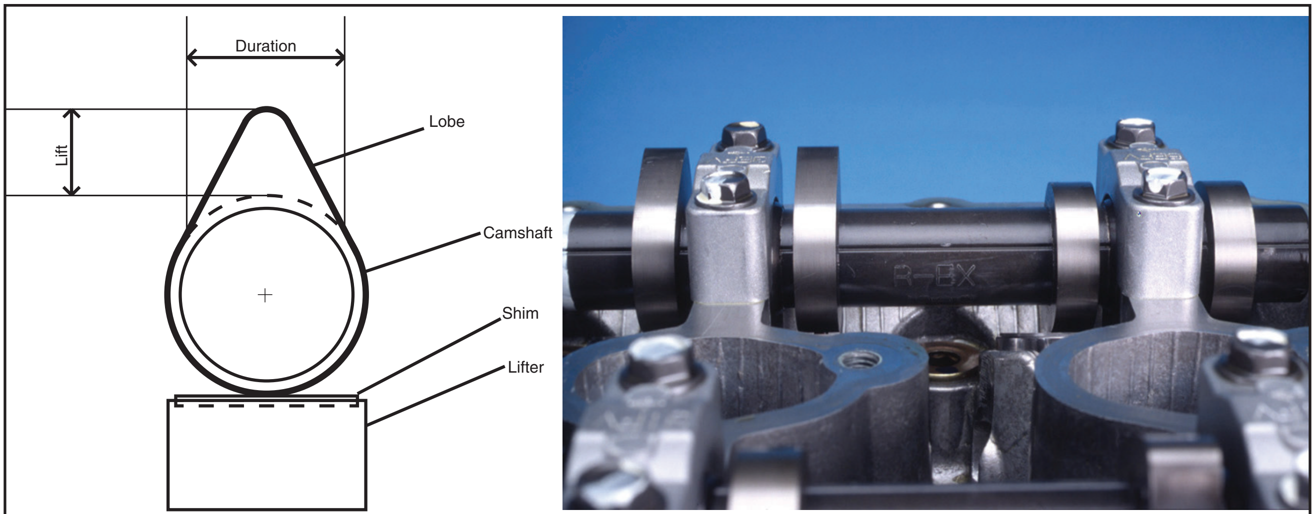
Valvetrain Configuration



Typical Valvetrain Configuration

Internal combustion engines can be equipped with a camshaft that resides internal to the block or internal to the cylinder head. An overhead valve type engine uses a camshaft located within the block to actuate pushrods to get the lift action to the valves in the head. This type of camshaft is usually gear or chain driven. An overhead camshaft engine has the camshafts located within the cylinder head; the camshaft lobes actuate the valves directly. This type of camshaft is belt or chain driven.

Camshaft and Lobe Design



4-10

Camshaft and Lobes

The camshaft is a shaft fitted with journals and lobes located at specific places. The journals are round and support the shaft within the head or block. The lobes are semi-circles with raised portions that the lifters or followers ride upon. Each lobe has a raised portion with a specific height and length. These are referred to as lift and duration and are explained below:

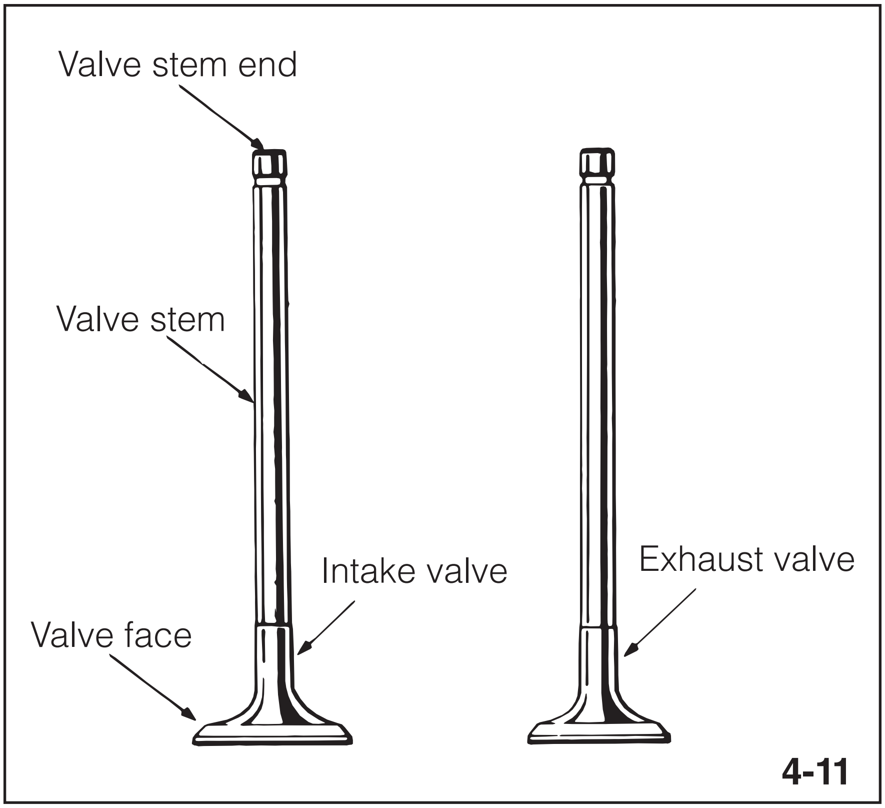
- Lift is the amount that the valve is opened and is measured in height
- Duration is how long the valve is held open and is measured in degrees

Camshafts come in many different types of profiles, the type of camshaft used will depend on what the engine will be used for. Example: passenger car or heavy duty truck.

An engine with increased camshaft lobe overlap will have lower power output in the lower rpm range, but will have higher power output in the higher rpm range. This type of camshaft would be used in a vehicle that mainly operates in a higher rpm range.

An engine with decreased camshaft lobe overlap will have higher power output in the lower rpm range, but will have lower power output in the higher rpm range. This type of camshaft would be used in a vehicle that mainly operates in a lower rpm range.

Valve Components



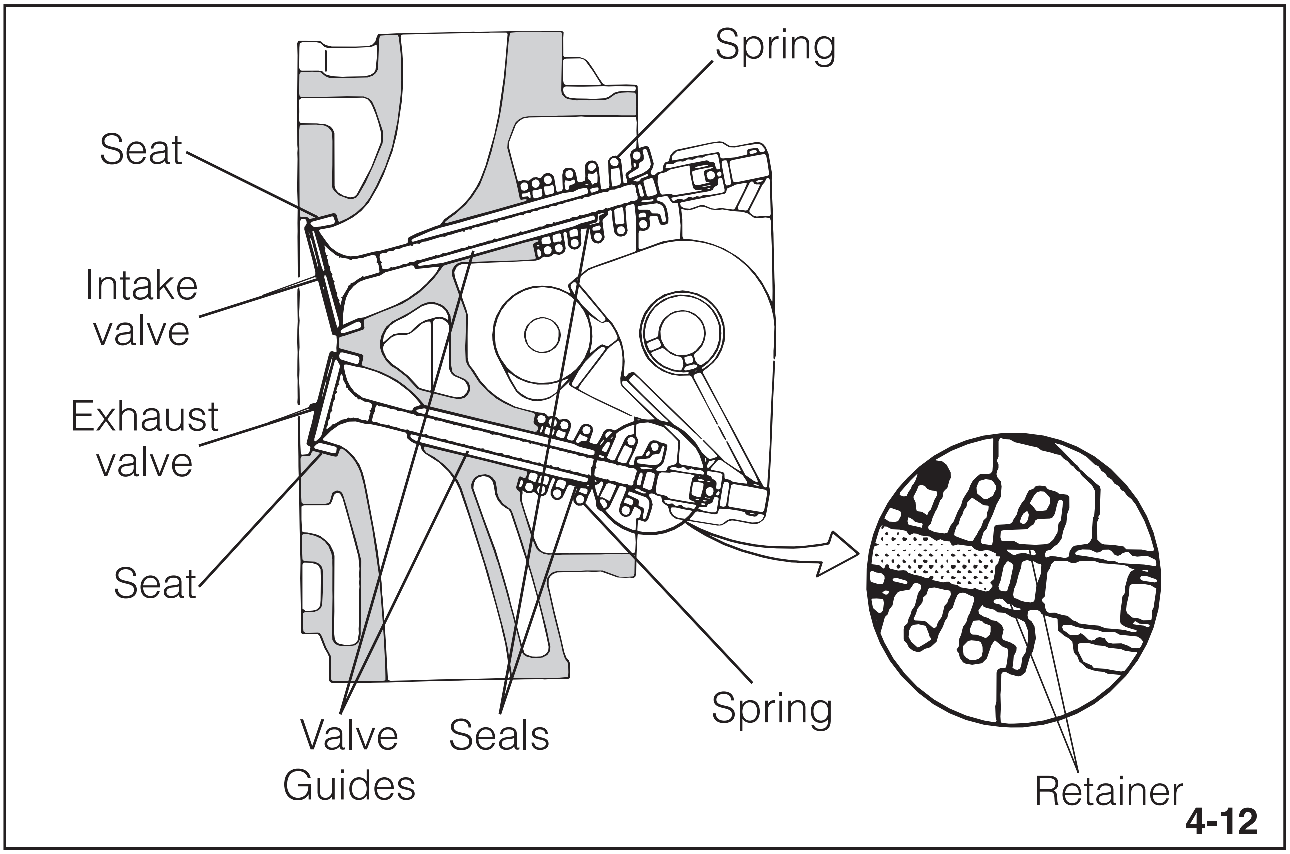
Typical Valve Components

Valves that control the intake of the air-fuel mixture are called intake valves, while those that control the discharge of exhaust gas are called exhaust valves. In the past, engines normally had one intake valve and one exhaust valve for each cylinder, but today many engines are designed with two intake valves and one exhaust valve, or with two intake valves and two exhaust valves per cylinder. Multi-valve engines have a greater potential for increased airflow into and out of the engine, especially at higher engine rpm.

Because valves are constantly being exposed to the high temperatures of burning gas, they must be capable of outstanding heat, corrosion, and wear resistance. A valve's face is rounded to a fixed angle so it seals against the valve seat without leaking, and completely seals the cylinder while the valve is closed.

The diameter of the intake valve is normally larger than that of the exhaust valve to enhance charging efficiency. Valve stem ends include a cotter groove, that supports a retainer, that holds the valve spring in place.

Valve Components Continued



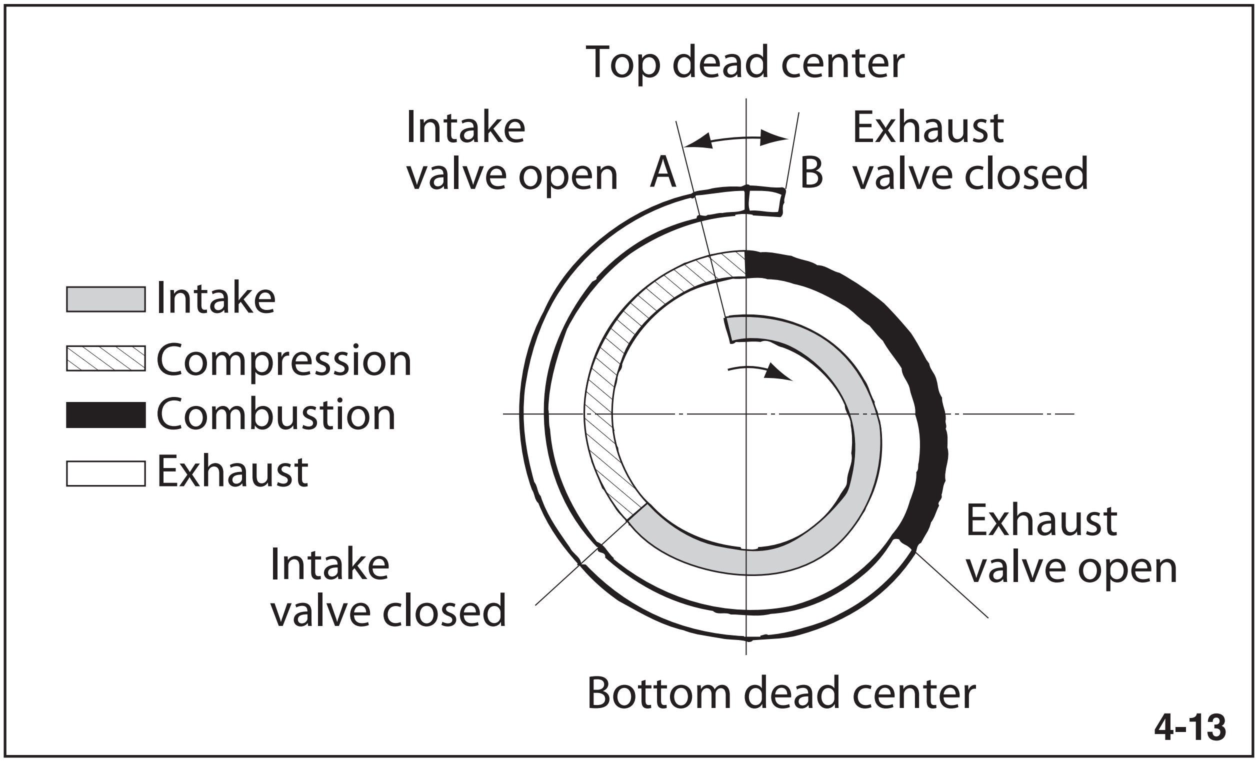
Valve Components

The valve spring must be able to close the valve as the camshaft rotates, so spring tension is critical for proper operation. A valve spring that is too weak reduces engine output because it allows gas to leak from the valve, while a valve spring that is too strong can cause output loss and premature wear of the valve operating mechanism.

Valve seats are press fit into the cylinder head to provide correct seating of the valve face and complete sealing of the compression chamber. Valve seats also serve to cool the valves. 70% to 80% of exhaust valve heat is dissipated through the valve seats. The surface of the valve seat that comes into contact with the valve face is precision finished to a fixed angle. This surface is made from iron-based, sintered alloy to ensure outstanding wear resistance.

Valve guides keep valves operating smoothly in the correct position. Valve guides also serve to dissipate valve heat to the cylinder head. Valve guides are made from iron-based, sintered alloy to ensure outstanding wear resistance. A valve stem seal is installed at the top of each valve guide to prevent oil inside the rocker case from entering the combustion chamber through the valve system. Stem seals are classified by color. This means the material of the stem seals is different between exhaust valve and intake valve.

Valve Timing

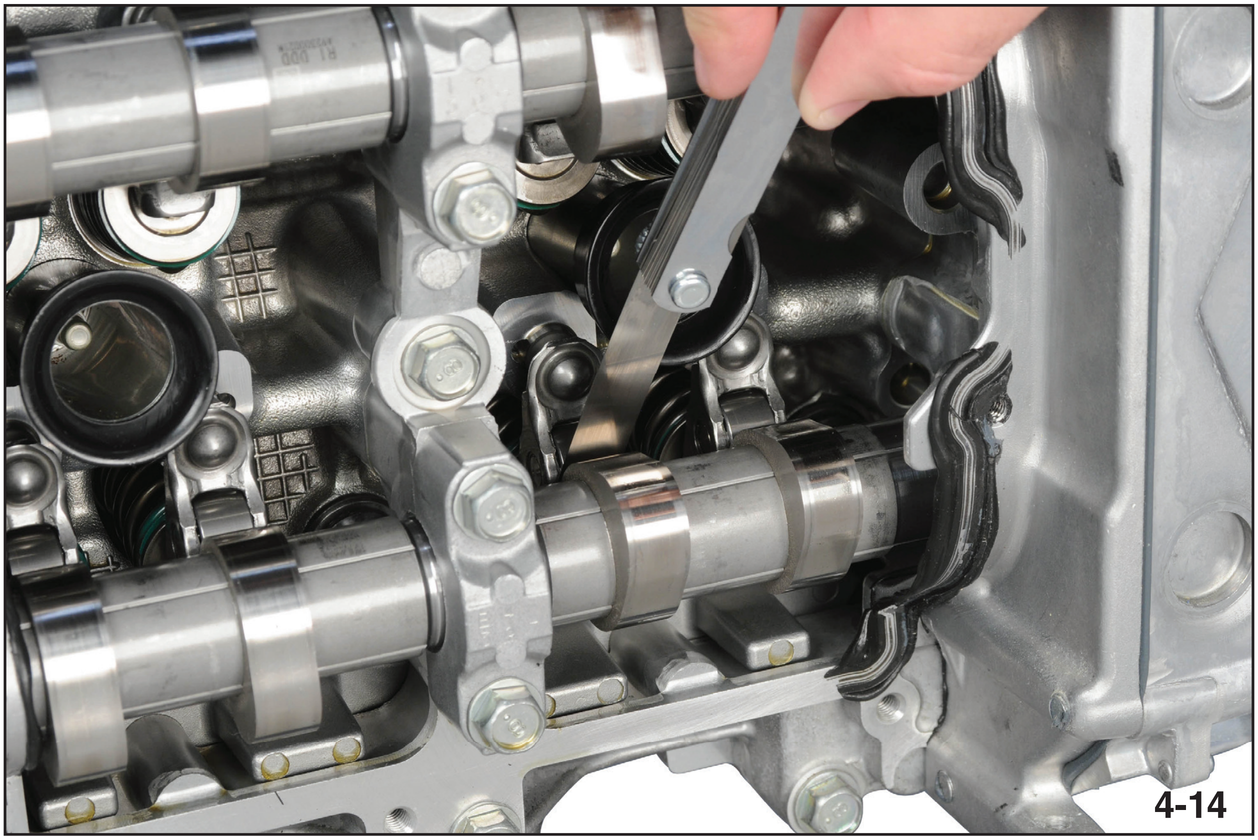


Camshaft/Crankshaft Relationship

The valve timing (opening/closing sequence of intake valves and exhaust valves) is expressed as the rotation angle of the crankshaft. The figure shows the valve timing expressed in a diagram form.

The condition in which both the intake valves and exhaust valves are both open, shown as A-B in the figure, is referred to as overlap. Generally, the purpose of overlap is to increase the volume of air that is drawn into the cylinder.

Valve Clearance



Valve Clearance

The valvetrain is designed to maintain a specified clearance or gap between the rocker/follower and the valve. This clearance is very small, but necessary due to thermal expansion of the valvetrain. This is why valve clearances are measured with the engine cold. As the engine reaches operating temperature, the valvetrain components expand and this clearance is minimized, allowing for quiet operation.

If valve clearance is too large, these types of engine symptoms will occur:

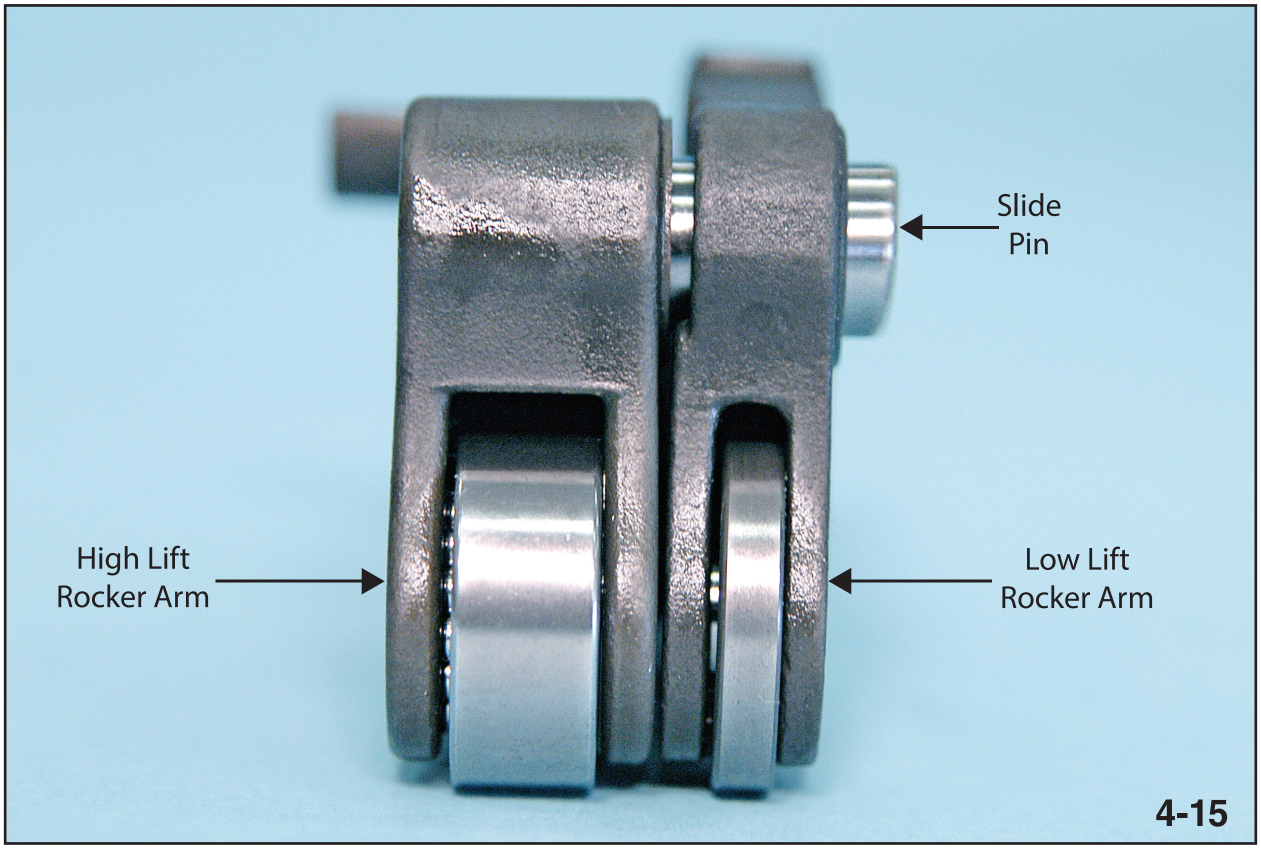
- Excessive noise
- Reduced engine performance

If valve clearance is too small, these types of engine symptoms may occur:

- Backfiring/popping through the intake
- Backfiring/popping through the exhaust
- Rough running or misfiring engine
- Poor engine performance
- Burned valve or valve seat

Variable Valve Lift System

Variable Valve Lift Components

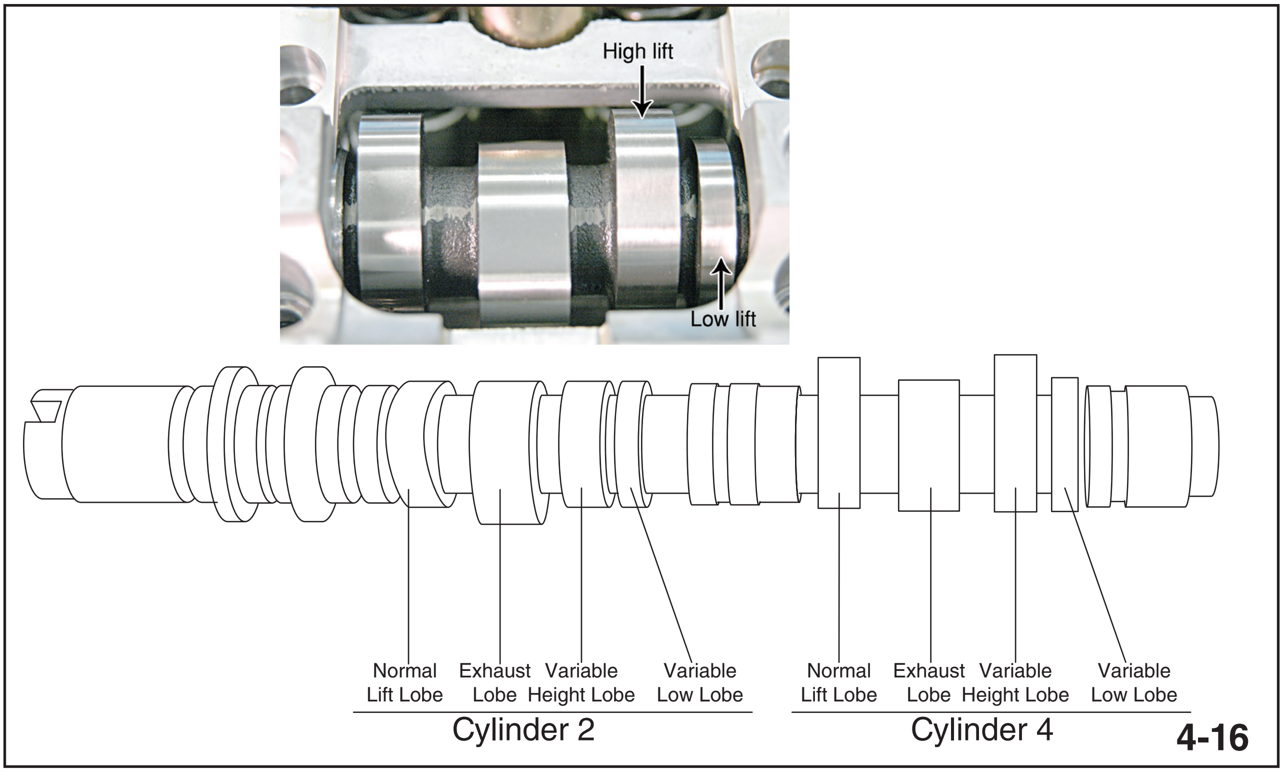


Variable Valve Lift System

The SOHC variable valve lift system improves fuel efficiency and engine output, while decreasing exhaust emissions. The system changes valve movement to low-lift or high-lift, depending on engine operating conditions. The variable valve lift system optimizes the intake valve lift by switching between a low lift cam lobe profile or high lift cam lobe profile depending on engine speed and load.

The variable valve lift mechanism that is provided to intake valve rocker assembly changes the lift amount of one side intake valves to high-lift or low-lift according to the engine speed and engine load. The variable valve lift mechanism is operated by the engine oil pressure that is controlled by the oil switching valve (OSV).

Camshaft

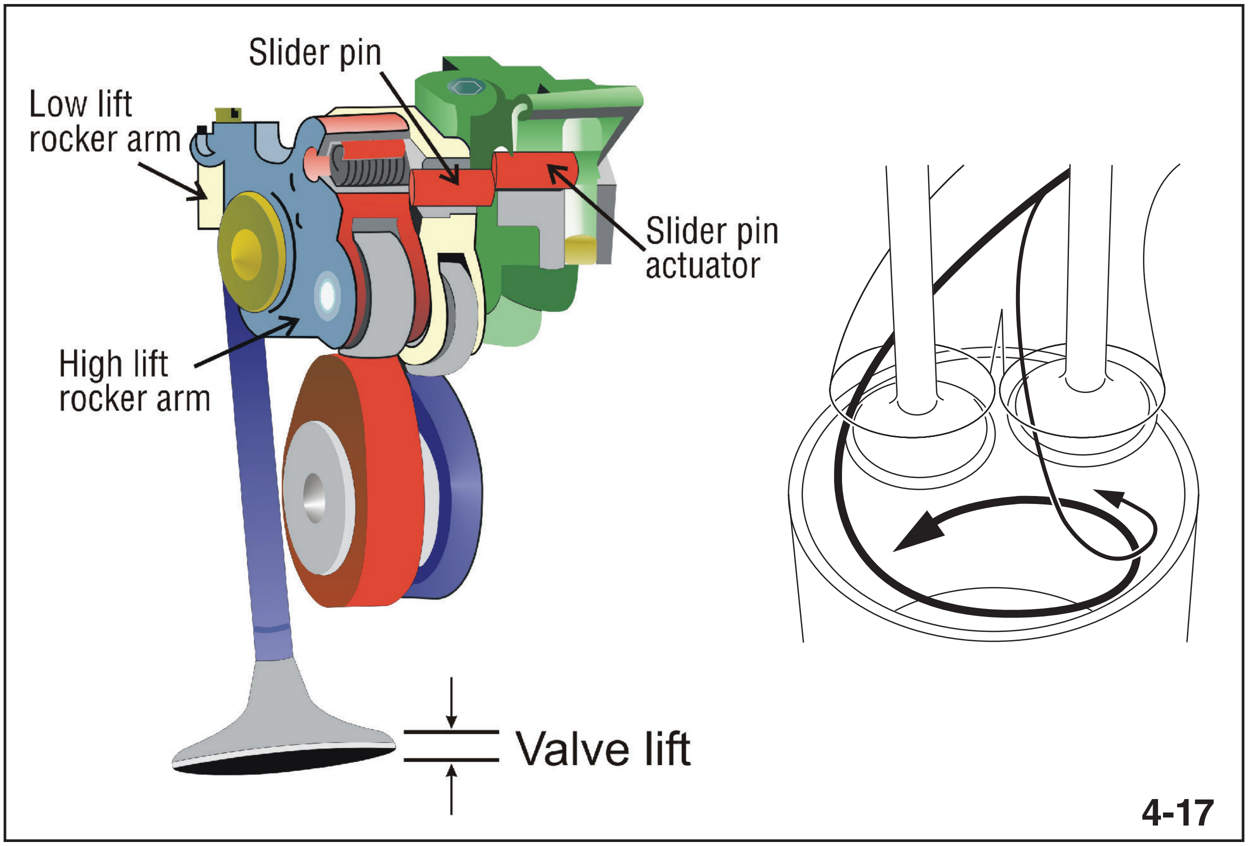


Camshaft Configuration

Three cam lobes are provided to each cylinder: the fixed lift lobe, the variable high lift lobe, and the variable low lift lobe.

The variable valve lift mechanism consists of a low lift arm, high lift arm, torsion spring, and a small cylinder that includes two locking pins and a spring. The engine oil pressure is fed from the OSV to the oil chamber.

Low Lift



Low Lift Operation

Low lift operation occurs when the low lift arm and the high lift arm are pushed up by the camshaft's rotation, the locking pin is in the unlock position. The high lift arm moves independent of the low lift rocker arm. In this condition the lift or opening of the low lift valve is minimal because the valve is being opened by the low lift cam lobe. The high lift arm is held against the high lift cam by the torsion spring, this eliminates any valvetrain noise when this arm is not engaged.

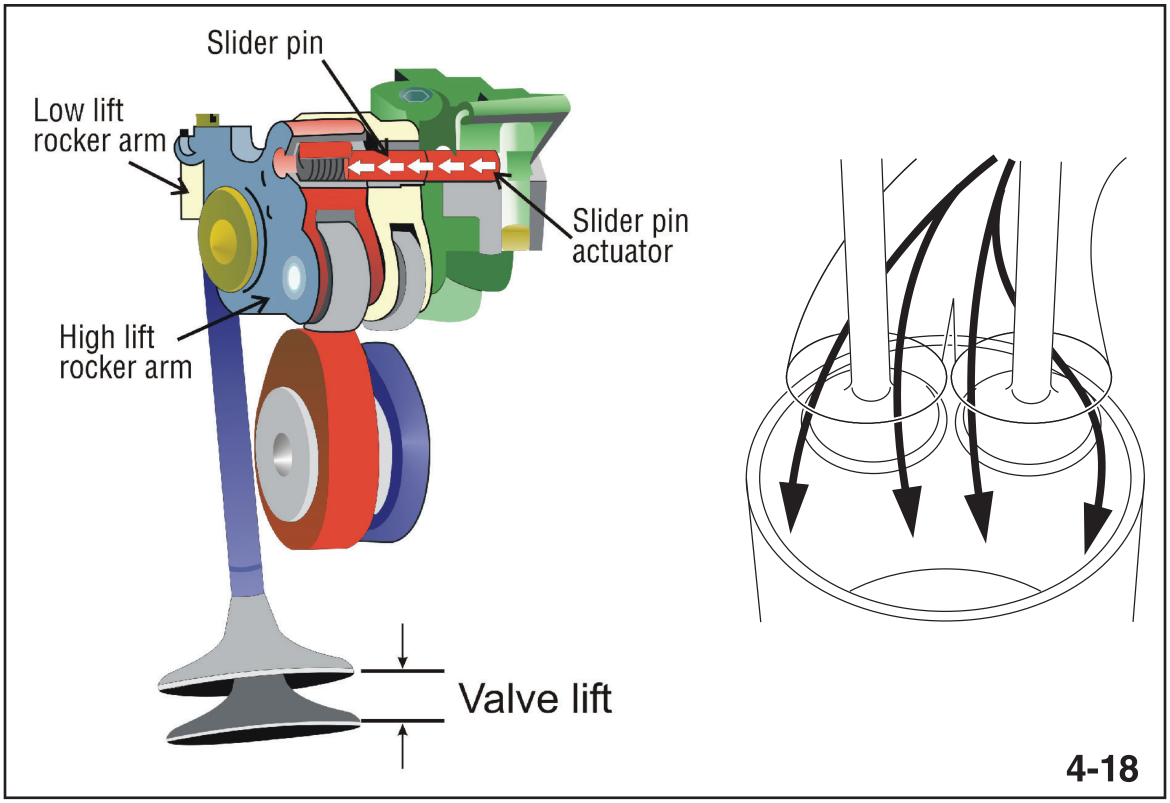
During the low lift operation the intake stroke creates a swirl effect because the velocity of air is restricted by the low lift valve not being fully opened. The velocity of air-fuel mixture in the combustion chamber is further sped up near TDC of the compression stroke. This is caused by the shape of the piston head and the squish area of the combustion chamber.

The high velocity swirling air/fuel mixture, better atomizes the fuel which improves combustion, torque, and emission performance.

Operation Change from Low Lift to High Lift

When the oil pressure provided from OSV to the oil chamber increases, the locking pin is pushed against the high lift arm side. Then, the return spring of small cylinder is compressed, and the locking pin of the low lift arm is pressed into the locking hole of the high lift arm. Through these operations, the low lift arm is locked to the high lift arm.

High Lift



High Lift Operation

High lift operation occurs when the low lift arm becomes locked to the high lift arm, this allows more air to enter the cylinder.

When the low lift arm operates upward or downward, the connecting position between the locking pin of low lift arm and the locking pin of support may change. But the low lift arm keeps integrating with the high lift arm because the locking pin of the low lift arm keeps being pushed.

With both intake valves opened equally, the air flow resistance of the valve opening is decreased. Valve overlap at TDC on the exhaust stroke is increased (because the valve opening angle of high lift cam is wider than the fixed lift cam).

When, the throttle valve is opened fully, the intake and exhaust inertia effect is utilized and more air can be drawn into the cylinder increasing the engines output.

Operation Change from High Lift to Low Lift

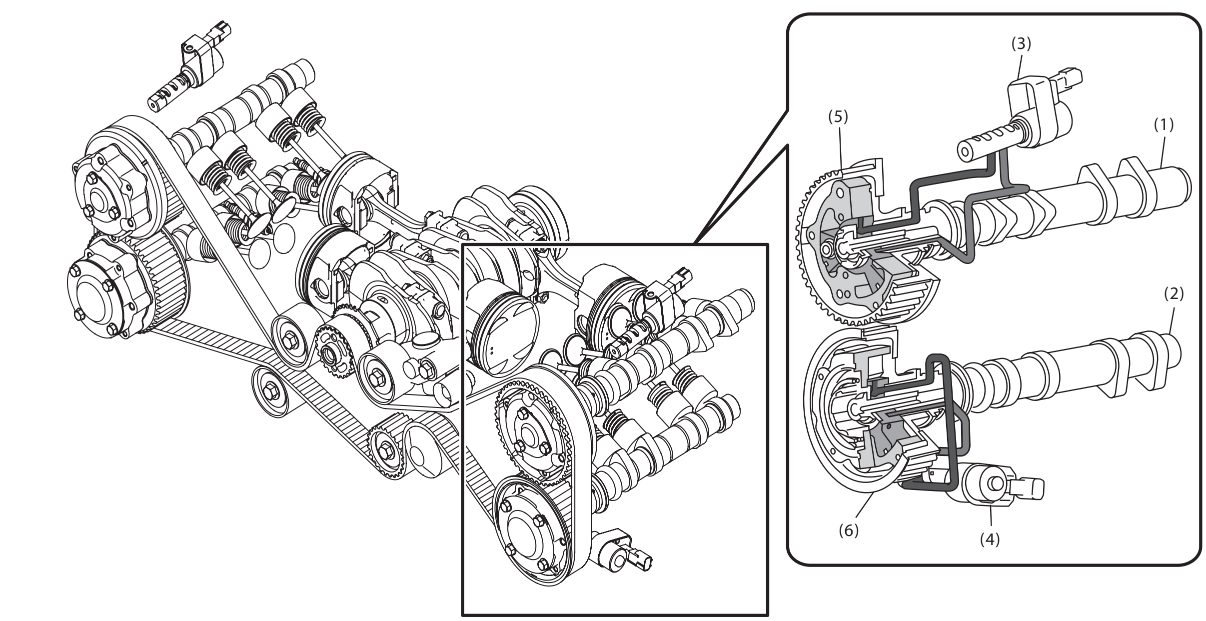
When the oil pressure from OSV to the oil chamber is decreased, the return spring within the small cylinder in the low lift rocker arm pushes back the locking pin of the low lift arm and the locking pin of the rocker shaft holder. This unlocks the lifter arms so they can move independently and the system is now returns to low lift operation.

Variable Valve Timing (VVT)/ Active Valve Control System (AVCS)

Some Subaru engines utilize a Variable Valve Timing (VVT) system to optimize valve timing, improving torque in the low and medium engine speed range, horsepower output in the high rpm range, fuel efficiency, and reducing undesirable exhaust gas emissions. The Engine Control Module (ECM) determines the optimal valve timing based on engine speed, vehicle speed, throttle angle, and other relevant engine data.

The VVT system may also be referred to as the Active Valve System (AVCS). Depending on the model/generation, an engine may have VVT on the intake camshafts only or both the intake and exhaust camshafts. Systems that vary both the intake and exhaust valve timing may be referred to as “Dual” AVCS.

Note: EJ/EZ series engines use a different system than FB/FA series engines. EJ/EZ system is shown in this chapter as an example.



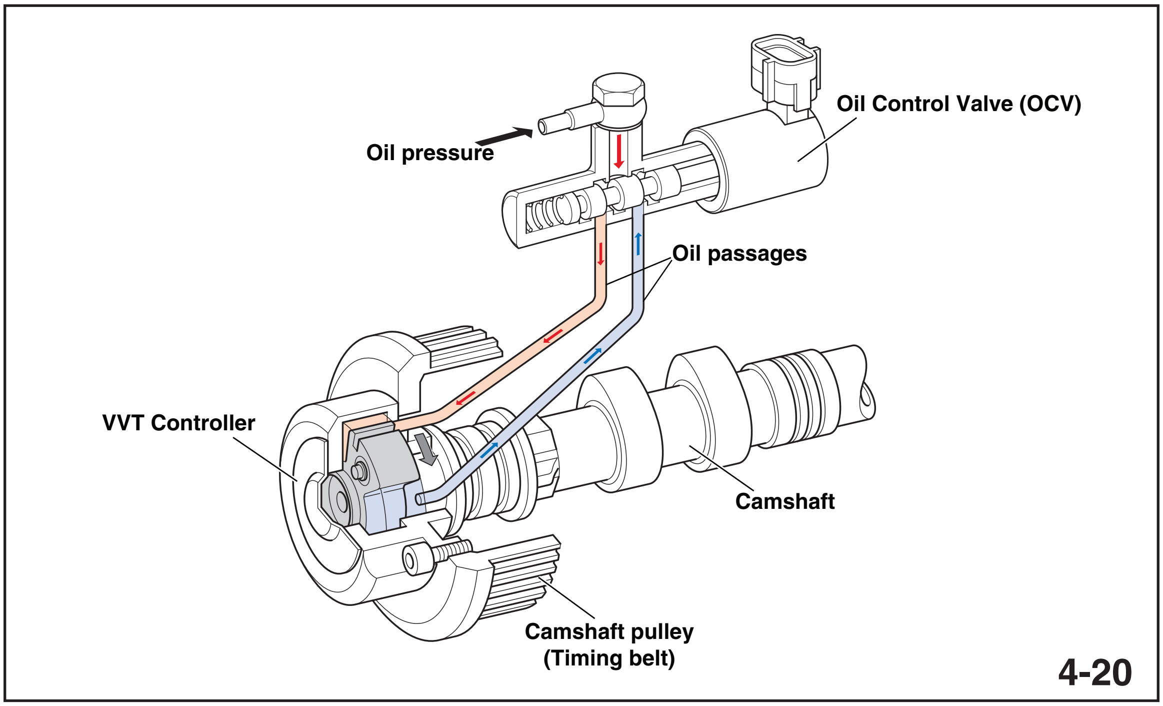
(1) Intake camshaft
(2) Exhaust camshaft
(3) Intake oil flow control valve
(4) Exhaust oil flow control valve
(5) Intake variable valve timing controller
(6) Exhaust variable valve timing controller

4-19

Dual Active Valve Control System

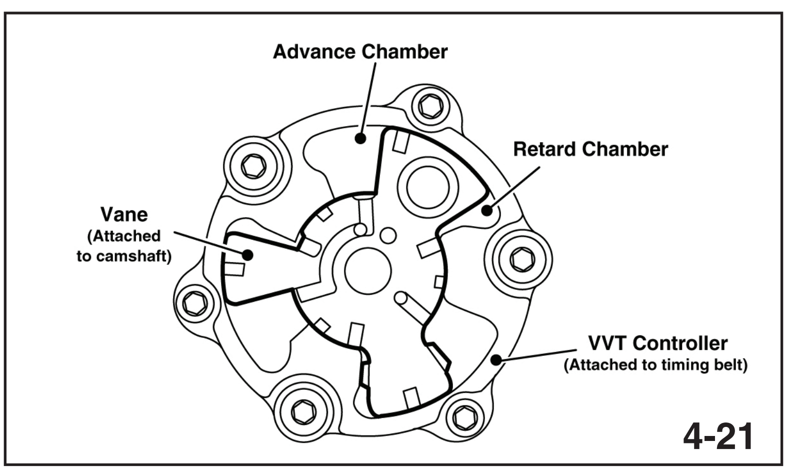
Each camshaft is fitted with a hydraulically actuated, Variable Valve Timing (VVT) Controller, regulated by an Oil Control Valve (OCV).

The VVT controller contains two distinct pieces that move independently from each other. The outer portion serves as the intake camshaft pulley and is driven by the timing belt. The inner portion is referred to as the hydraulic actuator and is affixed to the camshaft.



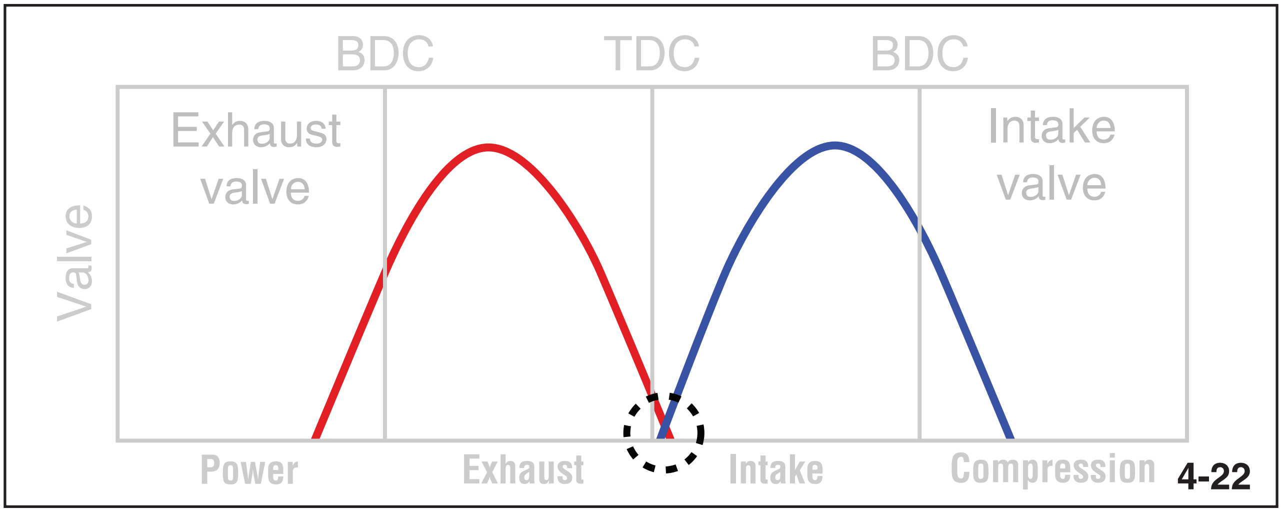
VVT Control System

The VVT controller's hydraulic actuator contains three chambers to move the camshaft in the clockwise direction and three chambers to move the camshaft in the counter-clockwise direction. The OCV directs pressurized engine oil through two passages in the cylinder head to the VVT controller, regulating the balance between the six chambers. If the actuator rotates in the clockwise direction, it is advancing the camshaft timing. If the actuator rotates in the counter-clockwise direction, it is retarding the camshaft timing. The OCV can also seal off the oil from the two passages to create a "hold" condition, fixing the valve timing at its current position.



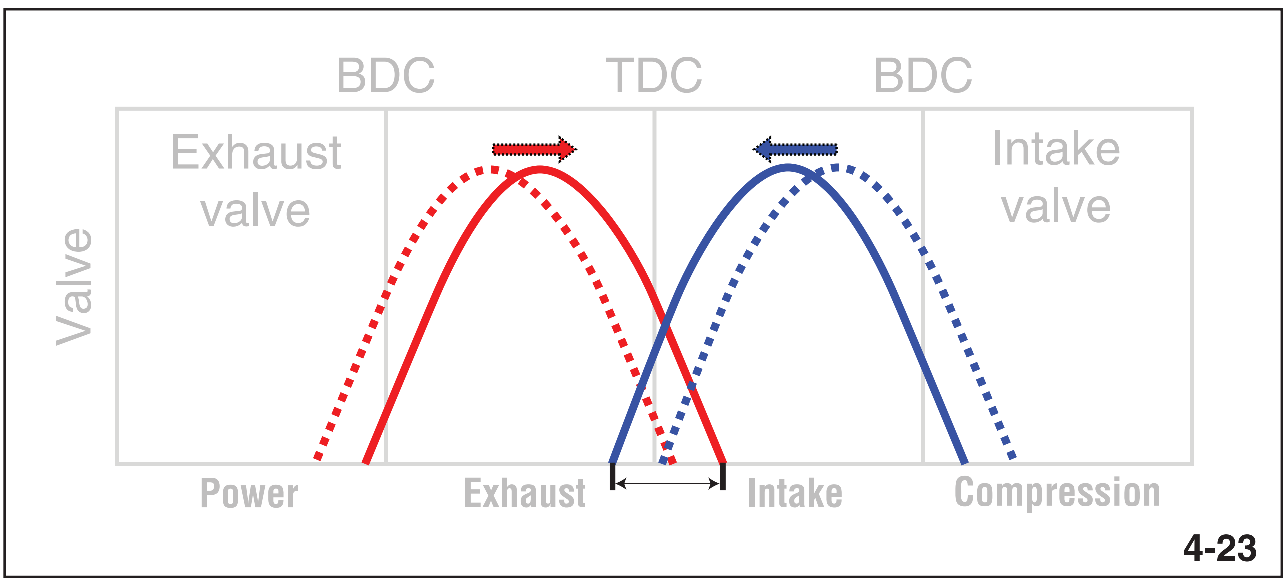
VVT Controller

In a fixed timing valve train, intake and exhaust valves share a fixed duration of valve overlap.



