Supercharged!
GM'S SUPERCHARGED VEHICLES

Devices for delivering air into an engine at pressures higher than atmospheric fall into two major groups -- mechanically driven (superchargers) and exhaust gas driven (turbochargers). GM's supercharged engines have historically incorporated the Helical Roots type supercharger produced by Eaton Corporation.

Current

Ecotec L4
- Saturn ION Red Line
- Chevrolet Cobalt SS Supercharged

Northstar V8
- Cadillac STS-V
- Cadillac XLR-V

3.8L V6
- Pontiac Grand Prix

Non-current

Pontiac Bonneville
Buick Park Avenue Ultra
Buick Regal GS
Buick Riviera

WHY SUPERCHARGING?

Airflow Volume (Throughput) -- It helps to think of an internal combustion engine as an air pump. That is, the engine draws air in, it is combined with fuel and combusted, then it is exhausted from the engine. The engine literally pulls air in on the intake stroke and pushes it out after combustion on the exhaust stroke. The amount of air being pumped through the engine is referred to as air throughput, and it can be measured as a volume.

Pressure -- In a naturally-aspirated (non-supercharged) engine, the amount of air that can be throughput is dependent on atmospheric pressure filling the partial vacuum created when each piston moves down on its intake stroke. The free flow of air is hampered by restrictions in the path that the air follows: air filter, throttle body, intake manifold walls, valves, exhaust manifold walls, exhaust pipe, catalytic converter and muffler.

Temperature -- Cooler air results in a given volume of air (density) and is also a key factor in prevention of detonation and the resulting need for spark retard.

Mass Per Volume (Density) -- Cooler air is denser than warmer air, which increases the amount of oxygen in a given volume of air. The oxygen contributes to the amount of fuel the engine can burn, and so, power the engine can produce. When heated by combustion, denser air expands more than warmer less-dense air, contributing to greater cylinder pressure. So controlling air temperature is a factor in air throughput and engine power.

Add A Supercharger

Pressure -- The supercharger increases engine power by forcing extra air into the engine. The intercooler (Charge Air Cooler) cools the air after being compressed. The additional dense air (compressed and cooled) coupled with fuel in the correct mixture produces the additional power.

Fuel throughput -- The amount of power an engine can produce is proportional to the amount of fuel consumed. And, the amount of fuel that the engine can burn is proportional to the amount of air throughput. That is, fuel and air must be mixed in the proper proportion, so with more air throughput, and more fuel throughput, more power can be generated.

HOW THE SUPERCHARGER WORKS

The supercharger is designed to transfer air into the intake manifold in a volume greater than the engine could pump on its own. The excess volume of air results in a backpressure, often called boost, in the intake manifold. Each time an intake valve opens and the piston moves downward in the intake stroke, more air is forced into the cylinder than would be possible without supercharging. When the appropriate amount of fuel is added to the compressed air, more power can be created than would be created in a comparable naturally-aspirated engine.

The supercharger drive belt is connected directly to the crankshaft and allows linear airflow delivery, meaning the supercharger displaces essentially the same volume of air per each rotor revolution, regardless of engine rpm. This increases engine torque across the entire operating range. Because the supercharger is always turning any time the engine crankshaft is turning, air pressure/density is always being increased in the intake manifold, and throttle response is immediate.

TIP: Compare this with a turbocharger, which depends on a build-up of exhaust pressure before full intake boost is available, resulting in a lag in throttle response, known as turbo lag.

The increased throughput of air and fuel allows more power to be produced with an engine of smaller displacement. This improves fuel economy when not under load, because the engine is consuming less fuel/air mixture because of the smaller engine size.

When the supercharger is operating in bypass mode (more on this later), the supercharger requires only one-quarter to one-half horsepower to turn. This minimal parasitic draw has a negligible effect on fuel economy when comparted to the gain from engine downsize.

Supercharger Operation

Two tri-lobed rotors are contained in a rotor housing. Air enters the housing through the inlet. It is trapped between the rotating rotor lobes and the housing. As the rotors turn, air is moved toward the supercharger outlet, and into the engine's intake manifold.

TIP: Twin Vortices System TVC/Gen6 quad-lobed rotors will be introduced in the 2009 model year.
The drive pulley is attached to one of the two rotors by a drive shaft. In some applications, an isolator coupling is used between the pulley shaft and the driven rotor. A set of gears transfers drive to the second rotor, so the rotors always remain in perfect timing to each other. The gears and bearings are sealed in a housing containing lubricant.

