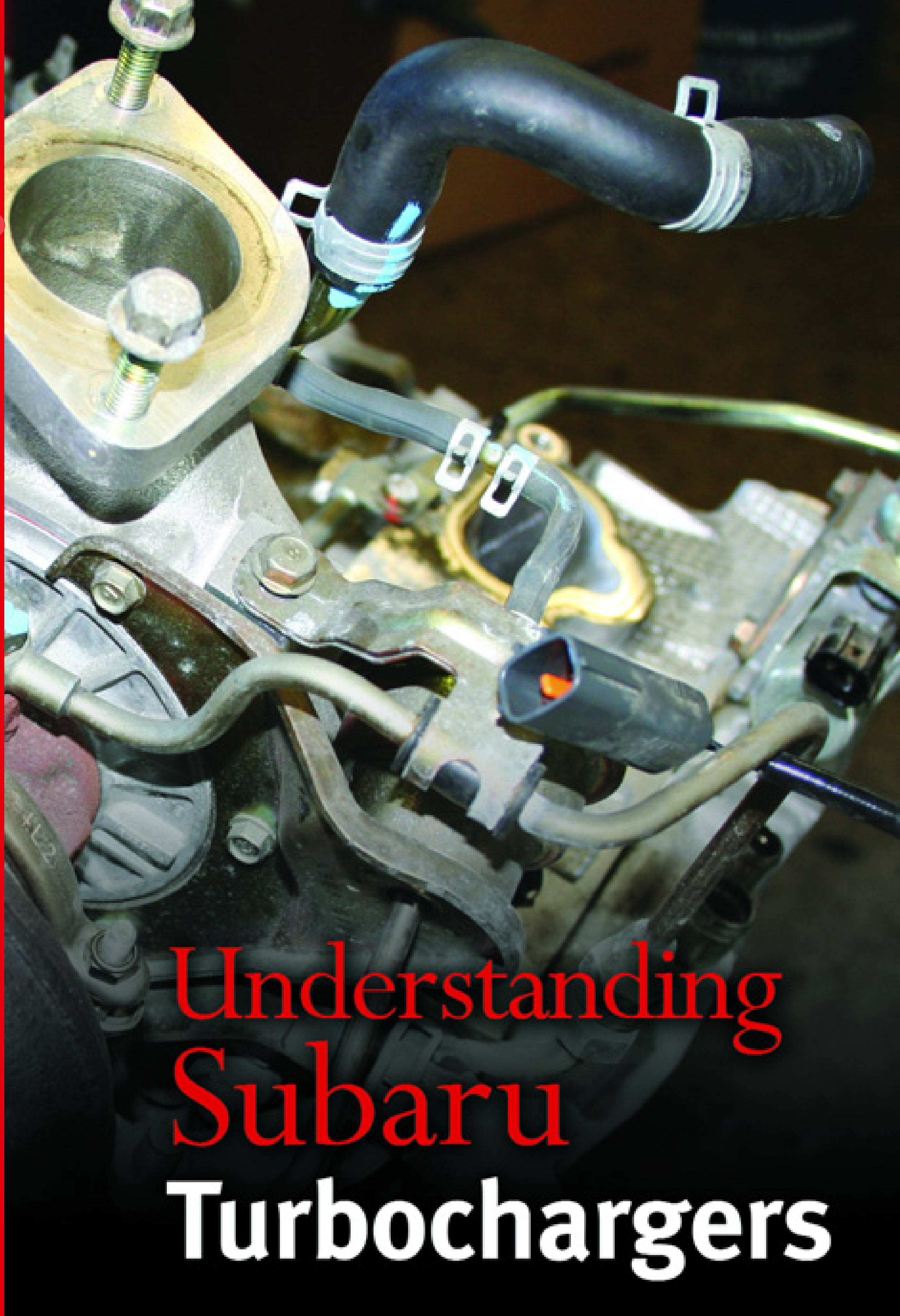


Understanding Subaru Turbochargers

Turbochargers are fairly simple in concept, but adapting the system to modern vehicles can be quite complex. This primer for those new to servicing turbos and review for veterans lays out the function and operation of turbocharging in Subaru vehicles.