Fixed Valve Overlap

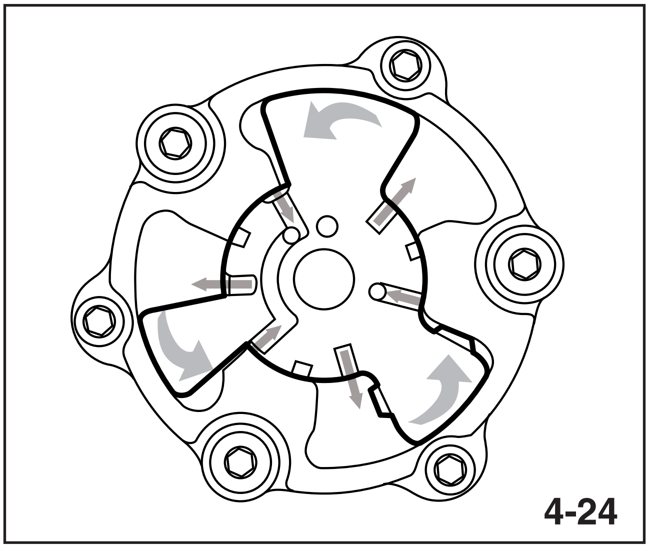
The variable valve timing system is used adjust the opening event of the intake valves to occur sooner (advancing) and the closing event of the exhaust valves to occur later (retarding). Adjusting the timing of these events increases the duration of valve overlap.



Varying Valve Overlap

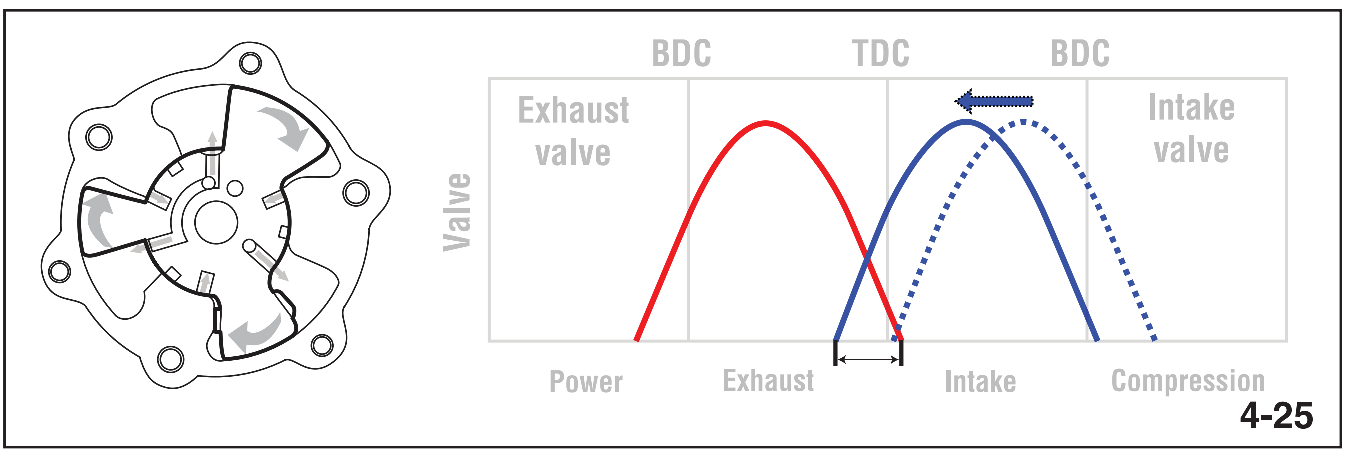
Intake Camshaft AVCS

When oil flow is directed to the retard chambers of an intake VVT controller, the internal vane is forced to the base position (Minimum advance).



Intake VVT Controller — Base Position

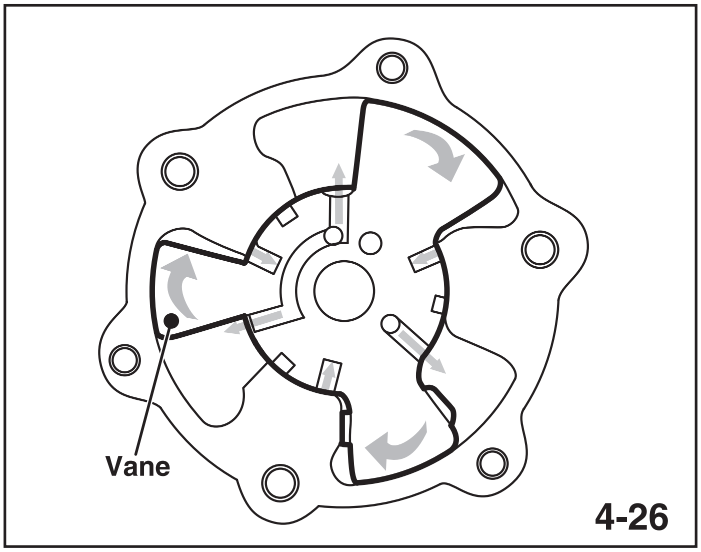
If the ECU determines intake camshaft advance is desired, oil flow is directed to the “advance” chambers of the intake VVT controller. This advance causes the intake valve opening event to occur earlier in the 4 stroke cycle resulting in more overlap with the exhaust valve closing event. Camshaft advance may be held constant at any position between the minimum and maximum advance angles depending on the OCV control. Maximum amount of VVT advance varies by engine type.



Intake VVT Controller — Advance

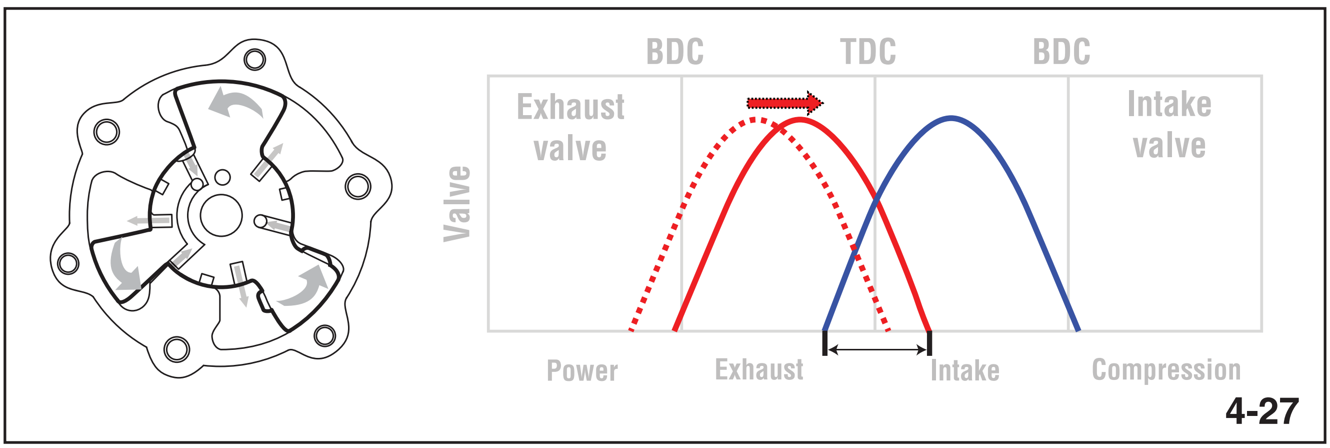
Exhaust Camshaft AVCS

When oil flow is directed to the advance chambers of an exhaust VVT controller, the internal vane is forced to the base position (Minimum retard).



Exhaust VVT Controller - Base Position

If the ECU determines exhaust camshaft retard is desired, oil flow is directed to the "retard" chambers of the exhaust VVT controller. This retard causes the exhaust valve closing event to occur later in the 4 stroke cycle resulting in more overlap with the intake valve opening event. Camshaft retard may be held constant at any position between the minimum and maximum advance angles depending on the OCV control. Maximum amount of VVT retard varies by engine type.



Exhaust VVT Controller - Retard

Ignition System

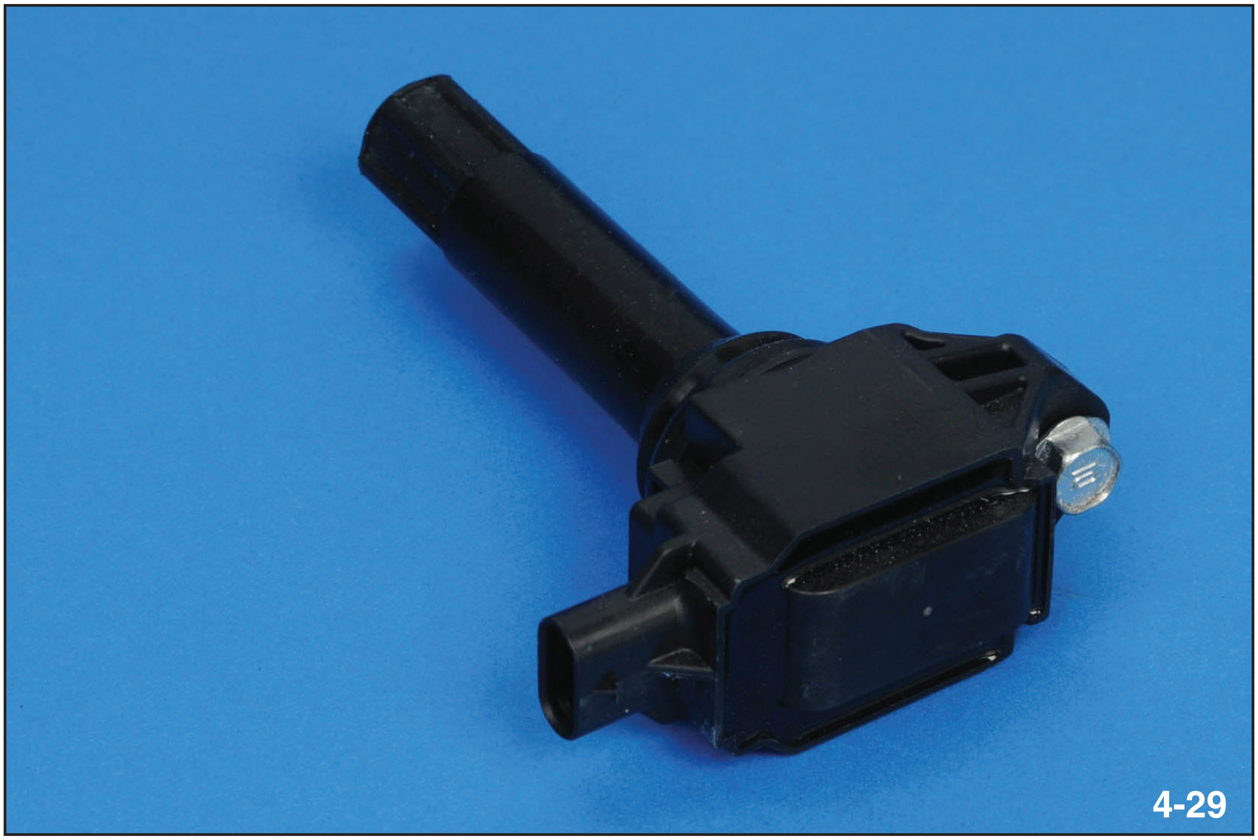
To create the spark that ignites the compressed air/fuel mixture within the cylinder, an electronic ignition system is used. The ignition system uses coil-on-plug technology and consists of the spark plug, ignition coil, and triggering device. This system provides accurate ignition timing control.

Spark Plug

Typical Spark Plug

The spark plug typically resides at the top of the cylinder. It must provide sealing to allow compression to occur and deliver the spark (heat) to ignite the air/fuel mixture. Always verify the proper gap of a new spark plug. For the procedure to correct an improper spark plug gap, refer to STIS.

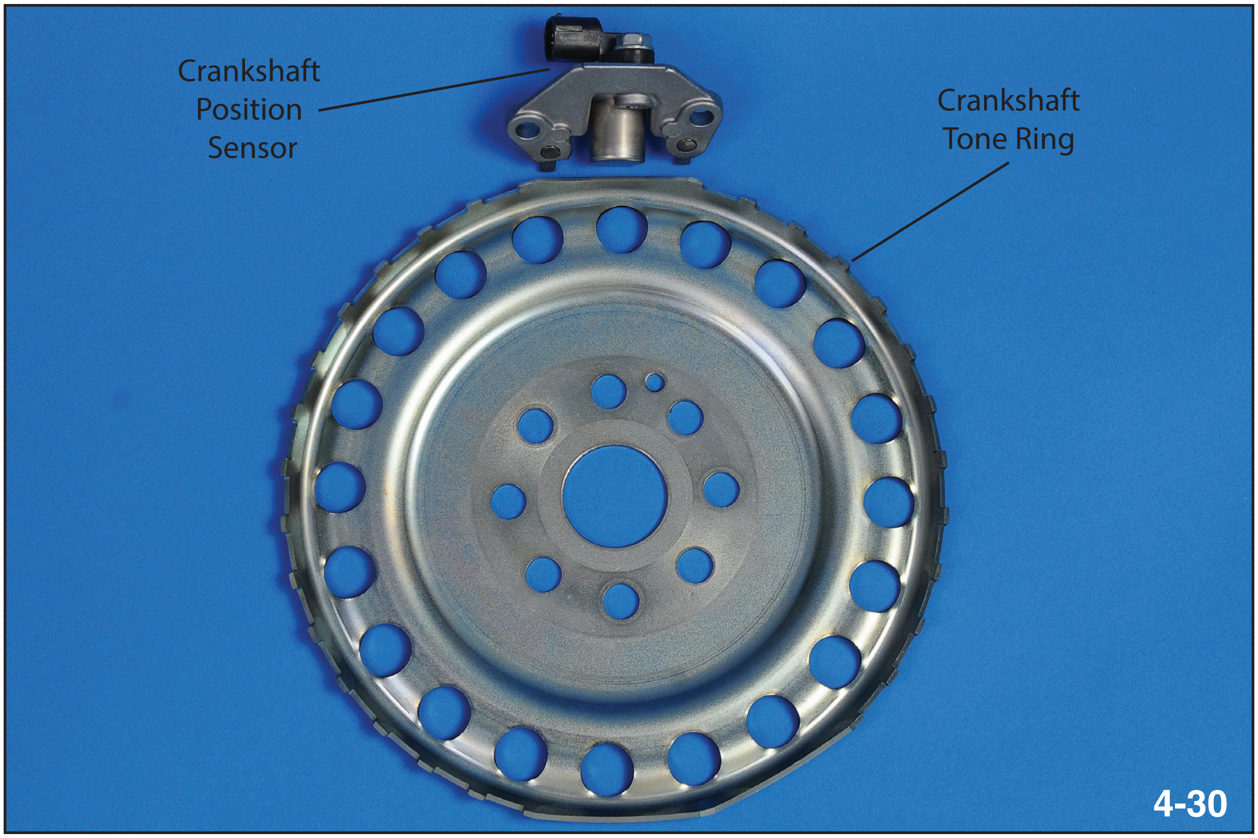
Ignition Coil



Typical Ignition Coil

The ignition coil converts battery voltage to 50kV (or higher). This voltage level is necessary to jump the gap in the spark plug and ignite the air/fuel mixture.

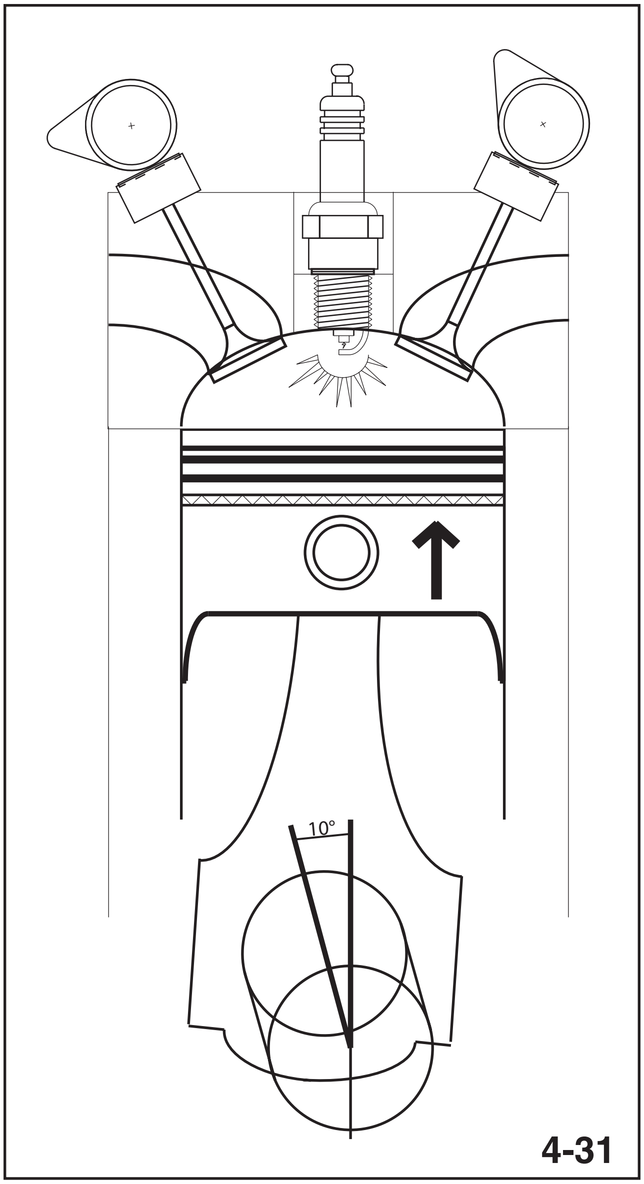
Triggering Device



Typical Crankshaft Sensor and Tone Ring

The engine control module (ECM) uses a crankshaft position sensor and tone ring to determine the position of the crankshaft. The ECM uses this information to control ignition spark and injector timing for optimum engine performance under all driving conditions.

Ignition Timing



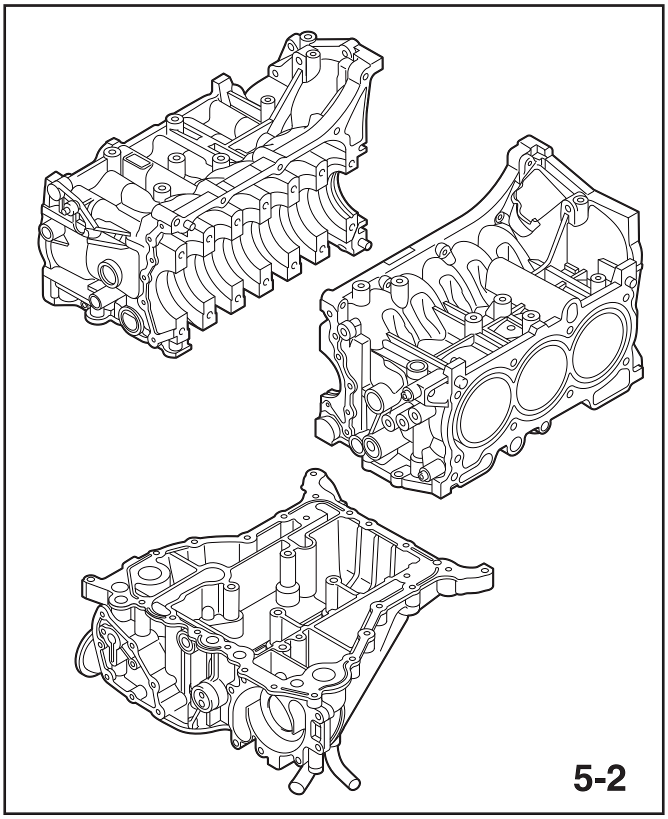
Ignition Timing

Ignition timing typically occurs just prior to the piston reaching TDC of the compression stroke. The spark plug is fired before top dead center (BTDC). The combustion process must initiate prior to the start of the power stroke, because the air/fuel mixture within the cylinder takes only milliseconds to complete. This allows the most work to be generated from the cylinder.

The ignition event takes a certain amount of time to occur. This time remains constant regardless of engine rpm. For engine firing to occur at the proper time as engine speed is increased, the ignition event needs to start earlier in the combustion process. This is called ignition timing advance.

Cylinder Block Components

Cylinder Block

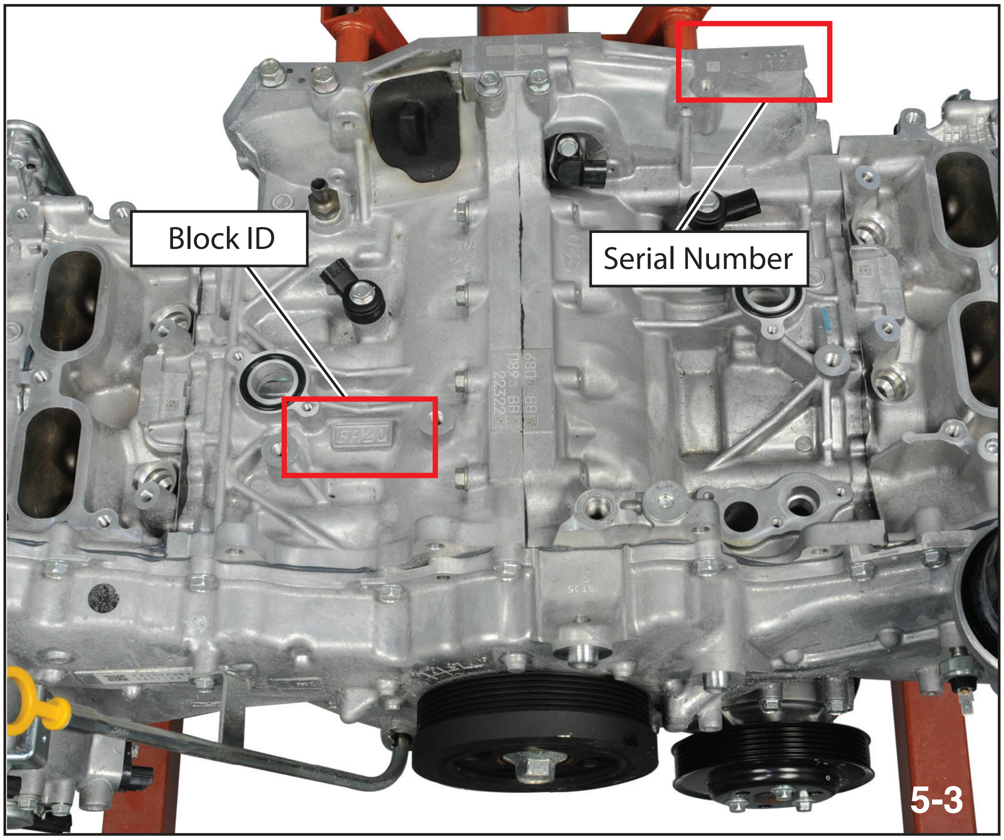


Typical Cylinder Block

The cylinder block is the main structural component of the engine; every component of the engine is mounted to the cylinder block. The cylinder block is made from cast aluminum and is split into two halves that are 180 degrees apart from each other. The two halves of the cylinder block support the crankshafts journals through the main bearings; the rear bearing is a flanged thrust bearing which controls the crankshafts end play. Integrated into the cylinder block during the casting process; cast iron cylinder liners create the bores that the pistons reciprocate in. Water jackets around the cylinder liners are open at the cylinder head side; this is called an open-deck design.

The aluminum die-cast upper oil pan section, located below the cylinder block, reinforces the connection between the cylinder block halves, provides structural support and a baffle effect to suppress large fluctuation in oil level. The upper oil pan contains passages for the oil and cooling circuits. The water pump and thermostat housings are also a part of upper oil pan.

Block Identification and Serial Numbers



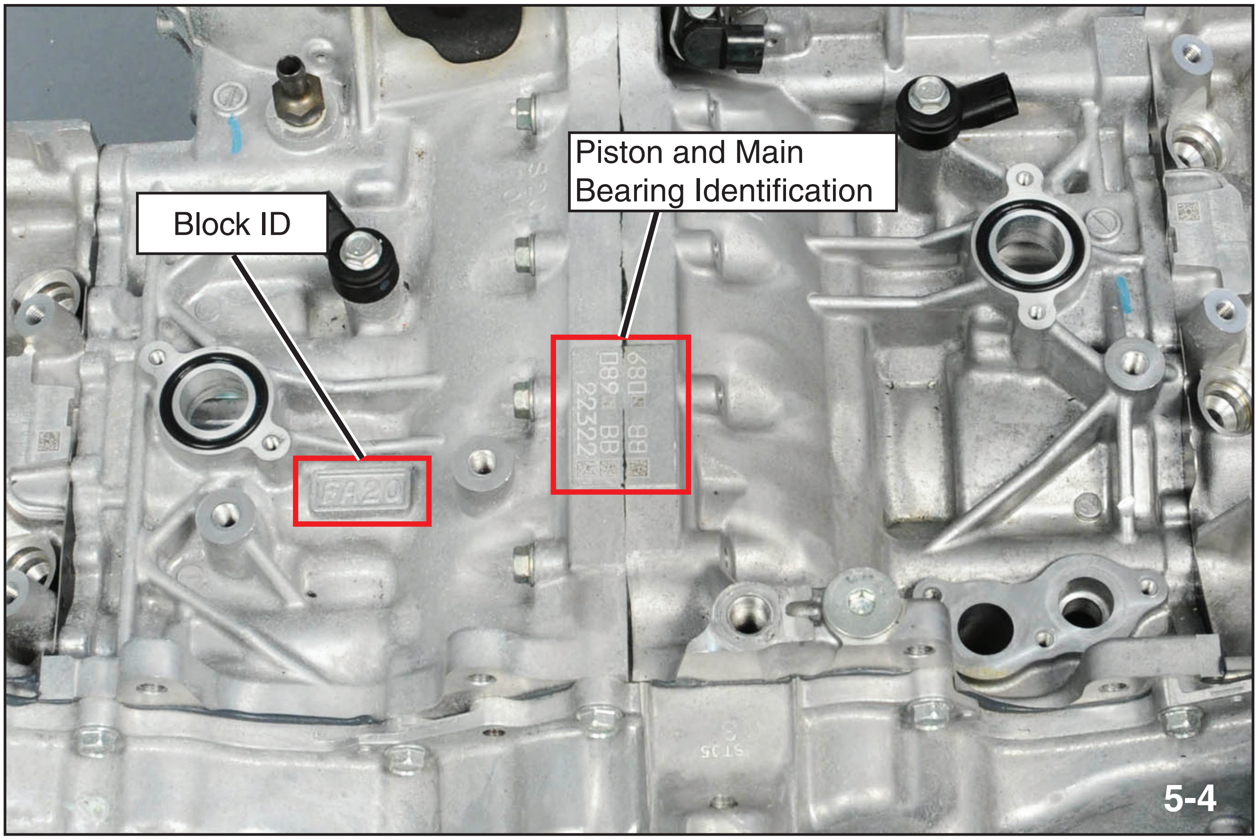
Engine Block Identification Numbers

Located on the cylinder block in several places are groups of numbers that identify the engine block, some of the information that is available are: serial number, engine type (size), piston bore size, main journal size.

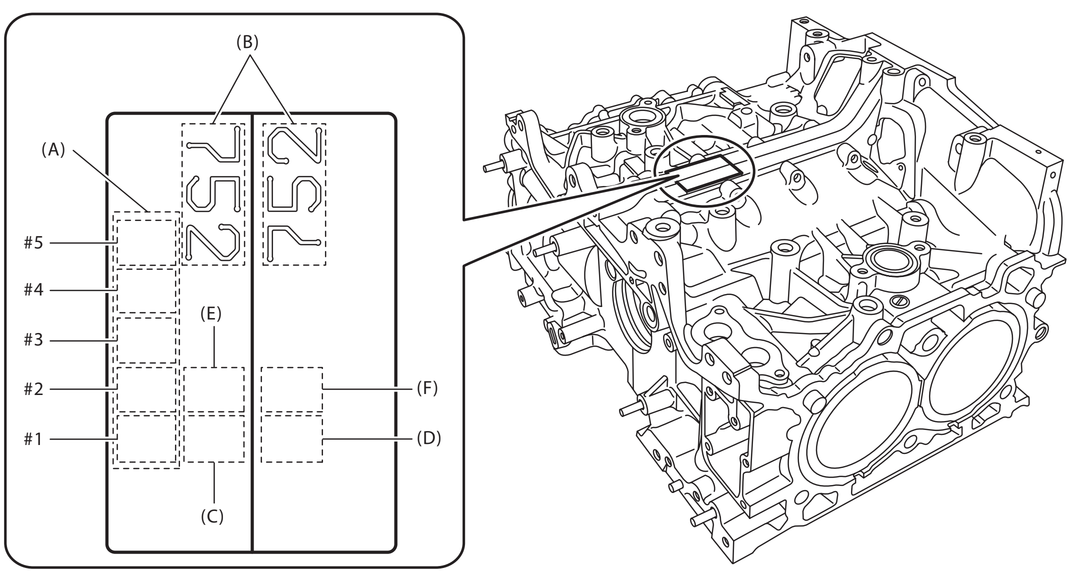
The table below is an example of an engine type identification table.

Digits	Code	Meaning	Details
1 and 2	FB	Engine type	FB: 4 cylinders
3 and 4	25	Displacement	25: 2.5 L
5	B	Fuel feed system	B: MFI non-turbo (DOHC)
6	A	Exhaust regulations	A: For states not using California emission standards C: For states using California emission standards
7	Y	Intake/exhaust system	Y: Intake AVCS, TGV, EGR
8	B	Mounted transmission	B: 6MT H: CVT
9 and 10	EB	Detailed specifications	Used when ordering parts. For details, refer to the parts catalog

Block Identification Numbers for Piston, Block, and Main Bearings



Piston, Block, and Main Bearing Identification



(A) Main journal size mark (1-5)

(B) Cylinder block (RH) – (LH) combination mark

(C) #1 cylinder bore size mark

(D) #2 cylinder bore size mark

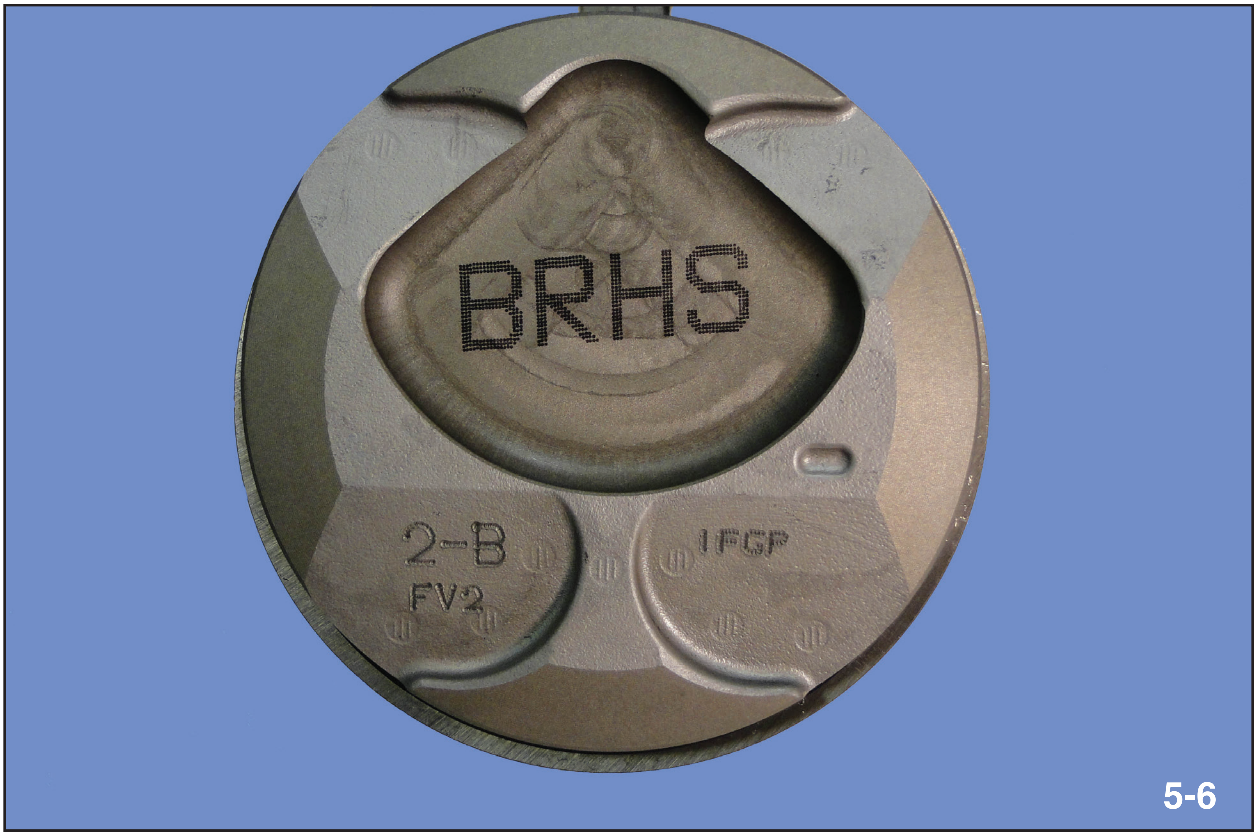
(E) #3 cylinder bore size mark

(F) #4 cylinder bore size mark

5-5

Identification

Piston Design

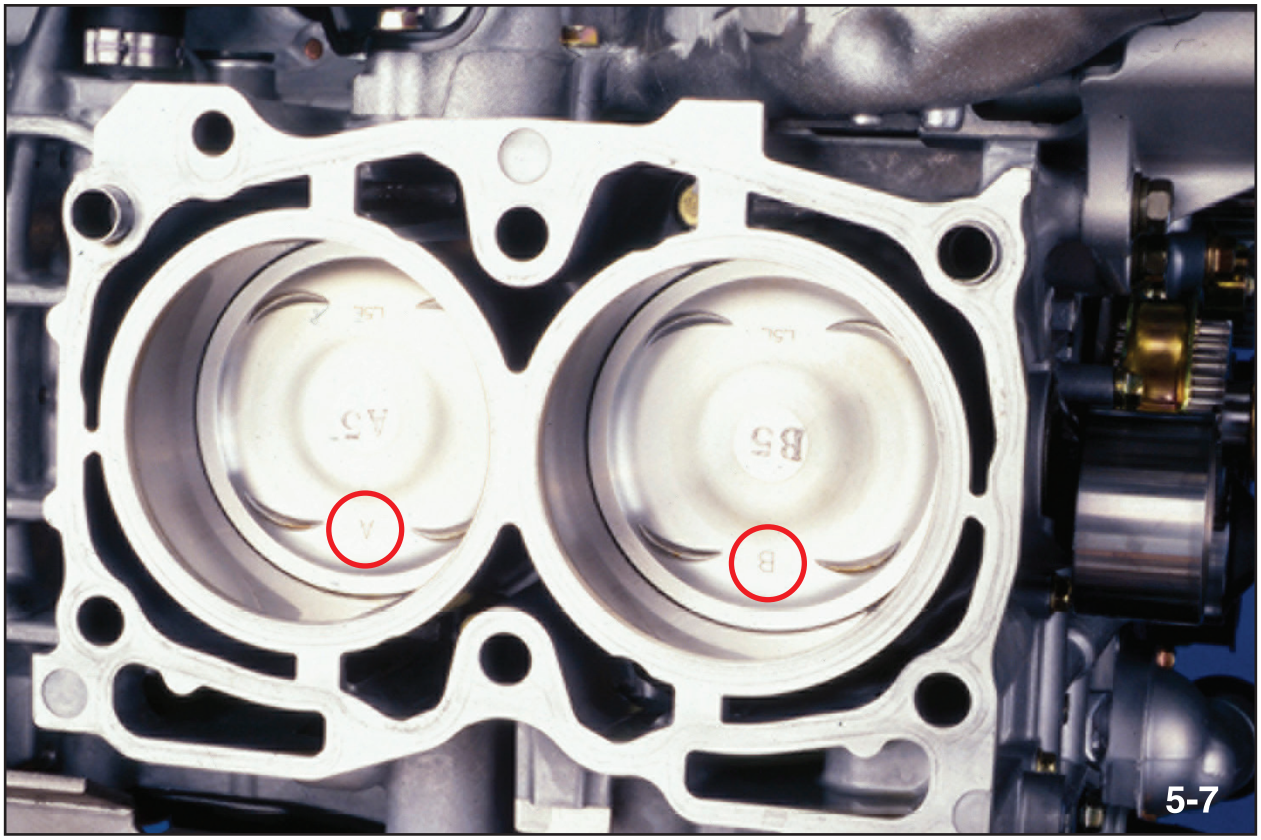


Piston Construction

The piston head has recesses to prevent interference with the intake and exhaust valves. It also has engraved marks to identify the piston size and the direction of installation. On some models, the piston heads are of concave design at the exhaust side to gather the flow around the spark plug and improve combustion. Some pistons are distinguished for left or right sides.

Markings in the piston indicate a specific direction that the piston must be installed; these markings could be an arrow, dots, or a triangle. Reference Subaru Technical Information System (STIS) for the specific marking on the engine you are working on.

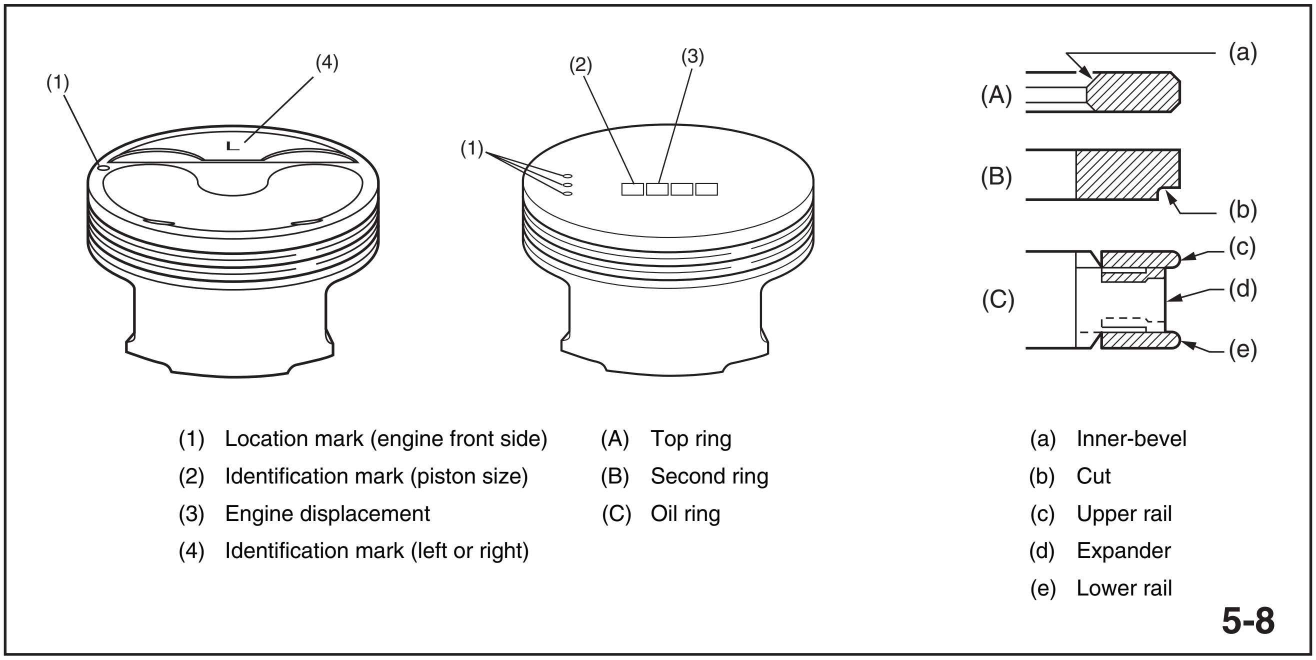
Piston Markings



Pistons with A and B identifiers

There are two standard size pistons that are available in every engine these are indicated by a letter A or B stamped on the piston. The indication of A or B is referenced using the identification markings stamped on the cylinder block.

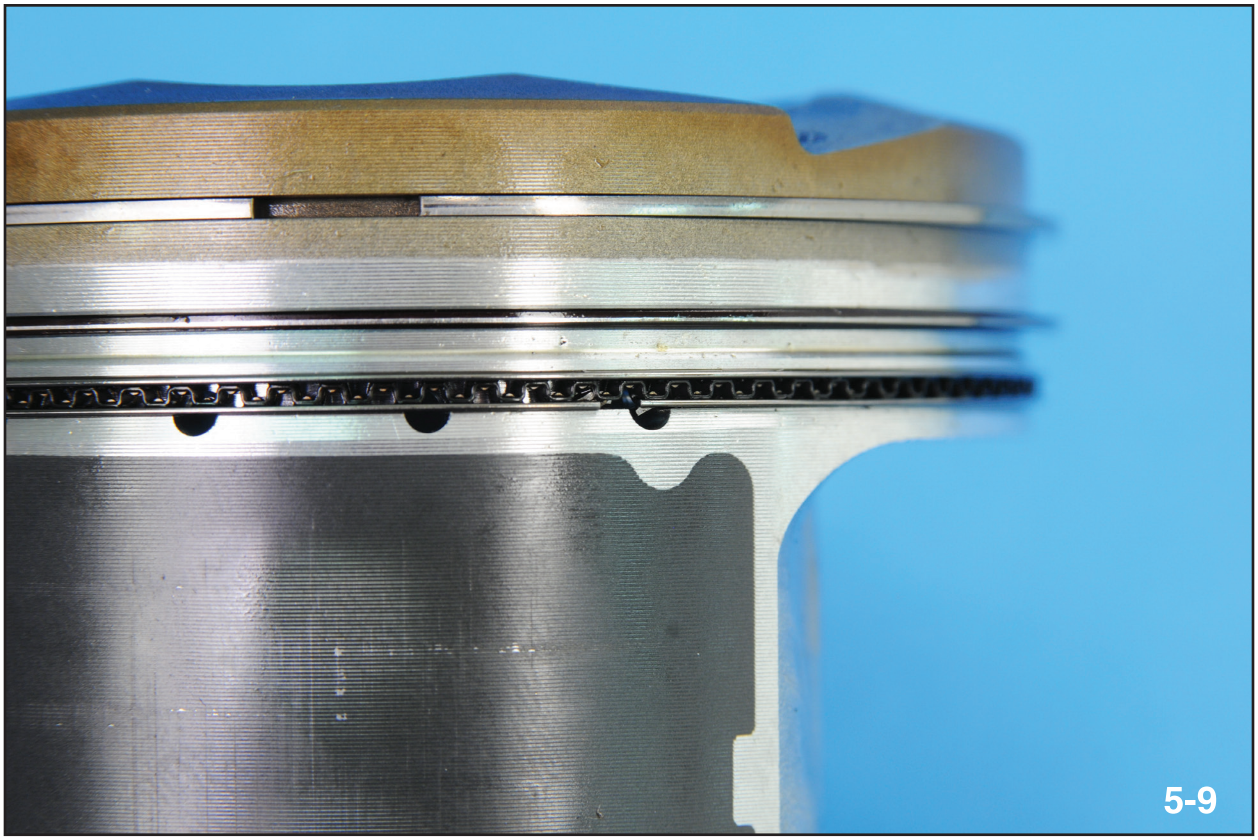
Piston and Piston Rings



Piston and Piston Rings

The pistons are constructed from aluminum for reduced weight and friction. The piston also features round oil drain holes in the oil control ring groove. The piston pin is offset toward the thrust side of the piston perpendicular to the wrist pin (Pistons 1 and 3 thrust side is on the downward side of the cylinder, Pistons 2 and 4 thrust side is on the upper side of the cylinder. The thrust side of the piston is identified as the side of the piston that is forced to slide against the cylinder wall during the compression stroke. The pin offset helps reduce piston slap noises.

