AutoTap

CATALYTIC CONVERTERS & O2 SENSORS

What is the most important emissions control device on a vehicle today? The catalytic converter, because it cleans up any exhaust pollutants that exit the engine. It's a hot job (literally) that operates at temperatures of 600 to 1000 degrees F. As long as the converter does its job efficiently, the vehicle will meet emissions and pass both a tailpipe emissions check and/or an OBD II plug-in emissions test. OEM converters are engineered to last well over 150,000 miles, but a number of things can interfere with their ability to clean up the exhaust -- and some may eventually cause the converter to fail.

The causes to be most concerned about include:

- Ignition misfire (fouled spark plug and/or shorted plug wire)
- Compression misfire (leaky valves or head gasket)
- Internal coolant leaks (cracks in head or leaky head gasket)
- Oil burning (worn valve guides, seals, rings, cylinders)
- Fuel contamination (lead)
- Rust or physical damage

TYPES OF CATS

Before we go any further, we need to take a quick look inside the converter to understand how it operates. Inside the stainless steel outer shell is a ceramic or metallic honeycomb coated with a very thin layer of precious metals. These include platinum, palladium and rhodium in various combinations. These metals all have the unique ability to trigger chemical reactions. They are not consumed or used up over time, but only serve to ignite reactions between the pollutants in the exhaust and oxygen.

The earliest converters dating back to 1975 were "two-way" or "oxidizing" converters because the catalyst only reacted with hydrocarbons (HC) and carbon monoxide (CO) in the exhaust. These older converters did nothing to reduce oxides of nitrogen (NOX) in the exhaust.

In the 1980s, "three-way" (TWC) converters made their appearance. These have two catalysts inside, one to oxidize HC and CO, and a second to reduce NOX. Some of the older TWC converters have an air pipe connected to an air pump or aspirator valve to supply air between the oxidation and reduction catalysts. Newer TWC converters don't need an air pipe and rely on oxygen in the exhaust to burn the pollutants.

To operate efficiently, three-way converters need an air/fuel mixture that alternates between rich and lean. When the air/fuel mixture is rich, it reduces the amount of oxygen in the exhaust. This allows the reduction catalyst to break down NOX. But to burn HC and CO, the oxidation catalyst needs more oxygen so the air/fuel mixture has to go lean. This allows the catalyst to momentarily absorb oxygen and trigger a reaction that burns up the HC and CO.

The powertrain control module (PCM) flip-flops the air/fuel mixture when the engine is warm by monitoring the rich/lean signal from the oxygen sensor in the exhaust. When the O2 sensor reads lean, the PCM makes the fuel mixture go rich. When the O2 sensor sends back a rich signal, the PCM shortens the on-time of the fuel injectors and leans the fuel mixture. The O2 sensor then send backs a lean signal, and the PCM increases the on-time of the injectors to make the fuel mixture rich again. By rapidly changing the air/fuel mixture back and forth, the overall mixture averages out and keeps emissions at a minimum.

On some newer vehicles, a new type of "wideband" oxygen sensor (also called an "air/fuel ratio" sensor) is used. Instead of producing a high or low voltage signal, the signal changes in direct proportion to the amount of oxygen in the exhaust. This provides a more precise measurement for better fuel control and tells the PCM the exact air/fuel ratio. On most applications, you can also read the air/fuel ratio or lambda value on your scan tool.

The new wideband air/fuel sensors are used on 1996 and newer Toyotas, also 1999 & up Volvo 2.3L, 2.3L & 2.8L, 2000 and up Volkswagen 1.8L, 2.0L, 2.6L & 2.8L, 2001 and up Porsche 911 3.5L, 2002 VW Passat 4.0L W8, 2000 and up Subaru Legacy & Outback 2.5L, and 2002 & up Audi A4 and Quattro 1.8L.

TECHNICAL ARTICLE

AutoTap®
OBD II Diagnostic Scanner

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CONVERTER PROBLEMS

Okay, so what have we learned? Three-way converters need a changing air/fuel mixture to work at peak efficiency. This, in turn, requires a good oxygen sensor and the PCM to go into "closed loop" when the engine is warm.

You can check the loop status of the PCM with a scan tool, and you can check the operation of the oxygen sensor by looking for a changing rich/lean signal when the engine is warm and running. If you don't a good O2 signal and closed loop, the converter can't operate at peak efficiency.

A bad oxygen sensor that prevents the PCM from going into closed loop won't damage the converter, but it may prevent the converter from reducing HC and CO as much as it could. A sluggish or dead oxygen sensor typically causes the engine to run rich, and will increase CO levels in the exhaust.

A faulty coolant sensor can also prevent the PCM from going into closed loop as the engine warms up. Other cooling-related causes that can prevent the PCM from going into closed loop include a thermostat that is stuck open, is leaking or has too low a temperature rating for the application. If the PCM does not go into closed loop as the engine warms up, the air/fuel mixture will be too rich.

CONVERTER MONITOR

On 1996 and newer vehicles that have OnBoard Diagnostics II (OBD II), there is a "catalyst monitor" that keeps an eye on the operating efficiency of the converter. A second oxygen sensor is mounted "downstream" or behind the converter to compare oxygen levels in the exhaust before and after the converter.

Under normal operating conditions, the downstream O2 sensor should have little switching activity. But if the rate at which the downstream O2 sensor is switching starts to increase, it tells the OBD II system converter efficiency is dropping and there's a potential emissions problem. If the problem may cause emissions to exceed 1.5 times the federal limit, the Malfunction Indicator Lamp (MIL) will come on and the PCM will log a diagnostic trouble code for "catalyst is below threshold efficiency" (P0420, P0421, P0422, P0430, P0431 or P0432). The bottom line here is you have a bad converter -- unless the problem is something else like a bad oxygen sensor or open fuel feedback control loop.