The rotors are precision-machined into a complex shape. On each rotor, there are three lobes (four on TVS) which are twisted around the rotor axis, much like a shallow screw thread. This is called an involute profile with a 60° twist (160° on TVS). The rotors run in opposite directions (counter-rotating), with the lobes meshed together.

It's interesting to note that the air is not compressed within the supercharger housing; it is simply displaced (moved from one side of the supercharger rotors to the other). The displaced air becomes compressed as it stacks up downstream of the supercharger, because the supercharger displaces more air than the engine can consume.

Due to the involute design of the rotor lobes, the modified Roots supercharger operates with lower noise than other types of superchargers.

TIP: Some whine noise is typical of all superchargers and is not a reason to replace the supercharger or other components. This is an acoustic characteristic resulting from 3 SC compressed volumes (4 for TVS) per engine revolution and interaction with gear tooth engagement, causing structural input.

Intercooler

The pressurizing process causes the temperature of the pressurized air to increase. From the earlier discussion, we know that higher air density expands more during the combustion process. Because air density decreases as temperature rises, it's necessary to remove heat from the air to increase its density before it enters the engine.

An air-to-water intercooler (Charge Air Cooler or CAC) is mounted between the supercharger outlet and the intake manifold. The intercooler works much like a radiator in reverse. It takes heat from the air passing through it and absorbs it into the coolant. The reduced temperature causes the air charge to be denser than it otherwise would be.

TIP: The intercooler uses its own cooling system with its own radiator, separate from the engine cooling system. An electrically powered pump circulates coolant through the intercooler and a separate radiator called the INtercooler Heat Exchanger (ICHE).

Air Path

All past and present GM North American supercharger applications use an upstream throttle body, with air passing through the throttle before passing through the supercharger.

Air flows through the air filter, to the mass airflow sensor, through the throttle body, and into the supercharger. Air is then displaced from the supercharger, through the intercooler, and into the intake manifold.

TIP: On the Cadillac engine, the intercooler is mounted above the supercharger. Air moves upward from the supercharger outlet, through the intercooler, then downward into the intake manifold on each bank of the engine.

Excess air, between the supercharger and the intercooler, is allowed to return to the supercharger inlet, by way of a bypass valve.

There are several advantages to the upstream throttle body. Both packaging and control are simplified, a smaller bypass is needed, and supercharger pulsations are better contained at part throttle.

Bypass Valve

During a typical driving cycle, a supercharged engine needs to be under boost only 5-10% of the time. So, for 90-95% of the time, the extra air provided by the supercharger is not needed. The bypass valve allows the excess air to be diverted back to the inlet of the supercharger and recirculated. This ensures that the airflow measured by the mass airflow sensor reflects the amount of air actually being consumed by the engine.

Using a bypass valve helps improve fuel economy. When the supercharger is under boost, the resulting backpressure makes it harder to turn the rotors, so power is drawn from the engine crankshaft. In bypass mode, the only parasitic loss is the approximately one-half horsepower needed to overcome the frictional losses of the supercharger bearings and shaft seals.

A second key benefit of the bypass valve is the reduction of noise during unloaded conditions (idle and cruising). Under high vacuum low load conditions, if not bypassed the pumping pulses result in supercharger gear rattle.

The bypass valve is operated by a vacuum/pressure actuator. Inlet vacuum and manifold pressure are used to open and close the bypass valve as needed.

ENGINE DESIGN CHANGES

Compression Ratio

Typically, a supercharged engine requires a lower compression ratio than its naturally-aspirated counterpart. And a smaller displacement is typically used, to improve fuel efficiency.

Naturally Aspirated Northstar V8	Supercharged Northstar V8
compression ratio 10.5:1	compression ratio 9.9:1
4.6L displacement	4.4L displacement
93mm bore x 84mm stroke	91mm bore x 84mm stroke
~ 300 HP	~ 445 HP

Accessory Drive

Supercharger drive design is critical to providing system performance, controlling noise and long life. The supercharger has typically both the largest belt-driven spinning mass and the highest drive load under maximum engine power output conditions.

Crank Train

The crankshaft nose, front bearing and drive pulley joint must be assessed for power transmission and oscillating force levels.

Rotating and Reciprocating

Engine loading is significantly higher due to both the power output and the power required to drive the supercharger at peak conditions. Piston assemblies, rings, rods and bearings are often upgraded.