Piston Ring Purpose



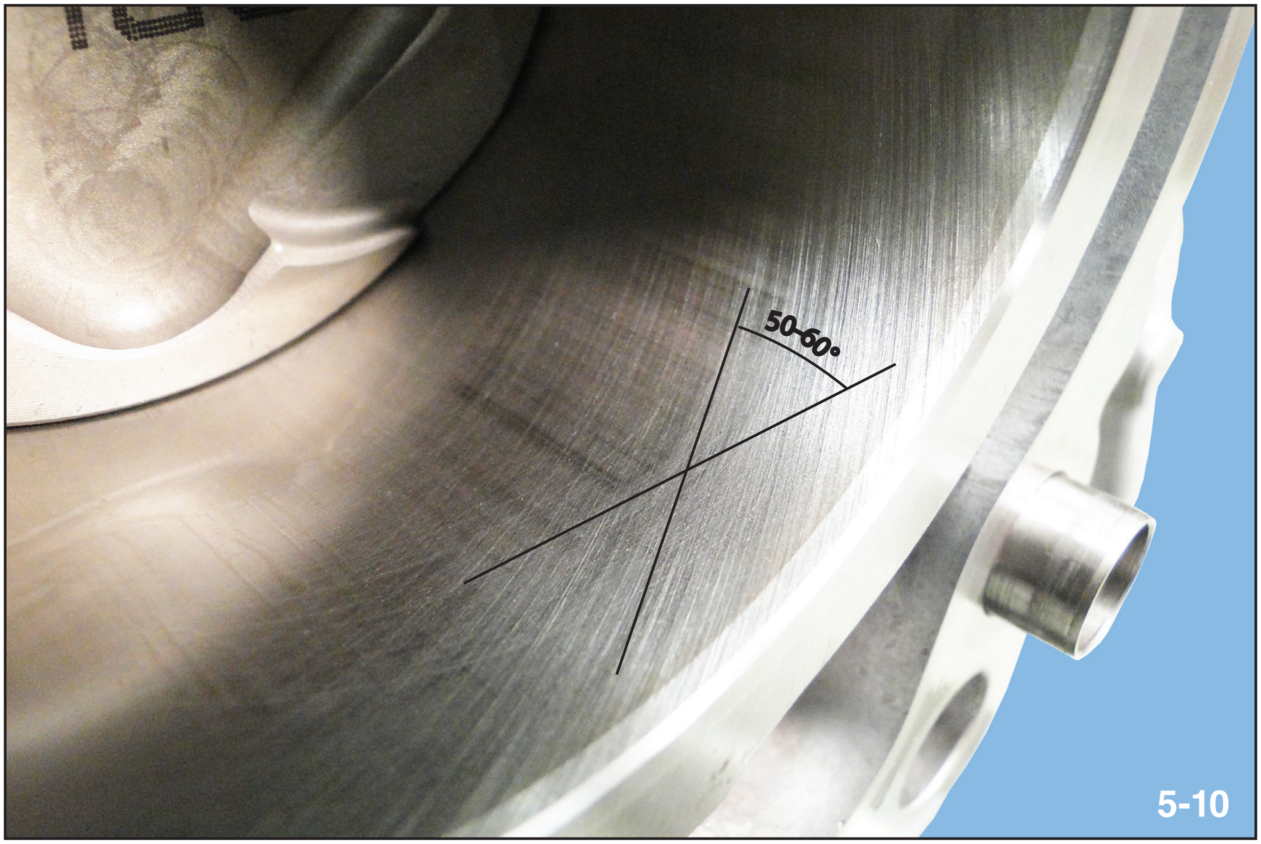
Oil Ring Locating Tabs

Pistons typically have three grooves that are located around the sides. Piston rings made of steel fit into these grooves and provide sealing between the piston and the cylinder wall. The top and middle (compression) piston rings provide most of the sealing to build pressure in the cylinder. The top piston ring has inner bevels and the second piston ring has an interrupt (cut) on the bottom outside to reduce oil consumption. The third ring is the oil control ring that is made up of three parts: two thin steel rings (called scrapers) that make up the top and bottom portion of the ring, and one expander to create and maintain the proper spacing between the two scraper rings. The oil ring controls the amount of oil that adheres to the cylinder walls for proper piston lubrication.

Piston ring tension is important to an engine's operation. The piston rings provide tension to keep gases from getting by the piston rings or oil getting from the crankcase into the cylinders. Piston tension in today's engines needs to be kept to a minimum to promote less friction and better fuel economy.

Due to the heat within the engine, piston rings need to have a small gap between the open ends to allow for expansion. As the engine gets to operating temperature the rings expand slightly and the gap closes creating a complete seal.

Cylinder Bore Crosshatch

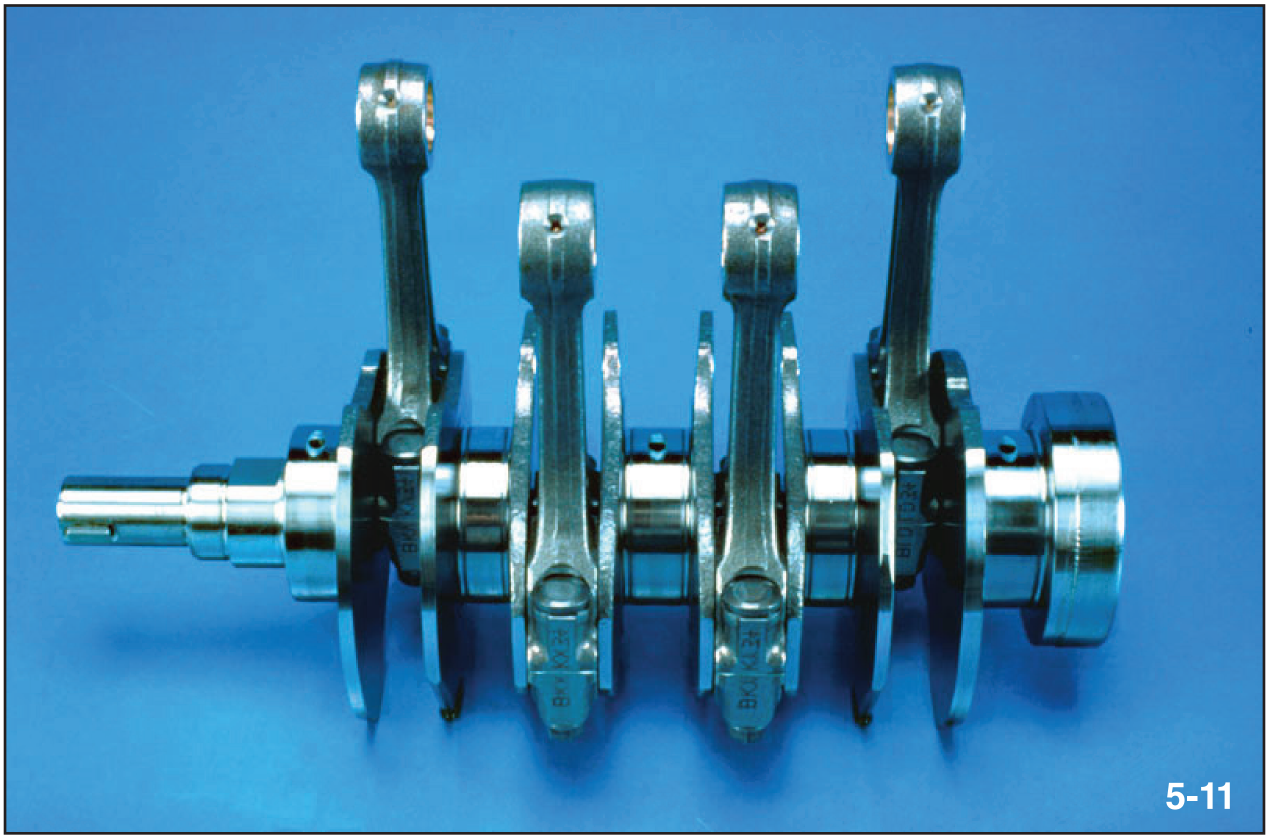


Cylinder Bore Crosshatch

The cylinder bore is cut using a boring machine and then a hone is used to give the cylinder surface a fine finish. The pattern that the hone produces is called crosshatch. The hone produces lines in the cylinder wall that intersect each other ideally at a 50 to 60 degree angle. This surface contains numerous diamond shaped protrusions that leave an area on the surface to which oil can adhere. Piston rings slide against this bearing surface, which provides the best wear-in and sealing for the piston rings.

A cylinder with a crosshatch angle too steep will not hold enough oil to create a bearing surface, causing premature piston ring wear. A cylinder with a crosshatch angle too shallow will cause the piston rings to float (hydroplane) from the cylinder surface, resulting in excessive oil consumption and poor piston ring sealing.

Crankshaft



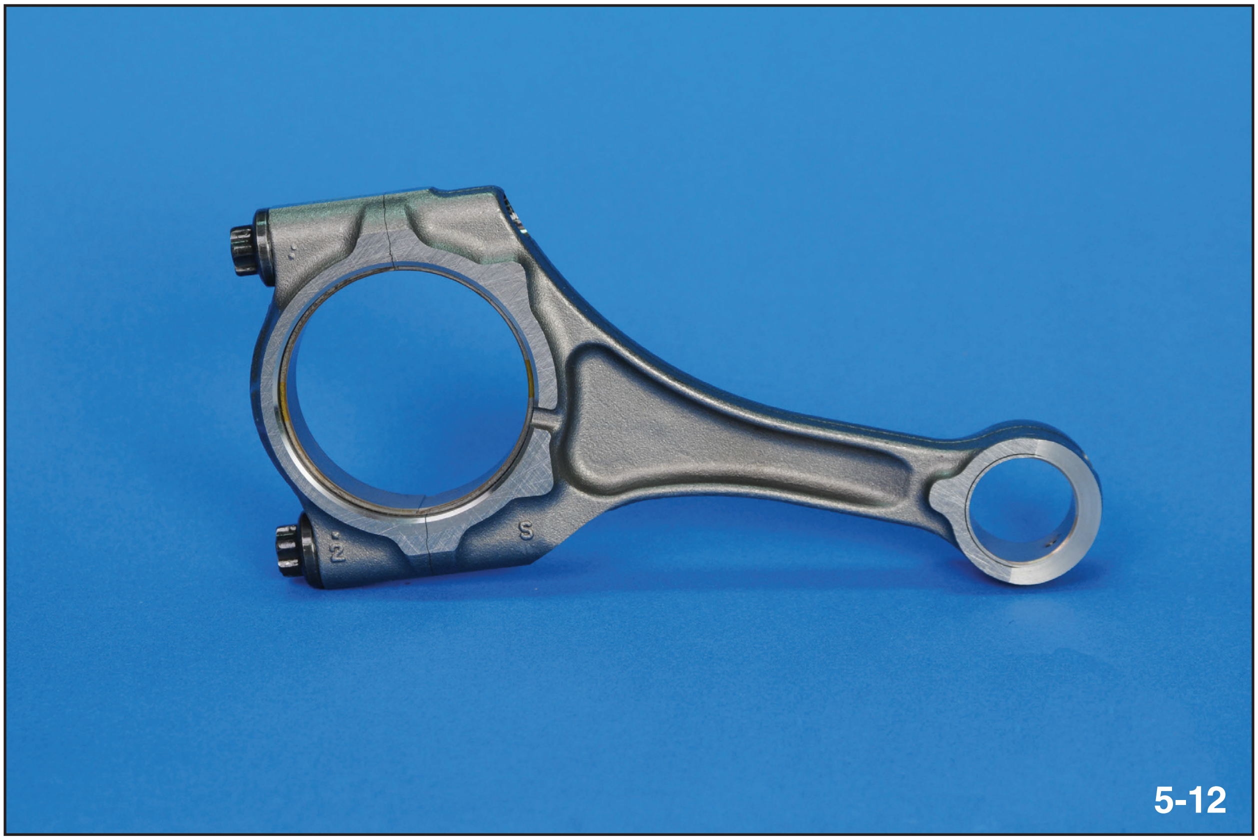
Crankshaft

Crankshafts are typically made from nodular iron, cast iron, or forged cast steel; they are then heat treated for long life and durability. Some crankshafts may also get a nitride coating to increase the machined surface's durability.

The main bearing journals at the center of the shaft are machined to very precise tolerances. The crankshaft main journals rotate on main bearings the block, allowing the crankshaft rotation. The crankshaft bearings are made of aluminum alloy, and the rear bearing includes a metal flange to support thrust forces.

The crankshaft rod journals are offset of the crankshaft main journals. These journals are machined to very precise tolerances. The piston rods contain bearings made of aluminum alloy that rotate on the crankshaft rod journals.

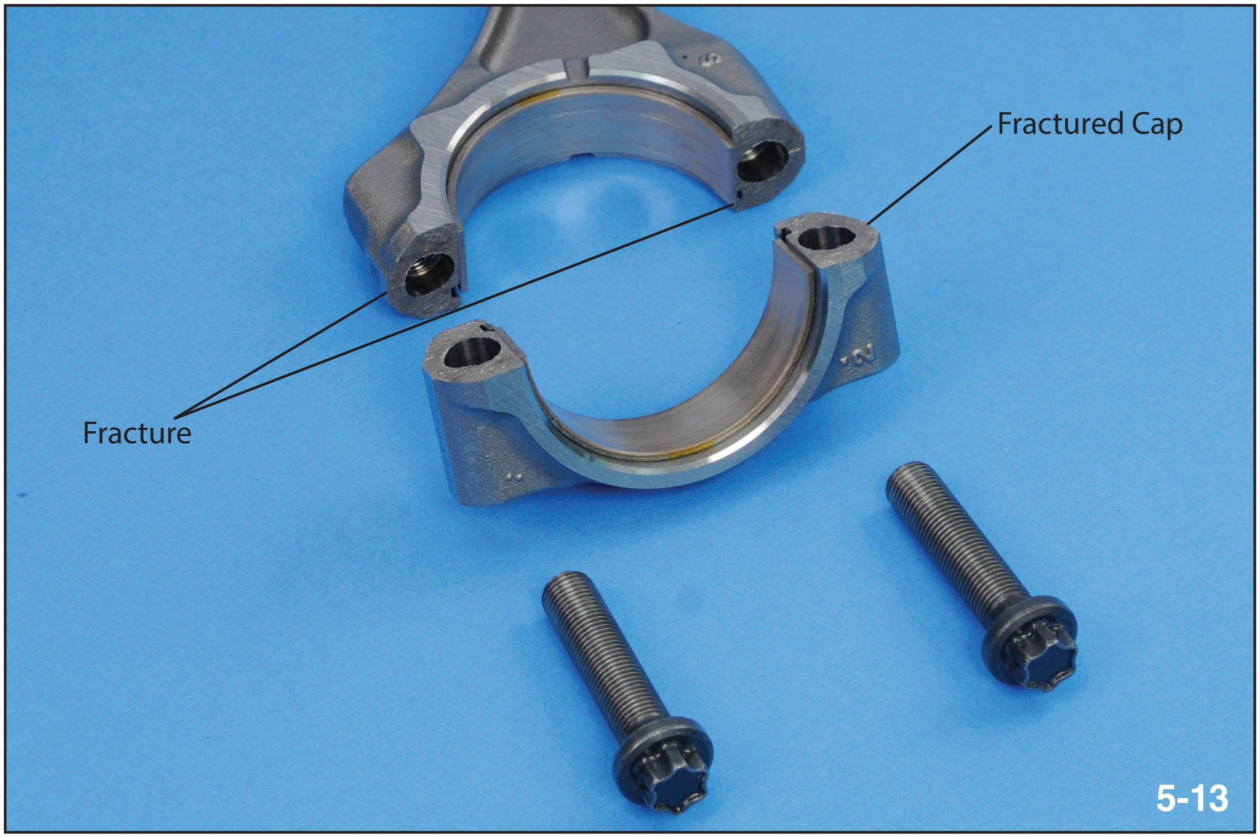
Connecting Rod



Connecting Rod

The connecting rod transmits the force of the piston to the crankshaft during the combustion cycle. The small end of the connecting rod attaches to the piston wrist pin. The center section of the connecting rod is formed in an I-beam shape for strength and minimum weight. The larger end houses connecting rod bearings and attaches to the crankshaft.

Connecting Rod Construction



Connecting Rod Construction

Connecting rods are typically made from high-strength steel, nodular steel, or cast iron. The end of the connecting rod that attaches to the crankshaft is made of two pieces: the lower part of the connecting rod is called the cap.

Conventional connecting rods are machined where they are split and the surfaces fit tightly together. On newer connecting rods, the caps are scored and then fractured to separate them; this is called a fractured cap style connecting rod. The mating surfaces are jagged and fit together in only one direction. The connecting rod and cap fit together to encapsulate the crankshaft and are fastened with bolts.

Note: Connecting rods are manufactured as a unit and must always be kept together.

The connecting rods are an offset directional type. There is a mark on one side of the connecting rod; this mark must face the front of the engine when installed.

NOTES:

STIS Service Manual

Engine Service Information in STIS

6-2

STIS Welcome Page

Subaru Technical Information (STIS) is a comprehensive database that provides service information on multiple model years of Subaru vehicles. The database is located at the following address: *http://techinfo.subaru.com/index.html*.

You will see the welcome screen when you enter the website. You can log in by entering a user name and password from the Login/My Account drop down. From the welcome page, you can view PDF-based service information by using the Online Reference drop-down.

The website has two main sections: Online Reference and Service Diagnostics. Service Diagnostics pull down menu displays a list of years and model specific vehicles that lead to specific service information procedures, specifications, wiring diagrams, diagnostic trouble codes, and visual contents that include links to other service procedures, component locations, and specifications that can be viewed by clicking on the amber chain link icon.

The online reference section includes the following PDF-based information:

- PDF-based Service Manuals
- TechTIPS Newsletters
- Technical Service Bulletins
- Technician Reference Booklets
- Owner Manual

Maintenance Schedules

		Maintenance interval [Number of months or km (miles), whichever occurs first]																		
	Months	3	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	82.5	90	97.5	105	112.5	120	132	Remarks
	× 1,000 km	4.8	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	220	
	× 1,000 miles	3	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	82.5	90	97.5	105	112.5	120	132	
1	Engine oil		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
2	Engine oil filter		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
3	Spark plug									R								R		
4	Drive belt(s)					I				I				I				I		
5	Fuel line					(I)				(I)				(I)				I		Note (1)
6	Fuel filter											R								Note (1)
7	Air cleaner element					R				R				R				R		Note (2)
8	Cooling system					I				I				I				I		
9	Engine coolant	Replace after the first 11 years or 220,000 km (137,500 miles), and every six years or 120,000 km (75,000 miles) thereafter																		6-3

Typical Maintenance Schedule

The scheduled maintenance requirements can be found in a separate Warranty and Maintenance Booklet. The booklet is located under the applicable vehicle>General Information Section>Periodic Maintenance Services PM>Schedule.

There are two maintenance schedules; Schedule A and Schedule B. Schedule A refers to maintenance items needed based on miles driven and time. Schedule B refers to maintenance items needed based on miles driven and driving conditions; extreme driving conditions require a shorter time interval for maintenance requirements.

The Service Manual Schedule Symbols in the chart indicate:

- R - Replace
- I - Inspection
- P - Perform

When operating vehicles in sever conditions (towing, dusty areas, cold climates) refer to maintenance schedule 2.

Schedule

PERIODIC MAINTENANCE SERVICES

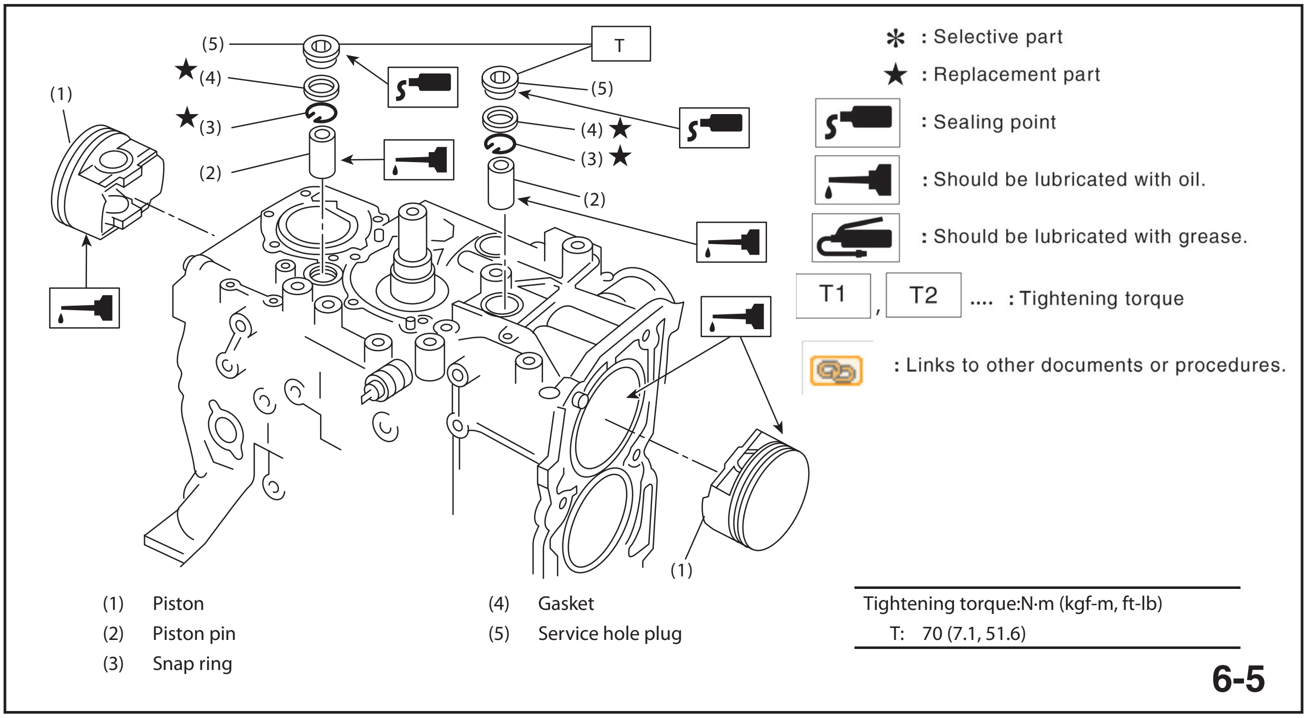
B: MAINTENANCE SCHEDULE 2

Item	Maintenance interval	Repeat short distance drive	Repeat rough/muddy road drive	Extremely cold weather area	Salt or other corrosive used or coastal area	High humidity or mountain area	Repeat towing trailer
Engine oil	3.75 months	R		R			R
	6,000 km						
	3,750 miles						
Engine oil filter	3.75 months	R		R			R
	6,000 km						
	3,750 miles						

6-4

Schedule

STIS Symbols/Icons



STIS symbols and Icons

In addition to scheduled maintenance, other symbols and icons found in STIS are described in the graphic above.

Definitions of Note, CAUTION, AND WARNING:

Note: Describes additional information to make works easier.

CAUTION: Describes prohibited matters to prevent vehicle and component damage, or matters that requires special attention during work.

WARNING: DESCRIBES MATTERS THAT MAY CAUSE SERIOUS DAMAGE TO THE OPERATOR OR OTHER PERSON, OR THAT MAY CAUSE DAMAGE OR ACCIDENT.

Engine Service Procedures

Engine	Model				2.5 L
	Cylinder arrangement				Horizontally opposed, liquid cooled, 4-cylinder, 4-stroke gasoline engine
	Valve system mechanism				Chain driven, double overhead camshaft, 4-valve/cylinder
	Bore × Stroke	mm (in)			94.0 × 90.0 (3.70 × 3.54)
	Displacement	cm^3 (cu in)			2.498 (152.43)
	Compression ratio				10
	Compression pressure (at 200 — 300 rpm)	kPa (kg/cm^2, psi)		Standard	1,050 — 1,400 (11 — 14, 152 — 203)
	Number of piston rings				Compression ring: 2 Oil ring: 1
	Intake valve timing		Open	Max. retard	ATDC 16°
				Min. advance	BTDC 39°
			Close	Max. retard	ABDC 80°
				Min. advance	ABDC 25°
	Exhaust valve timing			Open	BBDC 35°
				Open	ATDC 13°
	Cam clearance	mm (in)	Intake	Standard	0.13±0.03 (0.0051±0.0012)
			Exhaust	Standard	0.24±0.03 (0.0094±0.0012)
	Idle speed (For CVT model, select lever in “P” or “N” range. For MT model, gear shift lever in neutral position.)	rpm	No load	Standard	CVT model: 675±100
					MT model: 650±100
			A/C ON	Standard	CVT model: 700±100
					MT model: 800 — 850±100
	Ignition order				1- 3 - 2 - 4
	Ignition timing	BTDC/rpm		Standard	CVT model: 16°±10°/675
					MT model: 16°±10°/650

6-6

Engine Specification Charts

STIS engine service procedures are located by selecting the appropriate model year from the Service Diagnostics drop down, and selecting the appropriate model. From the Technical Information System page, select Engine from the Select a Major Components Section pull down menu. From there you will see three major groups. Each group contains a Specification chart located in the General Description folder. The Specification section contains the entire necessary engine component wear tolerances and recommended fluid types. Under General Description, the Component section contains torque specifications for engine components and exploded views.

Engine Service Special Tools

Engine Special Tools

Special Tools information can be found under the Information pull down menu>Links>SPX Kent-Moore Special Service Tools. At the Subaru Special tool website, click on ENGINE.

Notes:

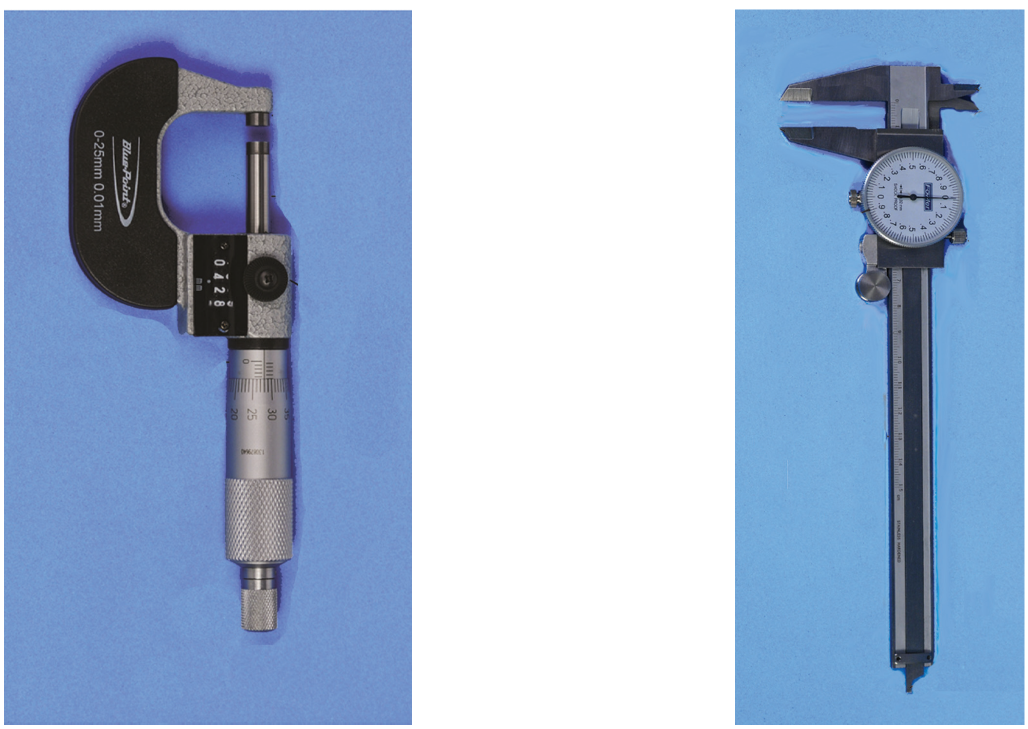
Precision Measuring

Engine inspection and repair often requires precise measurements. These measurements can help determine if components are worn or if adjustments are necessary.

Depending on the type of measurement, basic measuring tools like feeler gauges and steel rules may be required. To make more precise measurements, precision tools like micrometers, calipers, and dial indicators are required. This section covers the most common tools that are used to perform precision measurements.

Micrometers and Calipers

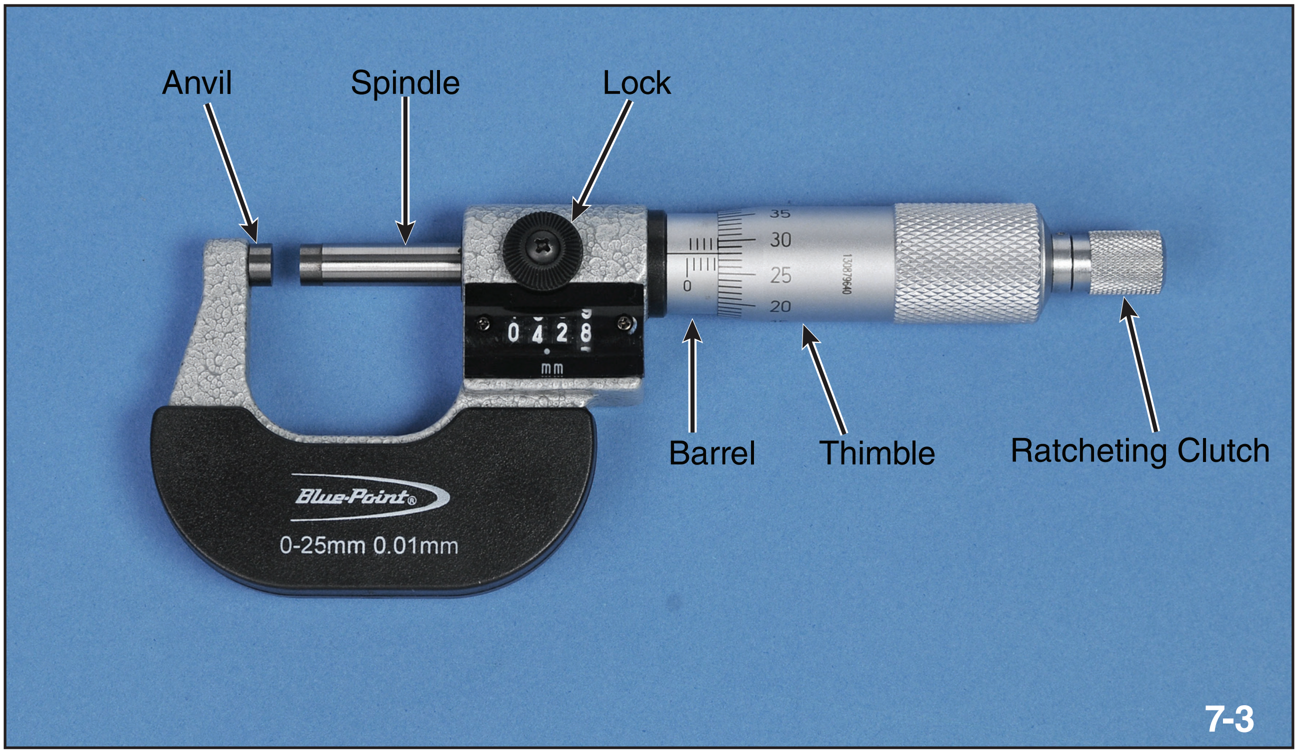
Micrometers and dial calipers are delicate measurement tools that must be cared for and maintained to ensure their precision and smooth operation. These precision measuring tools should always be stored in their protective cases. In addition, they should be inspected regularly and calibrated if necessary. Always clean the tool measuring surfaces and make sure the surfaces to be measured are also clean and dry. Any debris left on the surfaces can produce inaccurate measurements.



Micrometer *Dial Caliper* **7-2**

Precision Measuring Tools

Metric Micrometer

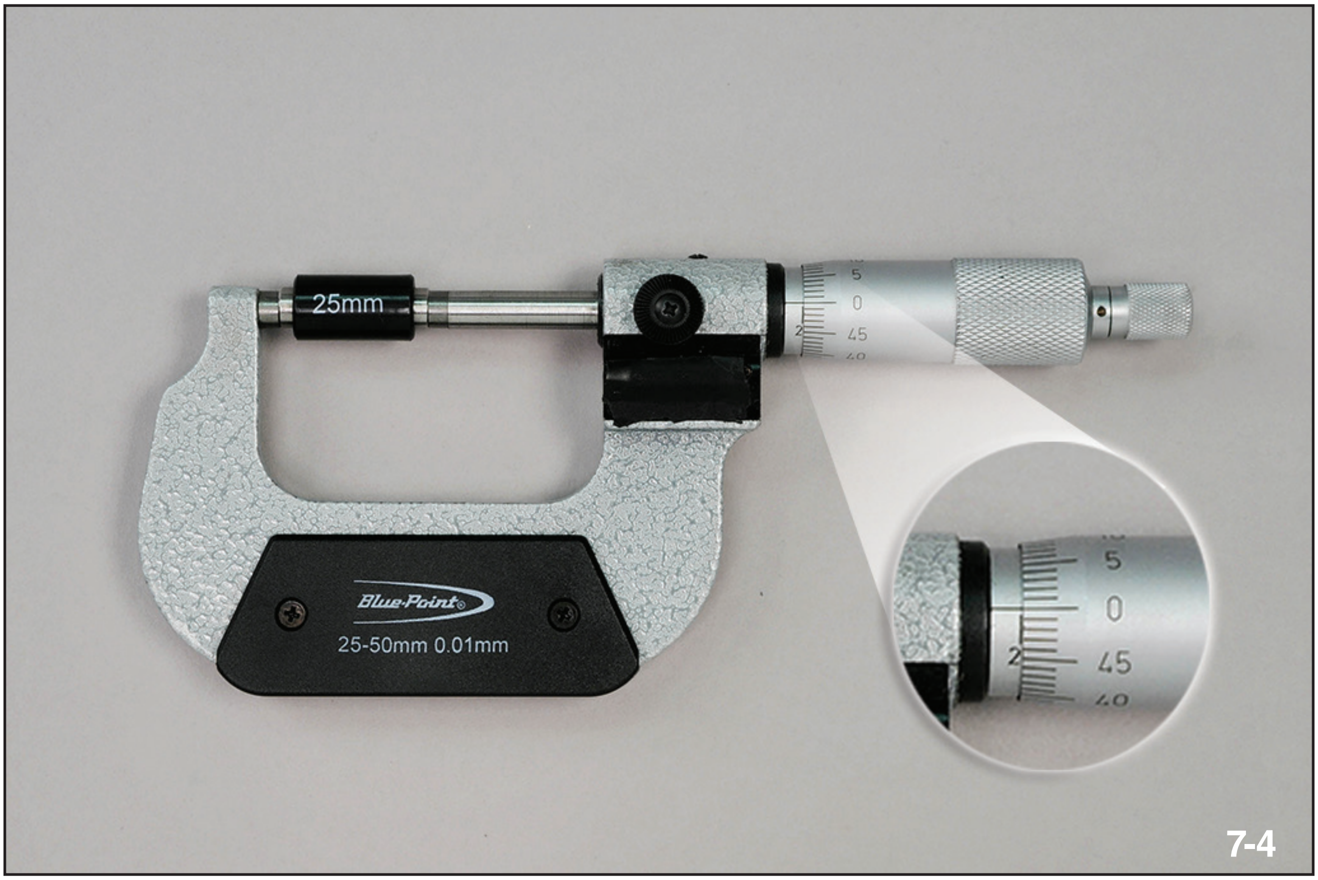


Micrometer Components

The micrometer measures items to the hundredth of a milimeter (.01).

Place the item being measured between the spindle and the anvil. Spin the thimble to extend or retract the spindle. The ratcheting clutch properly tensions the thimble and spindle to attain a consistent reading. The lock holds the spindle and thimble in place so the micrometer can be removed from the item for easier reading of the measurement.

Use a combination of the barrel scale and the thimble scale to calculate the measurement.

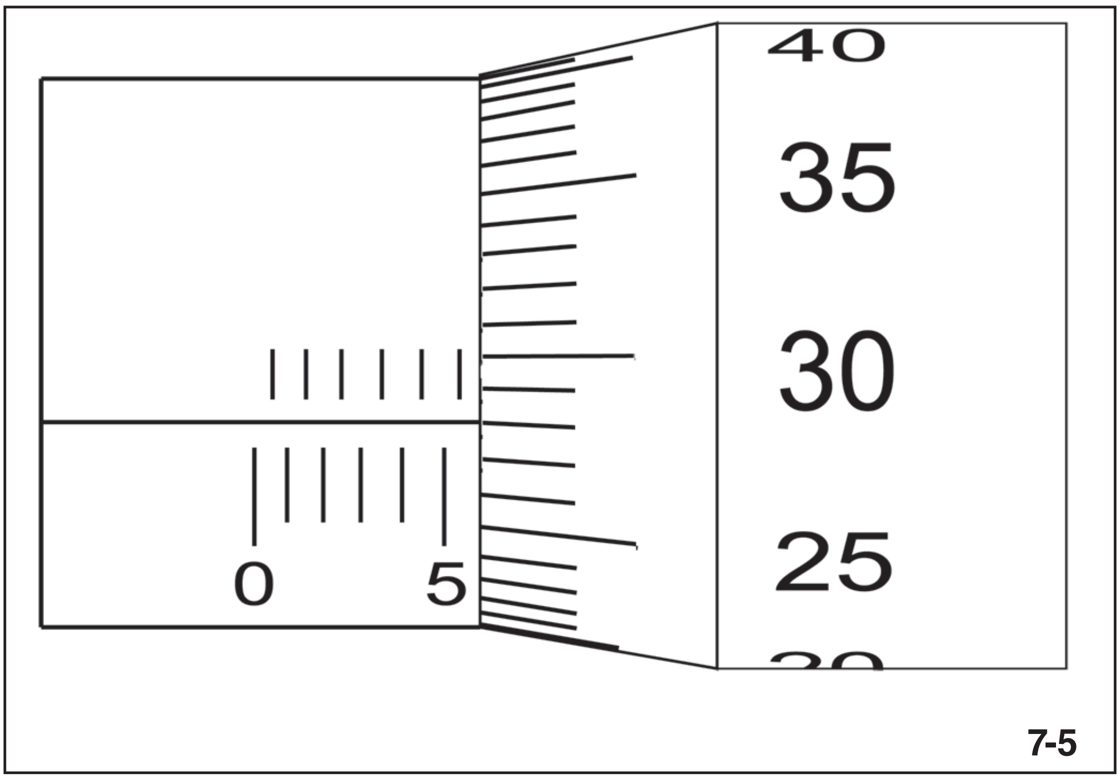


Micrometer Calibration

Before using the micrometer, clean the measuring faces of the anvil and the spindle. Bring the anvils together by turning the ratchet. If the line marked zero on the thimble does not coincide with the reference line on the barrel, follow the manufacturer's instructions on how to adjust it to read zero. Larger diameter micrometers use special calibration rods to calibrate their zero mark because the anvil and spindle cannot physically reach each other.

Reading the Micrometer Scale

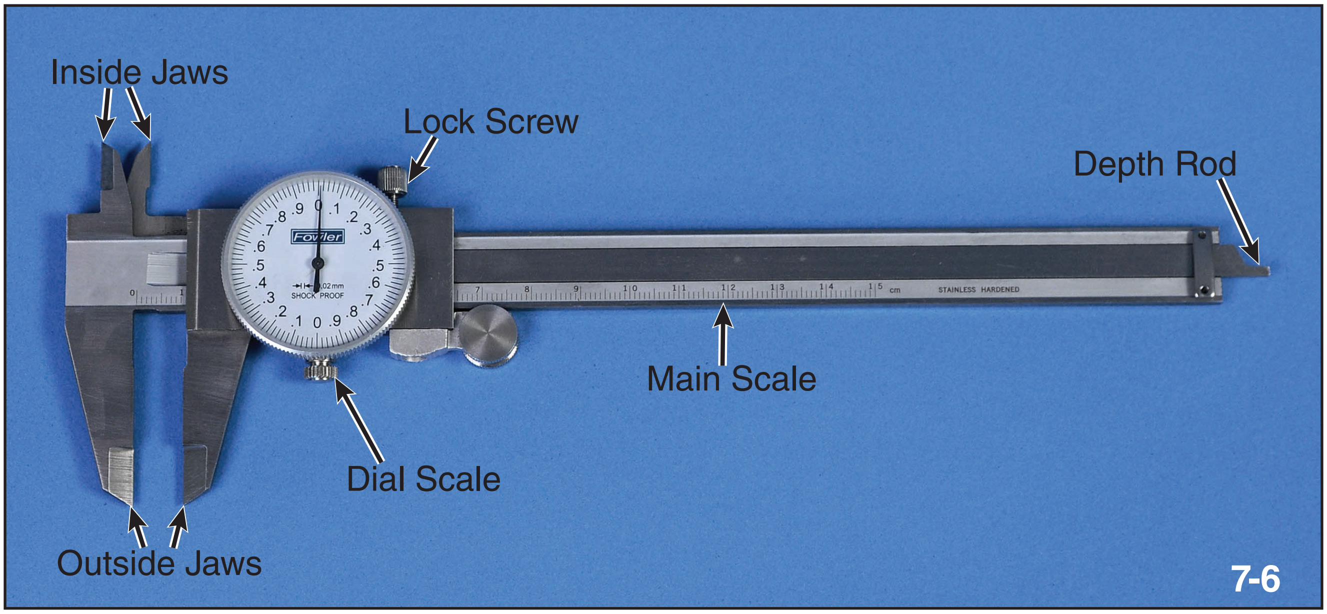
1. Note the largest number visible on the barrel. Each long line equals 1.0 mm.
2. Count the number of graduation lines to the right of the barrel number. Each short line on the barrel equals 0.5 mm.
3. Note the thimble graduation aligned with the horizontal barrel line. Each thimble graduation equals 0.01 mm.
4. Add the decimal values from steps 1, 2, and 3. The sum is the micrometer reading in millimeters. This example shows a reading of 5.78 mm.



Reading a Micrometer

Barrel Number	5	5.0 mm
Barrel Graduation	Half Line	0.5 mm
Thimble Graduation	28	0.28 mm
Total Reading		5.78 mm

Dial Caliper



Dial Caliper Components

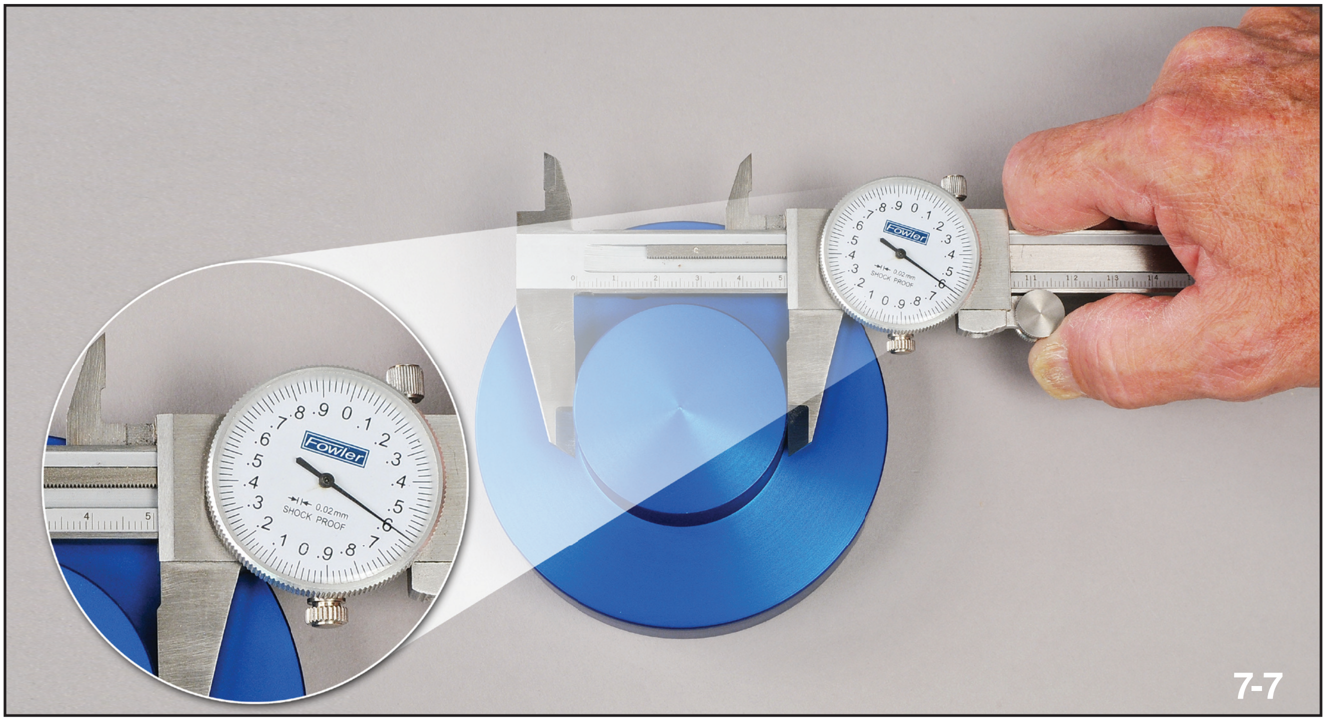
The dial caliper measures items to hundredth of a millimeter (.01 mm).

The dial caliper can measure the internal diameter, external diameter, depth, and height of an item.

Place the item being measured within the outside jaws, inside jaws, or the base of the main scale. The lock screw locks the two pieces of the caliper together so the caliper can be removed from the component for easier reading of the measurement.

A combination of the main scale and the dial scale are used to calculate the measurement

Reading the Dial Caliper Scale - Outside Diameter

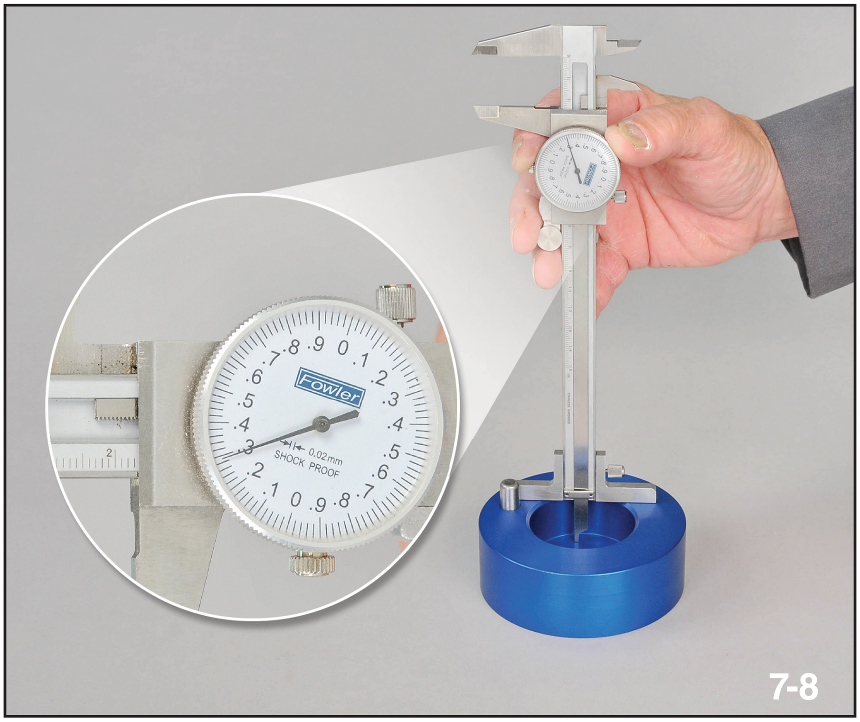


Dial Caliper Scale

1. Read the base measurement in millimeters from the main scale. The reading lines up either directly on or in between a main numbered centimeter marking on the main scale.
2 Read the dial measurement. Each graduation on the dial equals 0.02 mm.
3. Add the decimal values from steps 1 and 2. The sum is the dial caliper reading in millimeters. This example shows a reading of 50.60 mm.