If you have a dual trace digital storage oscilloscope (DSO) and want to confirm the diagnosis, you can hook your scope up to the upstream and downstream O2 sensors to compare their switching activity. If the downstream O2 sensor activity mirrors the upstream O2 sensor, the converter is dead and needs to be replaced.

You can also confirm a bad converter by comparing levels of CO and HC in the exhaust fore and aft of the converter. If you see little or no reduction in HC and CO levels, the converter has reached the end of the road and needs to be replaced.

CONTAMINANTS

When other reactive substances find their way into the exhaust, they can cause problems with the catalyst inside the converter. These include phosphorus, silicone and lead.

Prior to 1975, tetraethyl lead was used to boost the octane rating of gasoline and to lubricate the exhaust valves. When catalytic converters were added in 1975, leaded gasoline was gradually phased out. Fuel restrictors were incorporated into the fuel filler inlet pipe so motorists couldn't fill up with the leaded gasoline -- but many managed to defeat these devices because leaded fuel was cheaper than unleaded. Eventually, leaded fuel disappeared in the U.S. so this should not be a concern unless somebody fills up a car with racing fuel or is traveling south of the border in Mexico.

Phosphorus is the main concern today for fouling a converter. Phosphorus is found in motor oil. So is zinc, which can also cause trouble. Normally these trace metals do not cause a problem. But in a high mileage engine with worn valve guides, rings and/or cylinders, oil burning can pump enough oil into the exhaust to foul the converter. Once this happens, there is no fix other than to replace the converter. Trouble is, the new converter will eventually suffer the same fate as the old one unless the cause of the oil burning is also repaired -- which typically means overhauling or replacing the engine.

Sulfur is another contaminant. It is found in small amounts in gasoline. As long as the concentration is limited, it causes no problem. But too much sulfur in a batch of bad gasoline can create a rotten egg odor in the exhaust and cause the converter to light off at a higher than normal temperature, increasing pollution and possibly damaging the converter.

Silicone is an ingredient in traditional antifreeze. Silicone is used to provide corrosion protection for aluminum parts. As long as it stays inside the cooling system, it has no effect on the converter. But if the head gasket starts to seep coolant into the combustion chamber, or the head develops a hairline crack that leaks coolant, silicone can get into the exhaust and ruin the converter. As with phosphorus contamination, it is essential to eliminate the source of the coolant leak before the converter is replaced, otherwise the new converter will suffer the same fate.

You should also note that silicone, phosphorus and lead can also contaminate oxygen sensors, too. If the converter has failed because of contamination, the oxygen sensors should also be checked because they may be contaminated, too.

WHEN THINGS GET TOO HOT

The converter can handle quite a bit of heat. However, high levels of pollutants coming out of the engine cause the converter's operating temperature to soar. This can damage the converter. If the converter overheats (over 2000 degrees F), it can actually melt the ceramic honeycomb inside the shell. The result may be a partial or complete blockage that causes a sharp increase in exhaust backpressure and a big drop in engine performance and fuel economy. If the converter is completely plugged, it will cause the engine to stall.

Underlying causes here include things like fouled spark plugs, bad plug wires, leaky engine valves or a leaky head gasket. Any of these can allow large quantities of unburned fuel to pass into the exhaust. When the HC hits the converter, it will ignite and send the converter's temperature soaring.

Checking for restrictions is easier and doesn't require any special equipment. A restriction problem might be suspected if your engine lacks power, has been using a lot of gas lately, or stalls after it starts and won't restart.

A low intake vacuum reading is a classic symptom of excessive backpressure which may be due to a plugged converter. If the vacuum reading drops and the engine stalls, the converter may be plugged.

Note the reading at idle, then hold rpm at 2,500. The needle will drop when you first open the throttle, and then stabilize. If the reading then starts to drop, backpressure is building up in the exhaust system.

You can also attempt to measure exhaust backpressure directly. If the car has air injection, disconnect the check valve from the distribution manifold, and insert a pressure gauge. Or, remove the oxygen sensor and take your reading at its hole in the manifold or headpipe. Refer to the backpressure specs for the application. Generally speaking, more than 1.25 PSI of backpressure at idle, or more than 3 PSI at 2,000 rpm tells you there's a blockage.

A "thunk" test on the outside of the converter with a soft rubber mallet will tell you if the catalyst inside is loose. You should not hear any rattling inside a monolithic converter. If you do, it means the honeycomb inside is broken.
If you suspect a blockage, disconnect or remove the converter and look inside with a trouble light. If you can't see through the honeycomb, the converter is obstructed and needs to be replaced.

As with contamination failures, it's important to diagnose and repair the cause of the excess HC in the exhaust if you expect the new converter to last. Check the ignition system and compression, and do the required repairs.

REPLACEMENT

The EPA's rules for replacement are quite strict: a repair facility cannot replace a converter until it is out of warranty and a legitimate need for replacement has been established and documented (such as a blockage, failure of an emissions test, or to replace a converter that someone removed). The repair facility must also obtain your authorization for repairs in writing; keep the paperwork for six months and the old converter for 15 days. The

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replacement converter must be the same type as the original and installed in the same location. These rules do NOT apply to the vehicle owner, so you may replace the converter yourself if the converter is defective.

The federal emission warranty on OEM converters is 8 years or 80,000 miles. If your OEM converter is still under warranty, you should be able to get a free replacement from your new car dealer. If it is out of warranty, you can take it to any repair facility or change it yourself.

Replacement converters must be the same type as the original, and OBD II vehicles require an OBD II certified converter. The new converter must also be installed in the same location as the original.

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