

Next-generation *Northstar*

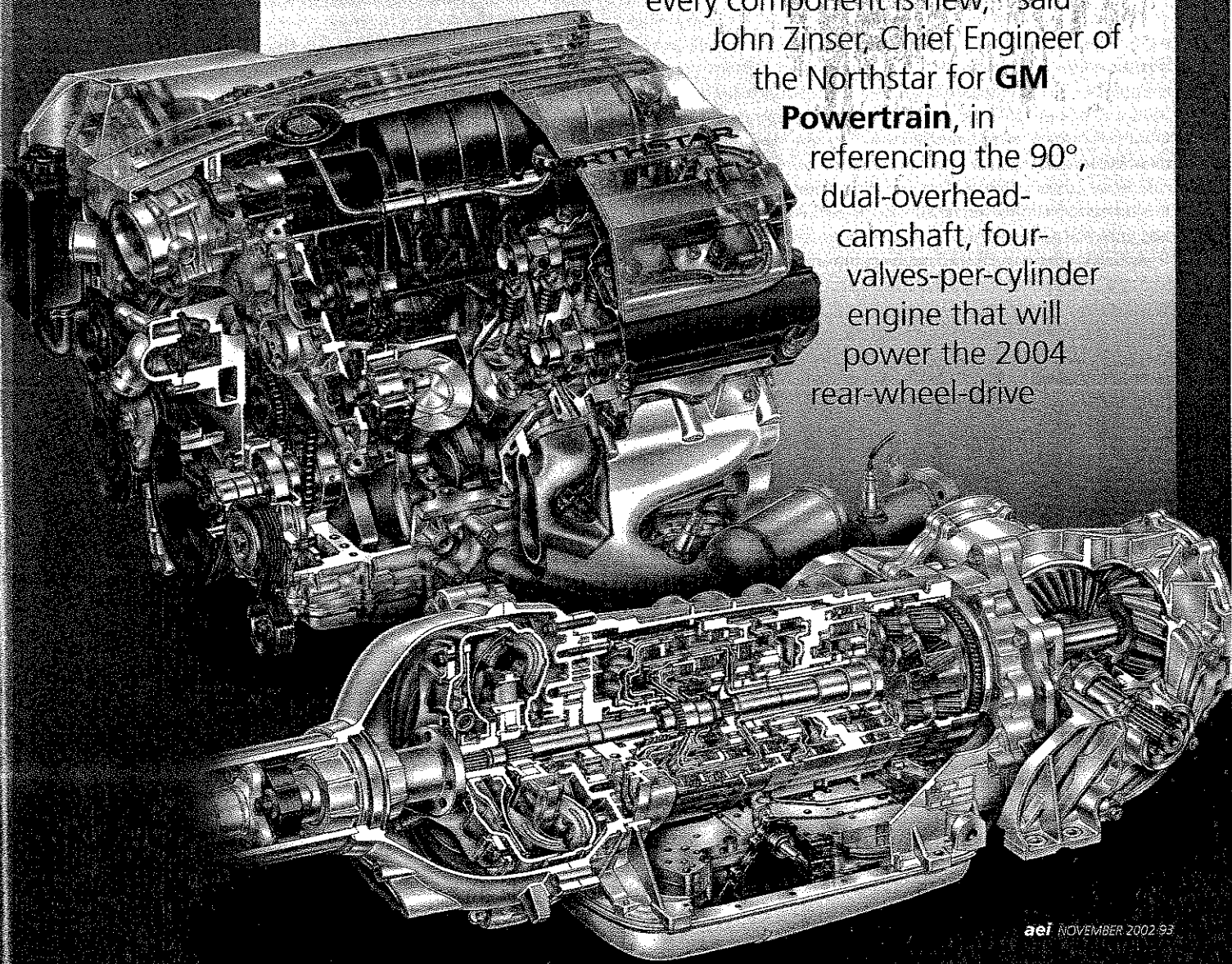
The engine/transmission combination has been significantly updated for new rear- and all-wheel-drive applications beginning with Cadillac's 2004 XLR and SRX.

