Edited by **Darlene Fritz**

DaimlerChrysler rolls out first BlueTec diesel

DaimlerChrysler is rolling out the first of the new generation of clean diesels certified to meet the tough new federal Tier II Bin 8 emissions regulations for model year 2007. The new regulations require diesels to have the same very clean exhaust as gasoline-powered light vehicles.

The diesels employ the **Mercedes-Benz** BlueTec technology, which is modular and can be improved in stages. A later phase of the technology involves injecting liquid urea—called AdBlue by Mercedes marketers—into the exhaust stream to help catalyze nitrogen oxides into nitrogen and water.

The Mercedes E320 BlueTec has an official fuel range of more than 600 mi (970 km), but in a test the cars went more than 1000 mi (1600 km) on a tank, traveling from Laredo, TX, to Tallahassee, FL.

The first stage of the technology features a new, all-aluminum DOHC 3.0-L V6 (72° vee) engine dressed with the expected common-rail fuel-injection system and variable-geometry turbocharger. The 72° angle was selected to leave space in the engine's valley for the turbocharger, explained Joachim Schommers, Director of Passenger Car Diesel Engine Development for Mercedes.

Vanes in the **Honeywell** variable-geometry turbocharger are made of a more heat-resistant alloy to better withstand the hotter exhaust gases that result from the exhaust valves staying closed longer to maximize the energy from each stroke of the piston. The nozzle design is more advanced, and airflow through the compressor has been optimized, Schommers said.

A higher-pressure, 1600-bar (23,200-psi) common-rail injection system and what Schommers describes as "third-generation" injectors complete the intake tract.

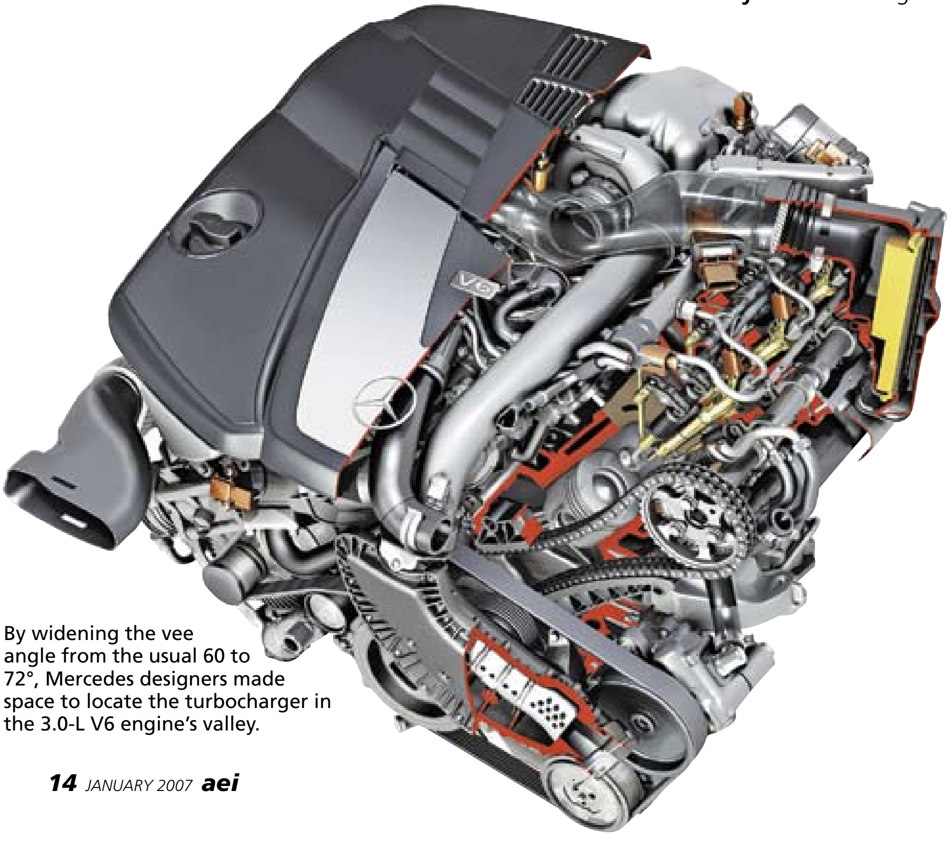
The engine has a slightly reduced 16.5:1 compression ratio to reduce production of nitrogen oxides that result from high compression. The reduction in compression ratio has very little effect on power output, said Schommers.

The engine's architecture is undersquare, with a reduced bore and increased stroke compared to the old I6 powerplant. To reduce internal friction, the engine employs a roller rocker arm valvetrain, and bearing journal size has been minimized.

The debut of BlueTec in the U.S. was delayed by limited access to low-sulfur diesel fuel, which is needed to avoid fouling the oxidation catalytic converter. A particulate trap further scrubs the BlueTec's emissions to the level of clean gasoline engines.