Base Measurement	5.0	50 mm
Dial Scale	.60	.60 mm
Total Reading		50.60 mm

Reading the Dial Caliper Scale - Depth

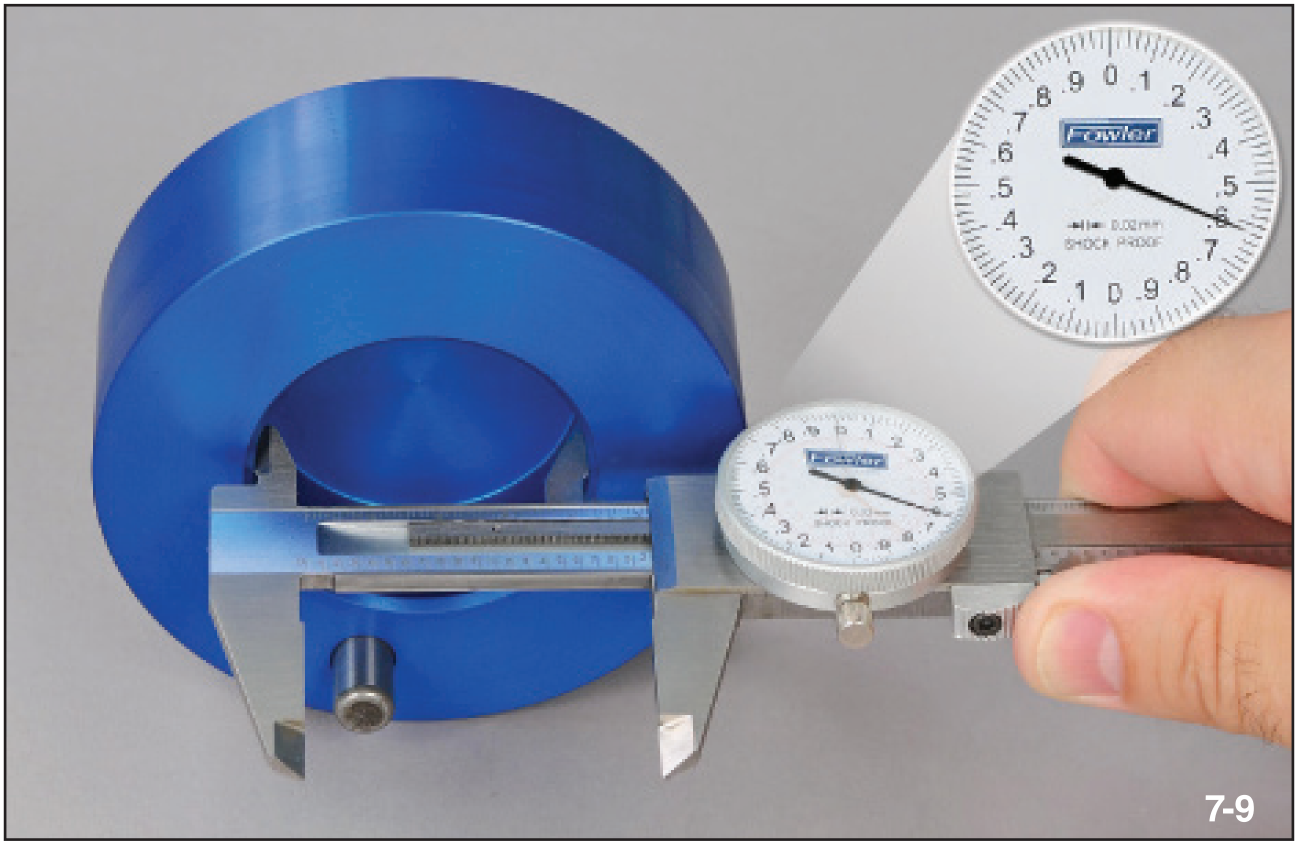


Dial Caliper Measuring Depth

1. Position the caliper squarely over the cavity to be measured.
2. Extend the depth rod to contact the desired surface within the cavity.
3. Read the base measurement in millimeters from the main scale. The reading lines up either directly on or in between a main numbered centimeter marking on the main scale.
4. Read the dial measurement. Each graduation on the dial equals 0.02 mm.
5. Add the decimal values from steps 3 and 4. The sum is the dial caliper reading in millimeters. This example shows a reading of 23.29 mm.

Base Measurement	2.3	23 mm
Dial Scale	.29	.29 mm
Total Reading		23.29 mm

Reading the Dial Caliper Scale - Inside Diameter

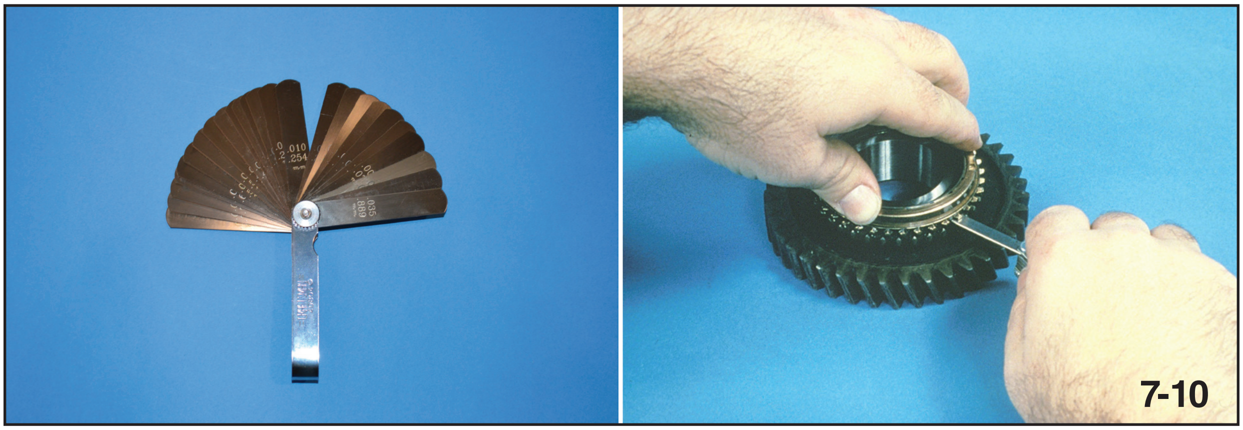


Dial Caliper Measuring Inside Diameter

1. Position the caliper inside jaws squarely into the bore to be measured.
2. Extend the jaws to contact the internal surfaces of the bore at its widest point.
3. Read the base measurement in millimeters from the main scale. The reading lines up either directly on or in between a main numbered centimeter marking on the main scale.
4. Read the dial measurement. Each graduation on the dial equals 0.02 mm.
5. Add the decimal values from steps 3 and 4. The sum is the dial caliper reading in millimeters. This example shows a reading of 50.62 mm.

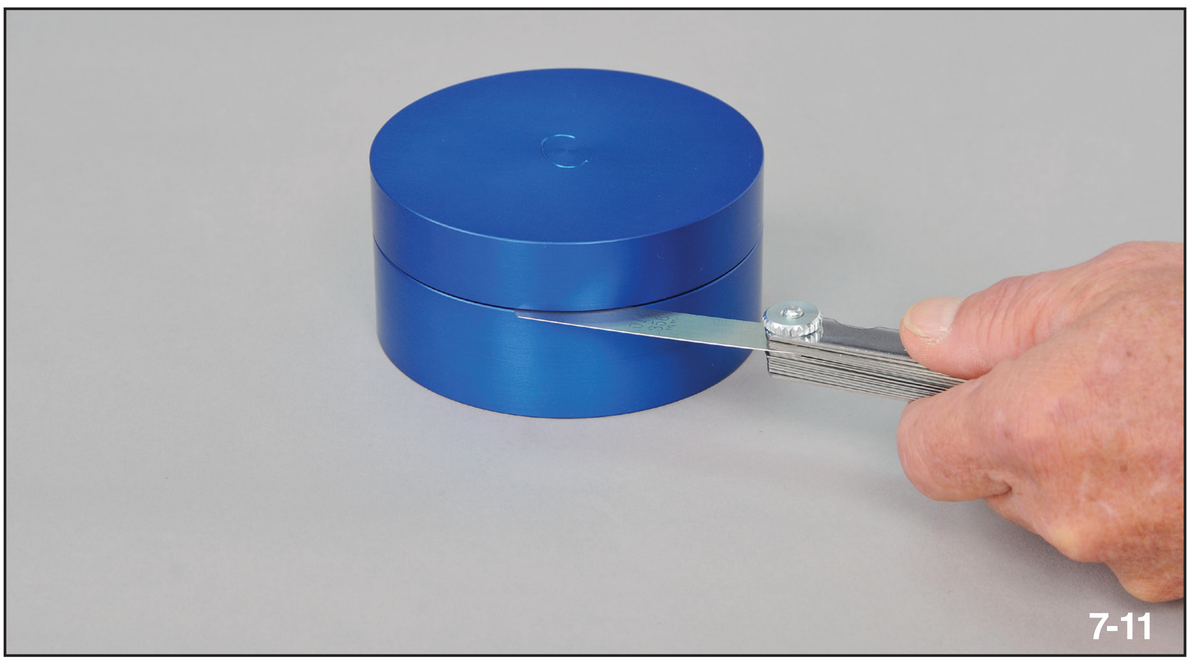
Base Measurement	5.0	50 mm
Dial Scale	.62	.62 mm
Total Reading		50.62 mm

Feeler Gauge



Feeler Gauges

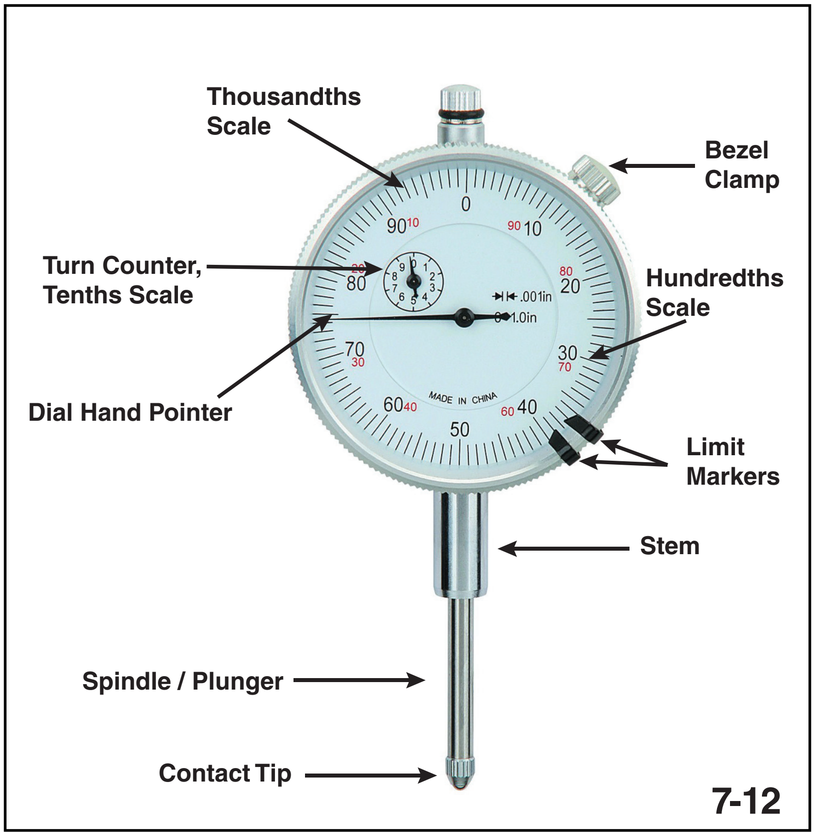
Feeler gauges are precision ground blades of steel or brass. Each gauge set has several different blades. Each blade is a different thickness and marked as such. This precision tool is used to measure the gap or space between two components.



Measuring Clearance with Feeler Gauge

Insert a feeler gauge blade approximately the size of the gap between surfaces. Move the blade in and out of the gap feeling for a smooth drag on the blade. When the correct size blade is determined, make note of the dimension printed on the blade for comparison with specifications.

Dial Indicator



Dial Indicator Components

A dial indicator is a precision tool that measures relative distances in very small increments, down to .001 inch (one thousandth of an inch). It is typically used in a machining process for quantifying precision metal parts. In the automotive industry, the dial indicator is used to measure endplay and backlash in driveline components. In addition, it can be used to measure the disc brake rotor or wheel hub for excessive runout and critical dimensions in an engine.

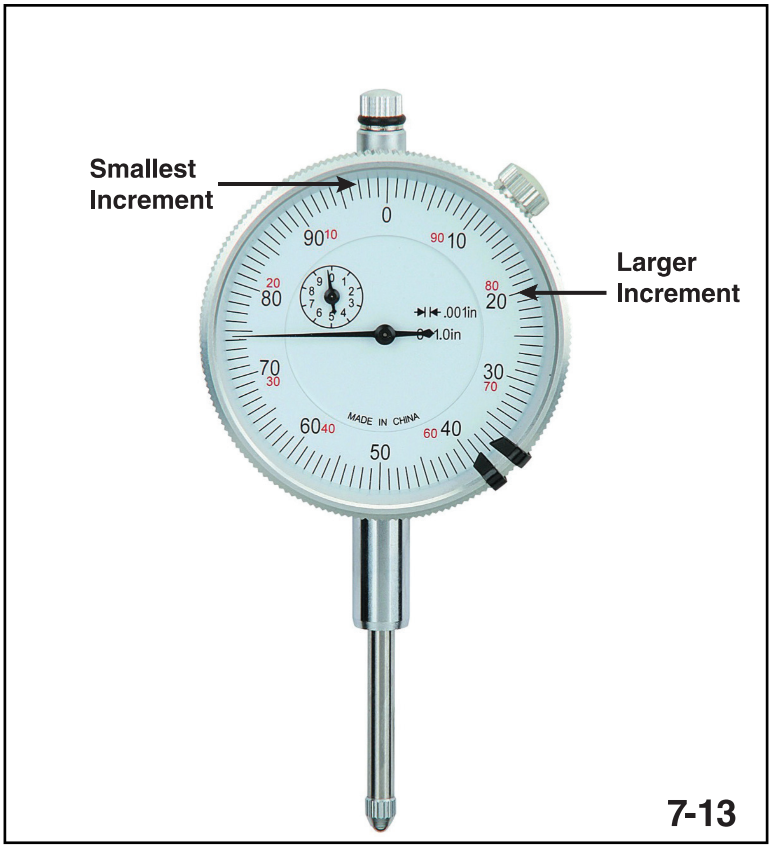
A dial indicator is delicate and must be handled carefully and maintained to ensure its precision and smooth operation. Store dial indicators in a protective case when not in use. Store dial indicators in a dry location; moisture can corrode the internal components and damage the precision movement.

When moving a dial indicator from a cold area to a warm area, allow the dial indicator to acclimate to the ambient temperature.

Keep the dial indicator away from oil, chemicals, and other fluids commonly used in a shop environment. These compounds can damage the internal mechanisms.

Regularly inspect and, if necessary, calibrate the dial indicator.

Reading the Dial Indicator (0–1 inch)



Dial Indicator Increments

The dial indicator has two dials: a large, outside diameter dial and a smaller dial in the center. The larger pointer turns clockwise while the smaller dial turns counterclockwise.

The smaller revolution (or turn counter) dial counts the number of times the larger dial pointer makes one complete revolution.

- On a 0–1 inch dial indicator, one complete revolution of the large pointer is equal to 0.01 in. (one hundredth of an inch).
- Ten turns of the large pointer is equal to 1.0 in.
- One turn of the smaller dial pointer is equal to 1.0 in.
- The smaller dial reads each revolution of the larger dial in increments of 0.01 in. (one hundredth of an inch).

Dial indicators have a bezel that rotates to allow the user to zero the indicator before taking measurements. A bezel lock prevents the bezel from moving.

Most dial indicators have moveable markers that can be used to record the maximum amount of needle travel in each direction.

The dial indicator must be mounted securely. If any movement is detected, the reading will not be accurate. After properly mounting the dial indicator, perform the following steps:

Zero the scale by setting both dials to 0.

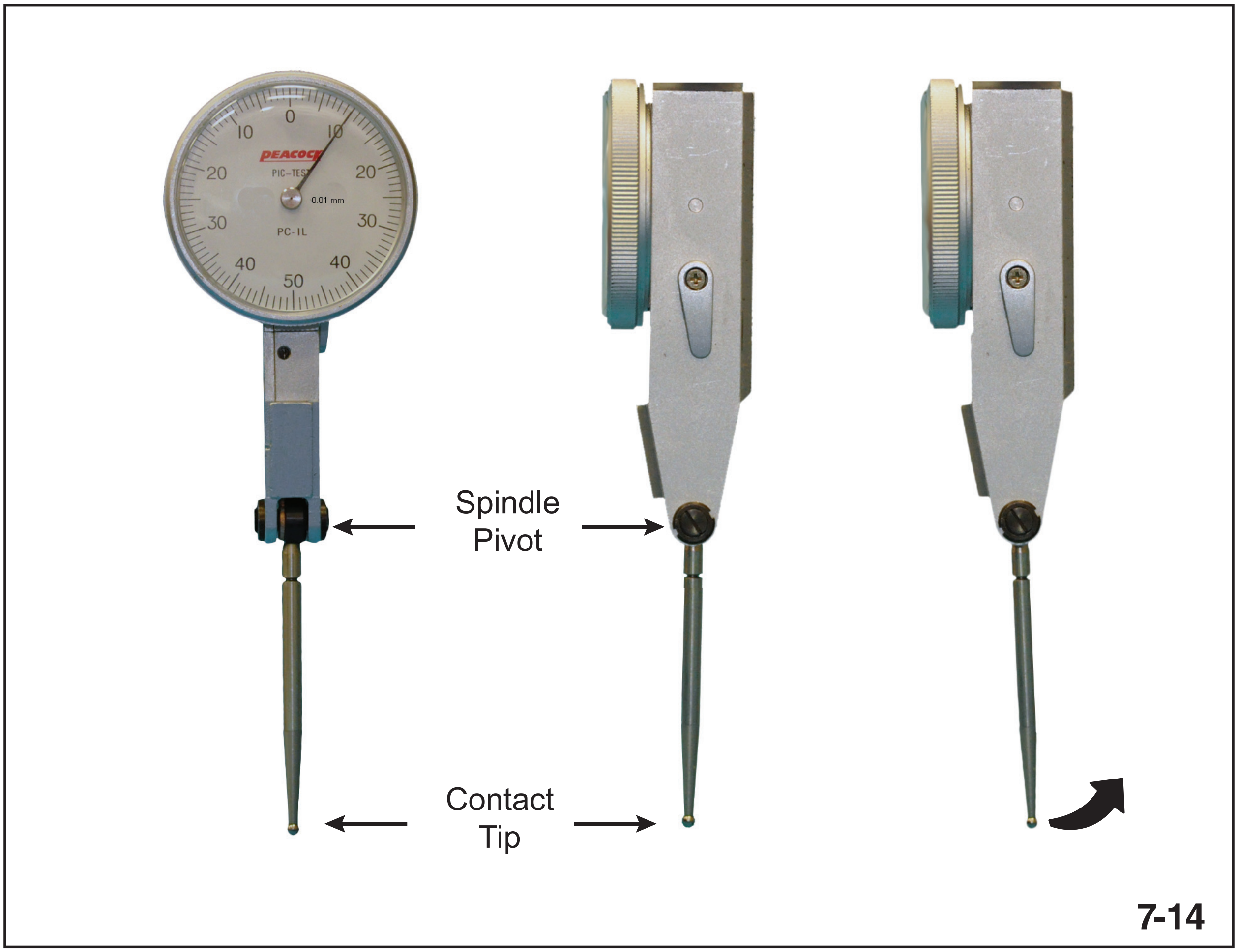
- Observe the large dial face on the indicator. The larger dial numbers are graduated by 10, from 0 through 90. Between each of the large increment numbers are smaller increments that are equal to .001 in. (one thousandth of an inch) each.
- Observe the smaller dial. The increments are equal to 0.100 in. (one tenth of an inch). There are numbers on the small dial face that are broken into 10 separate numbers. The range is 0 to 9, with 9 representing to 0.900 in. (nine tenths of an inch).

1. 18. Adjust the scale to zero by loosening the outer indicator bezel clamp. Rotate the bezel and tighten to adjust the .001 in. measurement ring. By moving the bezel, the calibration range can be zeroed to any position.
2. 19. If the indicator plunger is pressed so the inner smaller dial is at 4 and the larger dial is at 0.010 in., the inch reading is 0.410 in. (four hundred ten thousandths of an inch), which is just under a ½ inch.
3. 20. If the indicator plunger pressure is reduced, so the large dial reads between the 0 and 0.010 in., the reading is 0.405 in. (four hundred five thousandths).
4. 21. If the small dial is placed at the 0.1 in. (one tenth of an inch) increment, and the larger dial is at five increment lines past the 20, the reading indicates 0.125 in. (one hundred twenty-five thousandths) or 1/8 of an inch.

In summary, the first digit of the reading is the small dial reading, the second digit is the large number on the large dial, and the third reading comes from the small increments on the large dial between the numbers.

Each line on the large dial is the smallest increment reading. Each number on the small dial is the largest increment reading.

Lever-type Dial Indicator

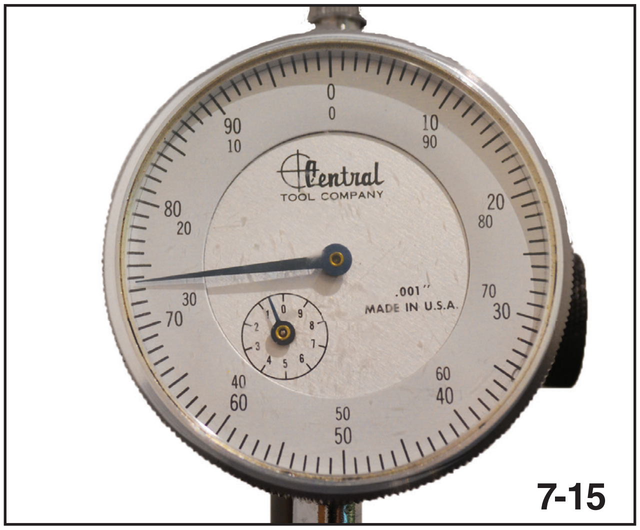


Pic Gauge

The lever-type dial indicator is used to measure backlash in differential units. It is read like all other dial indicators. The lever action of the spindle dectects lateral motion, unlike a standard dial indicator that detects linear motion. The dial face has a single zero point with graduations in both directions. This allows mounting the tool in multiple positions. The pointer rotates only one revolution in either direction.

A miniature bearing is used at the pivot of the contact point tip and provides good indication stability. The contact tip is inserted through the transaxle oil drain hole and contacts a tooth on the ring gear. Movement of the ring gear with the pinion gear held stationary indicates backlash. Always compare the backlash measurment with specifications when servicing a front differential.

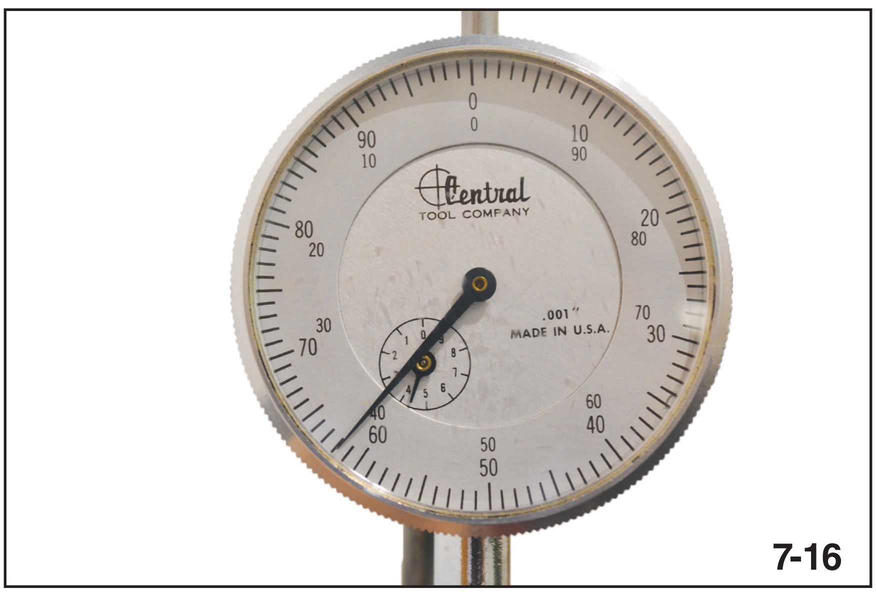
The following are examples of dial indicator readings:



Dial Indicator Reading of 0.074 in.

The dial indicator above is reading 0.074 in. (seventy-four thousandths of an inch).

0.070 + 0.004 (small increments) marks = 0.074 thousandths of an inch.



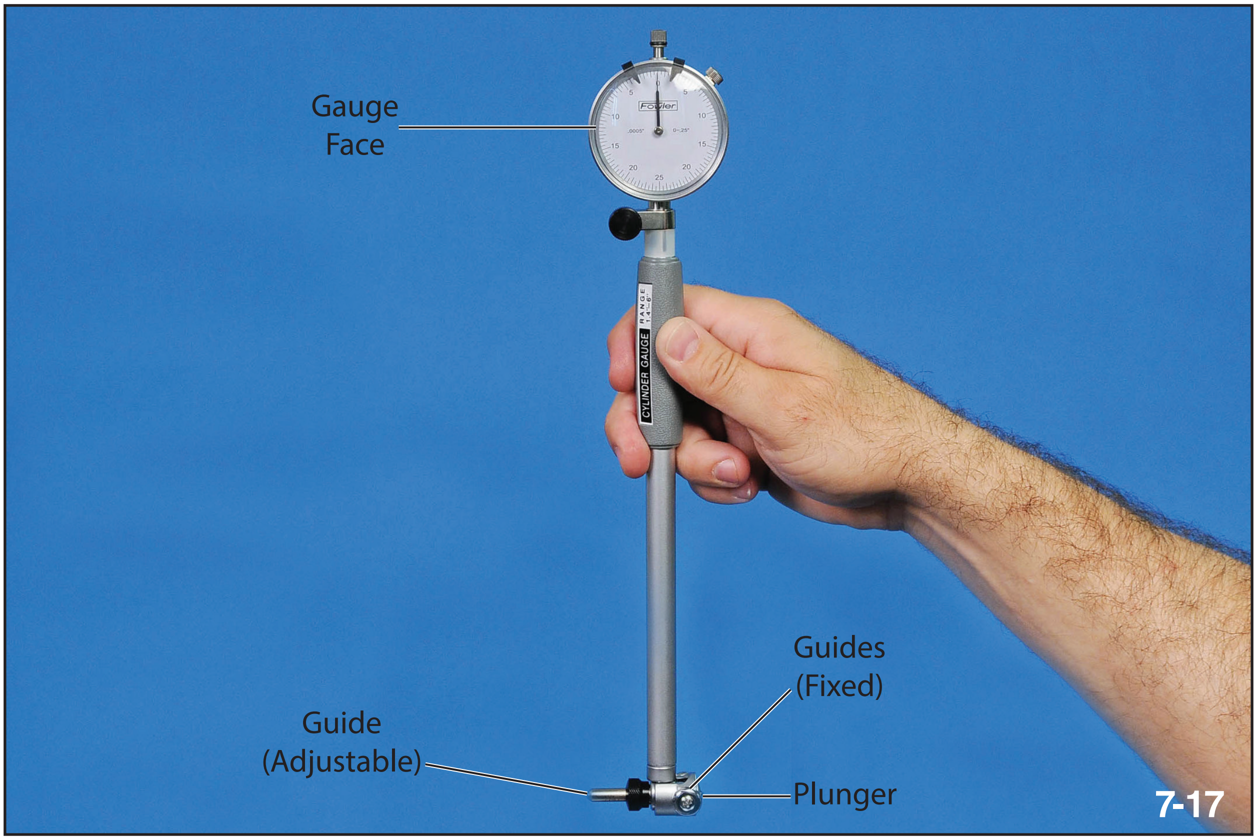
Dial Indicator Reading of 0.462 in.

The dial indicator above is reading 0.462 in. (four hundred sixty-two thousandths of an inch).

0.400 + 0.062 (small increments) marks = 0.462 thousandths of an inch.

The Dial Bore Gauge

Components



Dial Bore Gauge Components

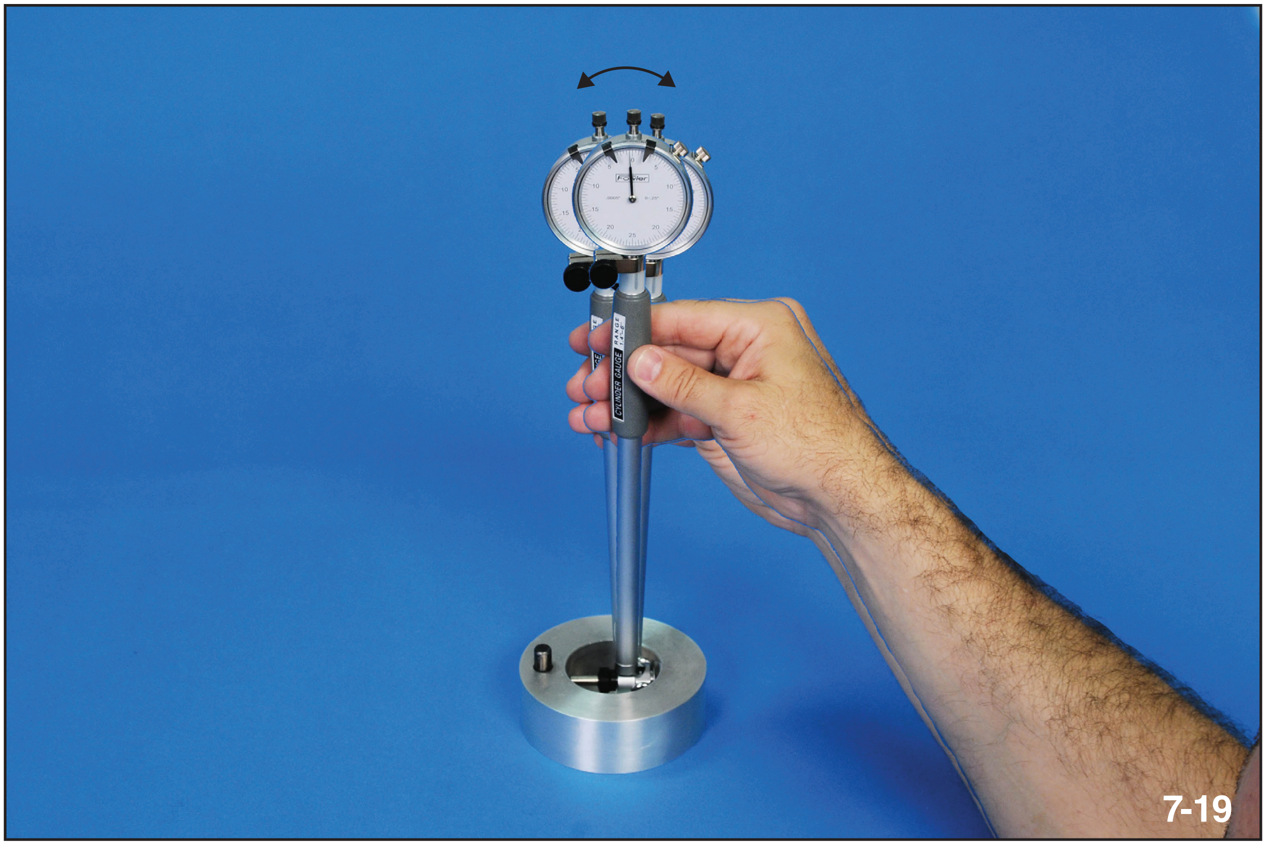
The dial bore gauge is a measuring instrument used to check cylinders for a difference in dimension. These differences are known as taper and out-of-round. Dial bore gauges include a shaft with a dial indicator at the top and a measuring sled at the base. The measuring sled consists of four components: two fixed guides, one adjustable guide, and an actuating plunger.

How to Set up a Dial Bore Gauge

Dial Bore Gauge Set-up

Use STIS to determine the bore size specification is for the engine you are measuring. Set a micrometer to the cylinder bore specification. Select the bore gauge guide that allows you to insert the gauge into the micrometer between the anvil and spindle. Adjust the bore gauge guide until it contacts the surfaces of the micrometer. Finally, align the dial needle with the zero mark on the face.

Measuring with the Dial Bore Gauge



Measuring the Cylinder

Insert the gauge into the bore at the first depth indicated. Rock it back and forth until it is properly inserted in the cylinder. You will know it is level when the needle achieves its highest reading on the dial face.

When measuring the bore, your readings should be at zero or on the minus side of zero if the bore is within specification. Readings above zero indicate wear and must be compared to specifications to determine the course of action.

Record your measurement and measure all the other points in the cylinder vertically, then turn the dial bore gauge 90 degrees and repeat the four measurements at the specified points within the cylinder.

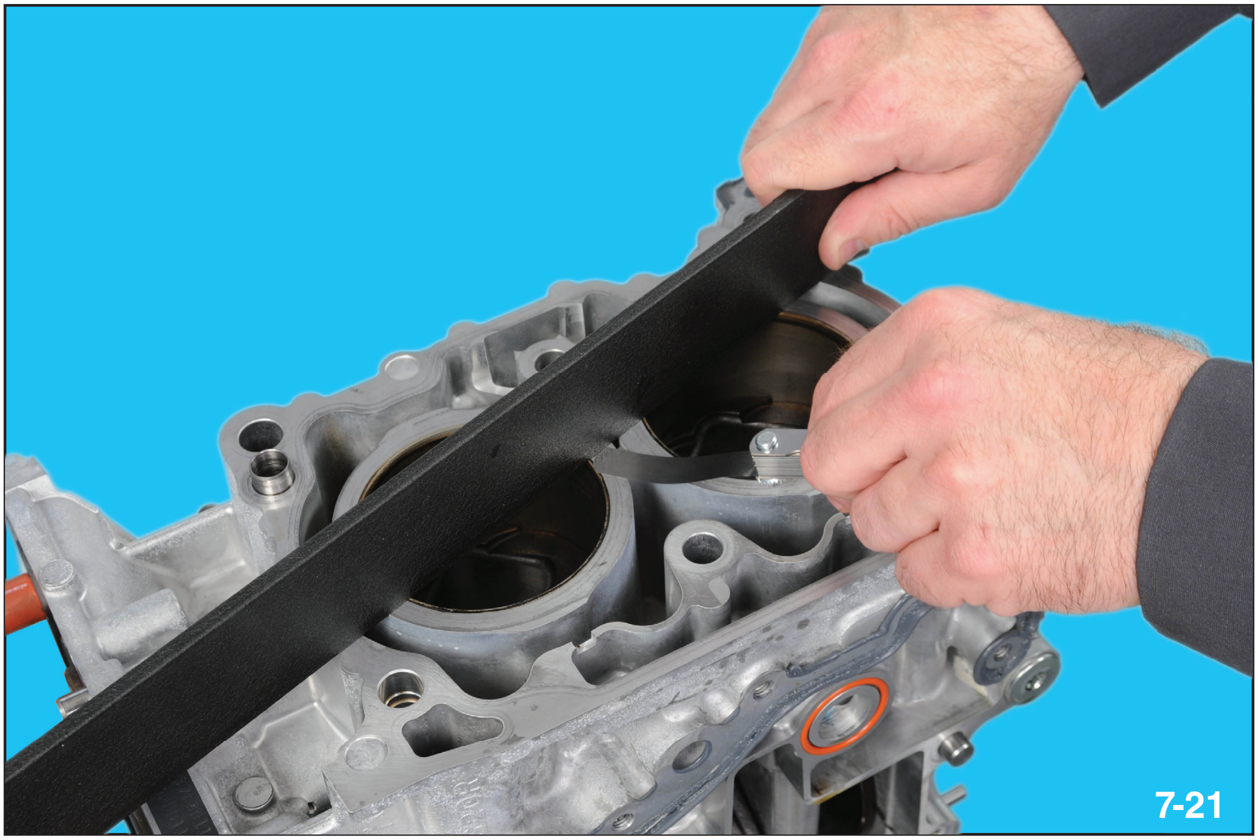
Use the measurements to calculate cylinder taper and out-of-round.

Straight Edge

Straight Edge

The straight edge is a bar of high carbon steel that has one or more precision ground edges. A straight edge is used to check mating surfaces for flatness. Always store the straight edge in its box when not in use. Be careful not to drop a straight edge or nick its precision surfaces.

Deck Flatness



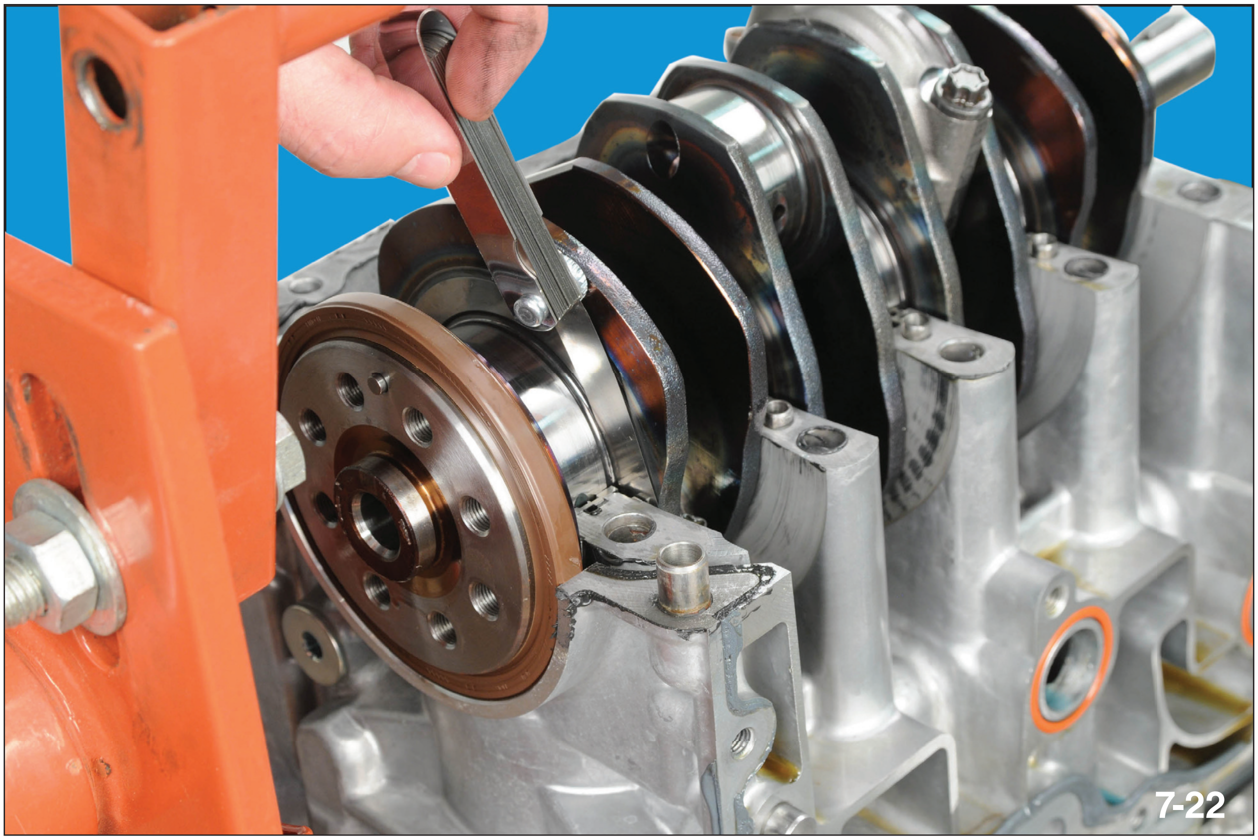
Checking Deck Flatness

The area of the engine block where the cylinder head meets the block is called the deck; this area needs to be flat because it will be mated with the flat surface of the cylinder head. First clean the surface being measured to remove any residual gasket material. To check the deck for flatness, use a straight edge and feeler gauge. Lay the straightedge across the block lengthwise. Hold the straight edge perpendicular to the surface, and use the feeler gauge to determine the amount of deck flatness variation. Check along the areas shown in STIS for flatness variation. If the measurements determine there is excessive flatness variation, the block may have to be resurfaced or replaced if material removal will put it past its service limit.

Some of the effects of a cylinder deck that is not flat are:

- Head gasket leaks, internal and external
- Oil or coolant loss

Crankshaft Thrust Clearance



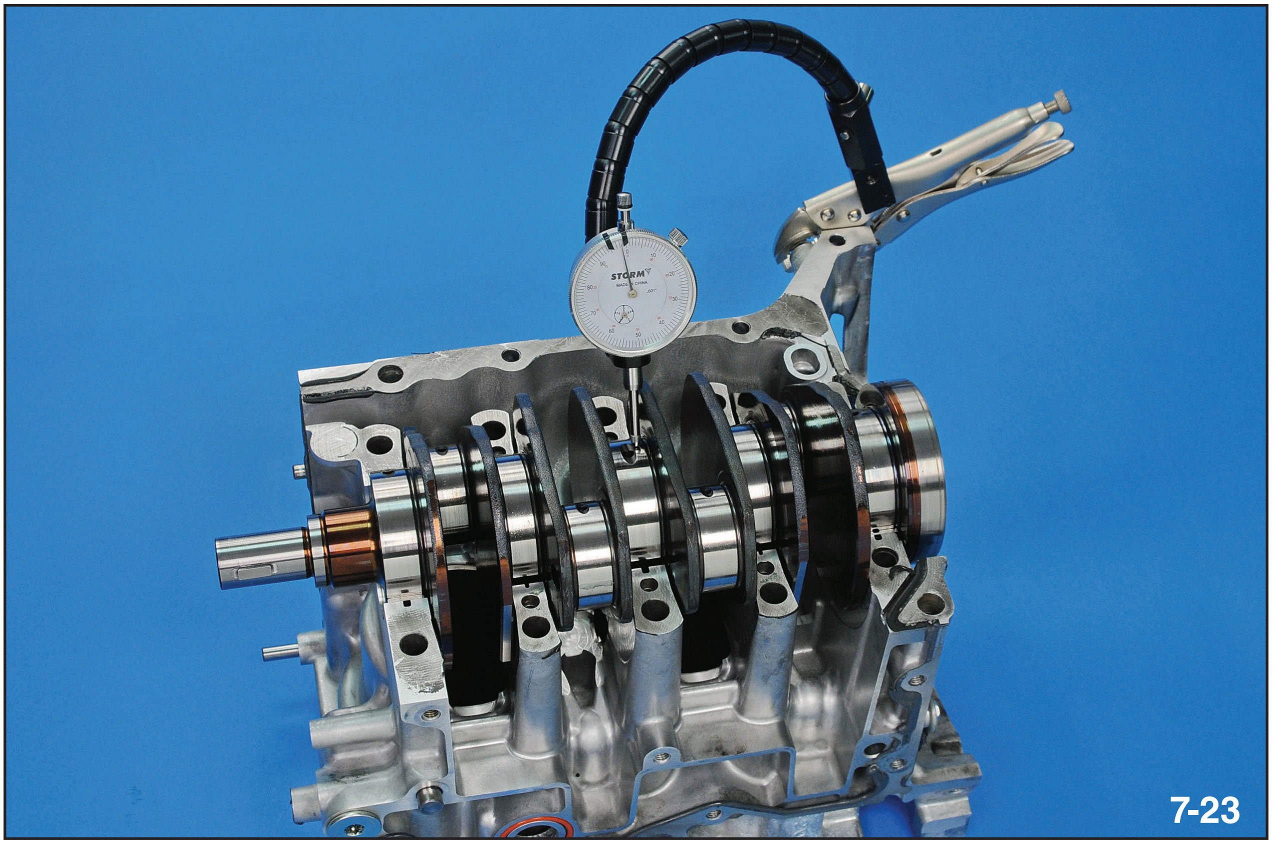
Checking Crankshaft Thrust Clearance

The thrust bearing incorporates two lateral bearing surfaces that maintain the crankshaft's position within the cylinder block.

To measure the crankshaft thrust bearing clearance:

1. Place the crankshaft in the block half.
2. Slide the crankshaft to the most forward position.
3. Use a feeler gauge to measure the clearance between the crankshaft and the thrust bearing surface.

Crankshaft Bend



Checking for Crankshaft Bend

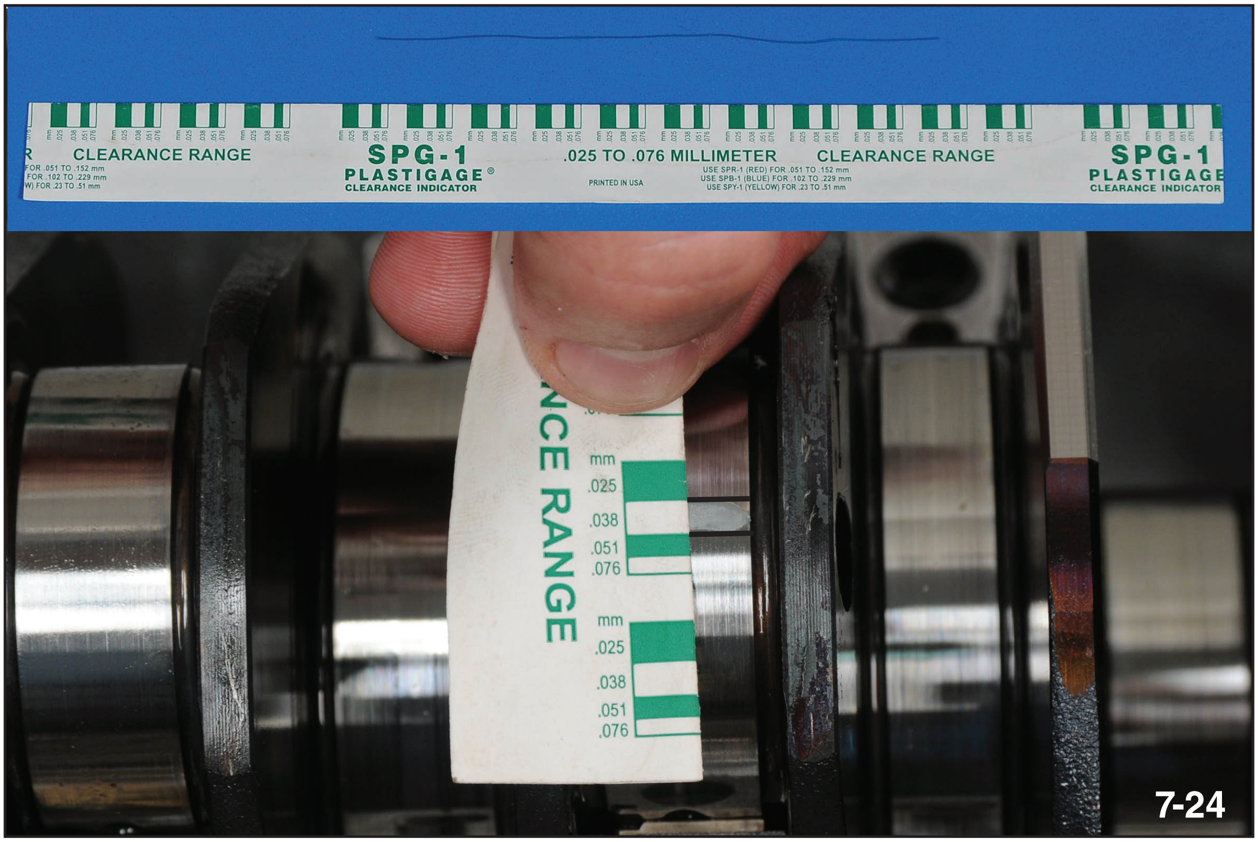
A bent crankshaft can cause a binding condition, premature crankshaft bearing wear, and oil pressure problems. Upon engine disassembly inspect the crankshaft bearings for uneven wear; this is an indication that the crankshaft may be bent, always verify by measuring for crankshaft bend.