The return of turbocharging in the 2002 Impreza WRX marked an absence of nearly a decade for Subaru vehicles. While the new generation has been around for half a decade, not everyone understands the function and operation of Subaru turbocharging systems.

Naturally, everyone knows these blowers are designed to get the maximum power out of engines by packing more air and fuel into the cylinders to get the biggest bang possible. Just how that is accomplished, however, may be a bit of a mystery to you. Here's a primer on turbocharging and how it applies to Subaru vehicles.

A Brief History of Turbochargers

Turbochargers were originally invented to increase the volume of air pushed into the cylinders of internal combustion engines, and, along with increased fuel, raise the level of energy produced by the combustion process.

Historical references indicate that Swiss engineer Alfred J. Buchi adapted the turbines from steam engines to diesel engines as a method to improve air induction, and, therefore, smoother operation in internal combustion engines. In 1905, Buchi's idea of powering the forced air induction by exhaust flow was granted a patent. Good idea or not, the fairly crude engines of the day could not sustain even or adequate boost pressures. Buchi worked another ten years before he could produce a working model of a turbocharged diesel engine. By that time, other companies had also produced turbocharging systems.

The massive building boom of internal combustion engines to supply ships, trucks and airplanes for World War I saw technologies take a giant leap forward. The first turbocharged diesel engines for ships and locomotives appeared around 1920. Shortly thereafter, European car manufacturers began incorporating them into factory race cars and a few sporty luxury models.

The next milestone for turbocharging came with the military build-up for World War II, when turbo systems were fitted to fighter planes and bombers to allow them to fly at higher altitudes where the thinner air could be compacted into the engines to provide sufficient combustion. However, direct-driven superchargers quickly proved more reliable, efficient and more easily controlled, leaving turbochargers by the wayside.

It wasn't until the mid-1950s when turbochargers started appearing on diesel trucks that modern turbos began to make a dent in the automotive market. Today, the vast majority of truck engines are turbodiesels.

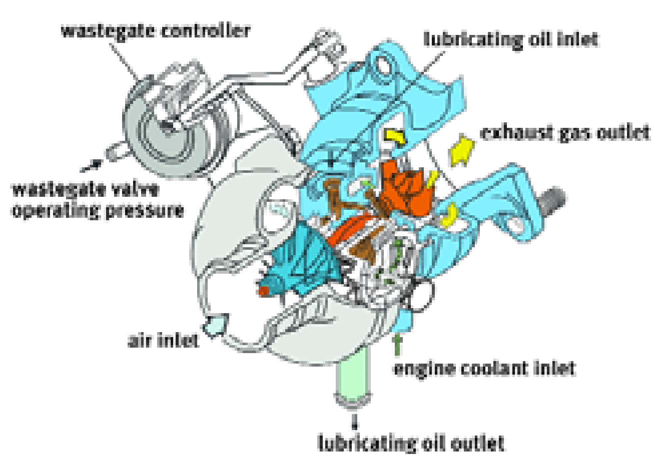
When turbocharged vehicles began to dominate the international racing scene in the 1960s, car manufacturers began to use them in sporty models to appeal to performance-oriented drivers. By the 1980s, turbochargers for cars were a bona fide success, particularly in Subaru vehicles, due to improved mettalurgy, intercooling and efficient boost controls.

The main components of a Subaru turbocharger system are a water-cooled turbocharger, an air-cooled intercooler, a wastegate control solenoid valve, sensors and a controller. Let's review the individual components and the role they play in the system.

The Turbocharger Itself

The turbocharger consists of a double-chambered housing encasing a turbine fan on one side and a compressor fan on the other, both mounted on a shared axle. It is positioned in the exhaust manifold and is driven by the exhaust gases coming from the cylinders. The gases enter the turbine chamber, forcing the turbine to rotate. The rotation drives the compressor, compressing intake air, which is sent to the engine intake.