The V6 diesel engine in the Mercedes E320 BlueTec luxury sedan produces 208 hp (155 kW) and 400 lb·ft (540 N·m), resulting in 0-60 mph (0-97 km/h) acceleration of 6.6 s. The engine is also used in the 2007 **Jeep** Grand Cherokee as a new diesel option. The engine's redline of 4600 rpm is lower than a similar gasoline engine because the compression-ignition combustion sequence takes longer than that in a spark-ignition engine, limiting maximum revs, Schommers said.

On the move, the engine does very little to betray that it is a diesel, though at idle that fact becomes apparent. Inside the cabin, with the windows closed, it would be easy to miss the sound of diesel



By widening the vee angle from the usual 60 to 72°, Mercedes designers made space to locate the turbocharger in the 3.0-L V6 engine's valley.

The GL320 BlueTec will package its AdBlue reservoir under the rear cargo floor, where it will carry enough fluid to last between oil-change intervals. The system consumes urea at the rate of 0.1 L per 100 km (0.1 qt per 620 mi).

clatter, but with the windows open the idling E320's sound is apparent. It is not intrusive, however, and during regular driving the clatter disappears entirely.

The second phase of BlueTec, with the AdBlue system, will arrive in late 2008, with diesel power for the Mercedes ML-, GL-, and R-Class SUVs. The aftertreatment system will include a selective reduction catalyst that converts ammonia from the AdBlue and nitrogen oxides from the engine to create nitrogen and water.

Replenishment of AdBlue by owners has been an obstacle to the system's use in the U.S. Manufacturers have been reluctant to strand owners by not allowing the car to start when the reservoir runs dry, while the U.S. **EPA** refuses to allow careless owners to drive around indefinitely generating excessive pollution.

"We will inform the driver early," said Schommers. "The notice comes more and more often, so he knows exactly when it won't start." During the warning period, the reservoir can be refilled at Mercedes dealers, and the company is in discussions with oil-change providers to supply AdBlue. Mercedes will maintain a telephone hotline to direct owners to the nearest source of AdBlue.

Filling the AdBlue reservoir with something else, such as water, might trick the system into letting the engine restart once. However, once the engine is running, sensors in the exhaust will detect that pollution levels are too high, and the engine will refuse to restart.

Mercedes investigated the possibility of producing ammonia on board from gasoline, but found that this is not an efficient solution, said Schommers. "The amount of ammonia you get is very low, and the amount of energy you consume is very high," he said. The energy use is enough to have a noticeable impact on fuel economy, he added.

Dan Carney

Lag reduced with GM 2.0-L turbo

Some enthusiastic U.S. consumers prefer supercharging, with its no-lag, immediate response to a push of the gas pedal. But supercharging comes at a price—parasitic loss, lower fuel economy, and NVH, so many Europeans prefer boosting by exhaust-driven turbochargers. Fuel economy combined with performance is now a worldwide requirement, and with the help of its European engineering centers, **General Motors** has introduced its first U.S.-produced, spark-ignition direct-injected (SIDI) turbocharged engine, with nearly lag-free acceleration.

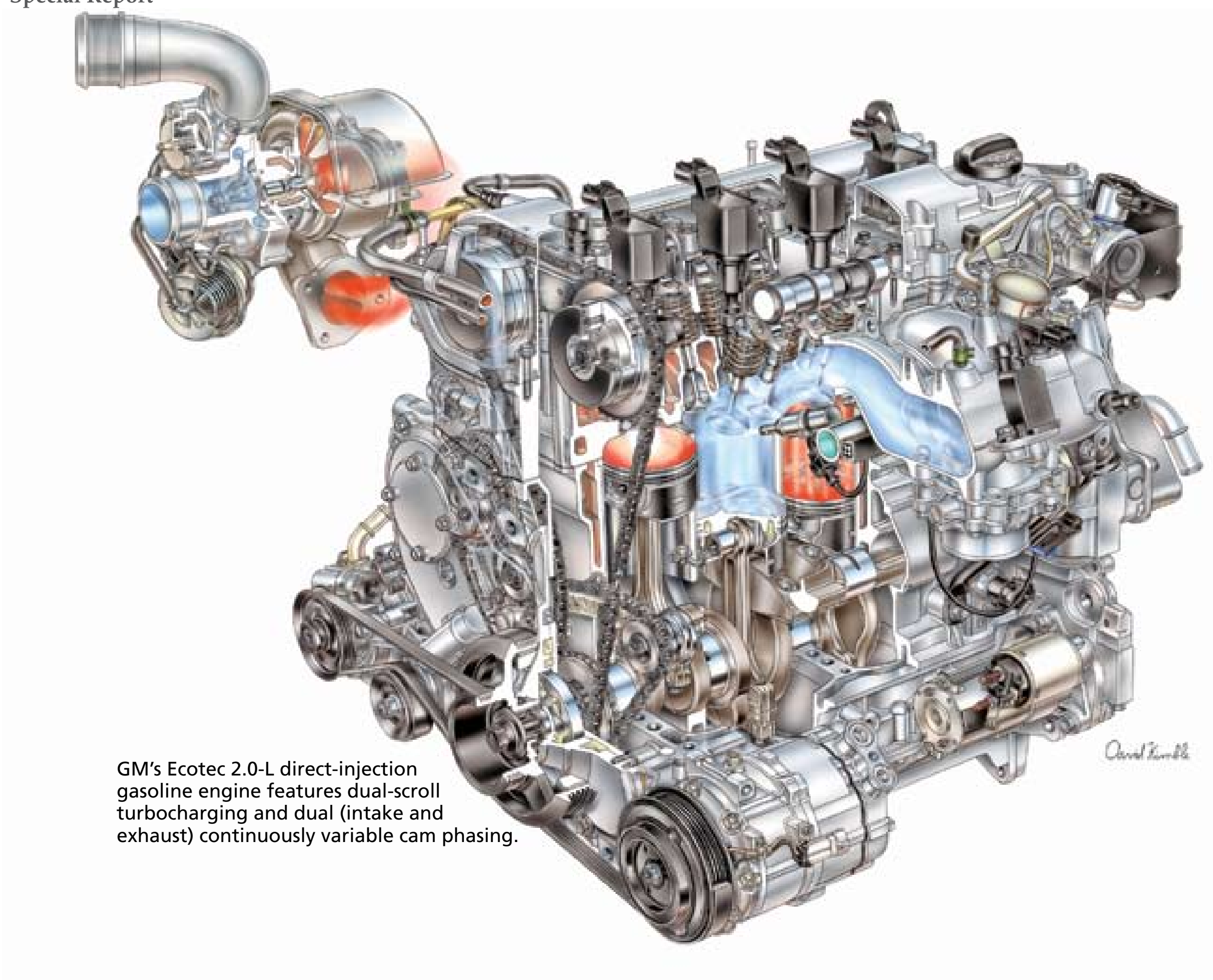
The engine's dual-scroll turbocharger has a horizontally split path for exhaust flow.