To check for crankshaft bend:

1. Place the crankshaft in one half of the cylinder block or on V-blocks.
2. Use a dial indicator and an adapter, set the indicator tip on each main journal one at a time.
3. Rotate the crankshaft slowly and monitor the dial indicator needle, record the maximum and minimum readings.
4. The difference between the maximum and minimum readings should not exceed the specification.

Crankshaft Oil Clearance

Use of Plastigauge



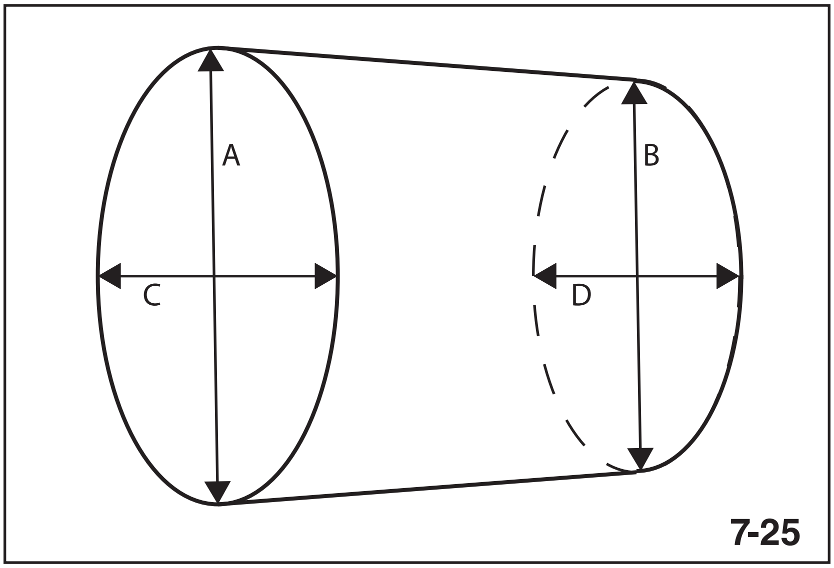
Plastigauge

A product called Plastigauge is used when checking main and rod bearing oil clearance. Plastigauge is a round or square strand of plastic that comes in certain sizes. A small piece of Plastigauge is placed between the crankshaft main or rod journal and the main bearing or rod bearing cap. The caps are then tightened to specification and then removed. When removed, the Plastigauge has flattened and is now wider than the original piece, the wider the compressed gauge material the narrower the bearing oil clearance. The Plastigauge is then compared to the widths on the wrapper, indicating the clearance between the two components.

- Do not rotate parts until the measurement is taken.
- Compare Plastigauge results to specifications.
- Do not scrape off Plastigauge with sharp tools.
- Remove all traces of Plastigauge.

Crankshaft

Journal Diameter



Crankshaft Journal Diameter Measurements

A vs. B = Vertical Taper

C vs. D = Horizontal Taper

A vs. C = Out-of-round

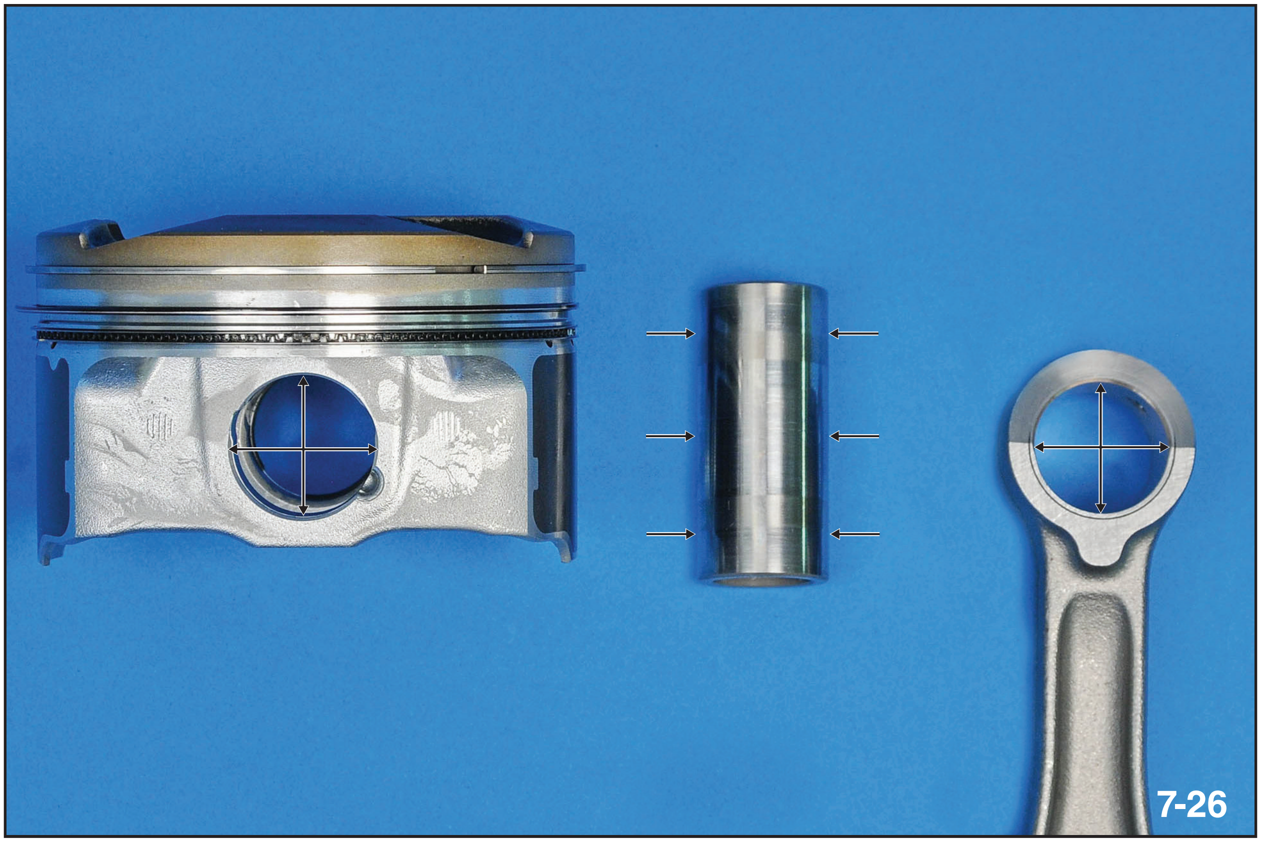
B vs. D = Out-of-round

Crankshaft main and rod journals need to be inspected for proper diameter, taper, and out-of-round measurements. Use a micrometer to check all of these points. These measurements will help determine if the crankshaft is good, needs to be machined, or needs replacement.

Effects of journals being out-of-specification:

- Rod knock
- Oil pressure loss
- Bearing wear

Piston Pin



Piston Pin Measurement

The piston pin to piston pin bushing clearance is very important because an out of specification piston pin could cause oil pressure loss or engine noises.

Measure the piston pin at two places 90 degrees from each other. Take measurements at each end and at the center of the pin. The smallest measurement should be used to determine if the pin and bushing clearance are within specification.

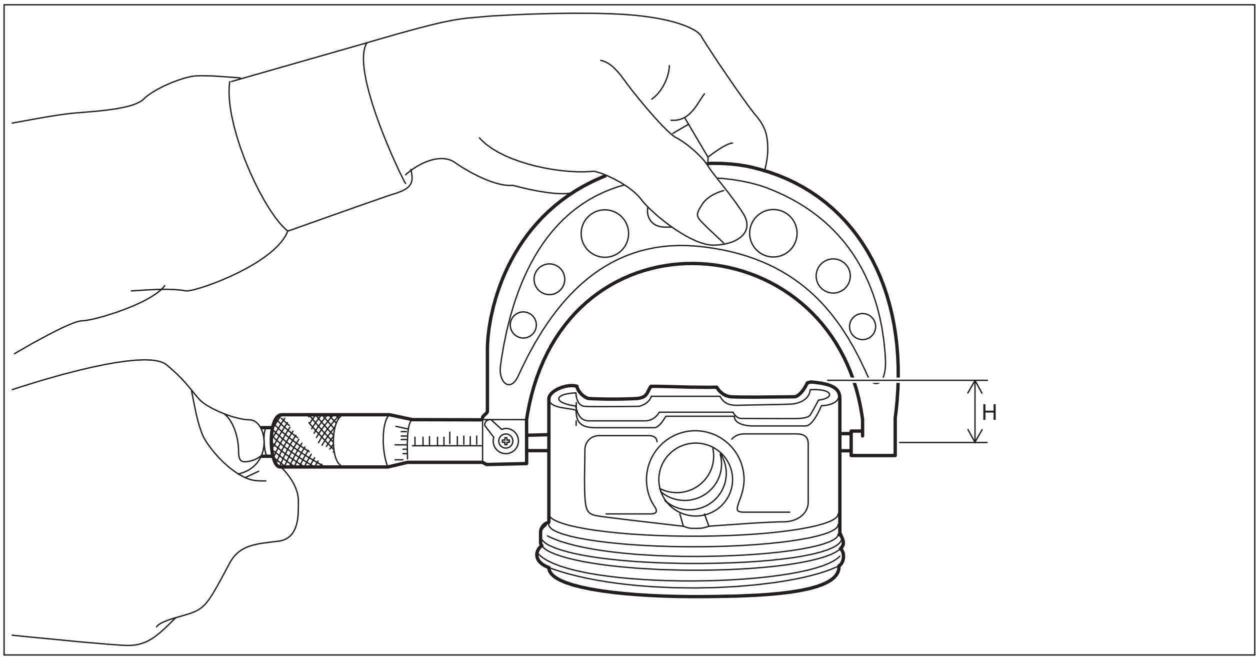
If the clearance between piston pin and connecting rod bushing is not within specification, replace the connecting rod bushing and piston pin as a set.

Effects of out-of-spec measurements:

- Rod knock
- Oil pressure loss
- Bearing wear

Piston

Diameter



7-27

Checking Piston Diameter

The piston diameter should be checked for out-of-round and size using a micrometer. Measurements are taken in the thrust direction and the piston pin direction at a specific distance from the bottom of the piston skirt. These measurements are then calculated to determine piston out-of-round and size. Here are some of the effects that an out of specification piston could create:

- Piston slap
- Loss of compression
- Binding
- Oil consumption

Ring End Gap

Checking Piston Ring End Gap

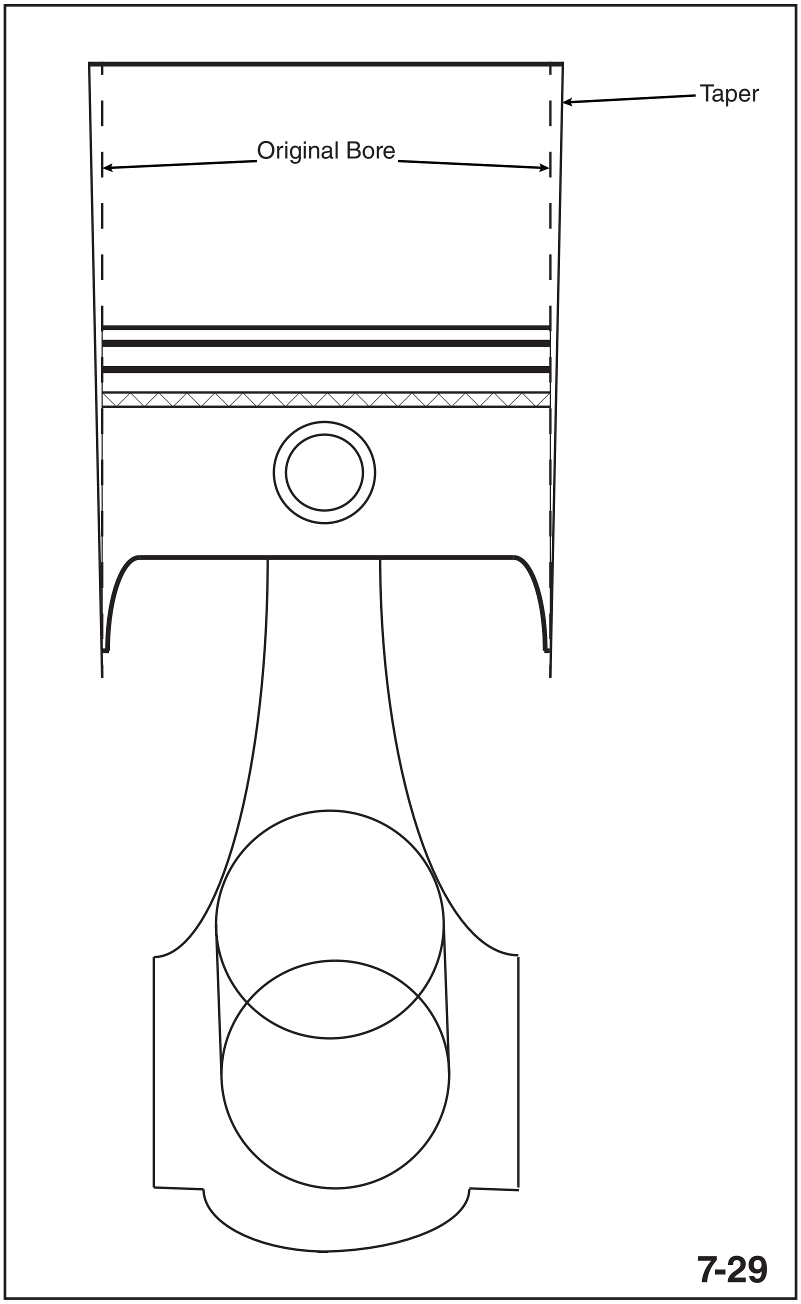
Worn piston rings can cause concerns like excessive oil consumption and low cylinder compression. It is important to inspect each ring for breaks, cracks, and excessive wear. Always verify piston ring end gap, because it is a good indicator of piston ring wear.

To perform this inspection insert the piston ring into the cylinder liner; use a piston without the rings installed as a guide so that the ring is perpendicular to the cylinder wall. Check the piston ring gap using a thickness gauge. If the measurement is greater than specification, replace the piston ring. If the measurement is less than specification, the ring ends touch, or overlap; the ring should be cut or ground to proper size. Repeat this procedure for each piston ring.

Cylinder Bore

To evaluate the cylinder condition, use a bore gauge to determine taper and out of round.

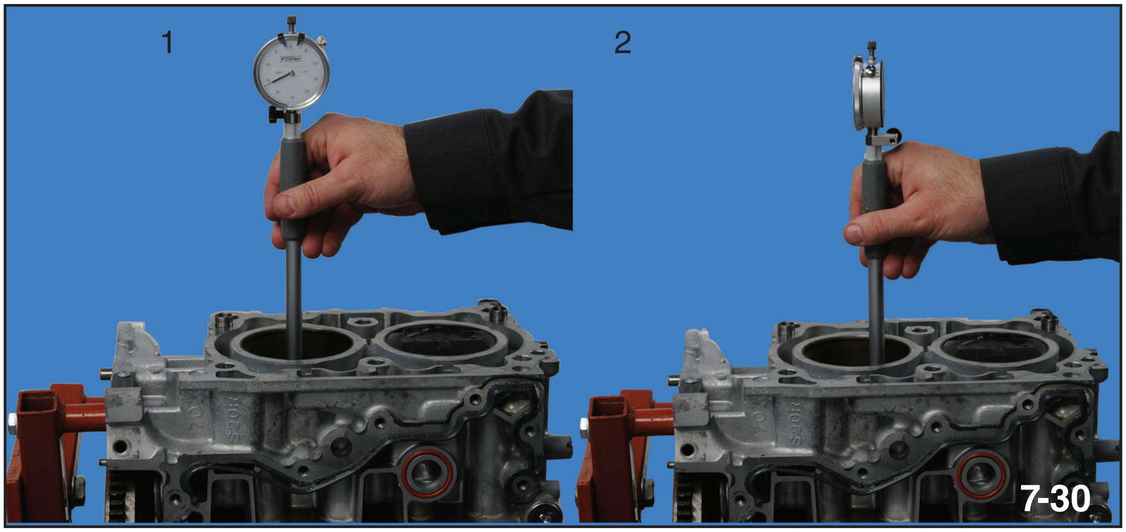
Cylinder Taper



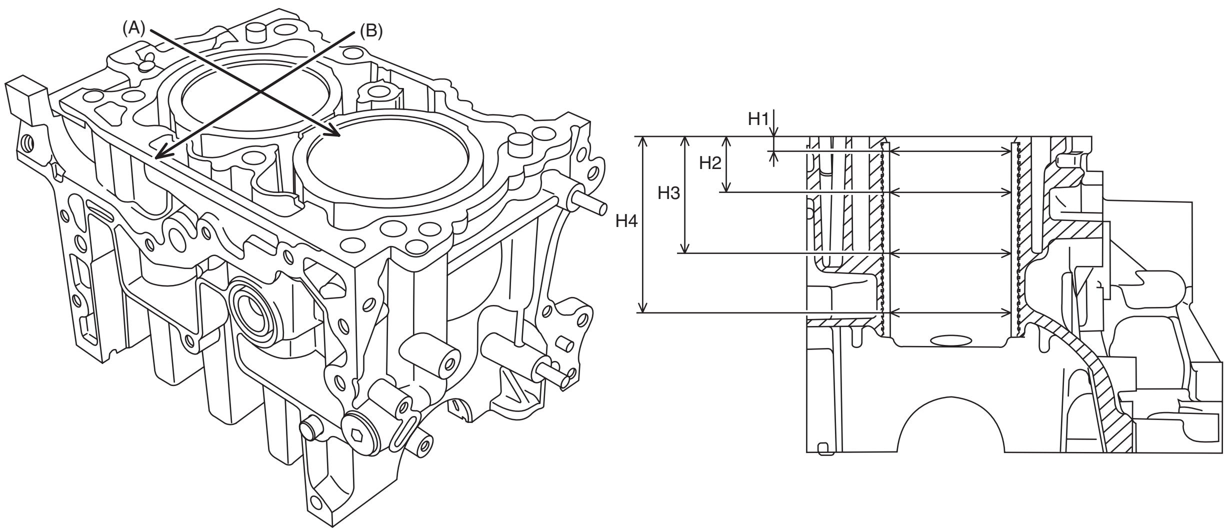
Cylinder Taper

Taper may occur over time as the friction or tension of the piston rings wear on the cylinder walls. This causes the area where the piston rings travel to wear more than in other areas of the cylinder.

Out-of-round



Checking Cylinder Out-of-round with Bore Gauge



(A)	Thrust direction	(B)	Piston pin direction
H1:	10 mm (0.3937 in)	H2:	45 mm (1.7717 in)
H3:	80 mm (3.1496 in)	H4:	115 mm (4.5276 in)

7-31

Bore Measurement Depths

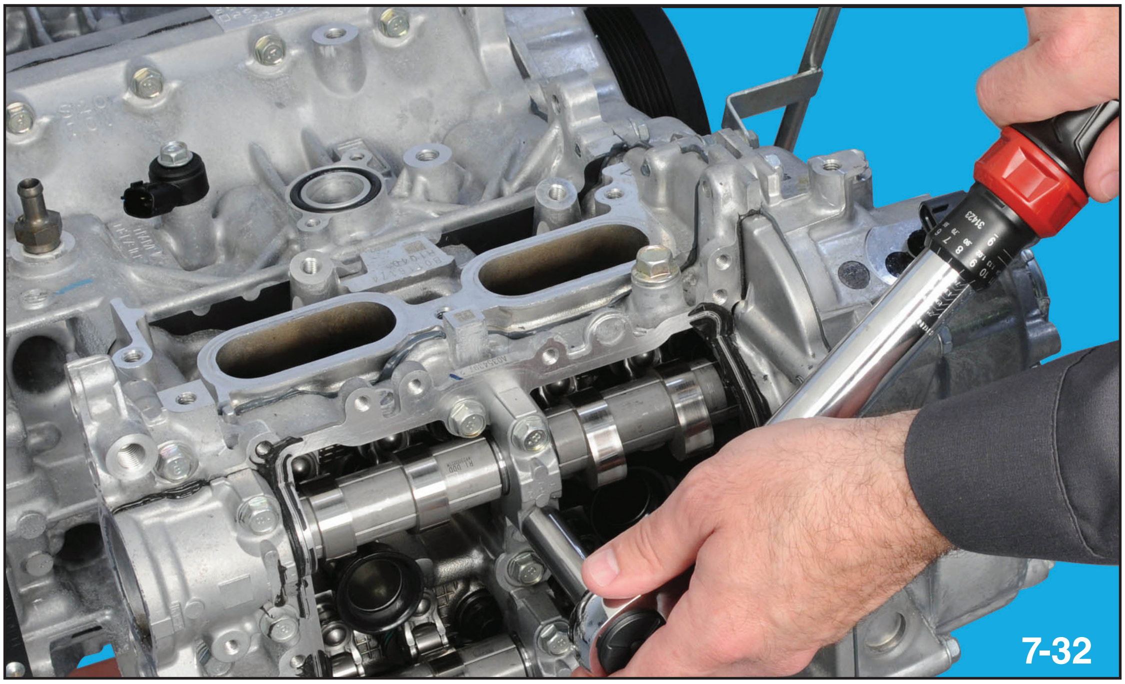
During the block inspection, cylinders need to be measured for out-of-round. This is the difference of the cylinder's diameter as viewed from the top of the cylinder measured in two locations 90° apart from each other. Measurements are taken at four different depths within the cylinder. These measurements are then compared to specification and cylinder out-of-round can be calculated.

Effects of Cylinder Taper and Out-of-round

An engine with cylinders that are tapered or out-of-round can experience concerns like; oil consumption, low compression, power loss, or noises like piston slap.

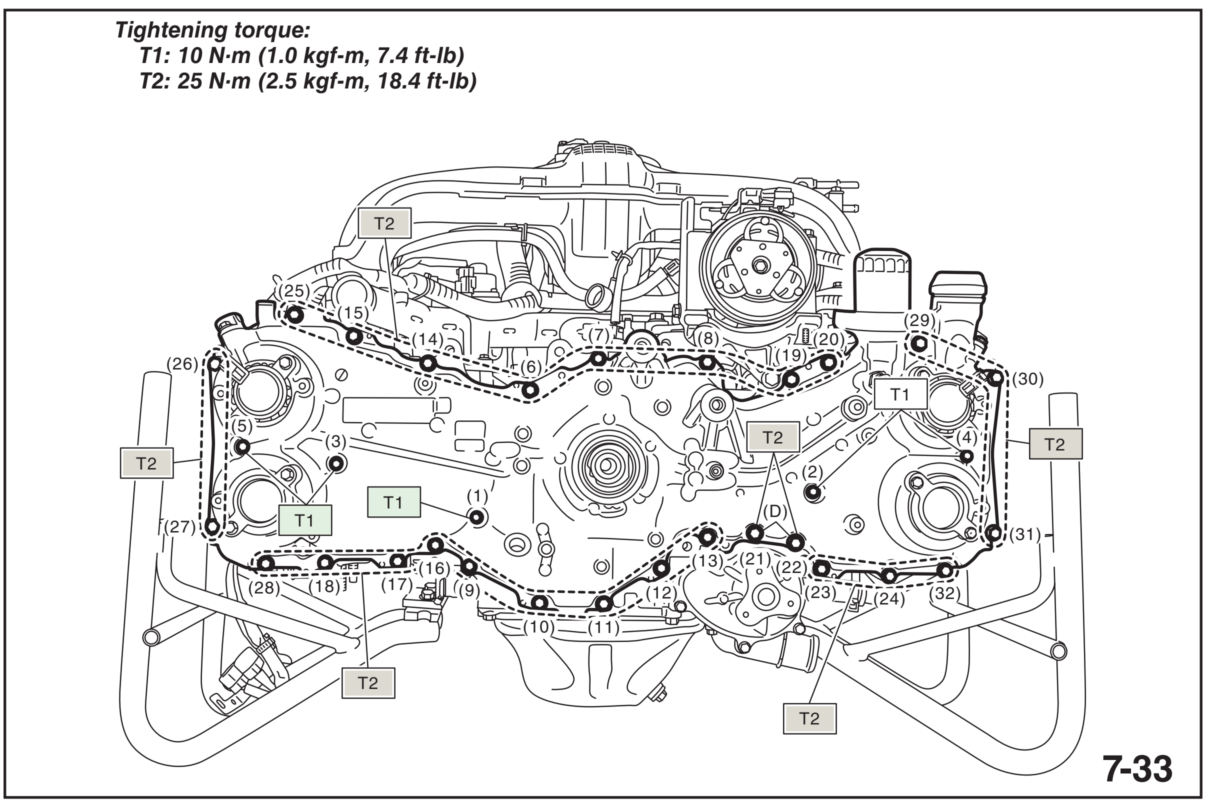
Torque

Torque Measurement



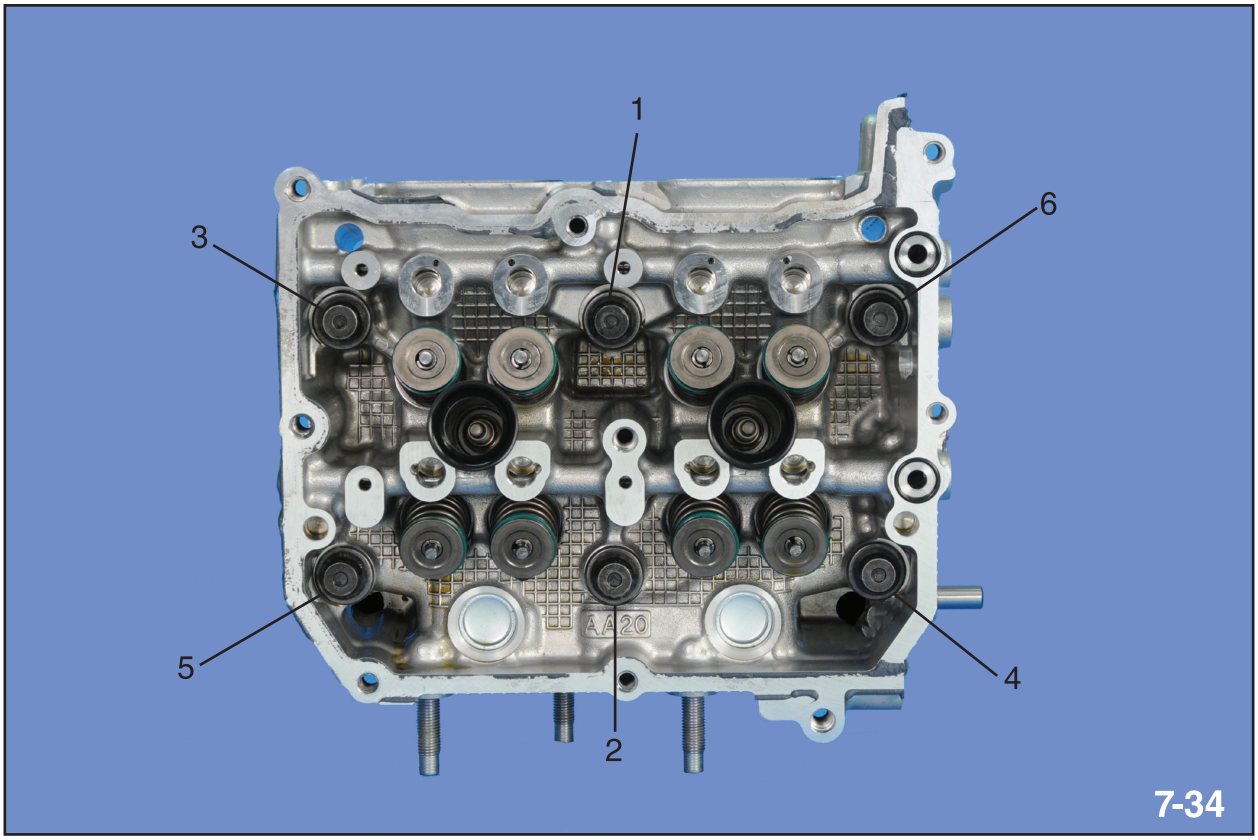
Torque Wrench Use

Precision components require proper clamping force. Always properly torque fasteners per the requirements listed in STIS.



Tightening Torque

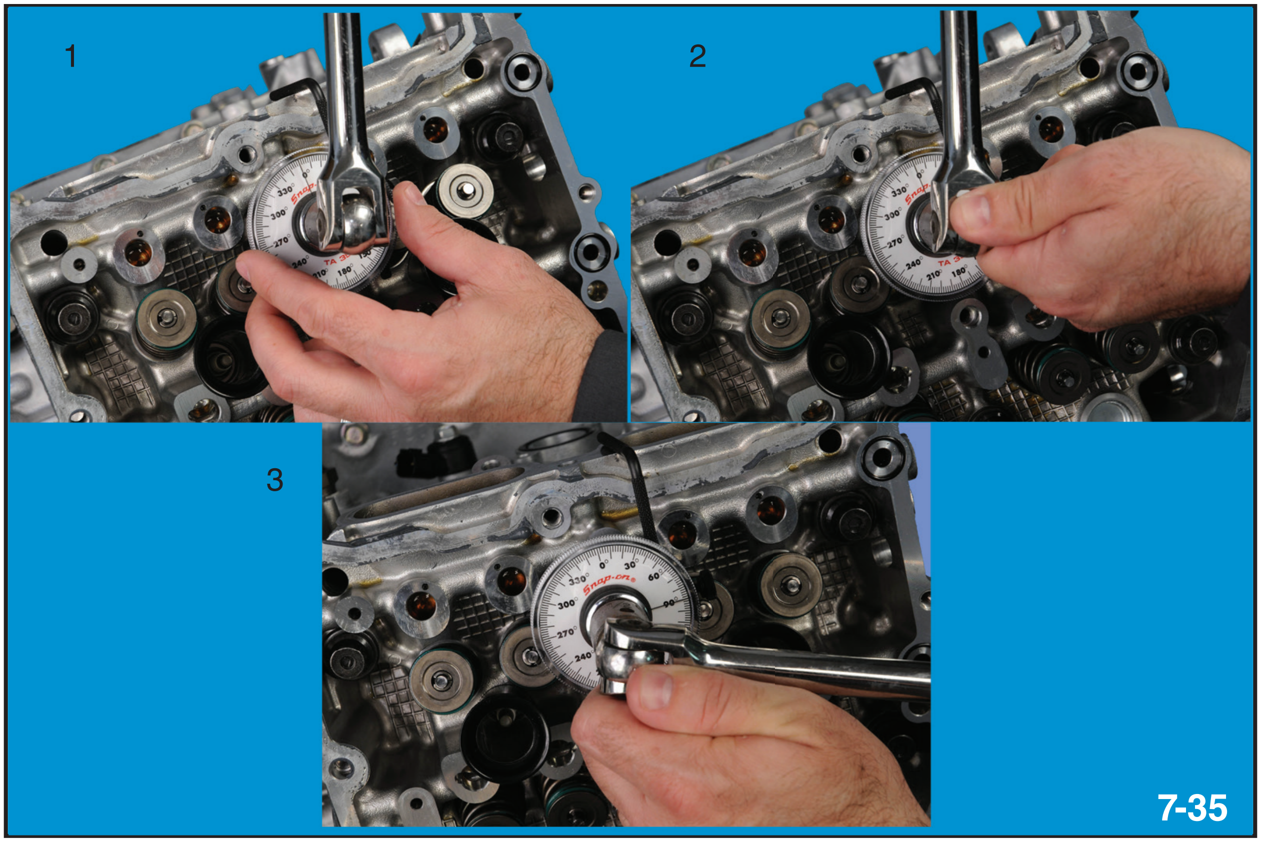
Torque Sequence



Typical Torque Sequence

When sealing components, it is critical to follow the torque sequence procedure in STIS for that component. The sealant, along with the proper torque and tightening sequence, are what provide the best results. Similar to tightening a wheel, torque sequencing evenly distributes the clamping force between the two component pieces.

Using a Torque Angle Gauge



Torque Angle Gauge Use

Use a torque wrench to apply the initial torque to the fasteners and then remove the torque wrench and install the angle gauge onto the socket. Attach the holding component of the gauge face to a solid part of the engine. Use a regular ratchet or breaker bar to apply the desired angle to the fastener. The torque plus angle method of tightening ensures a more accurate torque application and helps reduce fastener “jump” when tightening fasteners to high specifications.

NOTES:

Sealing

Gaskets

Gaskets are used to keep liquids or gases from escaping between two parts that are bolted together. Gaskets can also serve as spacers or vibration dampeners.

There are four different types of gaskets:

- Hard Gaskets
  - Typically made of steel, stainless steel, or copper
    - Head, exhaust or intake gaskets can be made of a metal casing surrounding a heat resistant compressible compound.
- Soft Gaskets
  - Typically made of cork, rubber, or a combination of both compounds
  - These type of gaskets may also be reinforced with a metal layer in-between the two soft gaskets.
- Silicone Gasket Sealant (hardening type)
  - Typically used in conjunction with a soft or hard gasket
    - Used to seal intersecting corners or uneven surface areas.
- Liquid Sealants and Adhesive Gaskets (non-hardening type)
  - Typically used with all metal gaskets
    - Creates a flexible non-hardening seal that prevents water, oil, gasoline, air pressure, or vacuum from leaking.

Head Gasket

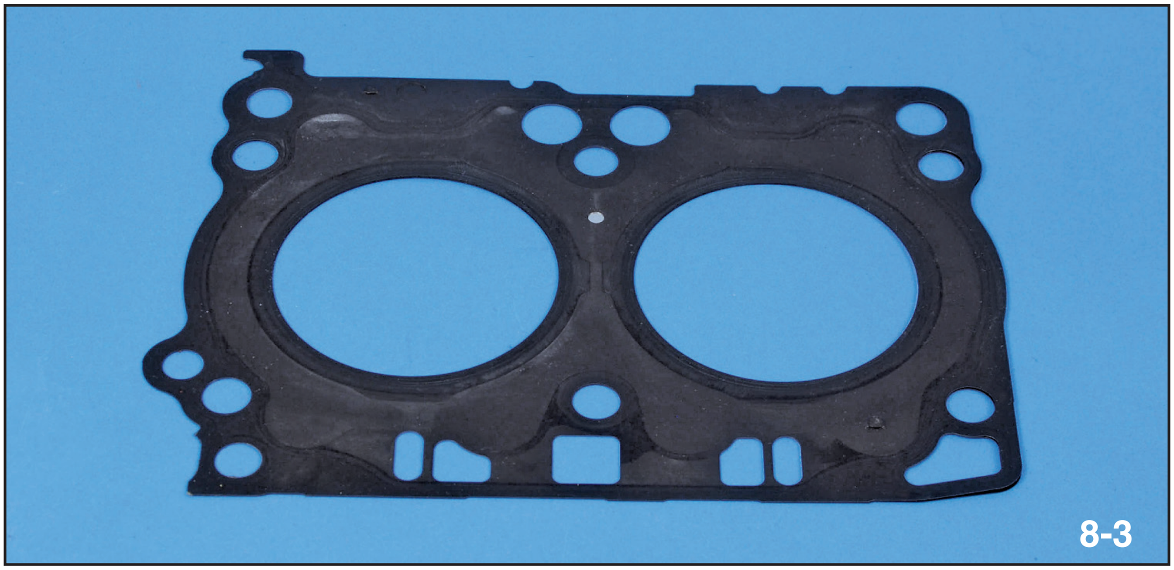
The head gasket is a multi-compound gasket as it must be able to withstand engine vacuum and combustion pressures as well as high combustion temperatures. It must also prevent coolant or oil leakage internal or external to the engine. The head gasket also needs to allow for movement between the surfaces of the cylinder head and the block as the engine temperature changes. It must also remain flexible enough to seal any small surface imperfections.

Composite Type

Typical Composite Type Head Gasket

The composite head gasket is a compressible, flat gasket consisting of a metal carrier sheet, onto which the composite material is rolled on both sides. Metal rings complete the seal at the combustion chamber and protect the composite material from overheating damage. The composite material surface contains additives that prevent the gasket from swelling when coming into contact with oil, water, or antifreeze. Elastomeric materials permit a partial increase of mounting surface pressure in specific areas such as oil pressure channels.

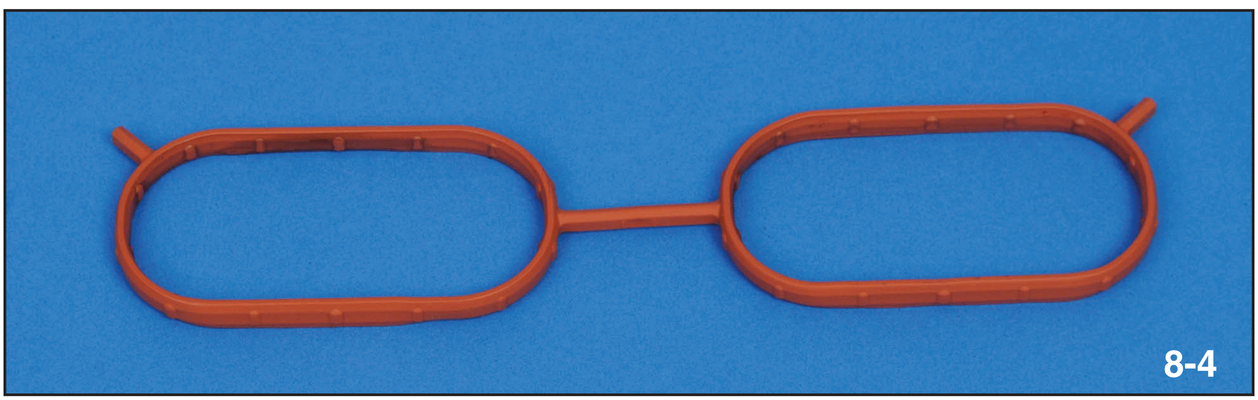
Multilayer Type



Typical Multilayer Head Gasket

The multilayer (MLS) type head gasket can consist of two to five layers of spring or carbon steel, sandwiched between sealing materials. The MLS type gasket is used for its improved sealing properties of gases and liquids. Beads around combustion chambers and oil/coolant passages increase the local sealing pressure while full-surface or partial coatings provide additional sealing tightness.

Intake Manifold Gaskets



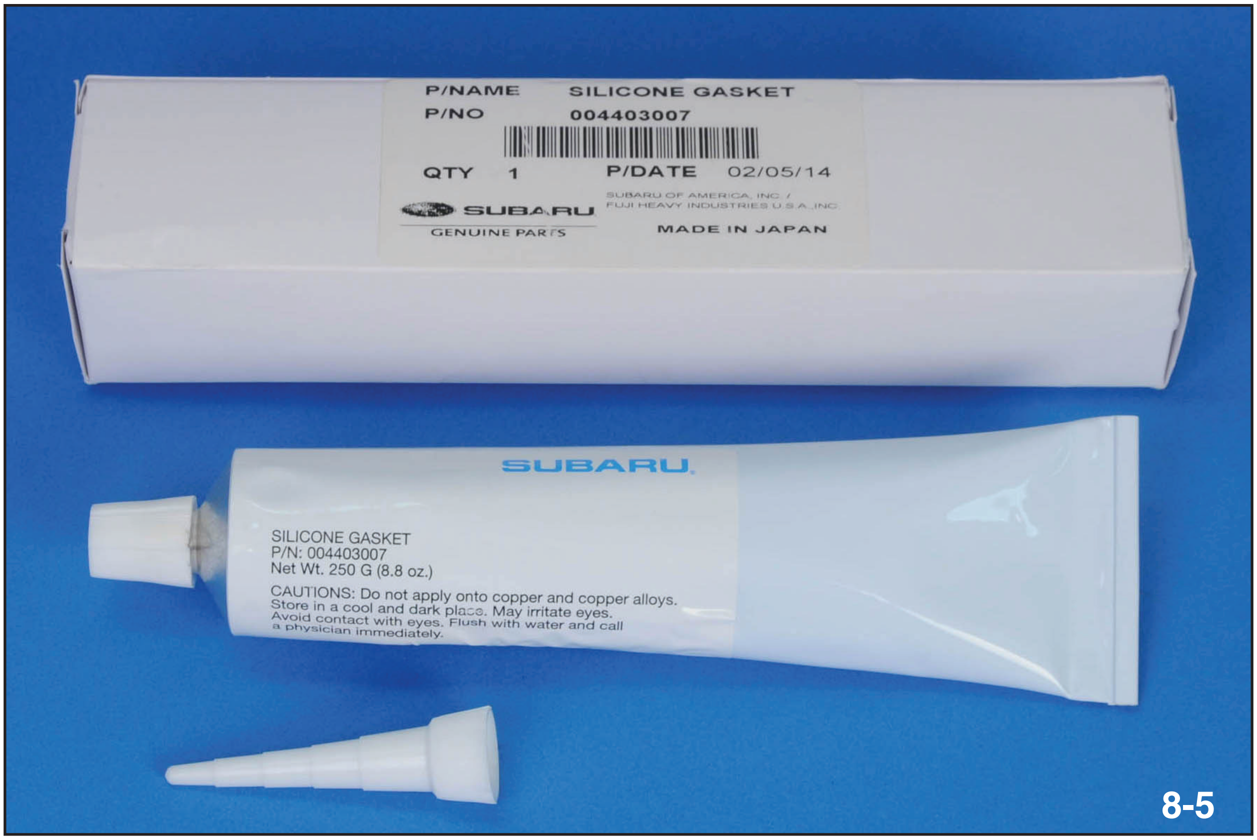
Typical Intake Manifold Gasket

Intake manifold gaskets can be made of reinforced fiber, rubber coated metal, or silicon o-ring. These gaskets seal the intake to the cylinder head and prevent unmetered air from entering the engine.

Exhaust Manifold Gaskets

Gaskets that are positioned in high temperature areas like the exhaust manifold are typically made of multiple layer materials such as embossed steel, high-temperature fiber material, or ceramic composites.

Types of Sealants



Typical Liquid Sealants

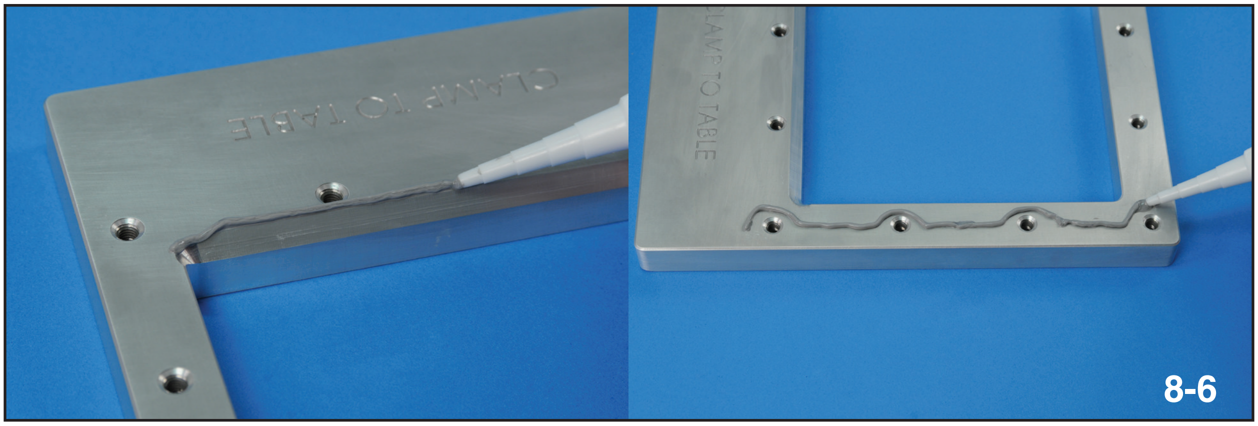
Fuji bond is a non-hardening liquid sealant used to seal different areas within the engine assembly. When using Fuji bond, all mating surfaces must be clean and dry prior to applying the sealant. The component should be installed within five minutes of applying the sealant.

Sealant Removal & Surface Preparation

It is very important that the surfaces to be sealed are clean and dry. It is also important to use the proper amount of sealant for the application. Too much sealant could cause lubrication or coolant starvation, eventually damaging engine components.

Never use abrasive media such as an aluminum oxide pad to prepare component sealing surfaces; damage to the surface will not allow proper sealing.