The unit is water-cooled and lubricated by oil, both of which circulate through the housing. The lubrication oil is on a circuit from the engine oil pump. The very high speed of the turbine and compressor shaft – 20,000 rpm at idle and up to 200,000 at full throttle – requires a constant supply of lubricant to the full-floating bearings in order to avoid damage or failure. The oil also helps cool the shaft.



Cutaway view of turbocharger.

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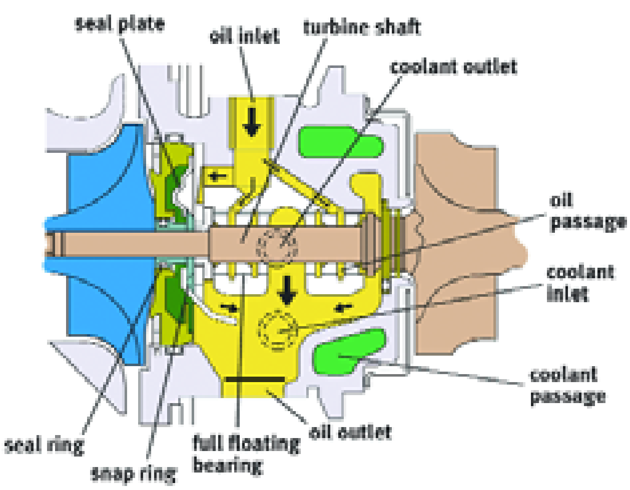
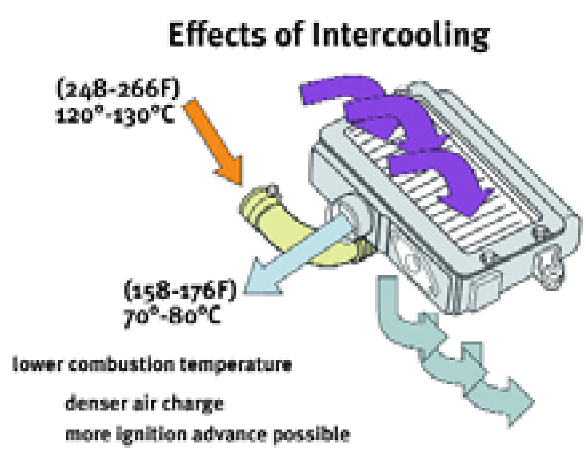


Cross-section view of a turbo housing.

Intercooler

The intercooler lowers the temperature of the air that has been heated in the process of being compressed by the turbocharger. Hot air expands and therefore lowers the efficiency of the turbocharging effect (increased power). Cooling the air makes it denser, so more can be packed into the cylinder to achieve the desired effect. Also, hot air increases the tendency for detonation to occur.

The intercooler is similar to a coolant radiator in that it dissipates the heat in the pressurized air into the atmosphere.

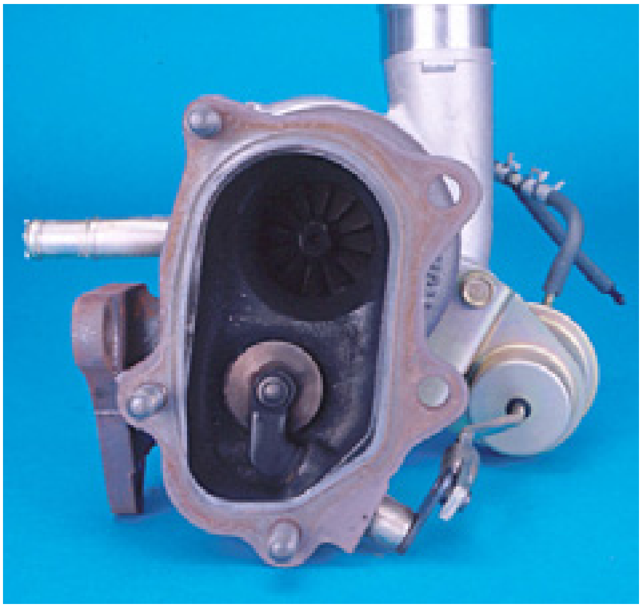


The intercooler acts as a radiator for the compressed air.