Valvetrain

The additional power produced comes with additional thermal and mechanical loads. Valves and seat materials must be assessed for temperature capability. Often upgraded materials and or valve cooling method such as sodium loaded hollow stem exhaust valves are used to transfer heat away from the valve head area.

PCV

PCV systems must be re-plumbed to use a check valve so as to not back flow under manifold boosted conditions.

Vacuum

A vacuum source may be needed for vacuum assisted brakes and other vehicle system.

Ignition System

The energy to create a spark adequate to ignite a high pre-combustion cylinder pressure (boosted) mixture is higher than that of a normally aspirated engine. Upgraded ignition is likely required, along with a different spark plug heat range.

SUPERCHARGER ATTRIBUTES and QUALITIES

Whine

Whine is a noise inherent to the Roots supercharger design. In mechanically driven superchargers, there is a direct ratio of supercharger pumped volumes to engine speed. This is approximately 2 supercharger revolutions to 1 engine revolution. In the case of GM past and current helical Roots type superchargers, there are 3 pumped volumes per supercharger revolution. The result is an audible character of 6 pulses per engine revolution heard as a characteristic whine. This noise is primarily airborne, with some element of structural excitation. Air induction system structure and acoustic resonators are designed to minimize whine. Also note that this is the noise character that is desired by many performance lovers.

Whistle

A whistle noise is generated by supercharger rotor spur gear contact (gear tooth contact frequency). This noise is gear tooth count-order generated and sweeps a large enough range of frequencies that it is likely that some structure somewhere will become a speaker. Typical conditions to light off a structure are mid-load / mid speed based under conditions of higher amplitude gear tooth engagements. The alignment of engagement energy amplitude, frequency and structure resonance is usually focused to small ranges of transient operation. Most are either corrected via structure changes to shift the tuning point or simply driven through so fast that the resonance is not significant to audible noise.

Occasionally design options are used up, leaving an obscure low level whistle noise inside the operating range of the vehicle. An example is 2300 to 2800 RPM at 80% load driving up a very long grade to enable holding the condition for an extended period of time. Most of these conditions are addressed by sound path isolation to the passenger compartment. Some can still be heard to a very critical ear.

Supercharger Rattle (Growl)

This is a noise that may be heard at low speed or idle, with the engine under light load.

At low engine speed under low load such as idle condition, the engine operates under vacuum similar to a non-supercharged engine. The supercharger gear driven rotor set is free spinning in a vacuum (very thin air). There is essentially no load in either the forward or rearward direction of the supercharger rotation, as any small amount of low density pumped air is circulating back to the inlet side of the supercharger rotors through the open bypass valve.

Also under this operation, the time between individual cylinder events is relatively long and the power produced by those events varies a small amount. The result is that the crankshaft speed speeds up for each cylinder firing and slows down due to loads and friction prior to the next cylinder event.

The supercharger, being driven by the crankshaft pulley through a belt, is also being accelerated and slowed down by the engine firing cycles. As the rotors and gears are a relatively heavy rotating mass set, they act like flywheel on the other end of a flexible belt drive and overshoot / undershoot as the uneven engine loads occur. The engagement of the gears is very precise, but as with all things there is a limit due to other design requirements. The forward/backward (oscillating) loading into the supercharger causes the very small gear clearance to impact back and forth on drive and driven sides of the teeth causing a rattle noise, also referred to as growl.

To understand the dynamics of this noise, it must be recognized that the oscillating load is not only affected by engine firing events, but also the way in which those events are modulated by the rest of the car. The torque converter or clutch assembly, the transmission, drive shaft, differential, right down to the tire contact to the surface of the road all have an influence. Each element acts like a spring with a mass, and they are all tied together, yanking on the back side of the crankshaft rotation clockwise and counterclockwise with minimal friction (no shock absorber) to control the oscillating motion. The result is that all this motion is yo-yoed up through the accessory drive belt (another rubber band) and into the supercharger drive gear set. There is a lot of energy. The design of gear set and supercharger drive from the crankshaft needs to be tuned to counteract all of the downstream system dynamics so as not to rattle.

Internal Isolator

Some current GM products incorporate an isolator internal to the supercharger, between the pulley and the rotor shaft. Off idle, the isolator is not functional. The drive pins are rested fully against their respective cushioned drive stops. Even in the bypass open mode, there is sufficient drive torque to hold the isolator against the drive stops.