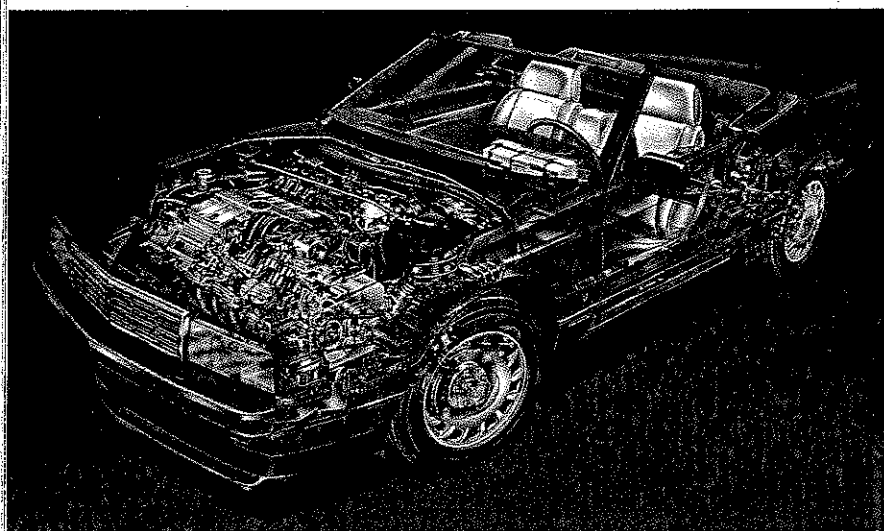
by Kami Buchholz

The front-wheel-drive 1993 Allante became the first Cadillac fitted with a Northstar engine, but rear- and all-wheel-drive vehicles soon will wear the next-generation version of the 4.6-L, 32-valve V8. "Just about every component is new," said

John Zinser, Chief Engineer of the Northstar for **GM**

Powertrain, in referencing the 90°, dual-overhead-camshaft, four-valves-per-cylinder engine that will power the 2004 rear-wheel-drive



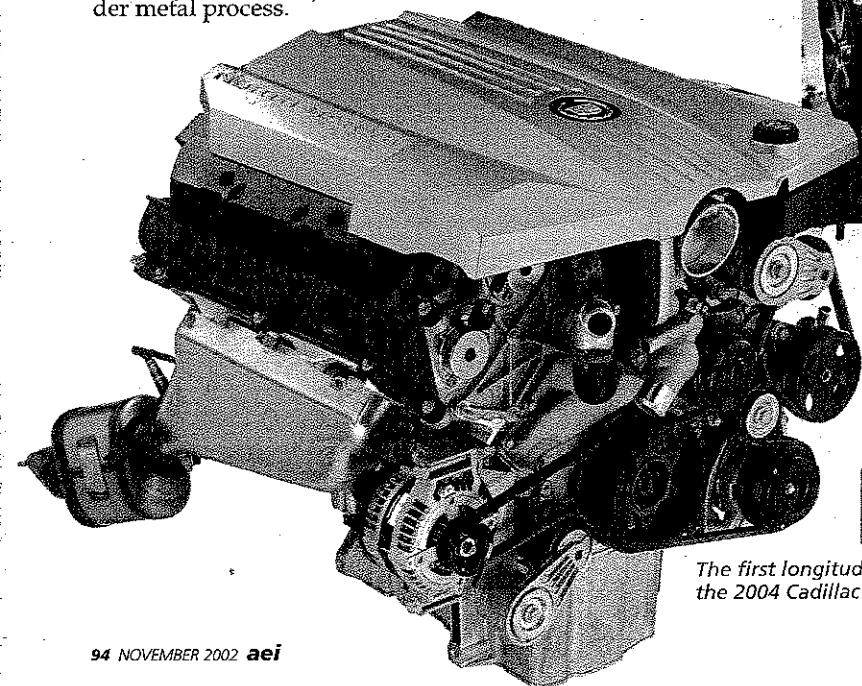


The first Northstar application was for transverse installation in the front-wheel-drive 1993 Cadillac Allante.

two-seat retractable hardtop convertible XLR as well as the SRX crossover vehicle, which will be offered in all- and rear-wheel-drive versions.