Wastegate

A wastegate is a form of bypass valve. It diverts a portion of the exhaust gases around the turbine, rather than through it. This limits the boost pressure the compressor supplies to the cylinders.

The wastegate valve is located in the turbo exhaust side housing.

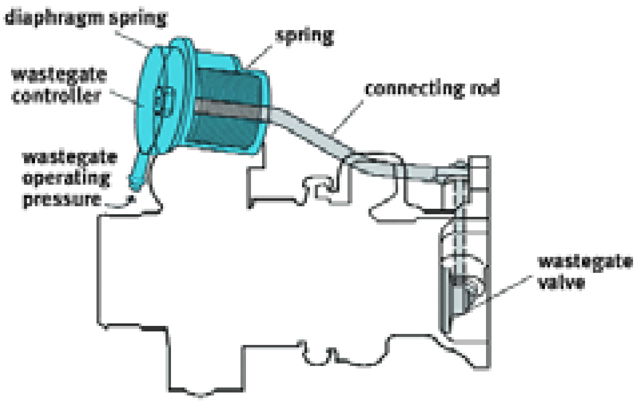


In this view, you can see the vacuum unit that opens the wastegate by means of linkage.

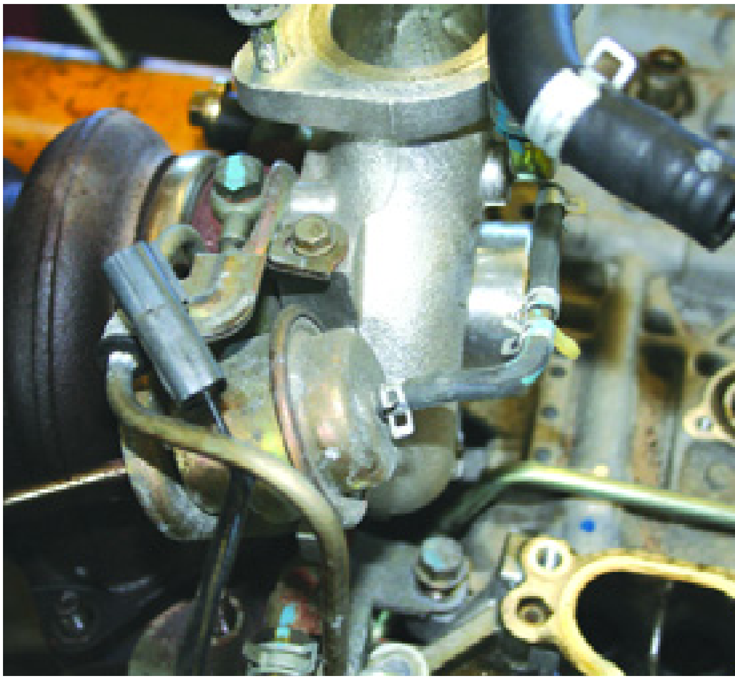
Wastegate Controller

The turbocharger control system regulates the charging air pressure according to atmospheric conditions and additional information from several sensors.

The wastegate controller adjusts charge pressure to optimum levels. The wastegate control solenoid valve switches the intake air pressure passages to the wastegate controller in response to signals from the engine control module (ECM). When the solenoid valve is closed, the intake air pressure upstream of the turbocharger unit is applied to the wastegate controller. When the solenoid valve is opened, the intake air pressure downstream of the turbocharger is applied to the wastegate controller.



Wastegate controller operation.