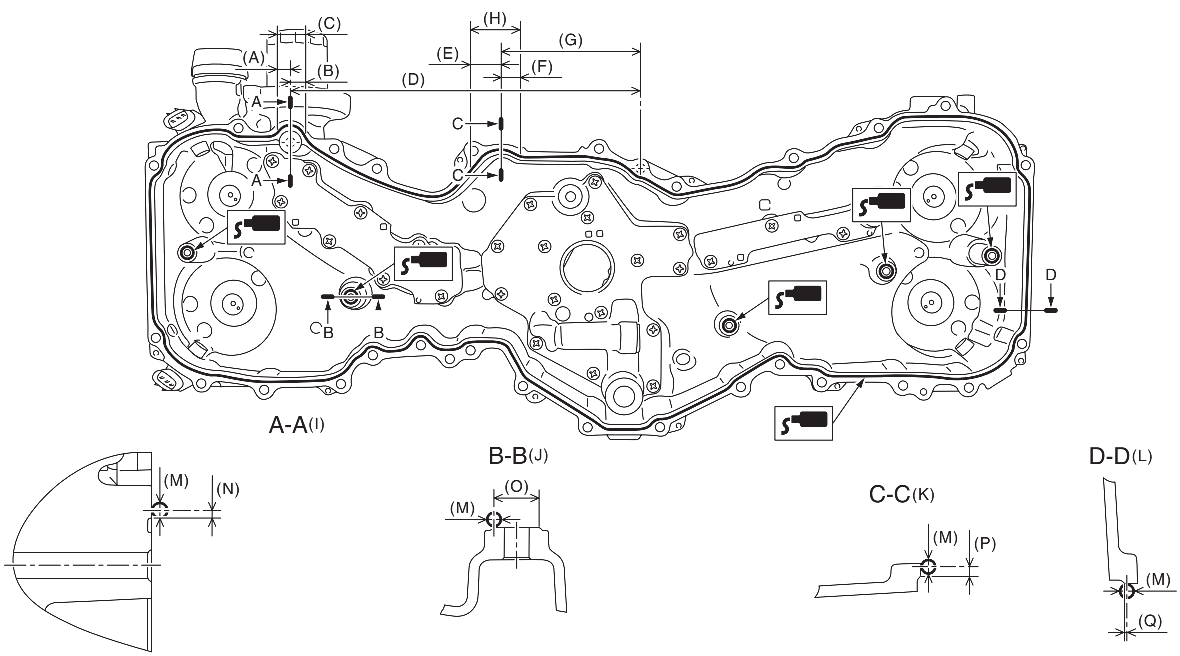
Sealant Application



Typical Sealant Application

Surfaces that are to be sealed using Fuji bond should be at room temperature and all mating surfaces must be clean and dry.

Use an appropriate size bead of sealant in the proper location per STIS recommendation for the components being sealed.

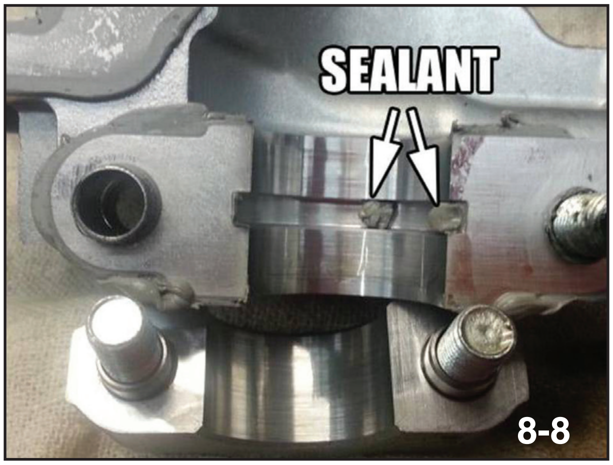


(A)	14.5 mm (0.5709 in)	(G)	127 mm (5.0000 in)	(M)	ϕ4±0.5 mm (0.1575±0.0197 in)
(B)	17.5 mm (0.6890 in)	(H)	Range B	(N)	2 mm (0.0787 in)
(C)	Range A	(I)	Liquid gasket applying position of mating surfaces of range A	(O)	ϕ12 mm (0.4724 in)
(D)	316.2 mm (12.4488 in)	(J)	Liquid gasket applying position of center boss (5 places)	(P)	2.5 mm (0.0984 in)
(E)	24.5 mm (0.9646 in)	(K)	Liquid gasket applying position of mating surfaces of range B	(Q)	0.5 mm (0.0197 in)
(F)	18.5 mm (0.7283 in)	(L)	Liquid gasket applying position of mating surfaces other than range A and range B		

8-7

Typical Sealant Application Guide

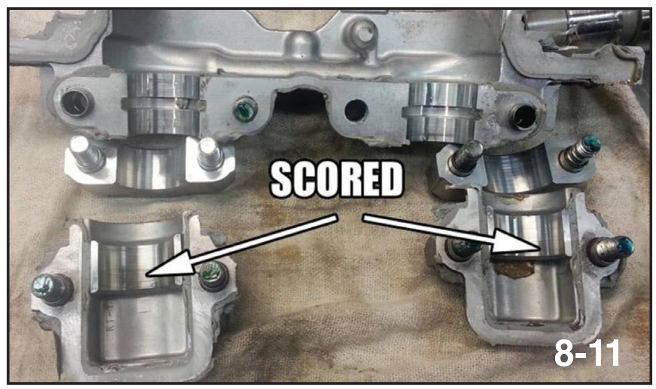
Improper Sealant Application Results



Sealant Plugging Lubrication Channel

Oil Strainer Plugged

Oil Screen Plugged



Cam Cover Scored

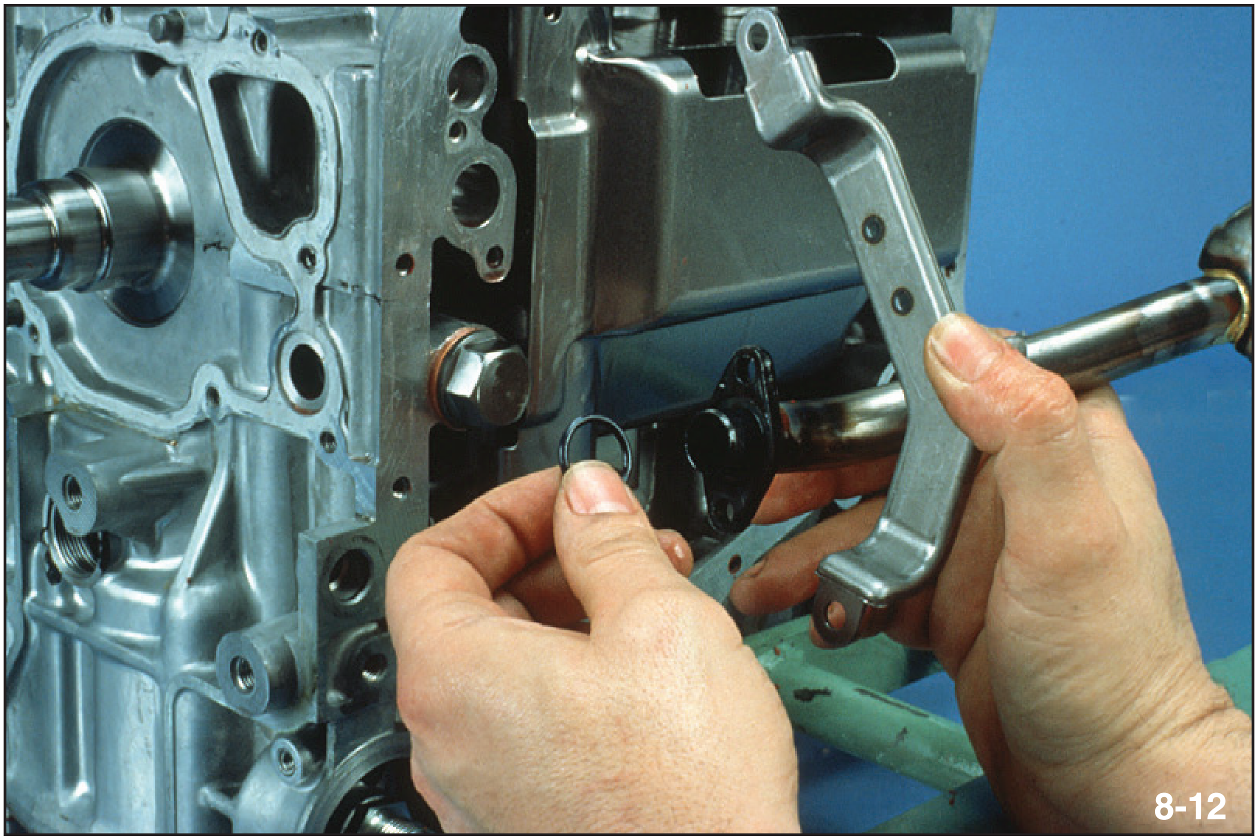
Sealant that is improperly applied can cause major engine problems like:

- Oil starvation due to blocked oil passages
- Engine overheating due to blocked cooling system passages
- Oil burning due to blocked oil return passages

The correct size bead size and proper surface application will make the difference between a leak, engine damage or a proper seal.

Rubber Seals

O-ring



Typical O-ring

O-rings are round seals with a circular cross section that are installed between two mating surfaces. The two surfaces compress the o-ring and form a seal. O-rings are typically used where fluid flow between two components is necessary and a conventional gasket will not perform well.

Garter Seals

Typical Garter Type Seal

Garter type seals are typically used on component cases where a rotating or reciprocating component passes through the case and must retain any fluids that the case may hold. The garter seal is made of rubber coated steel that is pressed into place using a seal driving tool. Pressing the solid part of the seal to the case seals the case. The inner part of the seal is made of rubber and is formed to produce a small lip; this lip makes contact with the component and provides sealing between the seal and the rotating shaft. To increase the sealing effect, a small spring (called a garter spring) is wrapped around the inner part of the seal to provide equal pressure around the seal's lip. This additional pressure keeps the seal at proper tension around the shaft as the case's internal pressure fluctuates. Common garter seals used on an engine are:

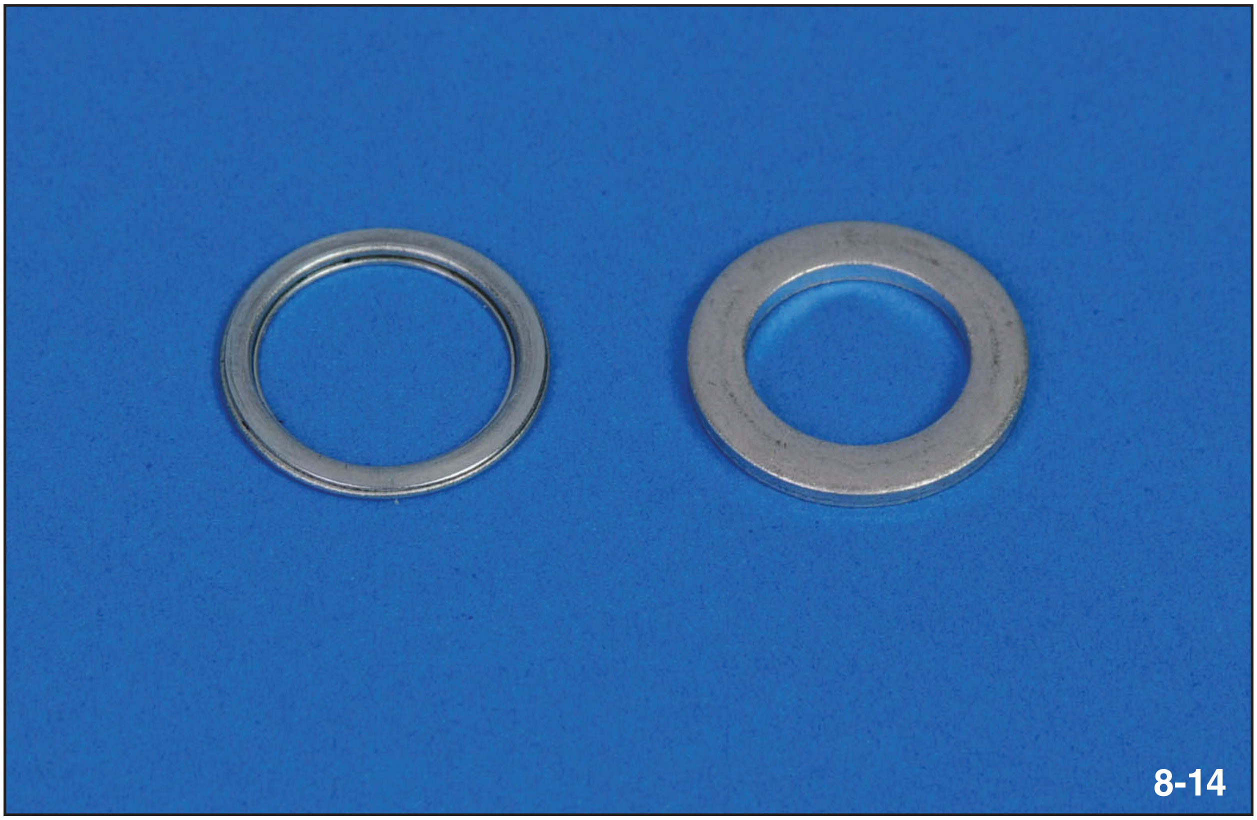
- Rear main seal
- Front cover seal
- Camshaft front seal
- Valve guide seal

Installation Method

Most garter seals are set in place using special seal installer tools, the seal needs to be fit evenly and to a specified depth. Always use the proper seal installer as referenced in STIS.

Crush Washer Seals

Construction



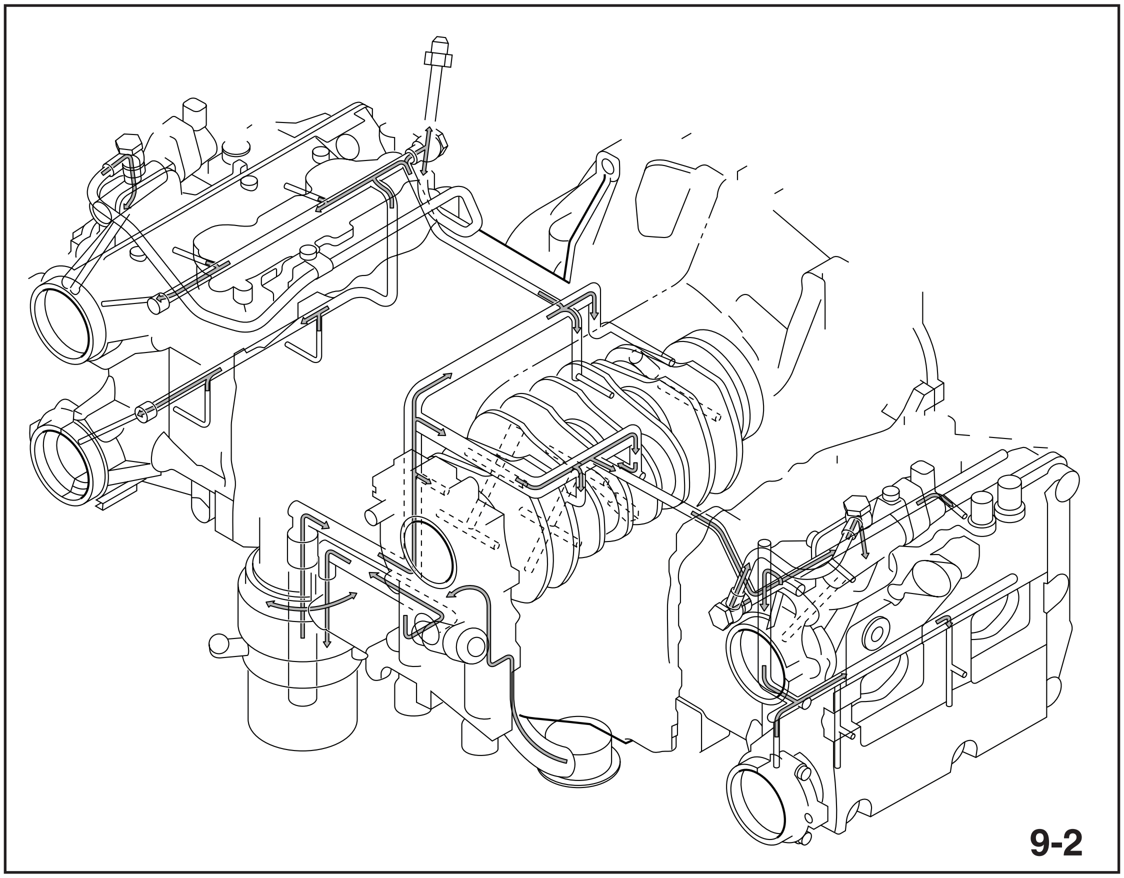
Crush Washer Type Seal

Crush washer seals are made of aluminum or copper and are used as a one time seal for drain plugs, fill plugs, or brake components. These types of washers must be replaced every time the fastener is removed and replaced. They are designed to be squeezed and fill any irregularities between the two surfaces. Always tighten fasteners to the torque specification found in STIS.

NOTES:

Lubrication System

Lubrication System



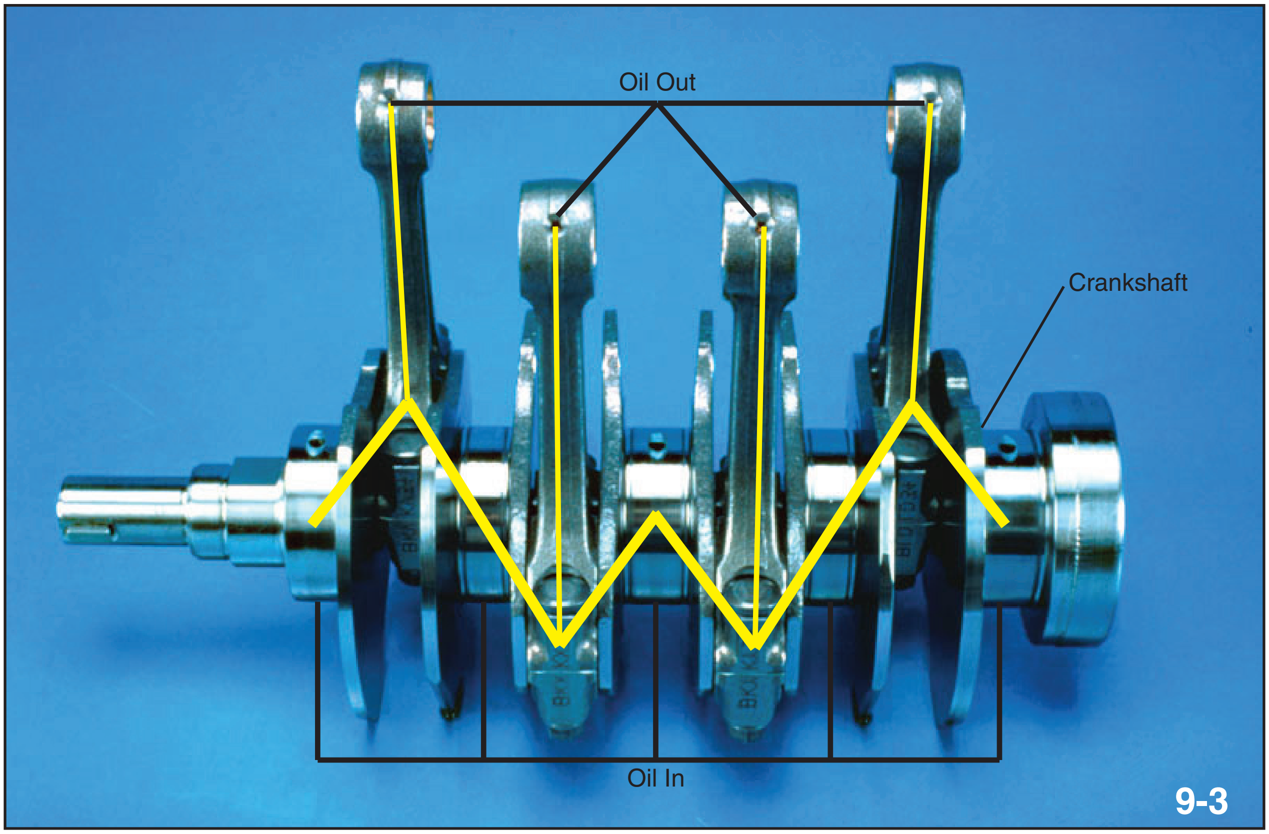
Lubrication System Operation

The lubrication system uses pressurized oil to lubricate and cool bearing surfaces and components within the engine, promoting long engine life. The lubrication system is made up of the pump, strainer, filter assembly, oil pan, pressure switch, and galleries within the block and heads.

The oil pump draws oil from the oil pan through the strainer. The pump rotor spins at engine speed, pressurizes the oil, and moves it through the oil filter assembly. The pressurized and filtered oil flows into the block, crankshaft, and head galleries to lubricate and cool the engine. The oil pressure is regulated by a relief valve built into the oil pump assembly. Any excess pressure is directed back into the inlet side of the pump.

Proper oil level and pressure are crucial to an engine. On some models, an oil level switch is incorporated into the upper oil pan to indicate a problem with oil level. When the oil level becomes too low, the sensor illuminates the oil lamp on the instrument panel. On all models, a pressure switch is attached to the oil filter housing; this switch monitors oil pressure. If the oil pressure is too low, the switch warns the driver by illuminating the oil light on the instrument panel.

Crankshaft Oil Distribution



Crankshaft Oil Distribution

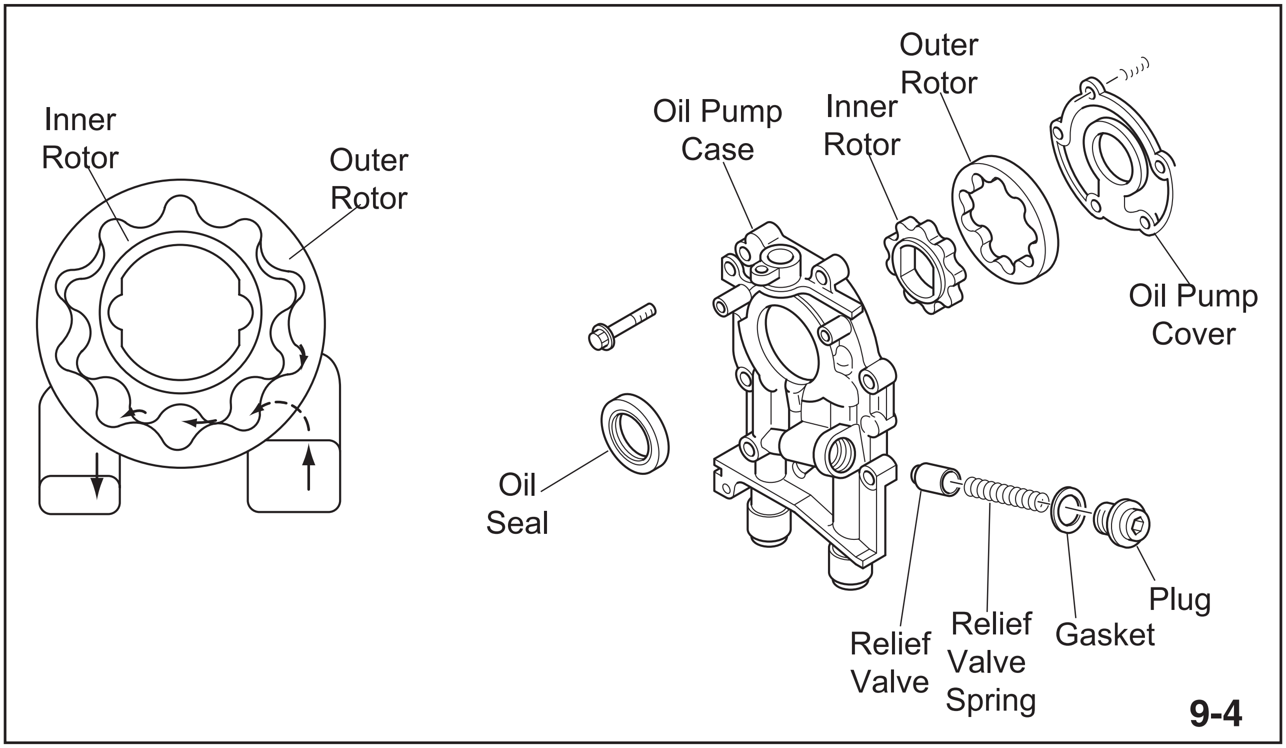
Lubrication passages within the crankshaft receive pressurized oil from the cylinder block main journals and distribute it to the other main and rod journals for lubrication. The pressurized oil creates a thin layer or surface that the crankshaft and piston rods float on; this keeps the contact between the crankshaft's highly machined surfaces and the aluminum alloy bearings to a minimum.

If oil pressure becomes low due to an out-of-round, tapered, or scored journal, excessive wear to the bearings will occur and eventually the bearing will fail.

Worn bearings will cause the engine to make noise and create low oil pressure problems.

Note: Crankshafts should never be dropped; distortion or bending of the shaft will cause engine damage. Any dings or dents in the finished surfaces will cause damage to the bearings.

Oil Pump



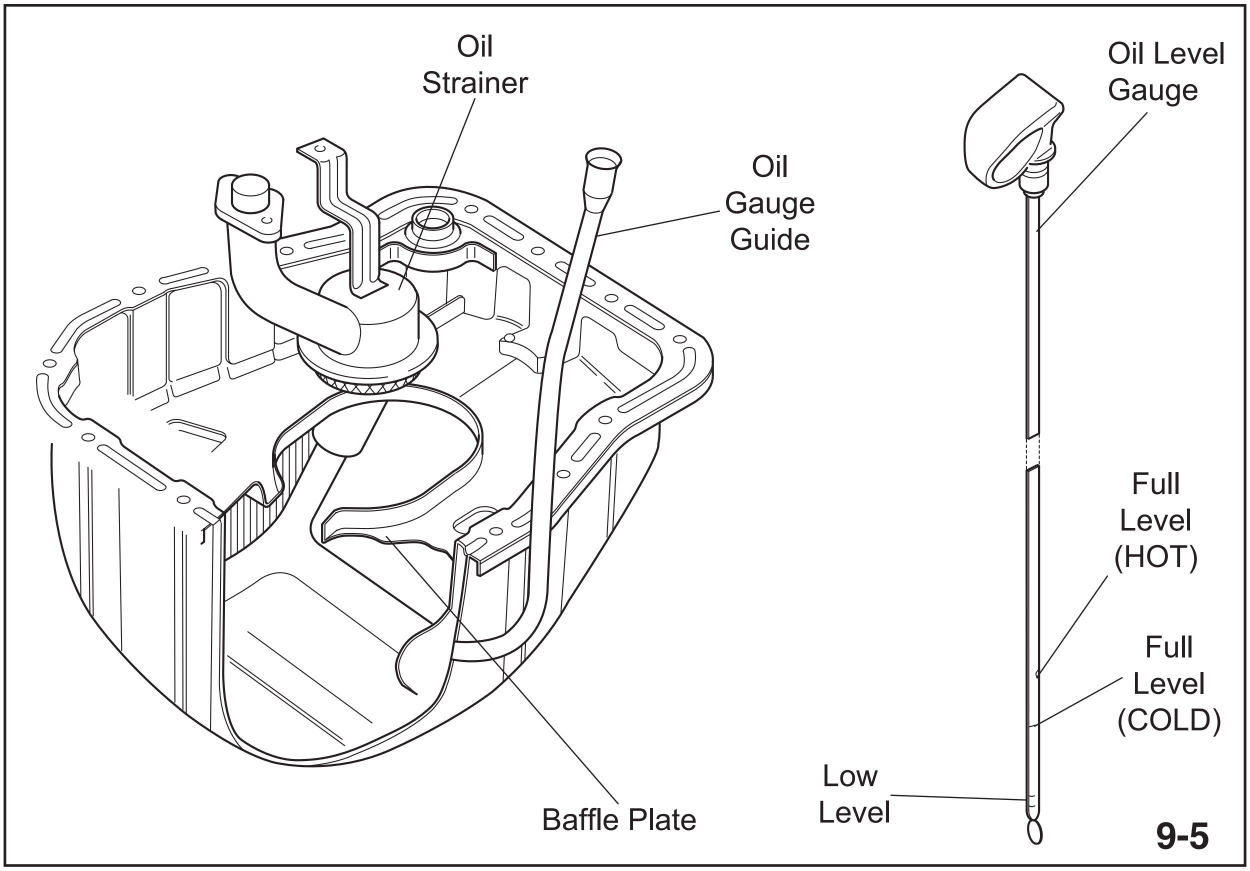
Typical Oil Pump

The trochoid rotor type oil pump consists of an inner rotor and outer rotor in a pump body. When the inner rotor is driven by the crankshaft, the outer rotor is rotated, changing the space between the inner and outer rotors. The change in spacing occurs because of the difference in the number of teeth between the rotors.

Engine oil is carried from the inlet port to the outlet port. As the pump rotates, the space carrying the oil becomes smaller and the oil is pressurized and discharged through the outlet port. Engine oil is discharged from the pump and delivered to components through galleries within the engine block and cylinder heads. Oil flow to the cylinder heads is controlled by metering orifices within the cylinder heads.

A relief valve is built in the oil pump on the discharge side. When the oil pressure becomes higher than the preset value, the relief valve regulates the pressure by sending excessive oil pressure back to the inlet side.

Oil Pan



Typical Oil Pan

The oil pan is typically a steel or aluminum pan designed to provide a reservoir of oil for the lubrication system. The oil pan is attached to the cylinder block, and uses a liquid gasket for sealing. To ensure an uninterrupted supply of oil to the pump when the vehicle is moving, the oil pan is fitted with a baffle plate. The baffel plate helps contain oil around the oil strainer.

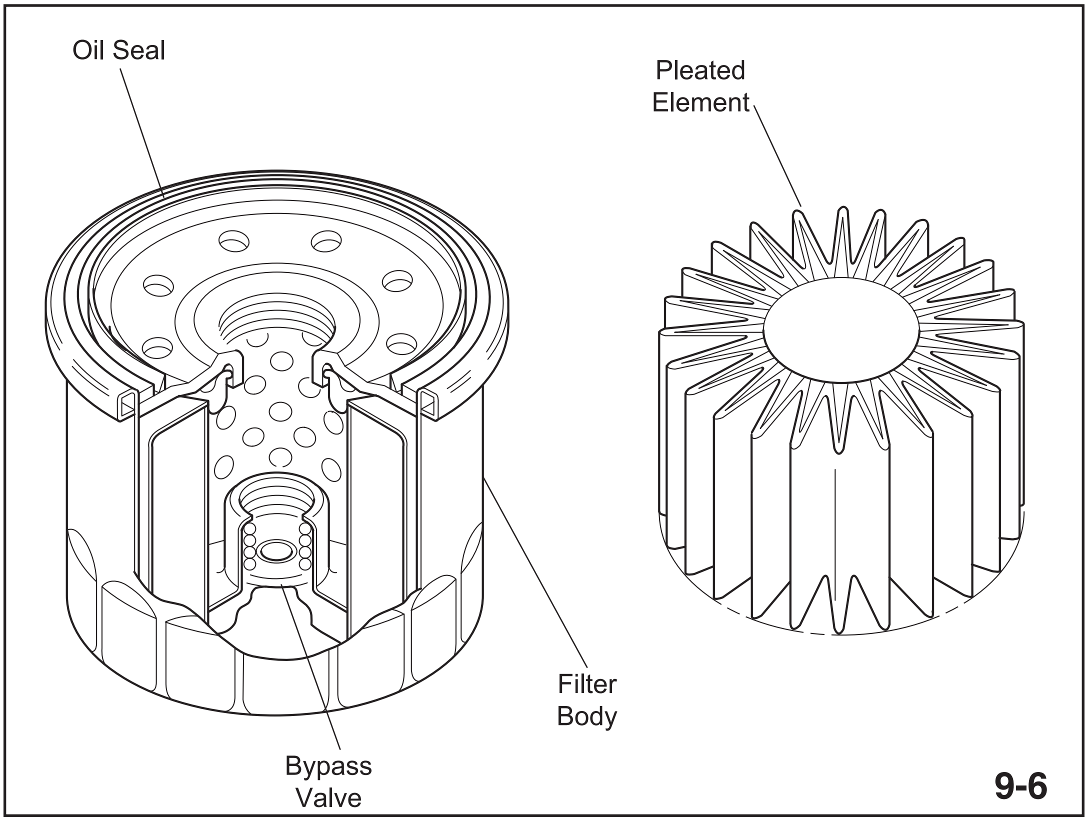
Oil Strainer

The oil strainer is a metal net type and is located in the middle of the oil pan. Its purpose is to remove large foreign particles from the engine oil. The pipe from the strainer is connected to the suction port of the oil pump.

Oil Level Gauge

The oil level gauge is simply a piece of spring steel or a rod that has indicator marks to indicate the engine's oil level. To check the oil level, make sure the vehicle is parked on a level surface. Remove the level gauge and wipe the end off with a clean cloth. Insert the gauge back into the oil gauge guide and immediately remove it. Take your oil level reading. Replace the oil gauge when you are done.

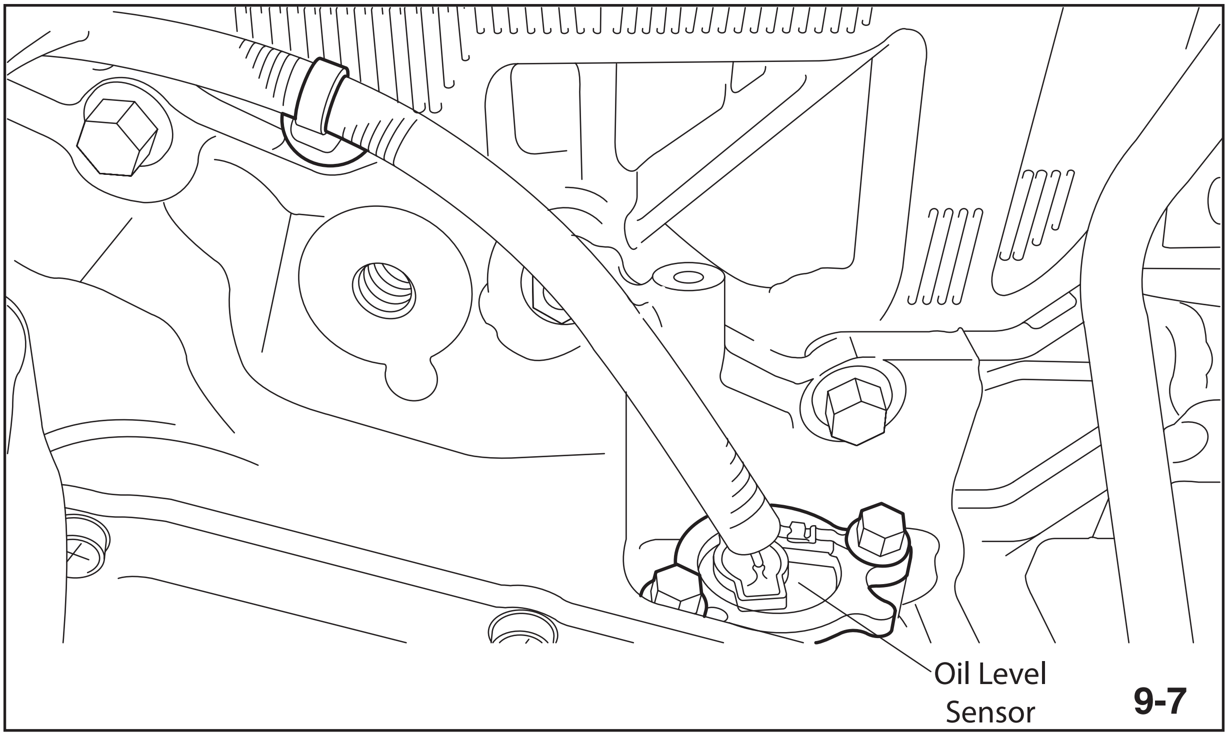
Oil Filter



Typical Oil Filter

The oil filter is a full-flow filtering, cartridge type filter that utilizes a paper element. The oil filter incorporates a bypass valve. If the filter gets clogged, causing the oil pressure to exceed the preset value, the bypass valve opens and causes the engine oil to flow around the filter. The filter element has a special pleat design that increases the effective filtering area.

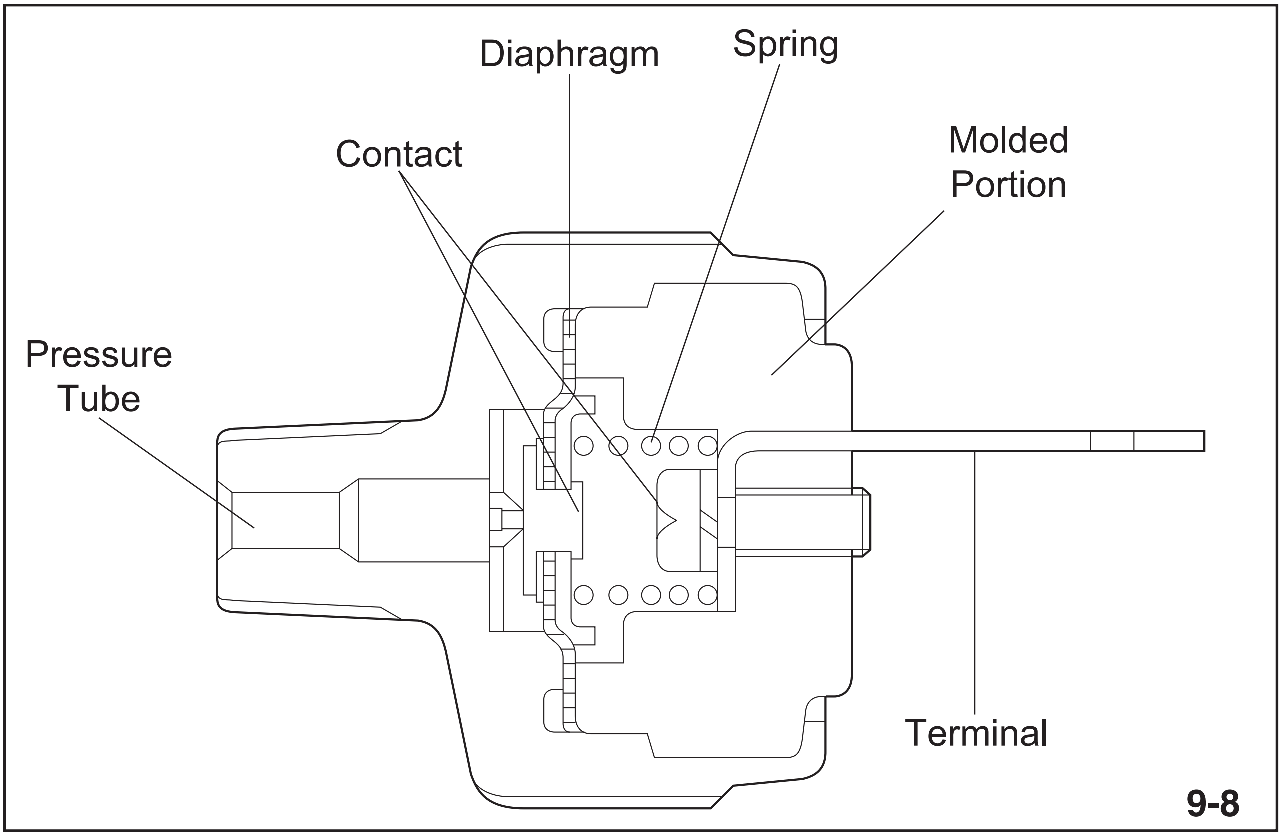
Oil Level Sensor



Typical Oil Level Sensor

Some models are equipped with an oil level monitoring system to warn the operator of a low oil condition. The oil level sensor is located in the upper oil pan assembly. When the oil level is too low, the sensor illuminates the oil light on the instrument panel.

Oil Pressure Switch



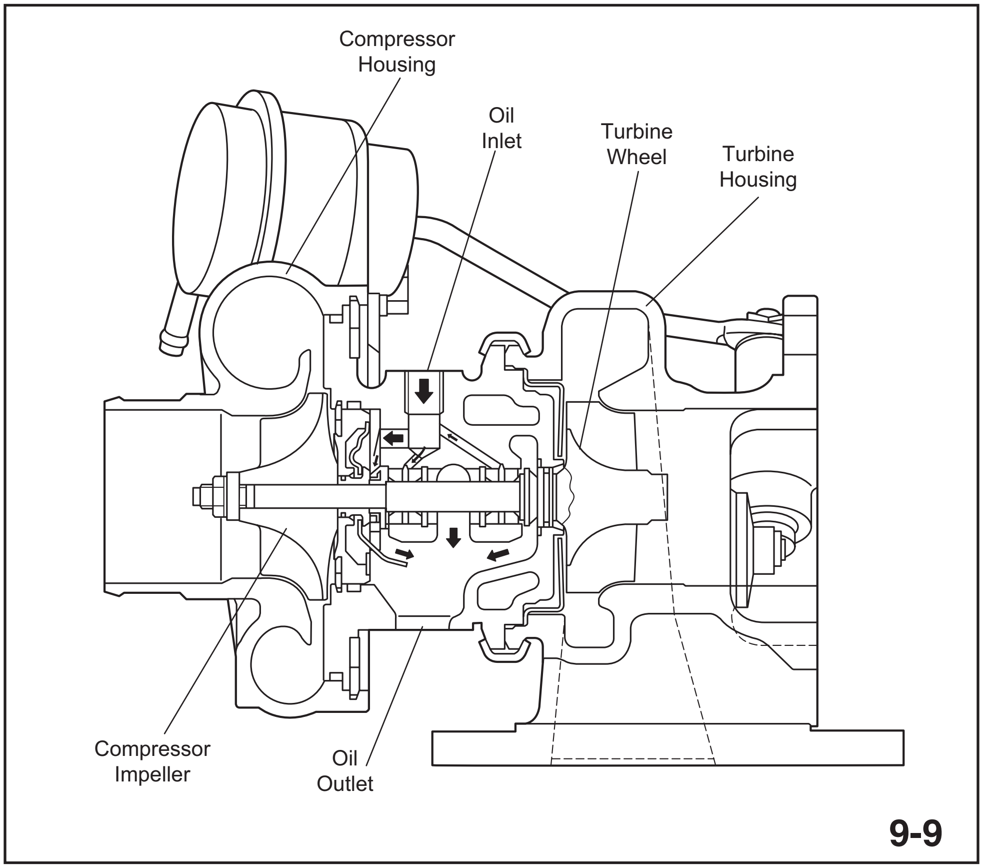
Typical Oil Pressure Switch

The oil pressure switch is located in the front upper portion of the right cylinder block bank. The purpose of this switch is to monitor the operation of the oil pump as well as the lubricating oil pressure when the engine is running.

When oil pressure does not build up (immediately after the ignition switch is turned ON), the diaphragm is pushed toward the cylinder block by the spring force (a force equivalent to the specified oil pressure). This closes the contact points, causing the oil pressure warning light in the combination meter to illuminate.

When oil pressure reaches the specified value (after the engine starts), the oil pressure pushes the diaphragm against the spring force after reaching the specified value. This opens the contact points and the oil pressure warning light goes out.

Turbocharger Lubrication

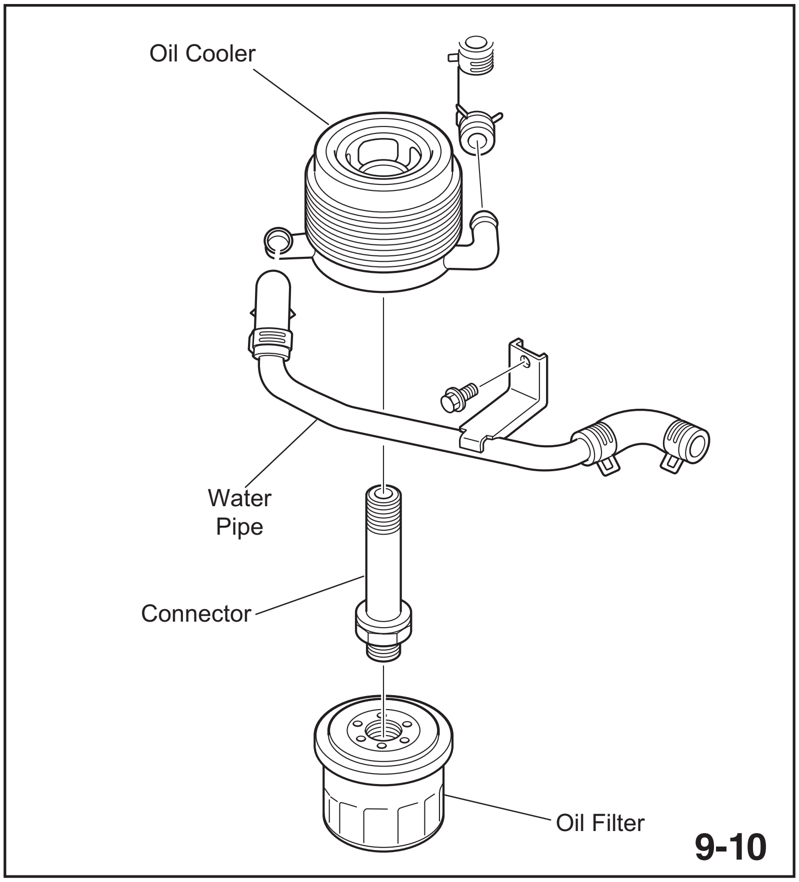


Turbocharger Lubrication

The turbocharger is lubricated by engine oil branched out from the oil pump. Full-floating type bearings form adequate oil films on their insides and outsides during operation to cope with the very high speed of the turbocharger turbine and the compressor.

The oil supplied to the turbocharger also cools the turbine so that heat from the exhaust gas does not transmit to the bearings.

Oil Cooler



Typical Oil Cooler

Turbocharged models use a water cooled heat exchanger to cool the engine oil. The oil cooler is located between the filter housing and the oil filter. Its purpose is to maintain proper engine oil temperature and prevent degradation of the oil.

Oil Specifications

9-11

Engine Oil

Engine oil certification labels are developed and trademarked by the American Petroleum Institute (API) to help customers identify engine oils recommended by the automobile manufacturers. The API symbol means that the oil has been certified by the API.

An oil displaying the STARBURST mark meets the current engine protection standard and fuel economy requirements of the International Lubricant Standardization and Approval Committee (ILSAC). Oils designed for gasoline engine service fall under API's "S" (Service) categories.

Oil Viscosity

Viscosity is the oil's resistance to flow, and is measured through a device known as a viscometer. The thicker (higher viscosity) the oil, the slower it will flow. Refer to the engine oil filler cap or STIS for the recommended engine oil viscosity. Also, remember that the "W" stands for winter, not for weight. If the wrong oil viscosity is used, it could cause abnormal engine wear or create other engine operating problems.

When there is a "W" indicated on a viscosity rating, it means that the oil's viscosity has been measured at colder temperatures. The numbers without the "W" are all tested at 100°C (212°F), which is considered an approximation of engine operating temperature. An SAE 30 motor oil is the same viscosity as a 10W-30 or 5W-30 at 100°C (212°F). The difference in viscosity occurs when it is tested at a much colder temperature.

As you check the oil, verify that it is at a normal level and of normal condition. The engine oil level should be within the safe range on the dipstick. An oil level that is excessively high or low may indicate a concern.

Note: On Subaru vehicles, it is acceptable to fill an engine with oil of another brand when replacing the oil, but make sure to use oil that meets Subaru specifications.