GM's new engine is a 2.0-L SIDI Ecotec four-cylinder with a dual-scroll turbo and aggressive valve overlap to enhance intake air scavenging of exhaust gases—more intake air pushes and flows out with the exhaust to spool up the turbo at low engine rpm. The result is a close-to-supercharged low-end—a nearly 0.75-s reduction in lag to under 1.5 s, compared with the comparable port-injected engine.

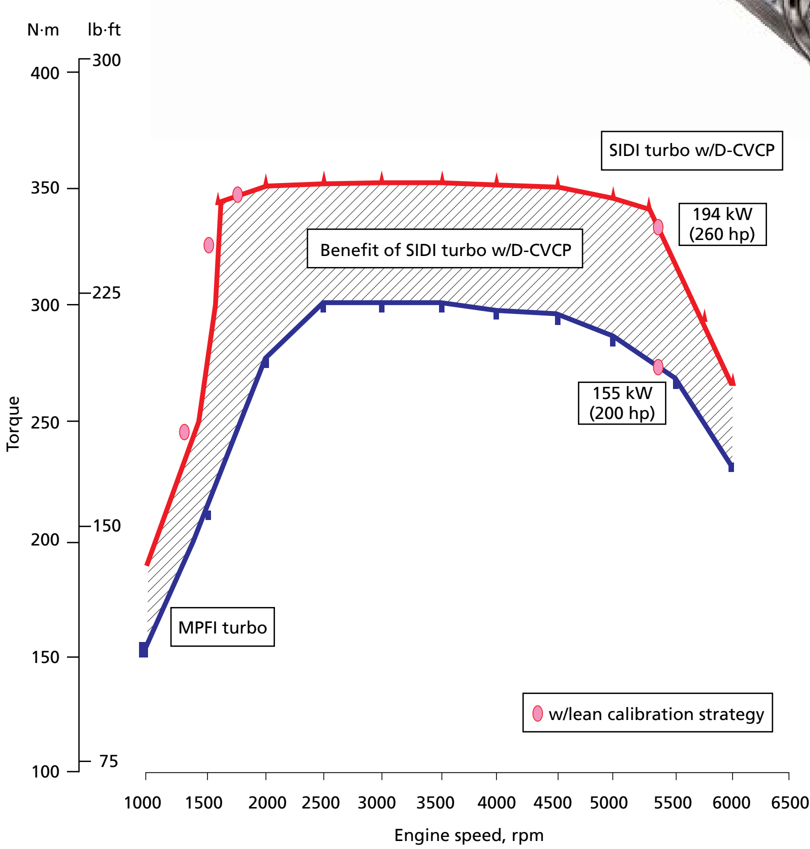
Low-rpm scavenging must be carefully limited in port-injected gasoline engines, because an increase in valve overlap to increase scavenging would produce an unacceptably large loss of air-fuel mixture, flowing out with the last of the exhaust gases. In the SIDI turbo with dual continuously variable cam phasing (D-CVCP), however, it's pure airflow. The strategy uses up to 50° valve overlap on both intake and exhaust, with injection timed to occur after the valves are closed. As much as 20% of the incoming air goes out with the exhaust at wide-open throttle, providing a 10% increase in turbine wheel rpm (from about 110,000 to more than 120,000 at 2000 engine rpm) and an increase in boost pressure that is partly proportional to the torque increase.