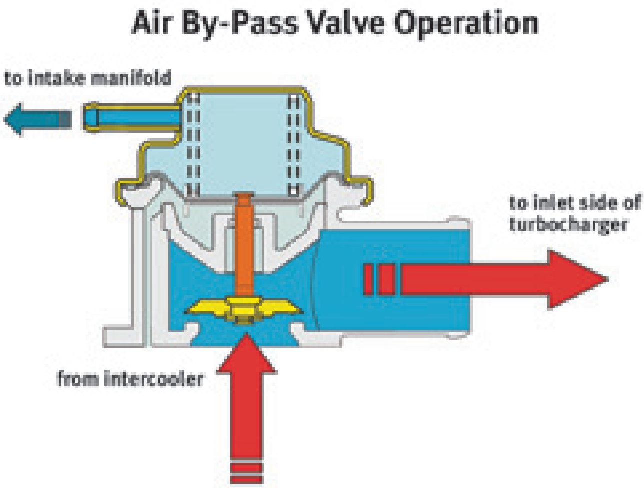
The wastegate controller solenoid is mounted on the side of the turbocharger.

Air Bypass Valve

The air bypass valve (sometimes called a blow-off valve), is a device to relieve pressure in the intake. It is located in the air path between the intercooler and the intake manifold.

When the throttle is closed rapidly, the airflow is quickly reduced, causing unstable flow and fluctuating pressures. The result is low air suction noise – audible evidence of surge, which may lead to thrust bearing failure.

To prevent this, an alternate air passage in the air bypass valve routes excess pressure, or boost, away from the intake, thus lowering the pressure within the system.



Subaru Late-Model Turbo Applications

Impreza WRX

The addition of turbocharging to the 2002 WRX 2.0L engine began the era of high-tech turbocharging for Subaru. Although turbos had been used on some models until the mid-1990s, the new systems are more sophisticated.

From 2002-2005, the 2.0L WRX engines were turbocharged. This changed for 2006 and later, when the 2.5L engines became the sole standard for turbos.

WRX STi Intercooler Water Spray System

Starting with 2004 models, the WRX STi incorporates a water spray system to help cool the intercooler, thereby further cooling the intake air.

Incoming air from the hood scoop flows through and over the intercooler to cool the unit. A water spray nozzle is mounted on the bottom of the hood scoop and, when activated, sprays water in a pattern to cover the full width of the intercooler. The resulting evaporation provides additional cooling to the air intake air as the water is pushed through the intercooler fins by the hood scoop.

The intercooler water spray is activated by a button control switch mounted to the driver's left, near the headlight leveler control. It sends a signal to a timer, located on the A pillar post, behind the glove box.

Low water level in the reservoir is indicated by a warning light below the speedometer on the combination meter.

The water reservoir is located in the right side of the trunk.

Note: Only distilled water should be used to avoid blockage of the intercooler fins by mineral deposits, which can also plug up the spray nozzle. In areas that experience freezing weather during the winter, the water reservoir should be kept no more than half full. A full reservoir would leave no room for freezing water to expand and could split the tank.

The intercooler water spray system activation button, found on 2004 and later STi models, is located on the left side of the steering wheel.

Baja

2003-2006 Baja 2.5L Turbo models were fitted with turbos.

Forester

2004 and 2005 Forester XT and XT Premium models were equipped with the 2.5L engine and turbos. For 2006 and 2007, turbo models are labeled XT Limited and Sports XT.

Outback

Outback joined the Subaru turbo team in 2005 with the XT models, all featuring the 2.5L engine.

Legacy GT

2005 and later Legacy GT Limited and Spec.B models are also fitted with turbos.

Service Procedures

Here are some service procedures, including steps to properly remove turbocharger components, and tests and inspections you can perform to check component operation.

Intercooler Removal

You may need to remove the intercooler to work on other components beneath it. Removal of the intercooler must be performed carefully so that no damage occurs.

1) Disconnect battery. Remove the two bolts that attach the bypass valve, then the valve.