Note: The proper viscosity oil helps the engine maintain its ideal temperature and cranking speed by reducing viscosity friction.

Maintenance Schedules

		Maintenance interval [Number of months or km (miles), whichever occurs first]																		
	Months	3	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	82.5	90	97.5	105	112.5	120	132	Remarks
	× 1,000 km	4.8	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	220	
	× 1,000 miles	3	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	82.5	90	97.5	105	112.5	120	132	
1	Engine oil		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
2	Engine oil filter		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
3	Spark plug									R								R		
4	Drive belt(s)					I				I				I				I		
5	Fuel line					(I)				(I)				(I)				I		Note (1)
6	Fuel filter											R								Note (1)
7	Air cleaner element					R				R				R				R		Note (2)
8	Cooling system					I				I				I				I		
9	Engine coolant	Replace after the first 11 years or 220,000 km (137,500 miles), and every six years or 120,000 km (75,000 miles) thereafter																		

9-12

Typical Maintenance Schedule

The scheduled maintenance requirements can be found in a separate Warranty and Maintenance Booklet. The booklet is located under the applicable vehicle>General Information Section>Periodic Maintenance Services PM>Schedule.

There are two maintenance schedules; Schedule A and Schedule B. Schedule A refers to maintenance items needed based on miles driven and time. Schedule B refers to maintenance items needed based on miles driven and driving conditions; extreme driving conditions require a shorter time interval for maintenance requirements.

The Service Manual Schedule Symbols in the chart indicate:

- R - Replace
- I - Inspection
- P - Perform

When operating vehicles in severe conditions (towing, dusty areas, cold climates) refer to maintenance schedule 2.

Schedule

PERIODIC MAINTENANCE SERVICES

B: MAINTENANCE SCHEDULE 2

Item	Maintenance interval	Repeat short distance drive	Repeat rough/muddy road drive	Extremely cold weather area	Salt or other corrosive used or coastal area	High humidity or mountain area	Repeat towing trailer
Engine oil	3.75 months	R		R			R
	6,000 km						
	3,750 miles						
Engine oil filter	3.75 months	R		R			R
	6,000 km						
	3,750 miles						

9-13

Periodic Maintenance Schedule

Cooling System

CAUTION: Prior to starting work, pay special attention to the following:

1. Always wear work clothes, a work cap, and protective shoes. Additionally, wear a helmet, protective goggles, etc. if necessary.
2. Protect the vehicle using a seat cover, fender cover, etc.
3. Prepare the service tools, clean cloth, containers to catch grease and oil, etc.

Prepare a container and cloth to prevent scattering of engine coolant when performing work where engine coolant can be spilled. If the oil spills, wipe it off immediately to prevent from penetrating into floor or flowing out for environmental protection.

Vehicle components are extremely hot immediately after driving. Be wary of receiving burns from heated parts.

When performing a repair, identify the cause of trouble and avoid unnecessary removal, disassembly and replacement.

Before disconnecting connectors of sensors or units, be sure to disconnect the ground cable from battery.

Always use the jack-up point when the shop jacks or rigid racks are used to support the vehicle.

Remove contamination including dirt and corrosion before removal, installation, disassembly or assembly.

Keep the removed parts in order and protect them from dust and dirt.

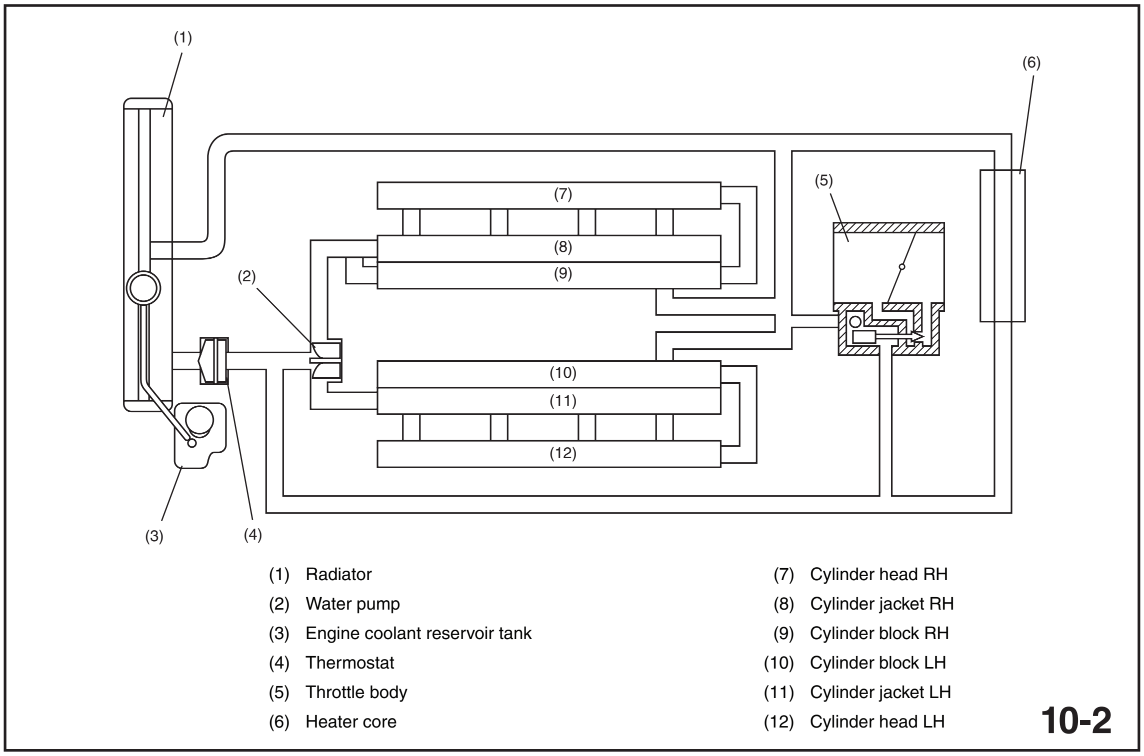
All removed parts, if to be reused, should be reinstalled in the original positions with attention to the correct directions, etc.

Bolts, nuts and washers should be replaced with new parts as required.

Be sure to tighten the fasteners including bolts and nuts to the specified torque.

Follow all government and local regulations concerning disposal of refuse when disposing engine coolant.

Cooling System



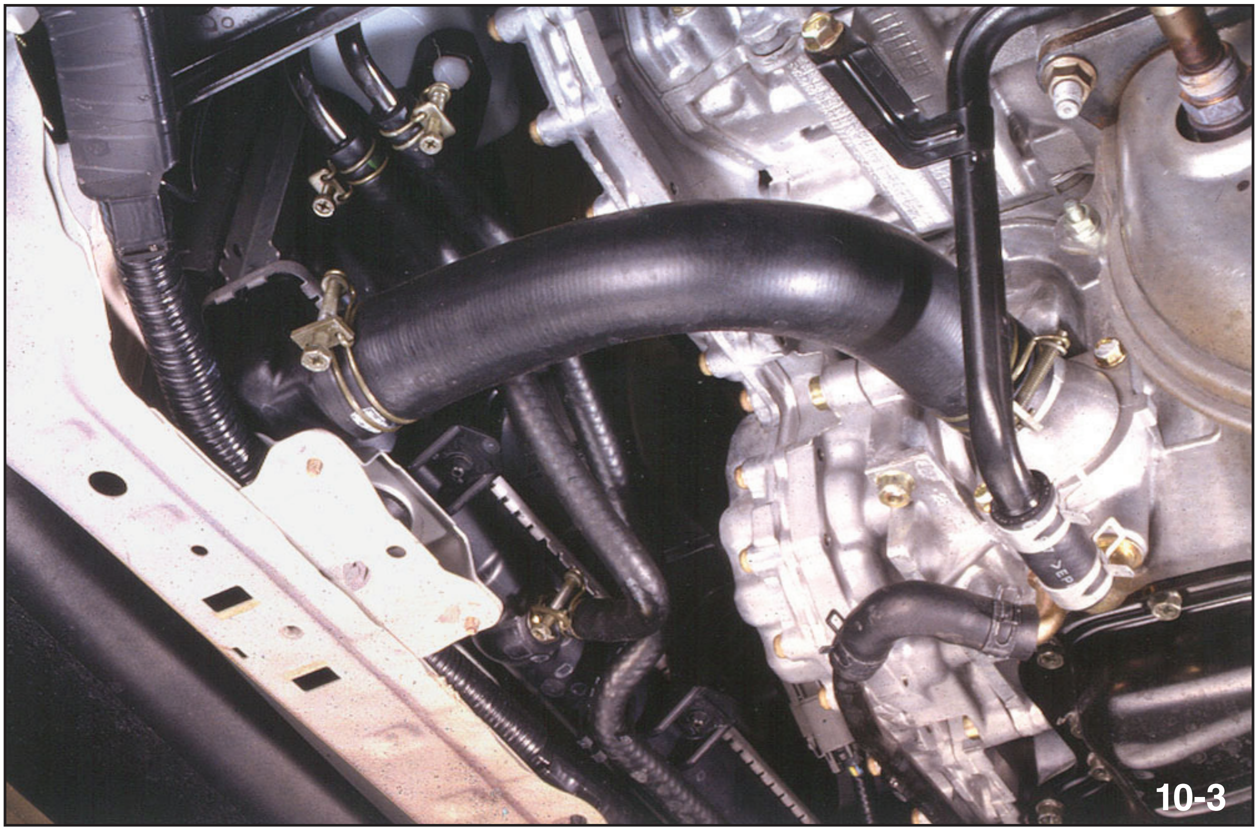
Typical Cooling System

The cooling system circulates coolant (a mixture of antifreeze and water) around critical components of the engine, transferring heat away from the components and out to the atmospheric air through a heat exchanger called a radiator. A thermostat maintains a consistent temperature within the engine by controlling coolant flow through the radiator. The coolant passages within the right and left cylinder banks are independent of each other, creating a parallel-flow design.

System Type

Subaru uses an electric fan and forced engine coolant circulation system. The system consists of a radiator, water pump, thermostat, heater core, coolant reservoir, temperature sensor, crossover tube, and connecting hoses. The ECM uses the inputs from temperature sensors to signal when the electric cooling fans operate.

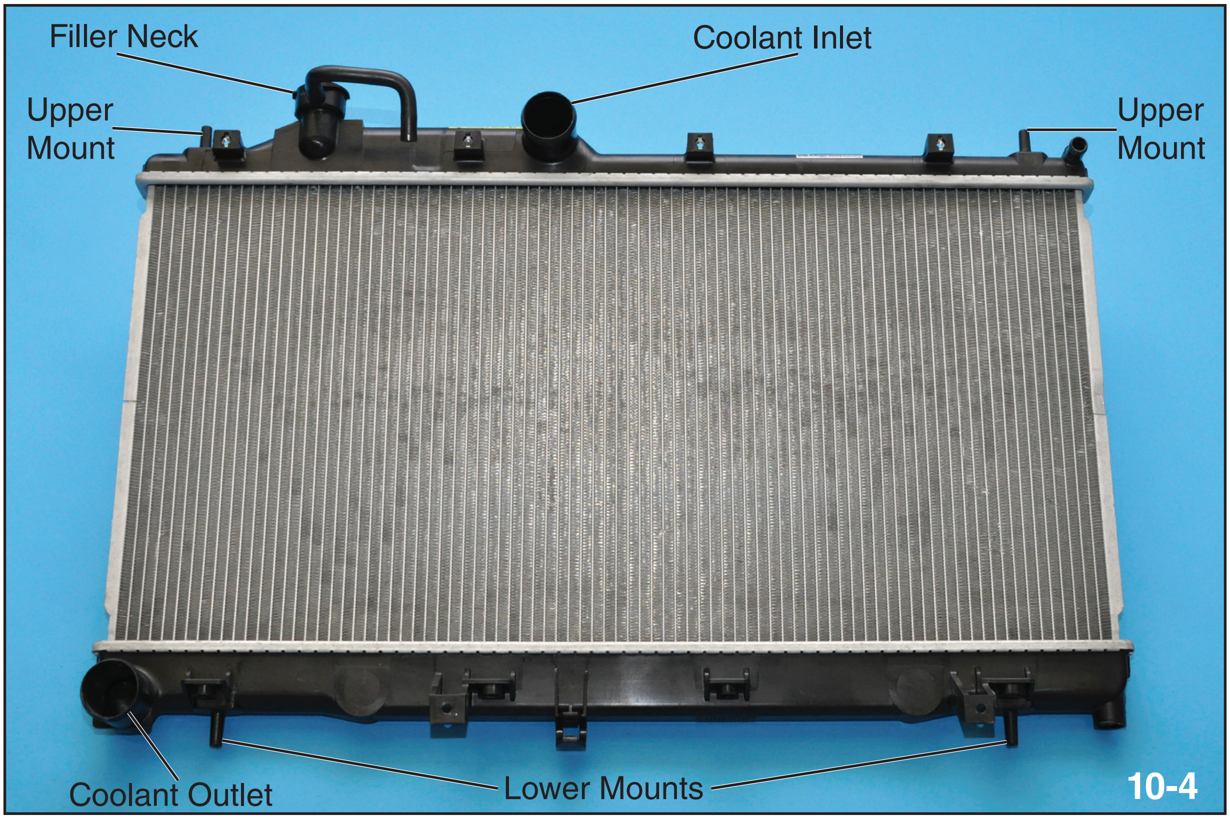
Hoses



Typical Cooling System Hose

All the cooling system components are connected via reinforced rubber hoses and held on by hose clamps. Always inspect hoses for cracks, bulges, and deterioration; if any of these conditions are evident replace the hose.

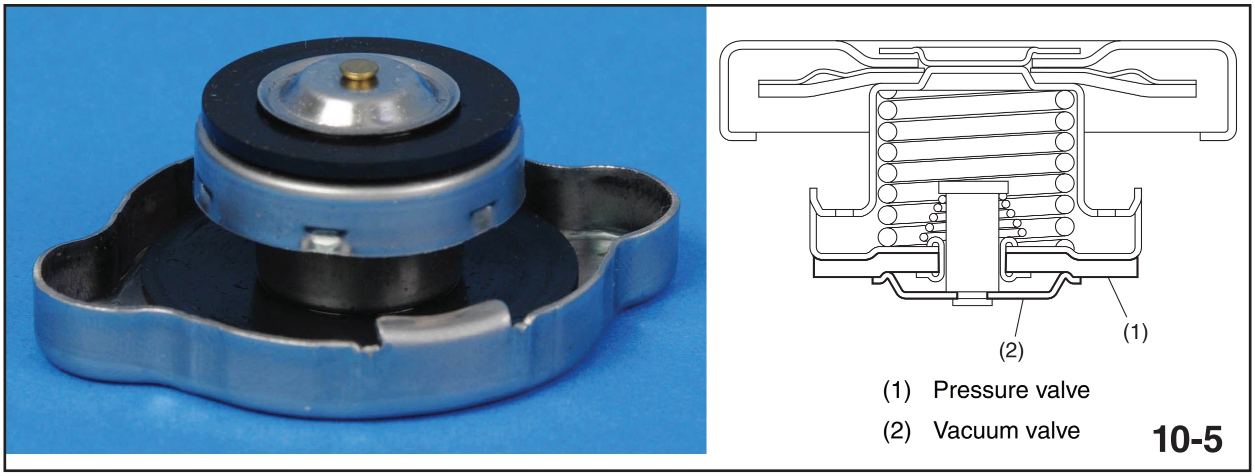
Radiator



Typical Cooling System Radiator

The radiator is typically made of numerous aluminum tubes with fins attached to their exterior. The ends of the tubes are attached to tanks that hold and distribute coolant. The radiator is designed so the coolant flows from the inlet tank through the tubes to the outlet tank. Heat from the hot coolant passing through the tubes is exchanged through the aluminum tubes and fins out to the surrounding air. Because of the way a radiator functions, it is important that the fins are kept free of any obstructions that affect air flow such as leaves, mud, or road debris.

Radiator Cap



Typical Cooling System Radiator Cap

The pressure cap is a critical component of the cooling system and is used to maintain pressure within the system. As the coolant is heated by the engine it expands, building pressure in the system slightly higher than atmospheric pressure. The increased pressure raises the coolant boiling point, which allows for increased radiator cooling capacity. For every 1 PSI increase in pressure, it will raise the boiling point approximately two degrees.

In addition to maintaining increased pressure, the cooling system pressure cap must also:

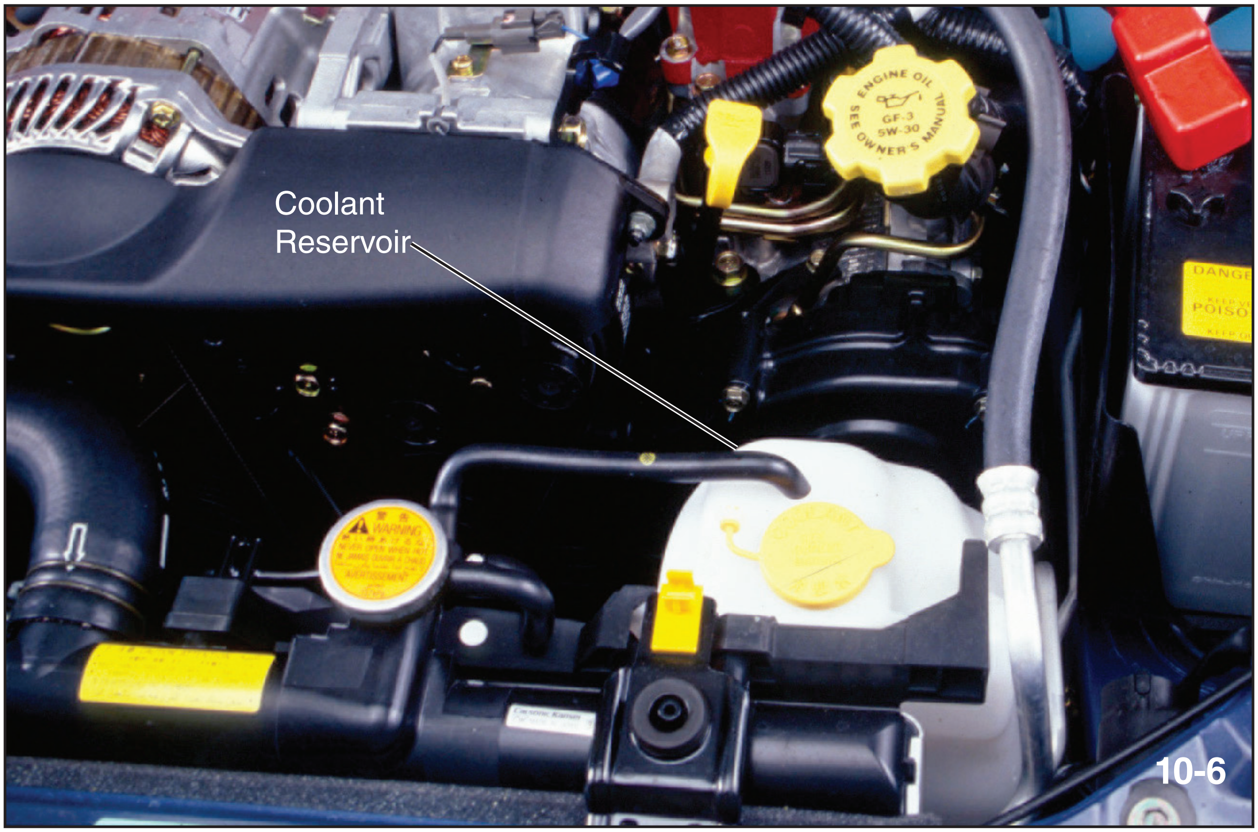
- Release excessive pressure (spring-loaded pressure relief valve) to prevent cooling system damage.
- Allow any expelled coolant to return to the cooling system from the coolant recovery bottle (spring-loaded vent/vacuum valve).

These functions prevent damage to the radiator and system components.

When diagnosing a cooling system, always check the radiator cap as part of the system. Make sure the seals are good and the cap is clean. Many cooling system problems can be caused by a defective cap.

Never fill a system with water only, corrosion within the system will occur and boil protection will not be sufficient. The coolant mixture also has lubrication properties that protect the water pump.

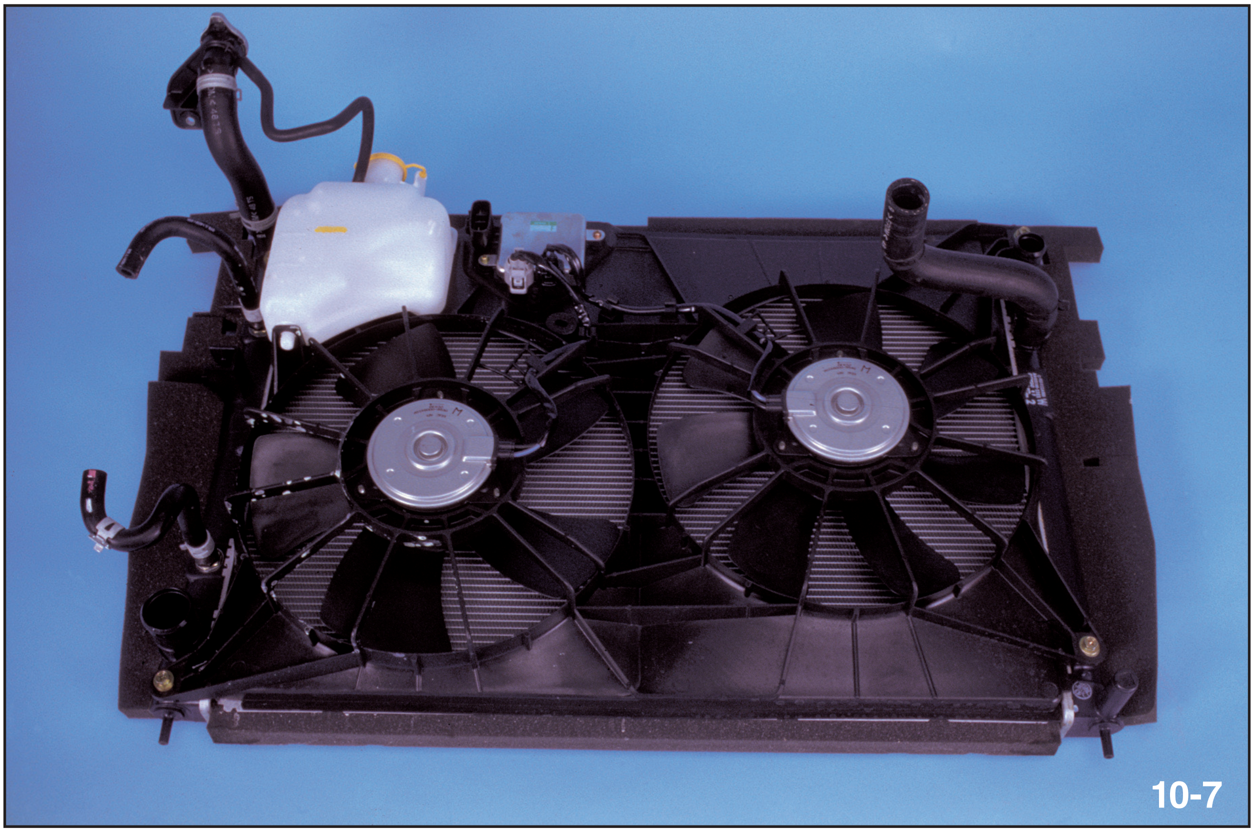
Coolant Reservoir



Typical Cooling System Reservoir

The reservoir tank stores engine coolant that exits the radiator when the system is pressurized and allows coolant to be reclaimed when the system cools. The coolant reservoir is made of translucent resin and enables easy confirmation of the coolant level. Coolant should be added to the reservoir tank when the system depletes to the low level.

Cooling Fans



Typical Cooling Fan Assembly

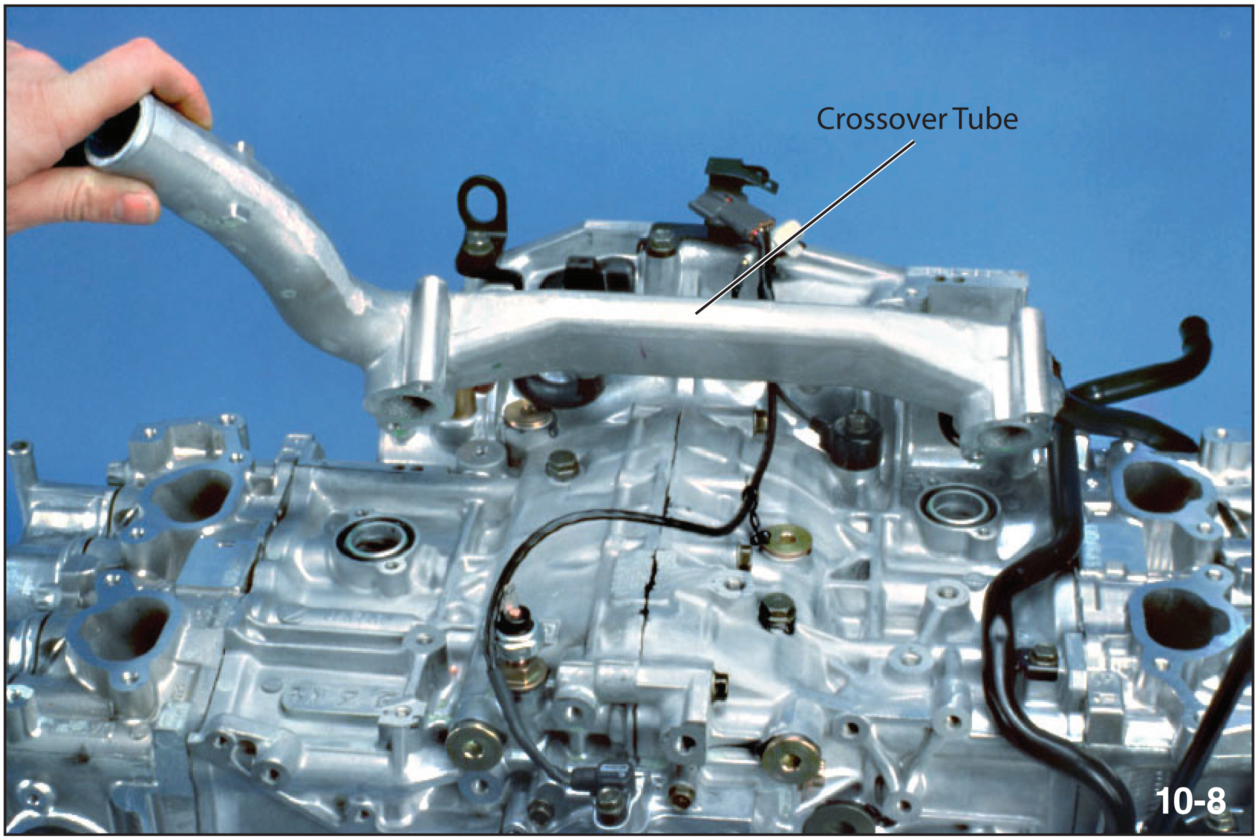
The electric cooling fan is typically mounted to a plastic shroud that helps direct airflow and assists in drawing air through the radiator, promoting heat transfer from the coolant to the ambient air.

The ECM uses relays to control electric fan operation. The ECM activates the electric fan when the temperature of the coolant reaches a pre-set value.

This system provides the following benefits:

- Dual speed controls
- Improved fuel economy
- Fan operation only when necessary

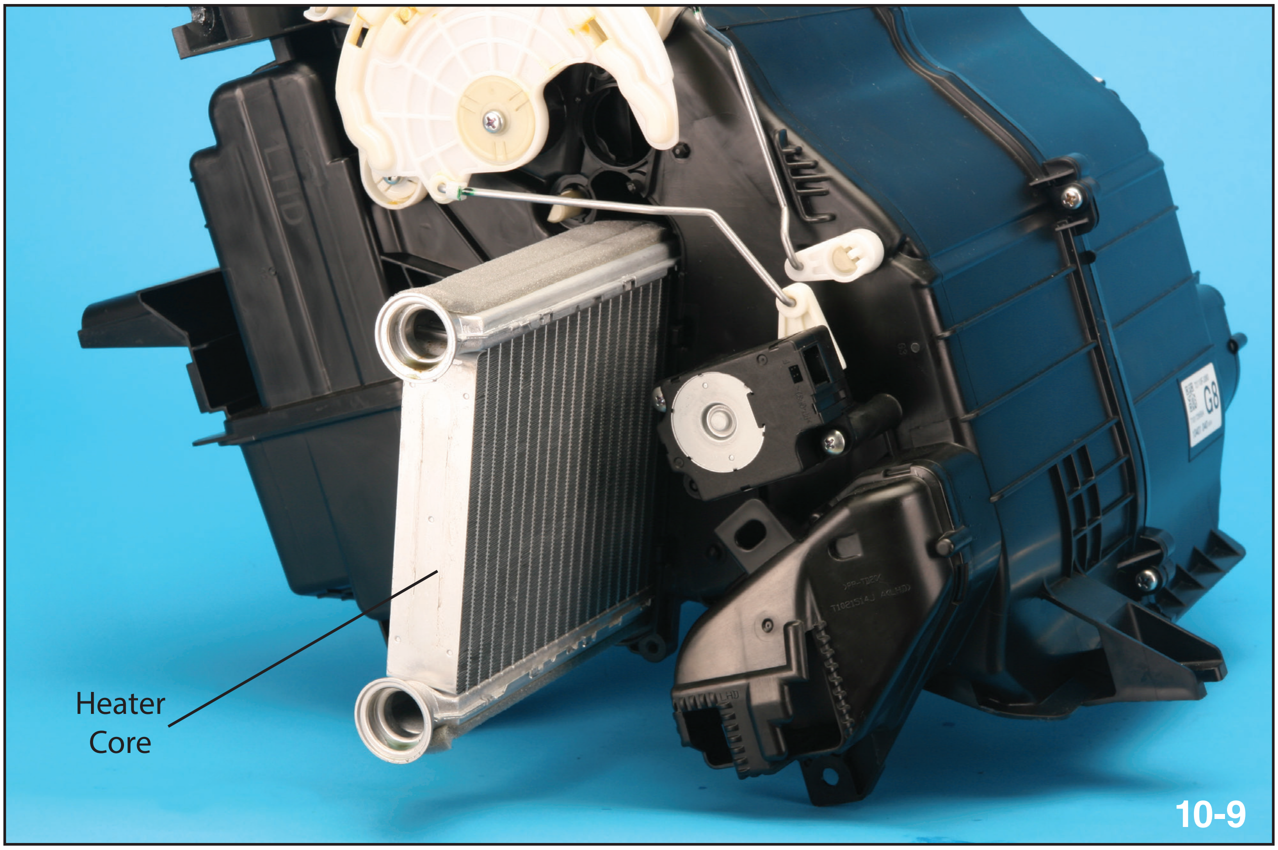
Crossover Design for Block Cooling



Cooling System Crossover

Because there are no internal coolant connections between each block half, a crossover pipe is used to collect coolant from both sides of the engine block and direct coolant to the rest of the system.

Heater Core

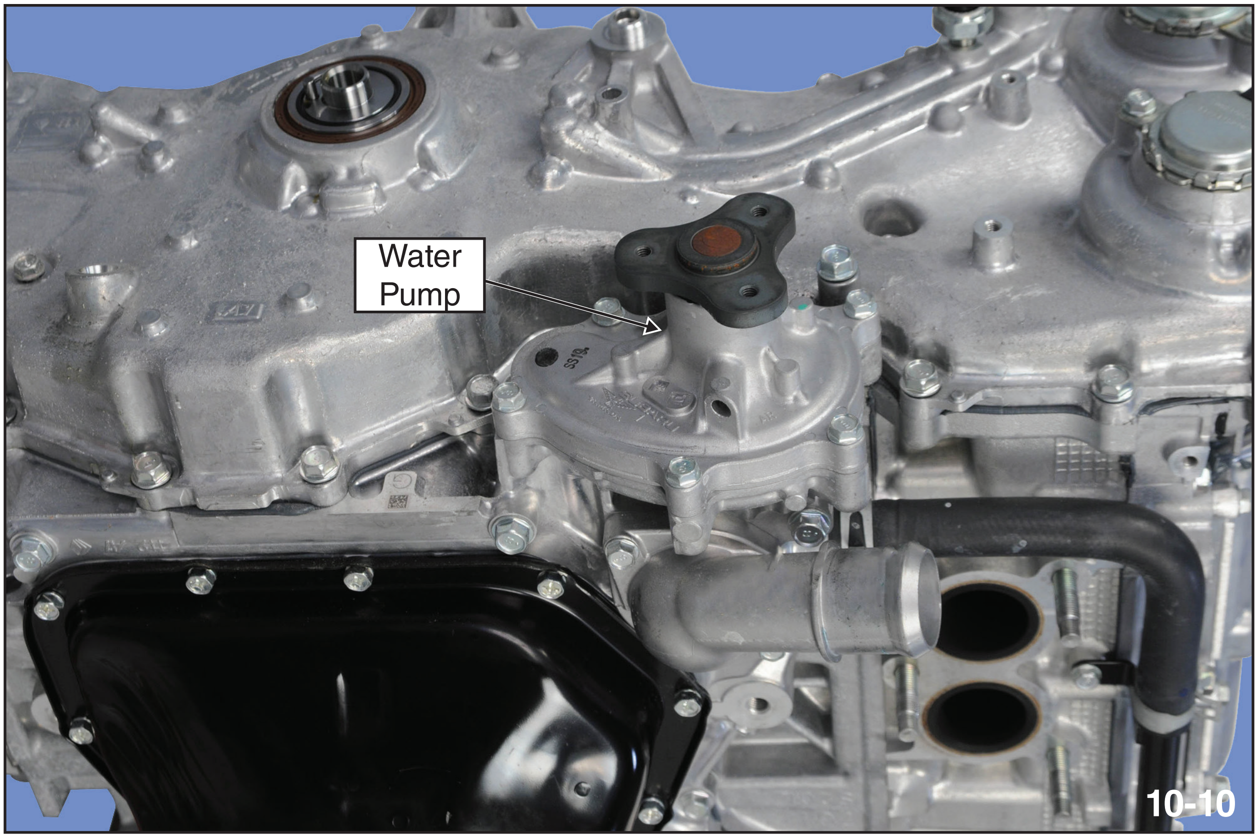


Typical Cooling System Heater Core

The heater core is mounted within the heating, ventilating, and air conditioning (HVAC) air distribution housing. The heater core is a heat exchanger similar to the radiator, but it transfers its heat to the air entering the cabin through the heating system ducts.

The heater core is positioned within the air distribution housing so only a select amount of air (based on control setting) passes through the heater core before it is distributed through the HVAC system ducts and outlets.

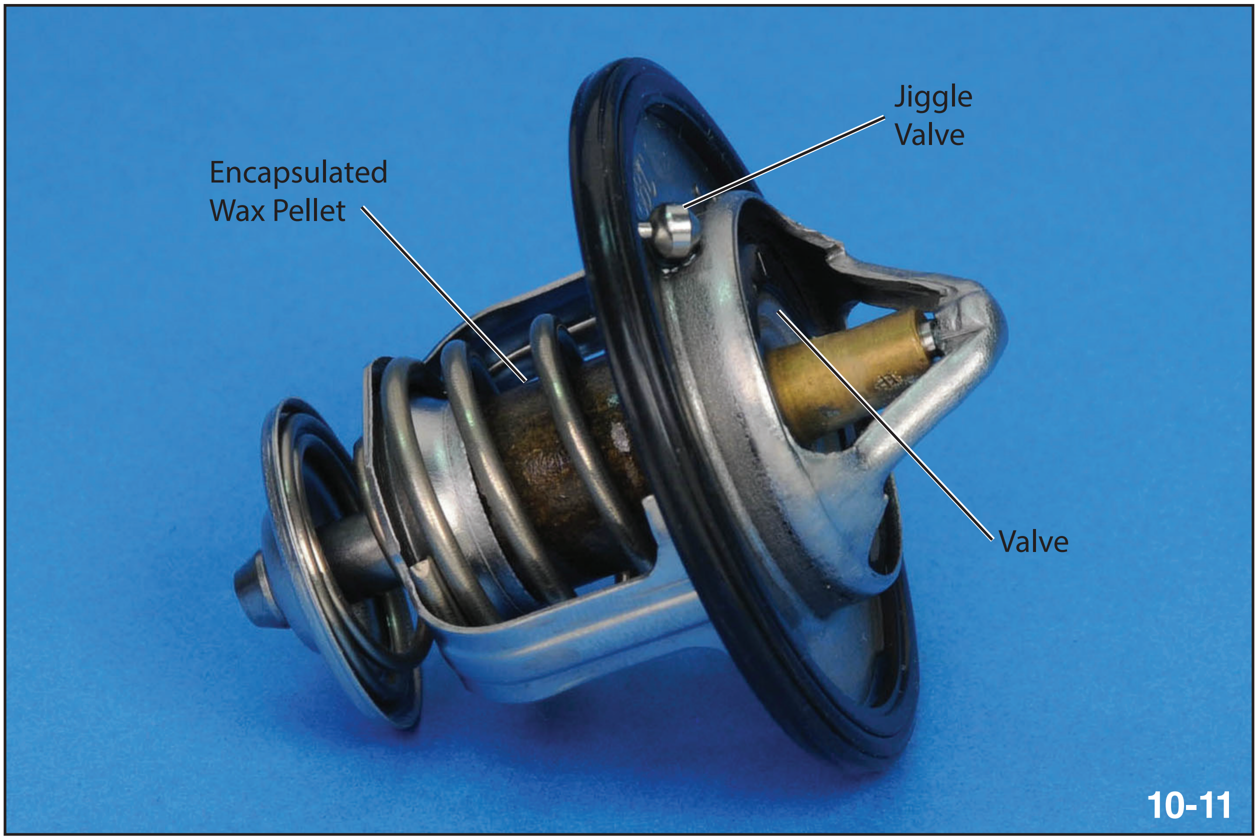
Water Pump



Typical Cooling System Water Pump

A centrifugal type water pump is located on the front of the engine. The water pump may be driven by an accessory drive belt or the timing belt, depending on the engine design. The cast aluminum housing is sealed to the block using Fuji bond that is applied to an o-ring gasket in a cast-in channel of the pump housing. The water pump is equipped with an integral weep hole. Slight staining around the hole is not an indication of a leaking water pump or a faulty seal. Coolant leaking from this hole is an indication of a faulty water pump seal. A leaking water pump may also be noisy.

Thermostat



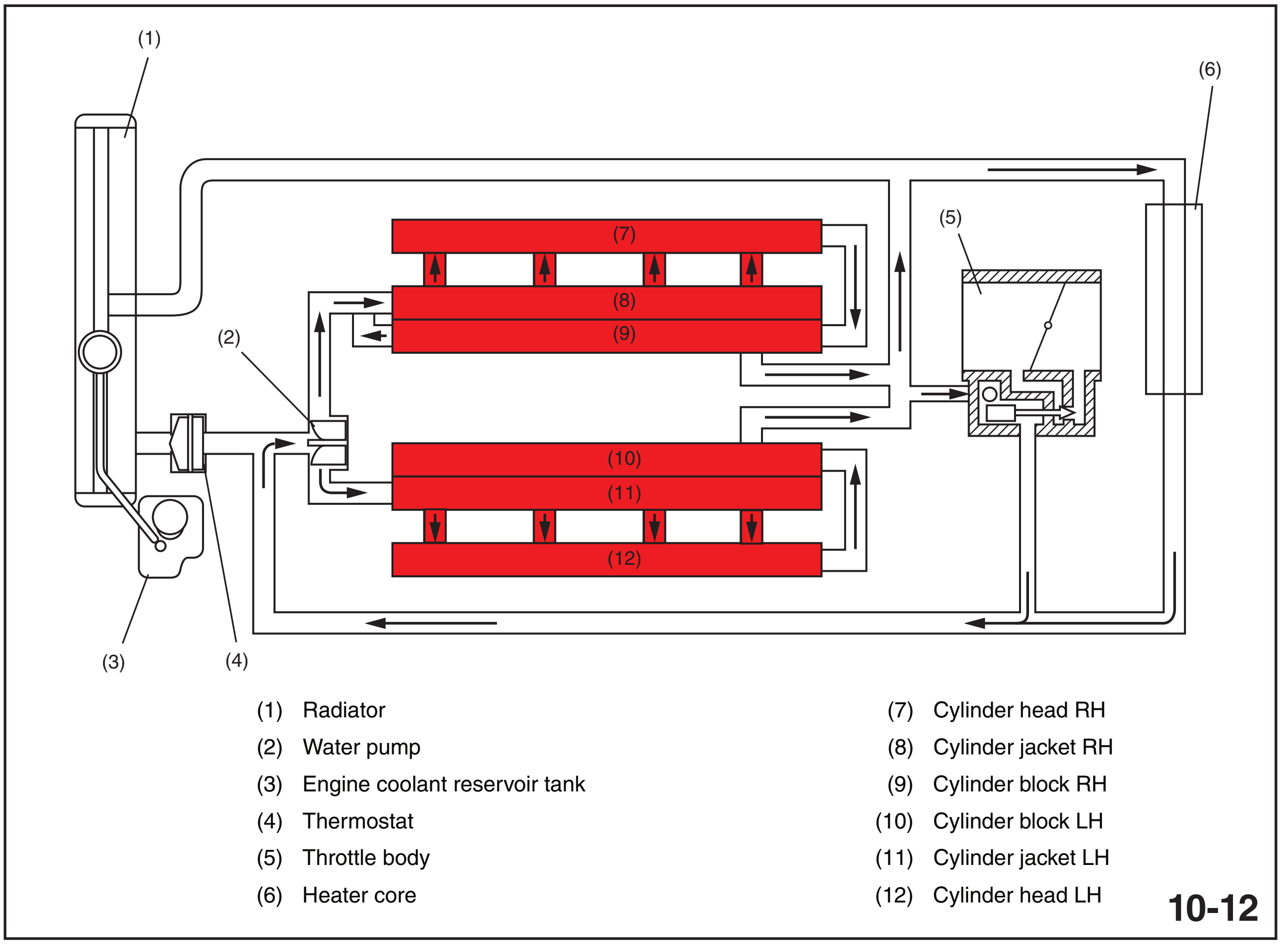
Typical Cooling System Thermostat

The thermostat consists of a housing, valve, spring, and an encapsulated wax pellet. When the engine is cold, spring pressure keeps the valve closed, allowing coolant to circulate through the engine only. As hot engine coolant flows past the wax pellet capsule, heat is transferred and the wax inside a capsule expands. The expanding wax pushes on the stem of the valve, working against the spring and causing the valve to open. With the valve open, coolant exits from the engine into the radiator. The thermostat typically opens between 87 – 91°C (189 – 196°F). When the capsule (wax pellet) cools, the wax contracts and spring pressure closes the valve.

System Operation

The system operates in three different phases depending on the temperature of the engine coolant:

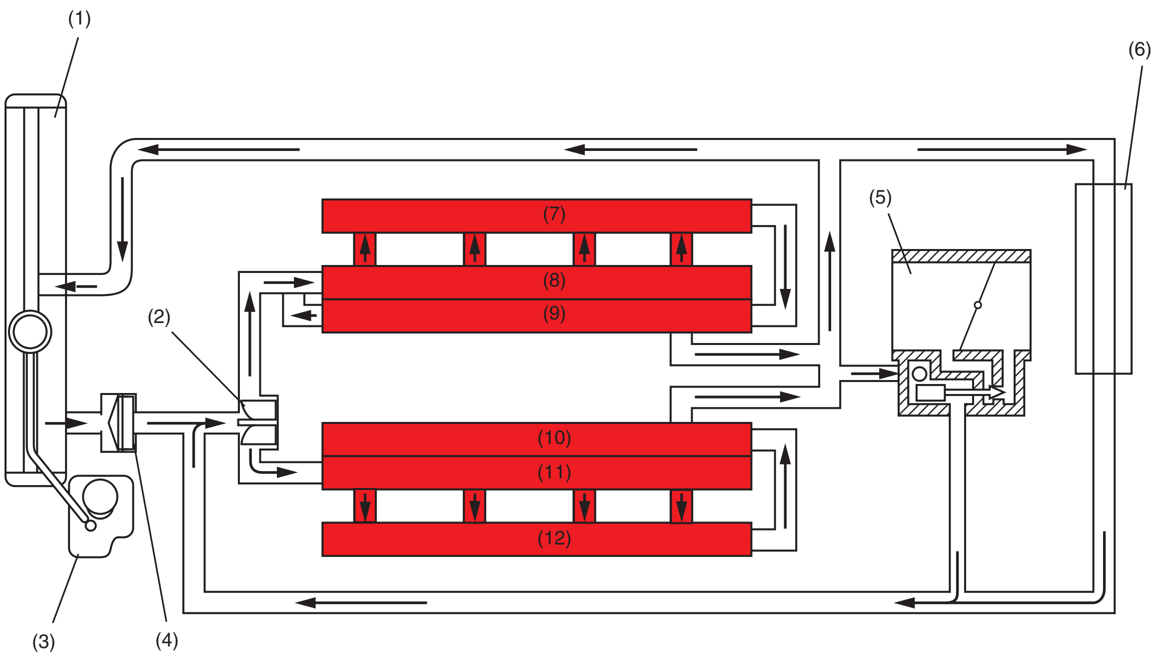
Thermostat Closed



System Flow with Thermostat Closed

When the engine coolant temperature is below a pre-set value, the thermostat remains closed. This prevents coolant from circulating through the radiator. The water pump circulates coolant through the heater circuit which serves as a bypass. This circulation allows the engine to warm up quickly and supply heat to the cabin.