The 2.0-L SIDI turbo is standard in both the 2007 **Saturn** Sky Red Line and **Pontiac** Solstice GXP. The engine, which is air-to-air intercooled, is **SAE**-certified at 260 hp (194 kW) and 260 lb·ft (353 N·m), compared with 210 hp (157 kW) and 221 lb·ft (300 N·m) on the port-injected turbo version. The SIDI turbo's torque peak is broad, from 2500 to 5250 rpm, with 250 lb·ft (339 N·m) available at 1750 rpm—vs. just 184 lb·ft (250 N·m) torque for the port-injected turbo—a 36% improvement. Estimated 0-60 mph (0-97 km/h) is under 5.5 s with manual or automatic transmission.

The dual-scroll turbocharger setup separates the exhaust flows—one to cylinders 1 and 4, the other to cylinders 2 and 3. This approach improves charging efficiency, explained Edward C. Groff of



GM's Ecotec 2.0-L direct-injection gasoline engine features dual-scroll turbocharging and dual (intake and exhaust) continuously variable cam phasing.



Direct injection helps to boost torque for the direct-injection (SIDI) turbo as compared to multi-point fuel injection (MPFI). Dual (intake and exhaust) continuously variable cam phasing (D-CVCP) helps to increase exhaust air, which provides a 10% increase in turbine rpm.

GM Powertrain, by preventing interference between the pressure pulses of the cylinders that fire consecutively.

Cylinder bores are 86 mm (3.38 in) with bore centers of 96 mm (3.78 in), which compares to 88-mm (3.46-in) bores for the 2.4-L naturally aspirated version. This increases the sealing surface between the cylinders, which is helpful for containing in-cylinder pressures.

The 2.0-L SIDI turbo, made at an engine plant in Spring Hill, TN, is a "World-Via-Internet" gasoline engine. A U.S. team led the overall project and was also responsible for base engine development and analysis. Turbocharger development took place in Sweden, direct injection development was conducted in Germany and Italy, and bench calibration and initial validation took place in Italy. Daily teleconferences and Internet meetings were held, and European engineers conducted real-time evaluation via the Internet using test-cell computers in Warren, MI.

Paul Weissler

Compact I6 powers Volvo's new S80

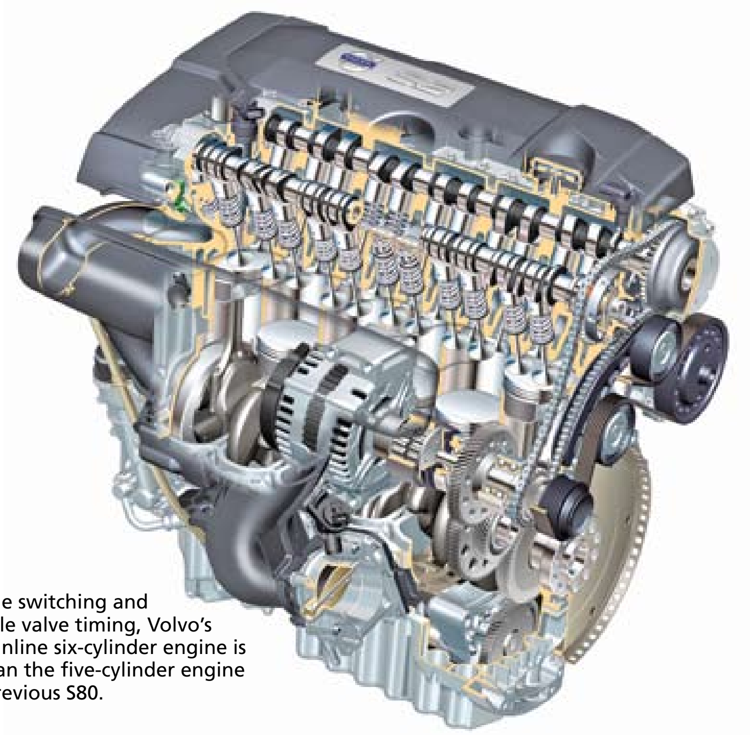
With the launch of its new S80 luxury sedan, **Volvo** will introduce a compact and efficient 3.2-L 24-valve inline normally aspirated six-cylinder engine. The transversely mounted port-fuel-injected I6 delivers 235 hp (175 kW) at 6200 rpm and 236 lb·ft (320 N·m) at 3200 rpm. The engine, which idles at 650 rpm and redlines at 6500 rpm, helps the S80 reach 0–60 mph (97 km/h) in 8.0 s and achieve 19 mpg city/28 mpg highway.