2) Remove the bolts from each end of the intercooler and disconnect the crankcase ventilation hoses from the intercooler.

3) Loosen the clamps at the throttle body and outlet of the turbocharger.

4) Gently move the intercooler side to side until the tension of the hoses at the turbo and throttle body loosen.

5) Remove the intercooler from the engine compartment and cover the open areas with tape to prevent foreign material from entering, which could cause damage to the engine or turbo after reinstallation.

Turbocharger Removal

1) After removing the intercooler, remove the intercooler mounting bracket.

2) Remove the eight bolts that secure the protective heat shield around the turbo.

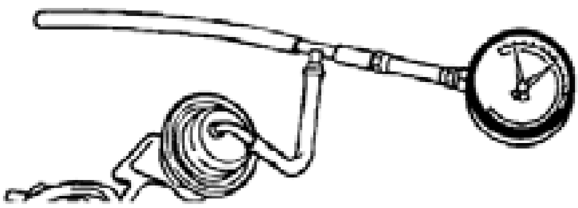
3) Raise the vehicle and disconnect the rear oxygen sensor harness, then remove the front exhaust pipe mounting bolt. Position the pipe so there is some movement.

4) Lower the vehicle and disconnect the wastegate hose to the vacuum hose leading to the wastegate control solenoid.

5) Remove the coolant hose from the reservoir that connects to the turbo.

Wastegate Testing

You can test wastegate control vacuum by attaching a regulated pressure supply to the wastegate actuator hose connector and using a vacuum gauge to read the actuation pressure. The actuator should begin to open at approximately 7.2-8.7 psi (50-60 kPa). Check all associated hoses for damage or loose connections.



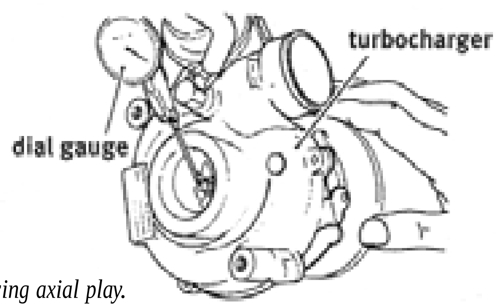
You can check the operation of the wastegate actuator using a vacuum gauge.

Turbine Shaft Inspection

The "Achilles heel" of turbochargers is the turbine shaft. Although made to precision specifications and using the finest materials, these shafts can fail due to the high rpm at which they spin and are vulnerable to lack of lubrication, debris and the quick spin-up rates that occur under high boost.

After the obvious visual inspection for damage, the turbine shaft should be measured for play. To inspect for turbine shaft wear, two measurements should be taken:

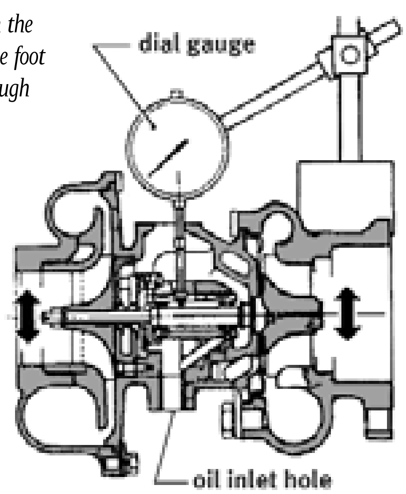
To measure the axial movement of the turbine shaft, position a dial indicator gauge against the end of the shaft at the turbine end, and push against the compressor end of the shaft. Axial play should not exceed .003 in. (0.09mm).



Measuring axial play.

To measure radial movement of the turbine shaft, place the dial gauge through the oil outlet hole and against the shaft. Rotate the turbine shaft and observe any fluctuations. Jiggle the shaft up and down, and back and forth, while observing the dial gauge. Radial play should not exceed .006 in. (0.17mm).

Check radial play in the shaft by inserting the foot of a dial gauge through the oil hole.