The engine—most recently updated in 2000—adds many first-for-Northstar features. Variable valve timing (VVT) and electronic throttle control are highlights of the engine, which features aluminum block and cylinder heads and a valvetrain configuration with roller finger followers. The Northstar's new four-cam VVT, which improves performance, fuel economy, and emissions, allows intake and exhaust valves to operate independently. "Intake can be advanced up to 40 crank degrees, and exhaust can be retarded up to 50 crank degrees," said Sheryl Balsley, Senior Project Engineer, Cam Drive/Valvetrain for Premium V Engines.

Cylinder head ports and exhaust manifolds were redesigned for optimum airflow and cylinder-to-cylinder distribution for maximum performance and emissions control. The engine uses a patented, Northstar-first camshaft cap design. "The 16 T-slot cam caps provide precise metering of oil to the cam lobes," said Zinser, noting the T-slot pathway is formed using a powder metal process.



The first longitudinal installations for the new Northstar powertrain will be in the 2004 Cadillac XLR (top) and SRX (SRX engine shown).

Lubrication of the next-generation engine mandated an additional passage—located in the lower crankcase—to connect an oil-feed tube mounted on the front face of the block. The tube feeds oil into two drilled passages in the upper block. "The additional oil passage was required for the variable valve-timing system," said Zinser.

The front-wheel-drive Northstar's water pump is relocated. "For packaging and cooling efficiency, we put the water pump to the front of the engine, and it's now driven by the accessory drive belt," said Zinser, noting the front-wheel-drive engine's water pump uses a camshaft-driven belt.

The engine has two new dual-belt torsional dampers to drive the two alternate configurations of vehicle accessory drives. Each damper has one pulley internal to the hub, and the other is driven through the bonded elastomer inertia ring. Two new flywheels were designed for rear-wheel-drive applications. On the XLR, a dual flex plate with inertia ring is used to reduce crankshaft oscillations at low engine speeds.

Close-coupled catalytic converters are mounted adjacent to the exhaust manifolds to meet emissions requirements. While the preceding front-wheel-drive Northstar has exhaust gas recirculation (EGR) and air injection reaction (AIR) systems, the next-generation engine does not "because of what we can do with the close-coupled catalytic converters and the cam phasers," said Zinser.

A new air induction system improves airflow and sound quality. The system features tuned resonators, additional resonators in the clean air duct, as well as isolator pads in the clean-air-duct mounting. Various material or design changes—including an acoustic engine cover—were made to reduce noise and vibration.

2004 Next-generation Northstar Technical Specifications

Configuration	4.6-l V8
Installation	Longitudinal RWD/4WD
Bore centerline spacing	102 mm (4.02 in)
Displacement	4565 cm ³
Bore x stroke	93 x 84 mm (3.66 x 3.31 in)
Valvetrain	DOHC, four valves per cylinder, four-cam continuously variable valve timing with roller finger followers
Connecting rod length	151 mm (5.94 in)
Compression ratio	10.5:1
Firing order	1-2-7-3-4-5-6-8
Fuel system	Sequential electronic fuel injection
Recommended fuel	Unleaded premium
Peak power	315 hp (235 kW) at 6400 rpm
Peak torque	310 lb•ft (420 N•m) at 4400 rpm
Engine mass as shipped	189 kg (417 lb)
Engine speed at idle	650 rpm
WOT upshift	6450 rpm
Cylinder block	die cast aluminum upper block, squeeze cast aluminum lower crankcase, cast iron liners
Cylinder head	319 alloy aluminum, semi-permanent mold; flexible graphite with steel core head gasket
Forged steel crankcase	64.4-mm (2.54-in) crankcase main journal diameter, 54-mm (2.13-in) crankcase pin journal diameter
Connecting rods	Forged powder metal
Piston/pin	Hyper-eutectic aluminum alloy and full floating piston pin
Oil pump	Gerotor type, 8 inner and 9 outer lobes
Engine oil/sump capacity	8 quarts 5W30 Mobil 1 with dry filter
Intake valve diameter	36 mm (1.42 in)
Exhaust valve diameter	29 mm (1.14 in)
Accessory drive	Dual serpentine belt, one double sided
Cooling system thermostat	Inlet side type
Intake manifold	Glass filled PA 66
Throttle size/type	80 mm (3.15 in) diameter throttle bore, electronic control
Fuel injectors	Dual spray
Fuel delivery system	Returnless rail
Ignition coils	Coil-on-plug
Spark plugs	Dual platinum electrodes

Polymer-coated pistons supplied by Federal Mogul Corp. help reduce noise radiation. "We can fit the pistons tighter to the bores, which reduces noise transmission," said Jim Cremonesi, Project Design Engineer, Rotating Cranktrain for Premium V Engines. A forged-steel crankcase, replacing a nodular iron unit, provides "about a 20% stiffness increase, which means on average about a 1-dBA reduction across the rpm range," said Cremonesi.