Bore and stroke measure 84.0 x 96.0 mm (3.31 x 3.78 in) with a 91-mm (3.58 in) center-to-center cylinder spacing for a total displacement of 3192 cm^3 and a compression ratio of 10.8:1. The all-aluminum engine has a mass of 180kg (397 lb). The cylinder block and bedplate are high-pressure die-cast AlSi9Cu3 aluminum alloy. The cylinder head, which is cooled by cross-flow cooling, is gravity-cast AlSi9Cu3, and cast-in iron cylinder liners are thermally sprayed for a porous AlSi12 coating. The high-pressure die-cast aluminum camshaft cover includes integrated upper cam bearing halves and incorporates a number of features such as oil distribution grooves for VCT and CPS control. All parts are made of recycled aluminum.

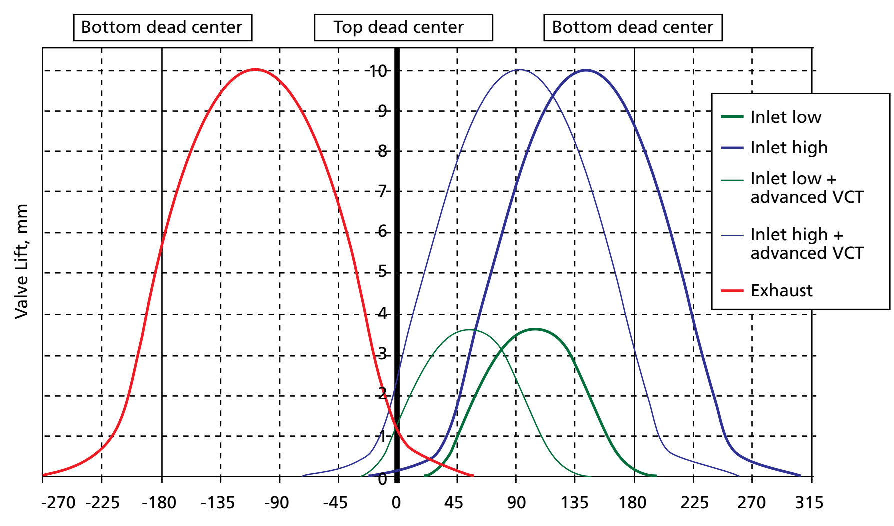
The engine's advanced valvetrain, which features cam profile switching (CPS) and continuous variable valve timing (CVVT), is controlled by a **Denso** engine management system with microprocessor-controlled fuel and ignition systems. CPS allows the engine's intake valves to be lifted to two heights based on demand using an intake camshaft equipped with three lobes per valve. The central lobe at each valve provides a low lift height of 3.6 mm (0.14 in), and two outer, equal-sized lobes provide the higher lift height of 10 mm (0.39 in). At low engine speeds and moderate throttle, low valve lift ensures maximum fuel efficiency and sufficient torque for good driveability. At higher engine speeds and full throttle, the CPS-tappet switches to engage the second set of cam lobes to produce high valve lift, which supplies a larger volume of the air-fuel mixture to each cylinder to yield quick, high-power engine response. The switch between low and high lift takes place between 1200 and 3300 rpm, depending on engine load.

To optimize the conflicting demands of fuel economy and performance, CPS is augmented by CVVT, which controls intake valve timing A variable intake system (VIS) equipped with two throttle flap valves helps to reduce the engine's pumping losses due to throttling, which translates to a 4% reduction in fuel consumption.

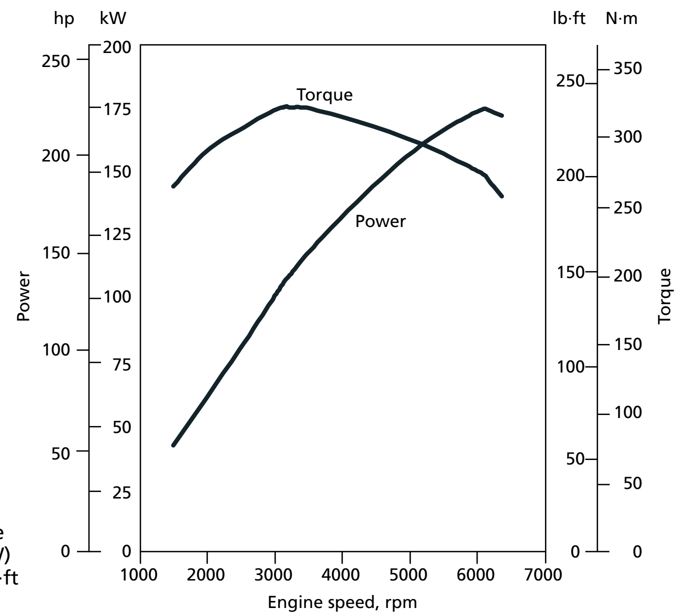
With the combination of CPS, CVVT driven by variable cam timing (VCT), and VIS, Volvo has optimized the I6 for volumetric efficiency under all conditions. For example, at engine start, the inlet valve closes at bottom dead center using low lift and late VCT for quick engine rev-up. At low and medium engine speeds and partial load, the inlet valve closes very early using low lift and early VCT to reduce pumping losses. At medium engine speeds and high load, the inlet valve closes early using high lift and late VCT for maximum volumetric efficiency. At high engine speeds and high load, the engine employs mid-position VCT and high lift for maximum volumetric efficiency.