Air Bypass Valve Inspection

The air bypass valve is located downstream of the turbocharger and provides a bypass passage for the compressed air intake back to the inlet side of the turbocharger. When deceleration occurs immediately after a period of high engine load (high boost pressure), a large pressure differential occurs at the compressor wheel of the turbocharger. This is due to the inertia of the turbocharger, which still generates boost pressure even though the throttle is fully closed. This high pressure may lead to increased noise, and possible damage to the turbocharger because of the high pressure that occurs in the compressor.

The upper chamber of the bypass valve is connected to the intake manifold and the negative pressure (vacuum) during deceleration opens the valve by acting on the diaphragm.

Operation of the bypass valve can be tested by attaching a hand-held vacuum pump to the intake manifold connection. Apply vacuum with the pump and confirm that the valve opens.

Turbo System Diagnostic Trouble Codes (DTCs)

There are only a few diagnostic trouble codes that pertain to the turbocharging system. They focus on problems with the wastegate solenoid valve, but may indicate other causes or additional problems.

PO244 Wastegate Solenoid "A" Range/Performance

Symptoms for this DTC may include poor idling, engine stalling, or poor driving performance. Refer to the correct service information for the vehicle you are servicing regarding inspecting and testing the wastegate control solenoid valve.

PO245 Wastegate Solenoid "A" Low

Symptoms for this DTC may include poor idling. Refer to the correct service information for the vehicle you are servicing regarding inspecting and testing the wastegate control solenoid valve.

The culprit may be one of the following:

- An open circuit in the harness between the ECM and the wastegate control solenoid valve connector.
- An open circuit in the harness between the main relay and the wastegate control solenoid valve connector.
- A faulty wastegate control solenoid valve.

PO246 Wastegate Solenoid “A” High

Symptoms for this DTC may include poor idling. Refer to the correct service information for the vehicle you are servicing regarding inspecting and testing the ECM.

After repair or replacement of faulty parts, always remember to clear the DTC from the ECM memory and recheck to see that it is fully erased.

The exact procedures for correcting the problems and erasing DTCs may vary according to model and year, so be sure to refer to the specific vehicle you are servicing for correct information. Log onto the Subaru Technical Information System at *http://techinfo.subaru.com* for accurate information or consult your local Subaru N.E.W. Horizons Dealer.

Service Tips

- When working under the hood on a model equipped with a turbo, don’t be tempted to lay tools or parts on the intercooler. It might look like a handy surface, but you could easily damage the delicate fins and affect the cooling ability of the intercooler. Take extra precautions not to drop anything on it.

Right*: Don’t lay tools or parts on the intercooler. Damage to the cooling fins is a real possibility.*

Understanding Subaru Turbochargers

- Two different models of turbochargers have been used in 2002 and later Subaru vehicles. Make sure you refer to the proper model and engine for parts and service information.

- A constant supply of clean oil to lubricate the turbine shaft and carry away heat is of utmost importance to turbo longevity. Dirty oil cannot conduct heat as well as clean oil and can leave sediment on the turbine shaft, which will cause damage to the rotating shaft and the seal. Always emphasize the need for oil changes at the required intervals outlined in the owner's manual to avoid turbo and engine damage.

- Excessive exhaust backpressures can quickly cause damage to a turbine seal. A clogged catalytic converter can create such pressures, as can a change in exhaust system plumbing. Aftermarket exhaust components may not match the backpressures of the original system and therefore create problems. Always stick with Subaru exhaust components for the best results. They are designed for proper operation with Subaru turbo systems.

- Poor incoming air flow can adversely affect turbo function. Be sure to check the air filter and PVC components for clogging. Aftermarket parts may not allow the proper air flow needed for turbocharger operation. Again, stick with Subaru parts that are designed for the vehicle.