There are two functions of this isolator. The first is to minimize a knocking sound heard when the engine is turned off. This is caused by the mass of the supercharger rotor set being suddenly jerked to a stop. A reaction spring is set in position between limit stops for this function. The second function is that of engine firing pulse isolation. The device is specifically tuned to minimize the normal engine firing pulse energy that is passed on to the supercharger rotor drive precision gears.

The device is active only at an unloaded condition produced when at a low engine speed point where boost is not requested by operator throttle opening. The bypass valve is open at this operating condition. The device operates by balancing the supercharger input drive loads, transmitted by 1 of 3 drive pins, against a tuned drive spring. For the calibrated operation point of idle range across a broad range of vehicle electrical/mechanical loads and ambient conditions, this system works better than standard industry available isolators. The downside is that if the engine is not operating to design intent, or if one of the components in the driveline is disabled (i.e., bad drive shaft damper), the isolator spring balance point may be pushed close to the drive stop. When this occurs, the normal isolation motion of the isolator pin collides with the drive stop and causes a harsh intermittent rattle sound. This sound often goes through cycles as the engine speed and other conditions change slightly.

This noise draws one's attention and is a condition that likely needs correction, but it would be uncommon for this to be corrected in the supercharger. It is likely and engine rotation oscillation above the normal range due to something like a misfiring cylinder or a possible driveline grounding if heard to an appreciable level when "drive" is selected.

SERVICE and TOOLS

Service to the supercharger itself is limited to the bypass circuit. Special procedures have been developed along with tools required in some cases. Refer to SI for specifics.

From model year 2002, GM superchargers need no lube oil maintenance.

DIAGNOSTIC TIPS

When diagnosing any supercharger suspected trouble, familiarize yourself with the Attributes and Qualities explanations provided in this document.

A supercharger is a mechanical device that provides great benefit. Like generators, power steering pumps, valvetrain drives and other systems within the powertrain, it has an associated characteristic low level noise. The unit itself is designed with care to avoid harsh and unusual noises of an objectionable nature. In some cases, a second layer of noise attenuation is in the vehicle system engine compartment close-outs and hood. Noises heard with the hood raised may be characteristic and are attenuated as part of the larger as-operated vehicle system.

Verify that both the engine and vehicle systems are in good operating condition.

The supercharger is a speaker for anything causing a rotational input disturbance. This includes fuel, other air delivery or measurement problems, ignition, sensors. Perform all system related diagnostics before focusing back on the supercharger unit. Disconnecting the supercharger drive belt and running the engine is not proof that the supercharger is the problem.

Check for Vacuum Leaks

A very common problem is a vacuum leak, especially following service R&R work. Additional care is needed to enure that all intake joints from the intake valve to the air cleaner element surface are sealed. Diagnostic codes are set for Intake Air Flow Rationality and Fuel Trim when the intake system has even the slightest leak.

Break-in

A break-in of 400 miles is needed before performing a full noise evaluation.

Typically, some level of rattle type noise exists on new vehicles with zero miles. Also, typically, this noise cleans up with additional miles.

The thought is that the new supercharger unit friction adds to the required torque to turn the unit, causing the isolator to operate out of targeted design range.

In the latest generation of Roots superchargers, an abradable coating is incorporated, resulting in a slight interference fit by design. This coating wears in. Before supercharger assemblies ship out, each unit receives a short spin (30 seconds) and evaluation for out-of-quality range noises as measured by an accelerometer and correlated to both component defects and vehicle NVH levels.

During this spin, the unit is bolted to a flat plate and does not wear in to any significant degree. Once bolted to an engine, the supercharger housing bores become distorted, and then again further distorted with thermal growth. In earlier designs, the rotor-to-bore clearance was set to accommodate the entire range of fit, distortion and thermal growth. In the 2004 and later products, the abradable coating was incorporated and the clearances closed down to yield the maximum efficiency (best sealing) for a fully broken in unit. This is the reason for the recommended the 400 mile break in.

When Transmission Reverse is Selected – XLR-V and STS-V 2006-08 MY Specific

On 2006-08 XLR-V and STS-V Supercharged Premium V engine family equipped vehicles, there is a unique situation in which a supercharger rattle noise may occur with the gear selector in reverse while at idle. This occurs as a function of the bypass valve closing under this condition, resulting in the supercharger working against a vacuum with no bypass to balance the pressure. In effect, the supercharger is in cavitation, coupled with the isolator operating at the limit of its designed range. The noise produced is low level but may be noticed by a technician listening critically with the hood open. This is normal to the system design. It will not be corrected by any mechanical repair or component change.

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