Featuring cam profile switching and continuously variable valve timing, Volvo's new, compact 3.2-L inline six-cylinder engine is just 3 mm longer than the five-cylinder engine that powered the previous S80.



Volvo incorporated variable lift and variable cam timing to optimize the I6's volumetric efficiency under all conditions.



The new 3.2-L I6 engine delivers 235 hp (175 kW) at 6200 rpm and 236 lb·ft (320 N·m) at 3200 rpm.

With characteristic dedication to safety and function, Volvo engineered the I6, which is also offered in the XC90, for minimized exterior dimensions so it can fit transversely into the engine compartment. The transverse configuration helps to reduce the risk of engine penetration into the passenger compartment in the event of an impact, and also conserves body length for the passenger compartment. Because the engine's cylinder spacing and all-aluminum block structure were to maintain roughly the same dimensions as its five-cylinder predecessor, Volvo attacked the size issue by streamlining the entire installation, comprising the engine, transmission, and ancillaries, into as compact a space as possible. To achieve the compact length, Volvo relocated a number of ancillaries above the gearbox. Ancillaries and overhead camshafts are now chain-driven by gears at the rear end of the crankshaft, with the gears partially integrated into the engine block. The crankshaft damper has also been moved inside the engine block, and the alternator, installed on the engine block, is directly driven.

Volvo refers to its design—which integrates the drive system into a small gearbox with an intermediate shaft inside the driveshaft—as a Shaft-in-Shaft design. Different gears drive the two shafts, delivering one speed for the camshaft drive and a different speed for the ancillaries. The design also incorporates a fluid-type internal viscous damper (IVD) inside the engine block to compensate for vibration along the relatively long crankshaft. The end result is an ultracompact engine that is just 62.5 cm (24.6 in) long—a mere 3 mm (0.1 in) longer than the five-cylinder engine that powered the previous S80 and XC90. That previous engine, a transverse-mounted 2.5-L turbocharged five-cylinder, produced 208 hp (155 kW) and 236 lb·ft (320 N·m).

Darlene Fritz

Turbo times 2 for 3 Series Coupe

BMW has not been enthusiastic about turbocharged gasoline engines in the past, preferring to use the technology mainly for its diesel engines. But now the 3 Series Coupe has arrived with not just one, but two turbochargers for the 3.0-L gasoline engine that powers the 335i version. The low-inertia turbos have been designed to work together to virtually eliminate turbo lag, combining flexibility with very high performance.

Peak torque of 400 N·m (300 lb·ft) is reached at 1400 rpm and continues to 5000 rpm. Acceleration from 0-60 mph (0-97 km/h) takes 5.3 s for the manually shifted car. Maximum output from the direct-injection straight-six is 300 hp (220 kW) at 5800 rpm.

Udo Lindner, BMW Project Leader, 3 Series Powertrain, said a special austenitic steel with a high proportion of nickel is used to accommodate the high exhaust temperatures in the turbochargers.

The identical turbos of the N54 engine are smaller and lighter than typical turbochargers, BMW says, which allows them to build up pressure much faster than a single large one and in so doing eliminate turbo lag. The front turbocharger feeds cylinders 1-3, the rear one cylinders 4-6. The turbos produce maximum absolute boost pressure of 1.6 bar (23 psi). Fuel injection pressure is 200 bar (2900 psi). Combustion chamber mean pressure is 16.9 bar (245 psi), peak pressure 130 bar (1890 psi).

BMW estimates that to approach the coupe's high levels of power and torque without turbocharging would have required the use of a 4.0-L V8 engine, increasing mass by about 150 lb (68 kg). Better weight distribution and better fuel economy are the additional benefits of using turbochargers vs. a larger engine.

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proportion of nickel is used to accommodate the high exhaust temperatures in the turbochargers, according to Udo Lindner, BMW Project Leader, 3 Series Powertrain. The steel, used in the spinning wheel, can accommodate temperatures up to 1050°C (1920°F). Lindner noted that BMW worked with **Mitsubishi Heavy Industries** to develop the turbochargers.

Another highlight of the N54 is an improved direct-fuel-injection system. Speedy piezo injectors co-developed with **Siemens** replace slower solenoids, helping to reduce fuel consumption by 2-3% and emissions by about 20%, according to BMW.

The piezo injector is the key enabler for what BMW calls second-generation direct fuel injection. Unlike first-generation direct injection, the fuel never touches the piston or the cylinder walls, where it can condensate. Lindner said the new system, with more precise injection, allows for up to three injections per cycle in certain conditions, such as high load.