Influences on Boost Pressure

Several factors can influence boost pressures and affect turbocharger efficiency. The key factors are:

- Ambient Air Temperature and Pressure

As the air temperature rises, the ability of the turbocharger to compress the warmer air decreases. This phenomenon is directly due to the decrease in air density and the physical limitation of the turbocharger. Even when the air temperature is low, the air density (barometric pressure) may be low. Under these conditions, lower than expected boost pressures may be experienced.

The diameter of the exhaust system will vary the pressure differential across the turbine. A larger exhaust allows the turbocharger to rotate faster, which results in higher boost pressures.

Any increase in boost pressures would require "re-mapping" of the ECM programs to accommodate different air flow rates and resultant ignition change requirements.

Over-revving of the turbine – trying to supply enough boost – can lead to turbocharger failure, particularly in conjunction with the increase in the pressure differential across the turbine.

- Fuel Octane Rating

The high combustion pressures resulting from the increase in volumetric efficiency of turbocharging require a high-octane fuel. If the octane rating of the fuel is too low, what's variously known as detonation, pinging, or spark knock will occur. The end result of this knocking is damage to the engine.

The ECM is programmed to retard ignition timing if detonation is detected. Excess spark knock will cause the ECM to enter a "Fail-Safe" mode wherein the boost pressure is reduced to the minimum value determined by the wastegate actuator.

- Turbo Lag

The pressure of the exhaust gas is low at slower engine speeds. As the turbocharger uses exhaust energy to operate, it does not respond immediately when the throttle is opened. This is referred to as "turbo lag." To overcome turbo lag, the turbocharging system and its controls are matched to each vehicle model, based on the vehicle's specifications, features and the expected use of the vehicle.

By now, it should be pretty evident that the basic concept of the turbocharger is relatively simple, but attaching it to an engine, controlling its operation and getting the best results is quite complex.

Subaru engines are perfectly matched to the turbocharging components for optimum function. The key factor to keeping them running at tip-top shape is following the correct maintenance procedures. Doing so will keep your customer – and you – happy.

Turbocharging Terms

The terms used to describe turbocharger operation can be confusing. Here are some definitions for common turbocharging terms:

- Boost Threshold

Boost threshold is the optimum engine speed to produce exhaust gas flow to create positive manifold pressure (boost).

- Turbo Lag

Turbo lag is the time delay between the point when the throttle is opened and the turbocharger boost reaches operational speed when the engine is running at boost threshold. Many factors affect turbo lag: engine tuning status; the condition of the rotating components; operational condition of the control sensors and components; the presence of any air leaks in the turbocharger system; the control settings; and even the weather.

Boost Leak

When air (boost) is leaking within the turbo system or intake, it is referred to as "boost leak." This may be caused by loose assembly of the components, a bad seal or a cracked component. Under such a condition, the turbocharger may not create enough boost pressure, or reach adequate levels.

Boost Spike

A boost spike is an erratic increase in boost pressure, mainly experienced when the vehicle is accelerating through the lower gears and the controller can't adjust to the changes in engine speeds as quickly as would be ideal.

Boost Creep

Boost creep is when boost pressure rises – or "creeps" – above the optimum level. It occurs when the wastegate, although fully open, may not bypass enough air to maintain the optimum level. Boost creep usually occurs at high rpm, when the boost is highest.

Shaft Play

Shaft play is a side-to-side looseness – or play – of the turbine shaft, caused by worn shaft bearings. This results in the shaft, turbine blades or compressor blades making contact with the housing. It usually can be identified by a whine or buzzing noise.

Turbo Whistle

Turbo whistle occurs when the throttle is lifted at or after full boost.

It is caused by the compressor side of the turbo experiencing aerodynamic instability. This is the result of incorrect settings or controls and normally only occurs with add-on turbochargers.

Intercooler Heat Soak

Heat soak occurs when the intercooler isn't able to adequately dissipate the heat from the turbocharger and becomes ineffective. This condition can occur for a number of reasons: problems with the intercooler, plugged fins, inadequate cooling air inducted to the intercooler, or high ambient temperatures.