Thermostat Open



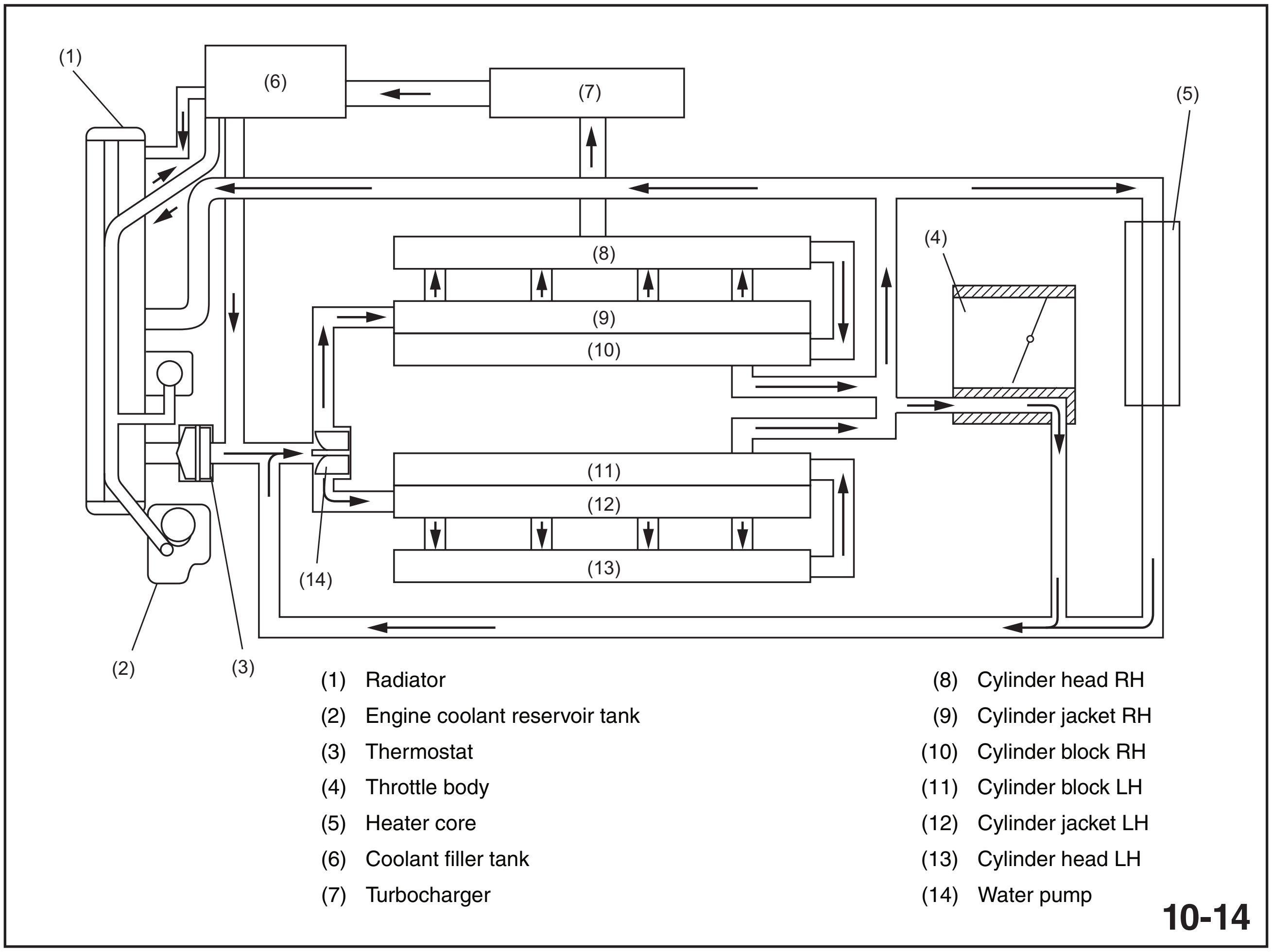
System Flow with Thermostat Open

When the engine coolant temperature reaches the pre-set value, the thermostat opens, allowing coolant to flow from the engine through the radiator where it is cooled. Coolant then re-enters the engine water pump and is circulated back through the engine. Coolant is still supplied to the heater core and used to heat the cabin if needed.

Thermostat Open and Radiator Fan Operating

When the engine coolant temperature becomes higher than the pre-set value, the ECM receives a signal from the engine coolant temperature sensor; the ECM makes the decision to turn the electric cooling fans on. The radiator fans can operate at a low or high speed. The ECM makes the determination to operate the fans on low or high speed depending on engine coolant temperature and vehicle speed.

Turbocharged Engine Cooling



System Flow Turbocharged Engine

Turbocharged engines require additional cooling capability because turbochargers are water cooled and reside in close contact with exhaust heat. Extra heat within the cooling system requires turbocharged vehicles to have lager radiators and larger capacity systems.

Turbocharged engines use a sealed type cooling system with a remote reservoir that is part of the pressurized system. The fluid level is not verified or filled at the radiator. The cap at the radiator does not have tabs to allow removal; instead the remote reservoir has the conventional pressure cap on it. This reservoir maintains cooling system level by drawing coolant from a non pressurized reservoir. Fluid level should be checked at the pressurized reservoir.

Bleeding the Cooling System

When the cooling system is opened or drained, air will get into the system. Upon refilling the system it is necessary to bleed all air from the system. Air pockets can cause hot spots that can damage the engine or cause it to overheat. Follow proper cooling system refilling procedures found in STIS.

Coolant Types

Ethylene Glycol

10-15

Ethylene Glycol Coolant Bottle

Most coolants are ethylene glycol-based. This compound is mixed with demineralized or distilled water and provides boil, freeze, and anti-corrosion protection.

Plain water boils at 212°F at sea level. A mixture of 50% coolant and 50% water can increase the boiling point +13°F to 225°F and also decrease the coolant freeze point to -35°F.

Genuine Subaru Long Life Coolant is a phosphate (non-amine) type and is specially formulated for all Subaru vehicles equipped with aluminum engines and radiators. Coolant of other types may not provide the proper protection to aid against corrosion of aluminum parts. If and equivalent must be used, make sure it is a phosphate (non-amine) type.

If a flushing machine has been used to service other brands vehicles with copper radiators, a chemical reaction between copper ions and Subaru coolant may occur, This could also cause clogging or the radiator. If regular flushing is required, only use fresh tap water, do not use hard water because it will create calcium build up which will clog the radiator.

Whenever the coolant is changed, you must add Genuine Subaru Cooling System Conditioner because it has been tested and approved for aluminum engines and radiators. Do not use aftermarket flushing agents because those chemicals could corrode aluminum parts.

Super Blue Coolant

10-16

Super Blue Coolant Bottle

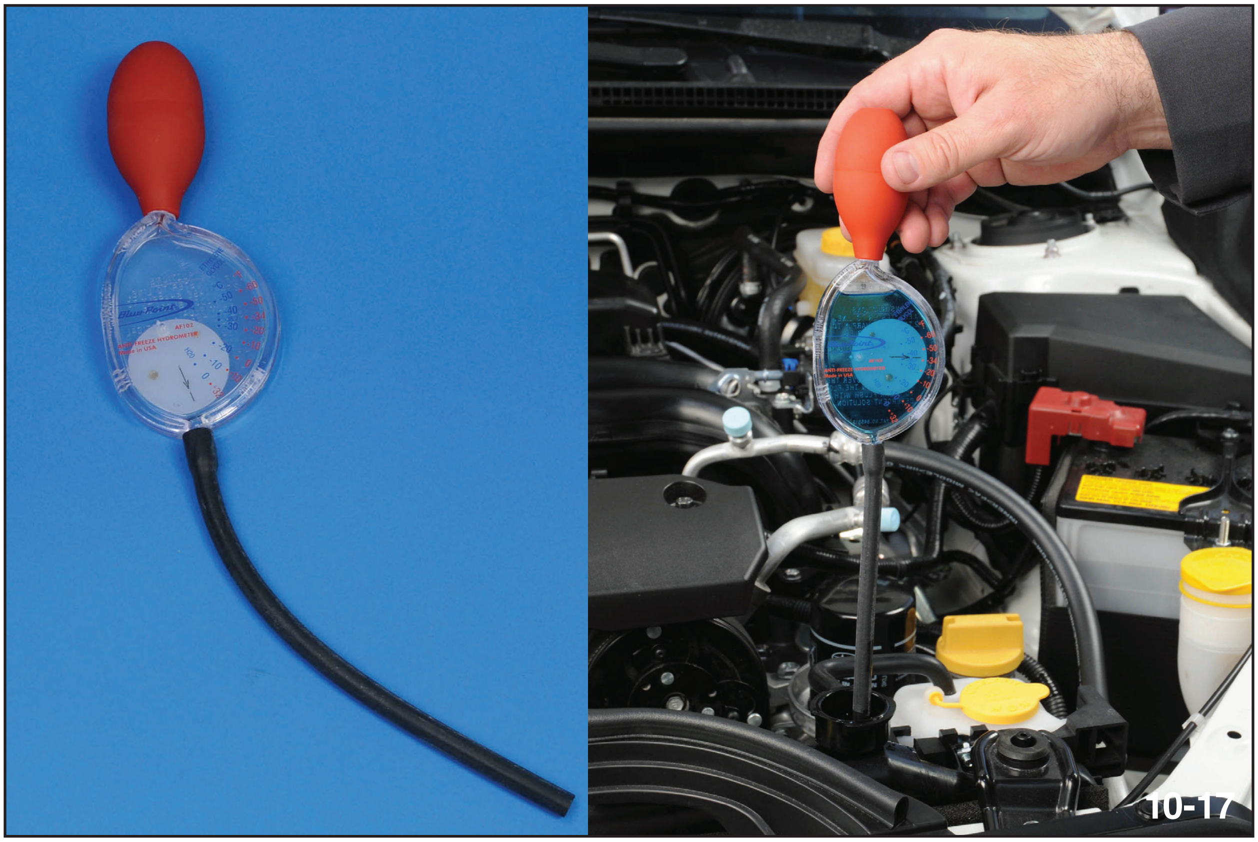
Super blue coolant is a long life coolant used in Subaru vehicles from 2009 model year on. The service life on this coolant is 11 years/137,500 miles. This coolant is not compatible with ethylene glycol type coolants. Mixing these coolants can cause cooling system failure.

Subaru has approved the Wynn's Power Flush III coolant exchange machine. This exchange machine removes a high degree of original equipment coolant from the system. Customers with older vehicles that were not equipped with super blue coolant can take advantage of installing this higher replacement interval coolant in their vehicles. This coolant extends the replacement interval to 6 years 75,000 miles.

Note: Always use a 50/50 mixture of water and coolant. Do not use straight coolant because it will not transfer heat properly and decreases the freeze point protection. Water is the component within the mixture that provides the heat transfer.

Coolant Testing

Testing Coolant Concentration



Hydrometer in Use

Relationship of SUBARU Super Coolant concentration and freezing temperature			
SUBARU Super Coolant concentration	50%	55%	60%
Freezing temperature	–36°C (–33°F)	–41°C (–42°F)	–50°C (–58°F)

10-18

Coolant Concentration Chart

A hydrometer is used to test the amount of antifreeze in the coolant mixture. The tester is made up of a reservoir with a needle and float, pick-up hose, and a squeeze bulb. To use the tester, insert the hose into the coolant. The bulb is squeezed and then released. Coolant is drawn into the reservoir. The float senses the gravity of the coolant solution and moves the needle to the corresponding reading on the gauge. If the reading shows the mixture being too weak, coolant mixture will need to be corrected or the coolant replaced. Improper coolant concentration can cause engine damage.

Pressure and Leak Testing

Cooling System Pressure Tester

Cooling System Pressure Tester Installed

When diagnosing a coolant leak, a cooling system pressure tester can be used. The cooling system pressure tester is basically a small pump with a gauge connected to it. Using an adapter, connect the tester to the radiator filler neck, start the engine, and run it until it is warm. Using the tester, apply the specific amount of pressure to the system. Monitor the gauge for any pressure loss. If the gauge indicates a loss of pressure, inspect the vehicle cooling system for external leaks. If no external leaks are found, the leak is most likely internal and further diagnostics will be necessary.

The cooling system pressure cap can also be tested using an adapter to verify it will hold system pressure and relieve pressure when necessary.

Maintenance Schedules

		Maintenance interval [Number of months or km (miles), whichever occurs first]																		
	Months	3	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	82.5	90	97.5	105	112.5	120	132	Remarks
	× 1,000 km	4.8	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	220	
	× 1,000 miles	3	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	82.5	90	97.5	105	112.5	120	132	
1	Engine oil		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
2	Engine oil filter		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
3	Spark plug									R								R		
4	Drive belt(s)					I				I				I				I		
5	Fuel line					(I)				(I)				(I)				I		Note (1)
6	Fuel filter											R								Note (1)
7	Air cleaner element					R				R				R				R		Note (2)
8	Cooling system					I				I				I				I		
9	Engine coolant	Replace after the first 11 years or 220,000 km (137,500 miles), and every six years or 120,000 km (75,000 miles) thereafter																		

10-20

Typical Maintenance Schedule

The scheduled maintenance requirements can be found in a separate Warranty and Maintenance Booklet. The booklet is located under the applicable vehicle>General Information Section>Periodic Maintenance Services PM>Schedule.

There are two maintenance schedules; Schedule A and Schedule B. Schedule A refers to maintenance items needed based on miles driven and time. Schedule B refers to maintenance items needed based on miles driven and driving conditions; extreme driving conditions require a shorter time interval for maintenance requirements.

The Service Manual Schedule Symbols in the chart indicate:

- R - Replace
- I - Inspection
- P - Perform

NOTES:

Diagnostics

General Diagnostics

General Engine Inspection

Engine System Visual Inspection

When diagnosing the engine, perform a visual inspection. Look for problems like:

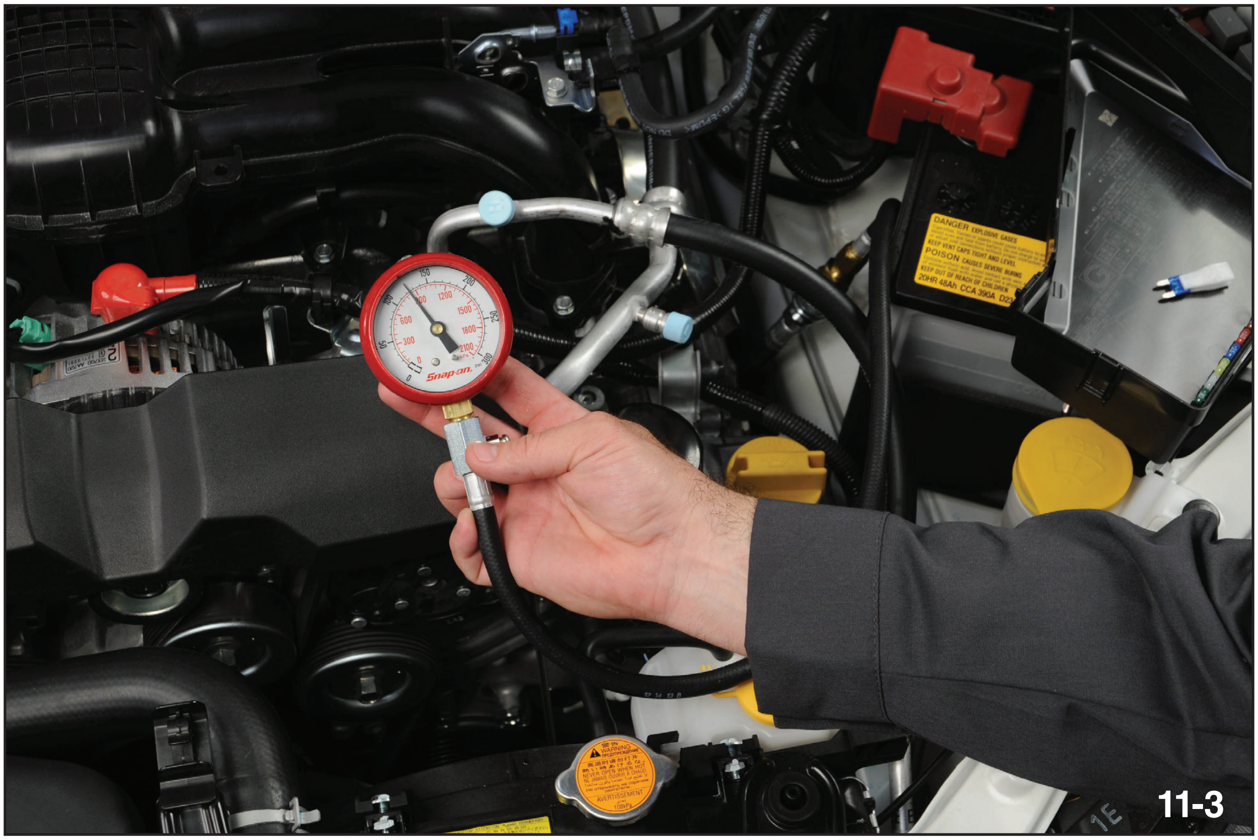
- Low fluid levels
- Oil or coolant leaks
- Worn components
- Loose components
- Cracked or dry rotted hoses

Use the following procedure to diagnose and repair customer concerns:

- Verify the concern.
- Determine related symptoms
- Analyze the symptoms
- Isolate the problem
- Repair the problem
- Verify the repair

Evaluating the Engine's Condition

Compression Testing



11-3

Compression Tester Installed

The internal combustion engine depends on a compressed air/fuel mixture to maximize the power produced by the engine. The upward movement of the piston in the cylinder with both valves closed creates compression. This compression value can be measured using a compression gauge. The compression gauge has divisions and values on the gauge face, usually expressed in kPa or PSI. Compression readings should be consistent from cylinder to cylinder on a properly running engine. Check with STIS for the specification for the engine you are working with.

Note: It is important to disable the fuel delivery system before performing a cylinder compression test. Doing so prevents fuel from entering the cylinder and washing the oil from the cylinder walls.

Performing a Compression Test

1. Start the engine, allow it to reach operating temperature, then turn the ignition switch to OFF.
2. Make sure the battery is fully charged. (Connect a battery charger)
3. Check the starter motor for satisfactory performance and operation.
4. Remove the fuel pump fuse from main fuse box.
5. Start the engine and run it until it stalls.
6. After the engine stalls, crank the engine for five more seconds.
7. Turn the ignition switch to OFF.
8. Remove all the spark plugs (use compressed air and a safety tip blow gun to blow debris from the spark plug area to keep it from entering the cylinder).
9. Disconnect the ground cable from battery.
10. Remove the air cleaner case.
11. Disconnect the connector from ignition coils.
12. Remove the ignition coils.
13. Remove the spark plugs with a spark plug socket.
14. Reconnect the battery ground terminal.
15. Install the compression gauge to the spark plug hole.

Note: When using a screw-in type compression gauge, the screw should be less than 25 mm (0.98 in) long.

16. Turn the ignition switch to ON.
17. Fully open the throttle valve.
18. Crank the engine and read the value when the needle of the compression gauge becomes stable (usually 3 to 4 Crankshaft revolutions).
19. Record your measurement, relieve the gauge pressure, and retest the same cylinder. Repeat this for each cylinder of the engine.

Note: When performing a compression test:

- Perform at least two measurements per cylinder, and make sure that the values are correct.
- If the compression pressure is out of specification, perform a cylinder leak-down test.

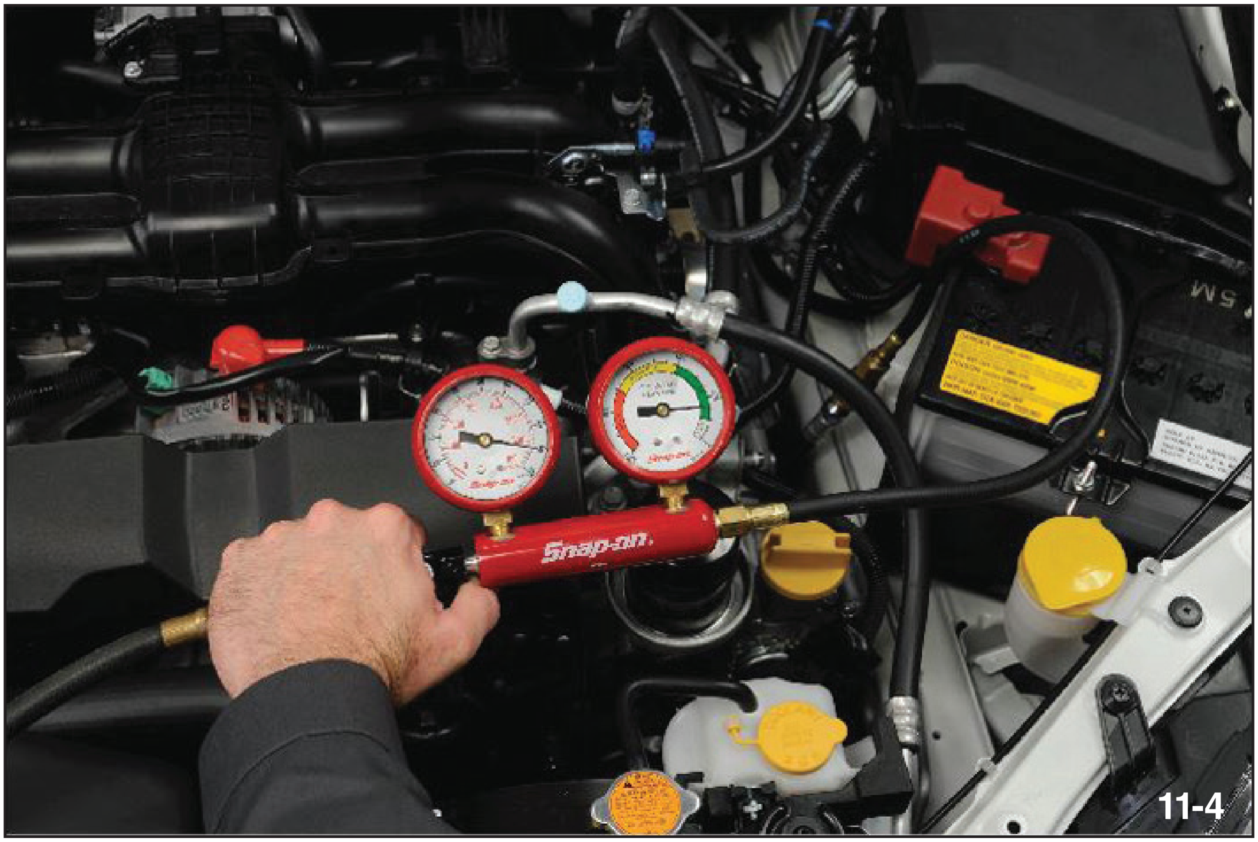
After inspection, install the related parts in the reverse order of removal.

Interpret Results of a Compression Test

If all cylinder results are within specification, mechanically the engine is considered healthy.

If any cylinder is determined to be out of specification, performing a cylinder leak down test will help determine where the concern lies.

Leak Down Testing



Leak Down Tester Installed

Cylinder leak-down testing is generally used as a follow-up to compression testing to assist in more accurately identifying the source of low compression. Additionally, some mechanical failures within an engine may not appear during conventional compression testing such as piston ring land damage.

Leak down testing forces a regulated amount of compressed air into the cylinder and calculates a relative percentage of cylinder leakage. Preparing the engine for a leak down test requires rotating the crankshaft so the cylinder being tested is at top dead center of the compression stroke. If the piston is in any other position, leakage through the intake or exhaust valves may occur or the piston may move causing the crankshaft to rotate.

Caution: If the piston is not correctly set a top dead center of the compression the crankshaft may rotate. Always ensure any tools used to rotate the crankshaft have been removed.

Leak Down Test Procedure (Example form Gauge shown)

1. Rotate the engine so the piston of the cylinder being tested to top dead center (TDC) of the compression stroke
2. Install (thread) the cylinder leak down tester adapter hose into the cylinder being tested
3. Connect shop air supply to the cylinder leakage tester
4. Zero the inlet gauge on the tester using the pressure regulator adjustment knob
5. Connect the adapter hose to the cylinder leakage tester
6. Determine the cylinder leakage from the gauge once the needle has stabilized and record the result
7. Repeat on all remaining cylinders and record the results
8. Interpret the results and determine source of the leakage
9. Select the correct course of repair action

Interpret Leak Down Test Results

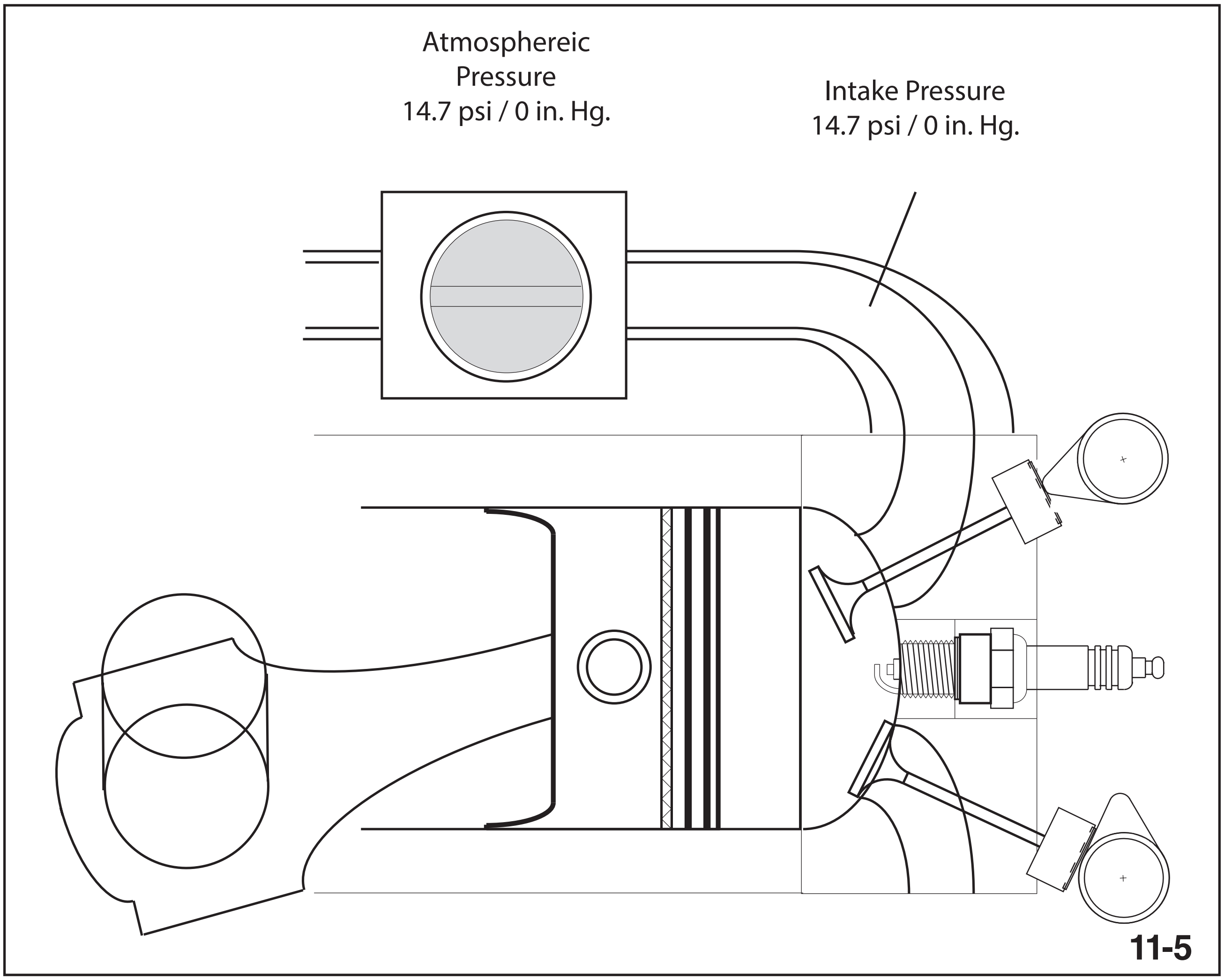
An engine in good mechanical condition should have fairly low leakage in each cylinder. Additionally, the consistency of leakage across all cylinders should be considered. A moderate to high level of leakage in any one, or all cylinders, indicates a possible mechanical issue.

Note: **Acceptable cylinder leakage specifications vary by manufacturer. Always refer to the tester manufacturer's instructions. Also, it is impossible for an engine to have "0%" leakage in a cylinder (perfect sealing). If this result is observed, confirm the gauge installation and refer to the tester manufacturer's instructions.**

If any or all cylinders exhibit excessive leak down, listen and observe for air escaping from the following locations while testing:

Source of Air Escaping	Likely Cause
Throttle Body	Intake valve
Exhaust	Exhaust valve
Crank Case (Oil dipstick tube)	Piston/Cylinder sealing (Ring, ring lands, etc.)
Coolant Overflow	Head Gaskets, Cylinder liner

Engine Vacuum

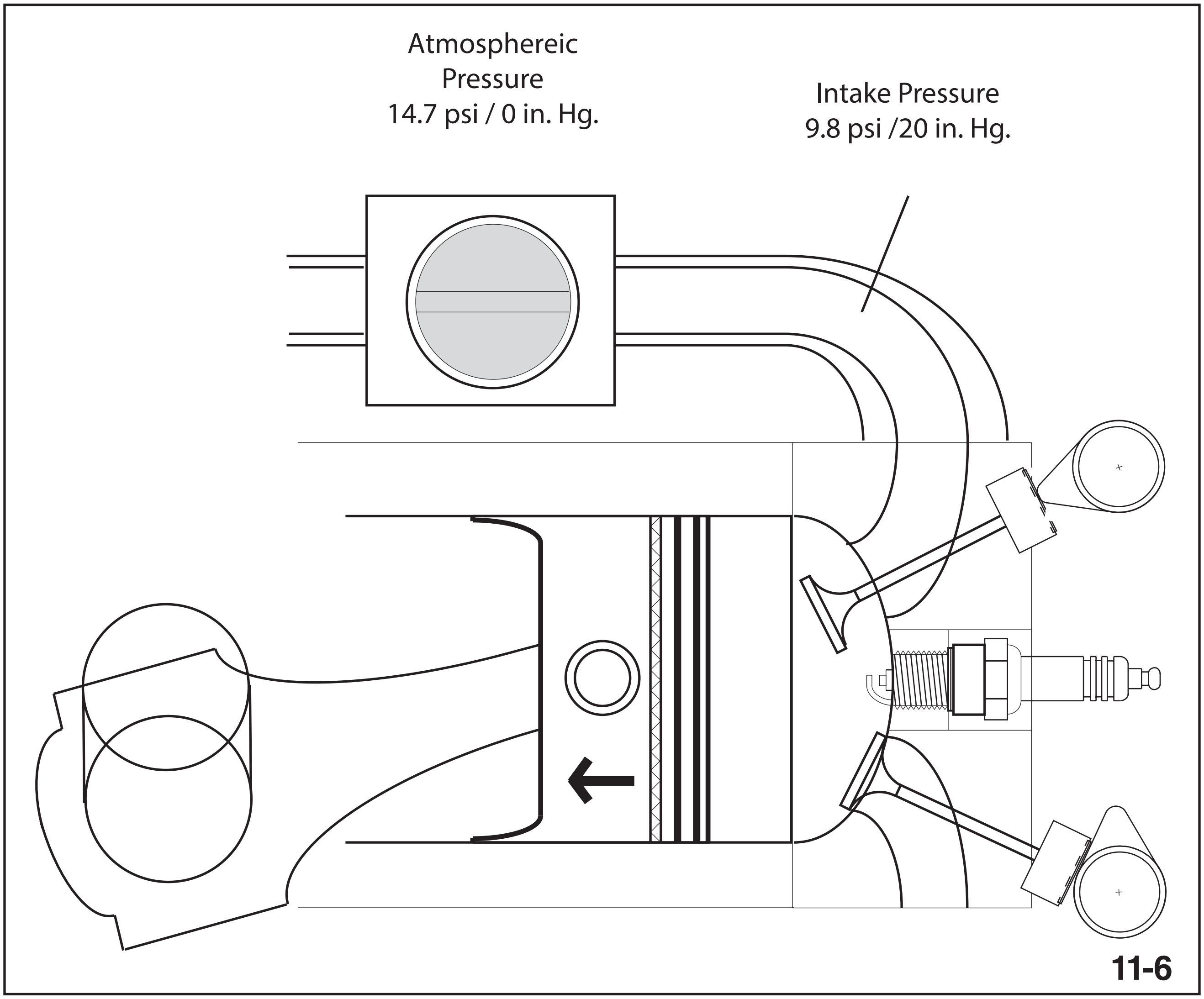


Key ON Engine Off: Vacuum Gauge Reads 0 in. Hg. (14.7 psi Absolute)

Vacuum is the difference between the air pressure of the engine's intake manifold and Earth's atmosphere. The pressure of the atmosphere at sea level is 14.7 psi. The vacuum gauge is calibrated to read zero at atmospheric pressure, this means the vacuum gauge reads pressure relative to atmospheric pressure. A typical vacuum reading for an engine in good condition, running at idle, at sea level is 18–22 in. Hg.

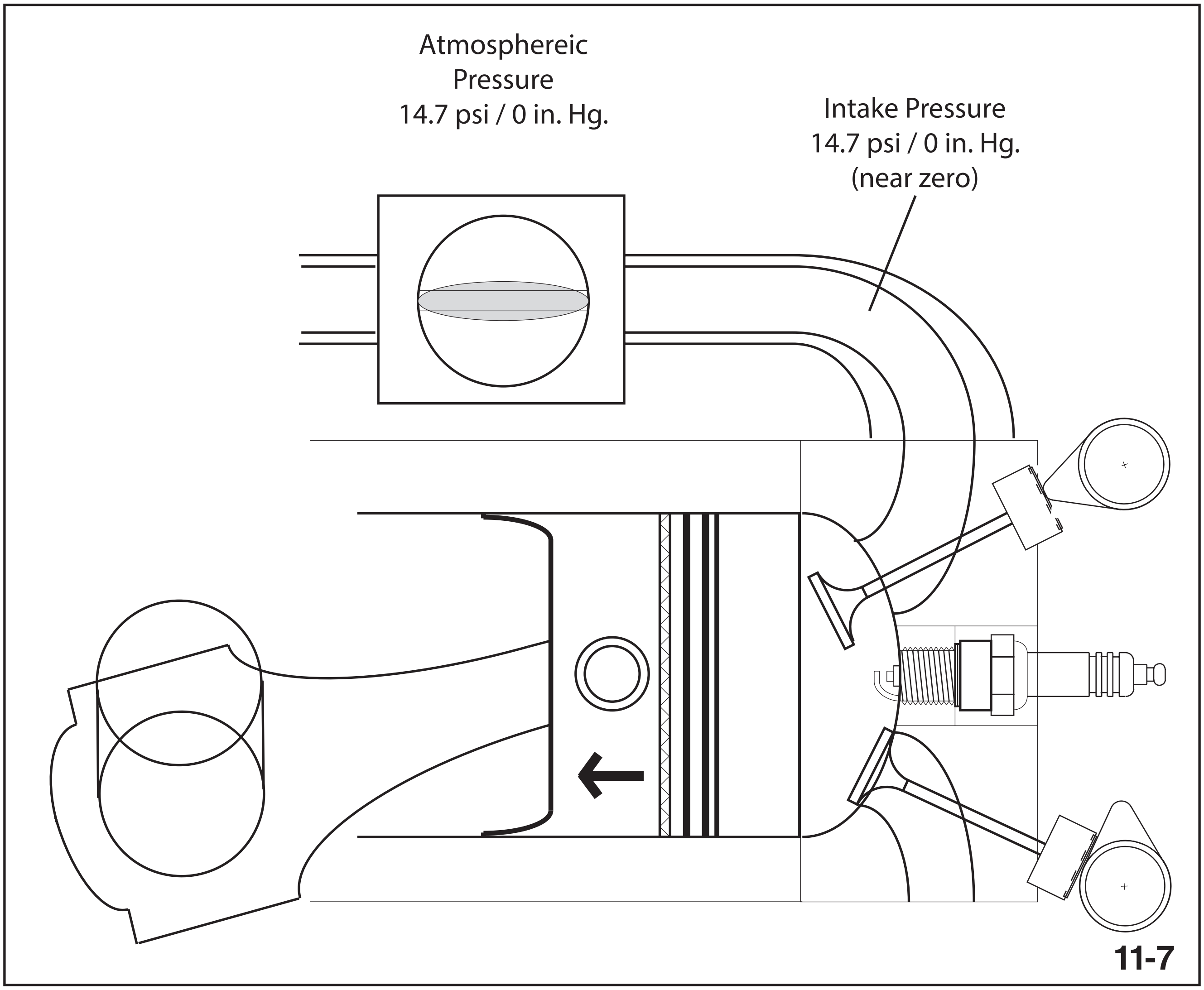
Engine vacuum readings are based on altitude. For every 1000 feet above sea level, vacuum will decrease about one inch.

Sea level	18–22 in. Hg
1000–2000 ft.	17–21 in. Hg
2000–3000 ft.	16–20 in. Hg
3000–4000 ft.	15–19 in. Hg
4000–5000 ft.	14–18 in. Hg
5000–6000 ft.	13–17 in. Hg



Engine Running at Idle: Vacuum Gauge Reads 18–22 in. Hg (At Sea Level)

When the engine is running at idle the piston is pulling air in through the valves, intake, and throttle blade. With the piston is on its downward stroke and the throttle blade is mostly closed; a vacuum is created within the intake manifold. The vacuum can be measured using the vacuum gauge. The gauge displays a measurement of the difference between intake pressure and atmospheric pressure.



Wide Open Throttle: Vacuum Gauge Will Read Near 0 in. Hg

When the engine is in a wide open throttle condition, the throttle blade is fully open; pressure within the intake is at or near atmospheric pressure, allowing maximum air flow. The pressure difference is minimal.

Note: When a turbocharged engine is in a boost condition, pressure within the intake will measure above 0 in. Hg., meaning above 14.7 psi atmospheric pressure.

Manifold Vacuum Testing

Engine Vacuum Gauge Installed

When the piston is being pulled downward during the intake cycle, air is drawn in through the intake and throttle body. If the throttle blade is mostly closed, a negative pressure is created called vacuum. Vacuum is measured with a vacuum gauge. When an engine is running properly, vacuum should measure (at Idle) between 61 – 68 kPa (18 – 20 in. Hg) and the needle of the gauge should be steady. The engine should be checked for a mechanical or valve timing issue if the vacuum within the engine is low or fluctuating.

Perform Manifold Vacuum Test

To perform an engine vacuum test:

1. Warm up the engine.
2. Disconnect the brake booster vacuum hose from the intake manifold.
3. Connect the vacuum gauge to the intake manifold.
4. Keep the engine at idle speed and read the vacuum gauge.
5. Intake manifold vacuum (at idling, A/C OFF):

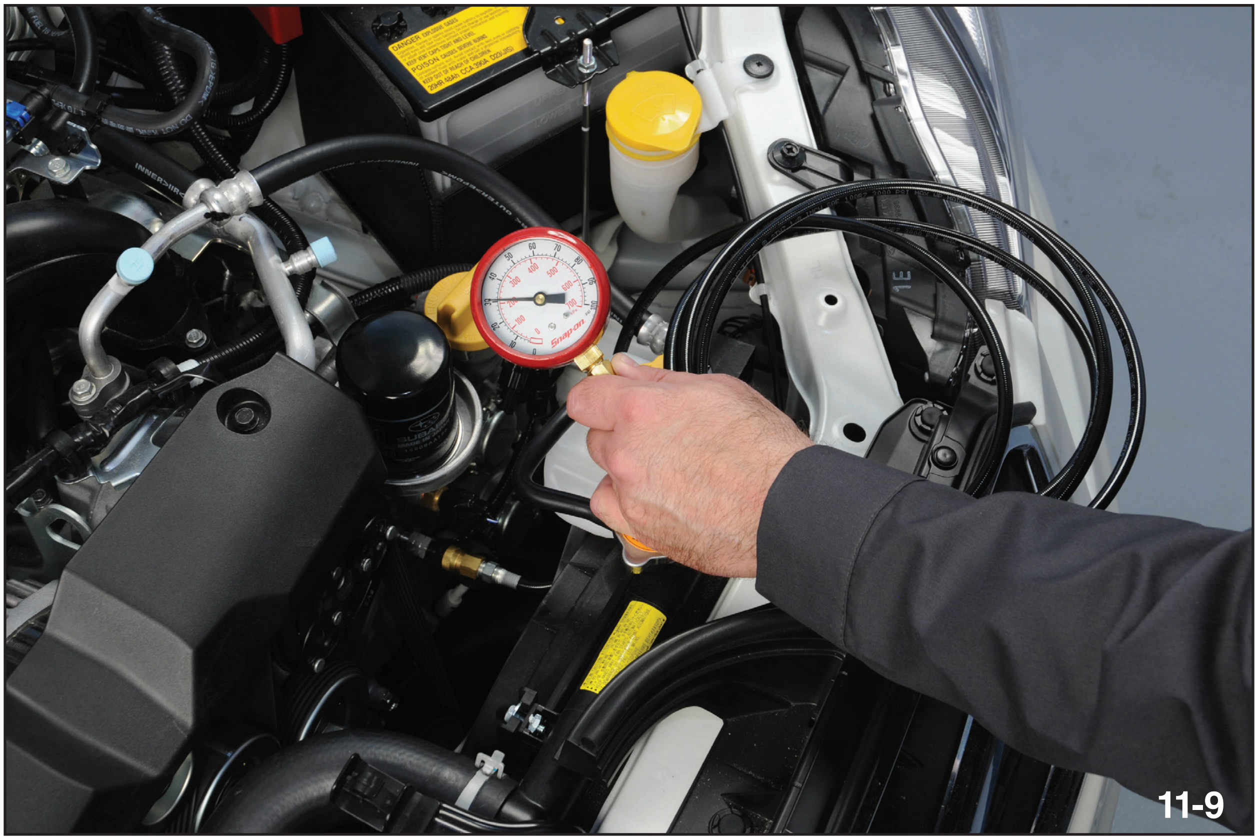
    60.0 kPa (450 mmHg,17.72 inHg) or greater

Note: The condition of the engine can be diagnosed by observing the behavior of the vacuum gauge needle as described in the table below.

Interpret Results of Manifold Vacuum Test

Intake Manifold Vacuum Indicators	
Vacuum Gauge Needle Behavior	**Likely Cause**
Needle is steady but lower than standard value. This becomes more evident as engine temperature rises.	Leakage around intake manifold gasket, disconnection or damage of vacuum hose
Needle intermittently drops to a position lower than the standard value.	Leakage around cylinder
Needle drops suddenly and intermittently from the standard value.	Sticky valve
When engine speed is gradually increased, needle begins to vibrate rapidly at certain speeds, and then vibration increases as engine speed increases.	Weak or broken valve springs
Needle vibrates above and below standard value in narrow range.	Defective ignition system

Engine Oil Pressure Testing



Oil Pressure Gauge Installed

The internal combustion engine requires proper oil pressure to create bearing surfaces and lubricate engine components. Low oil pressure is usually due to engine components that are excessively worn. Always validate engine oil pressure with the vehicle at operating temperature, otherwise your pressure reading may lead to an inaccurate diagnosis. Verifying oil pressure is another test that can help you understand the engine's state of health.

Perform Engine Oil Pressure Test

To perform an engine oil pressure test:

1. Disconnect the ground cable from the battery.
2. Remove the oil pressure switch.
3. Install the oil pressure gauge to the chain cover.
4. Connect the battery ground terminal.
5. Start the engine and check the oil pressure.

Note: Oil pressure testing:

- o Standard value is based on an engine oil temperature of 80°C (176°F).
- o If the oil pressure is out of specification, check oil pump, oil filter and lubrication line.
- o If the oil pressure warning light is ON and oil pressure is within standard, check the oil pressure switch.

Engine oil pressure: Standard specification

50 kPa (0.5 kgf/cm^2, 7 PSI) or more (at 600 rpm)
350 kPa (3.6 kgf/cm^2, 51 PSI) or more (at 6,000 rpm)

1. After inspection, install the related parts in the reverse order of removal.

Interpret Results of Engine Oil Pressure Test

If the engine oil pressure is below specification, engine removal, disassembly, and inspection will be required.

Safe Practices

Typical Vehicle Lifting Points

Sometimes it is necessary to remove the engine to gain access to specific components. When removing the engine for service, it is important to follow safe practices:

- Properly secure the vehicle on the lift
  - Refer to STIS for specified lift points for the vehicle you are working on.
- Discharge the A/C system prior to engine removal
  - Use the approved recovery machine and follow the procedures in STIS.
- Relieve the fuel system pressure when working on or around the system
  - This can be accomplished by running the engine with the fuel pump fuse disconnected
- Disconnect the battery before performing service on the vehicle mechanical or electrical system
  - Always disconnect the negative cable first.
  - Install the lift brackets per STIS instructions when removing the engine
- Use the appropriate lift brackets for the vehicle you are working on.
- Use approved lifting practices and components
- Use a floor jack or jack stand to support the transmission during and after engine removal.

Engine Noise Indicators

Internal Engine Noises		
Type of sound	**Condition**	**Possible cause**
Regular clicking sound	Sound increases as engine speed increases.	• Valve mechanism is defective • Incorrect cam clearance • Worn camshaft • Broken valve spring • Defective valve shim
Heavy and dull clank	Oil pressure is low.	• Worn crankshaft bearing • Worn connecting rod bearing
	Oil pressure is normal.	• Loosened flywheel mounting bolt • Damaged engine mounting
High-pitched clank	Sound is noticeable when accelerating with an overload condition.	• Ignition timing advanced • Accumulation of carbon inside combustion chamber • Wrong heat range of spark plug • Improper octane value gasoline
Clank when engine speed is between 1,000 and 2,000 rpm	Sound is reduced when the fuel injector connector of the noisy cylinder is disconnected.	• Worn crankshaft bearing • Worn connecting rod bearing
Knocking sound when engine is operating under idling speed and engine is warm	Sound is reduced when the fuel injector connector of the noisy cylinder is disconnected.	• Worn cylinder liner and piston ring • Broken or stuck piston ring • Worn piston pin and piton pin hole of piston
	Sound is not reduced if each fuel injector connector is disconnected in turn.	• Unusually worn valve rocker • Unusually worn valve shim • Worn cam sprocket • Worn journal of cam carrier and camshaft cap
Timing chain noise	____	• Loose timing chain • Timing chain contacting with adjacent part
Valve noise	____	• Incorrect cam clearance

External Engine Noises		
Type of Sound	**Condition**	**Possible Cause**
Squeaky sound	____	• Insufficient generator lubrication
Rubbing sound	____	• Poor contact of generator brush and rotor
Gear scream when starting engine	____	• Defective ignition starter switch • Worn gear and starter pinion
Sound like polishing glass with a dry cloth	____	• Defective automatic belt tensioner adjuster assembly (Loose V-belt) • Defective water pump shaft
Hissing sound	____	• Insufficient compression • Air leakage in air intake system, hose, connection or manifold

When disconnecting the fuel injector connector, the malfunction indicator light illuminates and diagnostic trouble codes (DTCs) are stored in ECM memory.

Perform the Clear Memory Mode and Inspection Mode after connecting the fuel injector connector.

NOTES:

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