Other notable features of the engine include dual overhead camshafts, 24 valves, and aluminum construction with cast-iron cylinder liners. BMW's Valvetronic system is not employed. The electrically driven coolant pump runs on 200 W and is actuated only when needed.

The non-turbo gasoline alternative is an uprated version of the inline six used in the 2006 325i and 325xi sedan and sports wagon. Used in the 2007 328i and 328xi, the aluminum and magnesium N52 3.0-L unit delivers 230 hp (170 kW) and 200 N·m (150 lb·ft), comparing favorably to the heavier, previous-generation M54 that delivered 184 hp (137 kW) and 175 N·m (129 lb·ft). The new unit has one external belt drive instead of two, and so is slightly shorter.

The high precision of the fuel-injection system helps to reduce 335i Coupe fuel consumption by 2-3% and emissions by about 20%.

Diesel versions for Europe are the 330d with 231 PS (228 hp) and 500 N·m (369 lb·ft) from 1750 rpm, and the twin-turbo 335d with 286 PS (282 hp) and 580 N·m (428 lb·ft) from 1750 rpm, sufficient to provide a 0-100 km/h (0-62 mph) time of 6.1 seconds and average fuel consumption of only 7.5 L/100 km.

Six-speed manual transmissions are standard—a **ZF** unit for the 335i and different **Getrag** units for each of the others. The ZF unit features "tall" ratios for gears 1-4 to take advantage of the N54's torque for higher speeds in first through fourth. In each transmission, fifth gear is direct and sixth is overdrive.

Six-speed automatics are offered. The previous-generation 3 Series Coupe offered a five-speed. Even with an extra gear, the new unit is lighter and can reduce fuel consumption (particularly in sixth gear at cruising speed), BMW says. To be offered first in the 335i, the automatic is an updated ZF 6 HP 19 unit that features more effective damping of torsional vibration in the torque converter. This allows the converter's lockup to be engaged more of the time, translating to less slippage and better fuel economy (3%). The updated transmission also provides for faster shifting, BMW says.

New to the 3 Series Coupe is Steptronic, BMW's name for its automatic transmission system that provides for normal, sport, and manual shifting modes.

Patrick Ponticel and *Stuart Birch*

Audi S6, S8 sport V10 FSI engine

Driving the new **Audi** S6 and S8 from Montreal through the Laurentian mountains—first on highways, then twisty rural roads—the high-performance nature of these luxury sedans could truly be appreciated. At the heart of this performance is a new 5.2-L V10 FSI engine, the first 10-cylinder available with direct injection, said Patrick Hespen, Media Relations and Motorsport Specialist for Audi.

"The biggest story of the car[s] is indeed the V10 engine," said Filip Brabec, General Manager of Product Planning at an October press event introducing the

The S6 (shown) and S8 both feature driveline and chassis modifications to suit the engine's power. The new S models are equipped with a standard six-speed Tiptronic transmission and the latest generation of quattro all-wheel drive with asymmetric/dynamic torque split.

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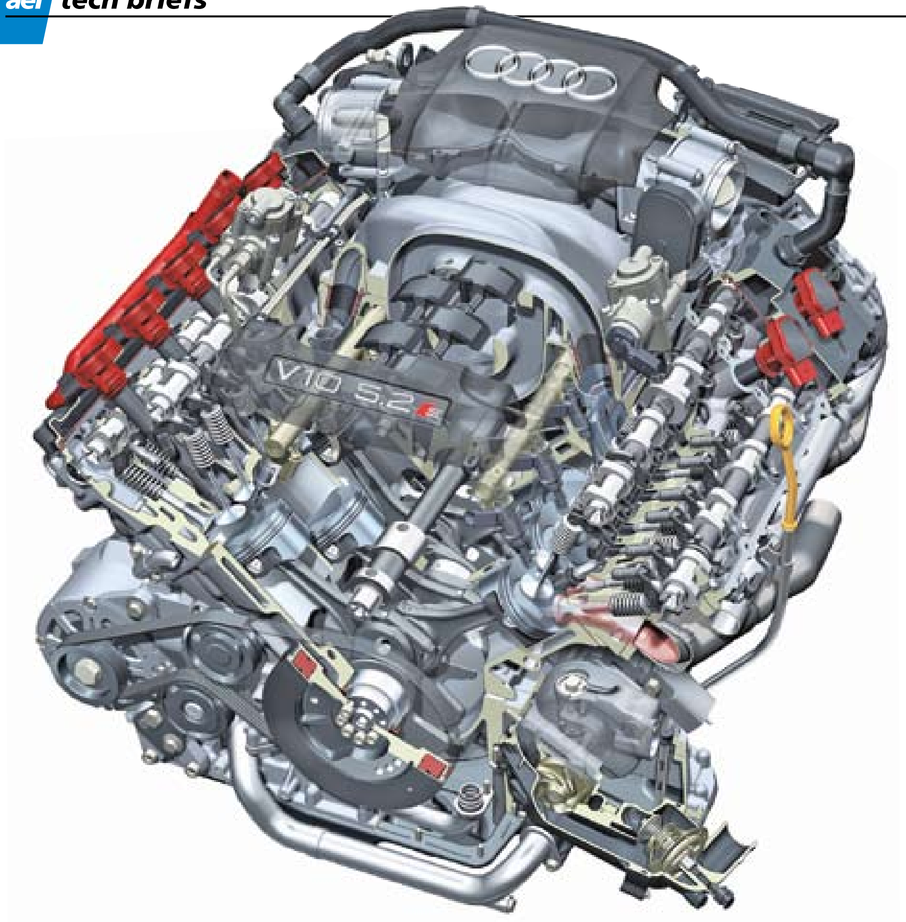

The first ten-cylinder engine with direct injection, Audi's 5.2-L V10 FSI delivers 398 lb·ft (540 N·m) and 435 hp (325 kW) in the S6 and 450 hp (335 kW) in the S8.

new S6 and S8. He noted that the V10 is part of Audi's chain-driven V-engine family, which also includes a 3.2-L V6 and a 4.2-L V8.

The new V10 delivers 435 hp (325 kW) at 6800 rpm in the S6 and 450 hp (335 kW) at 7000 rpm in the S8. The difference in power output is due to exhaust and engine programming. "The S8 has a more free-flowing exhaust," said Hespen.

Maximum torque for both cars is 398 lb·ft (540 N·m), available between 3000 and 4000 rpm. The S8 goes from 0-60 mph (0-97 km/h) in 4.9 s, and top speed is electronically governed at 155 mph (250 km/h) for both S models.

"Ninety percent of the peak torque is available already at 2300 rpm, reaching all the way to 6200 rpm," said Brabec. "What you see is a very broad range of power delivery, and that's exactly what we wanted to achieve with this engine."

For the S8, the vehicle's weight-to-power ratio "is something like 10 lb/hp, so it really offers sports car level performance," Brabec added.

There are no shared components between this new V10 and the one that powers the **Lamborghini** Gallardo, according to Hespen. "It's a common misconception that they are shared engines," he said. "The Audi S models have their own block, heads, chain drive, and internals. Everything used in/for the Audi V10 FSI is unique to that engine."

There are two significant differences between the Audi V10 and the Gallardo engine, said Hespen. One is the larger bore and displacement in the S cars; the other is the FSI direct injection. (The Lamborghini has manifold port injection.)

"Both of these modifications help to give the Audi V10 a higher torque output…compared to the Lambo's 376 lb·ft at high rpm," Hespen said. "The Lambo also has a higher redline of 8000 rpm. The Lambo was designed as a high-rpm engine; the Audi V10 [was] designed for torque."

All of Audi's next-generation V-engines have a 90° included angle and spacing of 90 mm (3.54 in) between cylinder centers.

The V10's bore measures 84.5 mm (3.33 in) and stroke is 92.8 mm (3.65 in). The engine is 26.9 in (683 mm) long, 31.5 in (800 mm) wide, and 28.0 in (711 mm) tall, with a mass of 485 lb (220 kg).

Its crankcase is produced by low-pressure die casting, from a hypereutectic aluminum alloy. The cylinder liners are honed, exposing the hard silicon crystals. A "bedplate design," or intermediate frame, gives the crankcase high torsional rigidity and improves its vibrational behavior, says Audi. Cast-in grey cast-iron bearing bridges reduce the thermal expansion of the aluminum casing.

The connecting rods are made from forged steel, and the pistons from an aluminum alloy. Oil-jet cooling of the pistons prevents temperature peaks. With its crankpin offset of 18°, the V10 fires at a 72 crank angle degree interval. A balance shaft within the vee reduces free inertial forces of the first degree and contributes to engine refinement.

All four camshafts can be adjusted continuously by 42 crank angle degrees via hydraulic camshaft adjusters, depending on the load and engine speed, to modify the valve opening overlap. This optimizes filling of the combustion chambers and improves engine response, says Audi.

The camshafts—along with the balance shaft, oil and water pump, and auxiliaries—are driven by maintenance-free chains. They actuate the 40 valves via roller cam followers with hydraulic valve-play compensation. The diameter of the intake valves is 32.5 mm (1.28 in), and 28.0 mm (1.10 in) on the exhaust valves, which are sodium-filled for a cooling effect.

FSI direct injection, managed by **Bosch** Motronic MED 9.1, allows for a "very strong" compression ratio of 12.5:1, said Brabec. The common-rail injection system delivers fuel directly to the combustion chambers at up to 1470 psi (101 bar).

The variable intake manifold incorporates electronically controlled tumble flaps that induce a swirling movement in the air drawn in at low engine speed and load, resulting in a more efficient internal-combustion process. Audi explains that the two-stage layout of the magnesium intake manifold serves the same purpose: Depending on load and engine speed, at around 4000 rpm an electronically controlled valve switches from the long intake paths that measure 26.6 in (676 mm) to the short paths that are 12.1 in (307 mm) long—placing more emphasis on output rather than torque.

Ryan Gehm