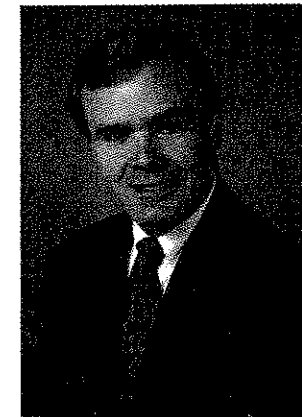
The new engine also has a more rigid block. "We added structure—primarily relating to ribbing—to the rear face of the block to handle the bending modes that you get with a longitudinal-mounted engine and transmission combination," said Will Wistehuff, Senior Project Engineer, Cylinder Block for Premium V Engines. The block assembly and engine components were designed in three-dimension using EDS Unigraphics software. Finite-element and computational-fluid-dynamics analyses were used to predict coolant flow and heat transfer as well as enable precise construction of foundry tooling.

One of the more challenging tasks was designing an oil pan for the low-ground-clearance XLR roadster. "Because of the shallow pan, you need to keep the oil from aerating, which would create foaming," said Zinser. The resulting oil pan uses specially designed drainbacks and baffles. "That was about a nine-month (for final design) process," said Zinser, referencing the development of a lubricant system to deliver oil during the varied engine operating conditions of a high-performance car.

Mating to the next-generation Northstar is a new Hydra-Matic 5L50-E automatic transmission, a modified version of the Hydra-Matic 5L40-E used in the Cadillac CTS. "We fit it in the same size case as the 5L40-E transmission," said Rich Mardeusz, GM Powertrain Hydra-Matic 5L50-E Assistant Chief Engineer. Although contained in the same package size as the 5L40-E, the 5L50-E was designed to handle a minimum 25% increase in power and torque.

The 5L50-E marks the first use of a dual-plate torque converter. It also employs a redesigned second clutch pack. Gearset changes include new geometries, alterations to gear shapes and sizes, internal case dimensional modifications, and valve body differences. The new transmission integrates driver shift control, performance algorithm "liftfoot," and performance algorithm shifting.

Driver shift control permits the driver to switch from automatic to clutchless five-speed manual operation by moving the gearshift lever into a tap up/tap down mode for upshifts or downshifts. Performance algorithm liftfoot prevents upshifts—while



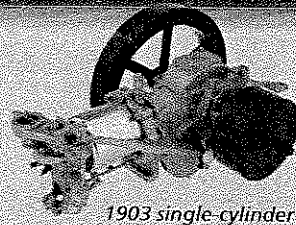
Chief Engineer John Zinser says that "just about every component is new" in the next-generation Northstar engine for all- and rear-wheel-drive applications.

Hydra-Matic 5L50-E Technical Specifications

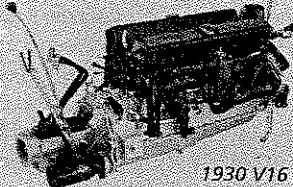
Type	Rear-wheel drive, electronically controlled five-speed automatic transmission with torque converter clutch and Driver Shift Control
Maximum engine torque capacity	310 lb•ft (420 N•m) for gasoline applications
Gear ratios	
First	3.42:1
Second	2.215:1
Third	1.60:1
Fourth	1.00:1
Fifth	0.76:1
Reverse	3.02:1
Maximum shift speed	6500 rpm
Maximum validated gross vehicle weight	2550 kg (5620 lb)
Case material	Die-cast aluminum
Converter size	258 mm (10.2 in)
Fluid type	Dexron III
Transmission mass	86 kg (190 lb)
Fluid capacity (approximate) by application (dry)	9 l (9.5 qt)
Final drive ratio	2.92:1

100 Years of Cadillac Powertrain Milestones

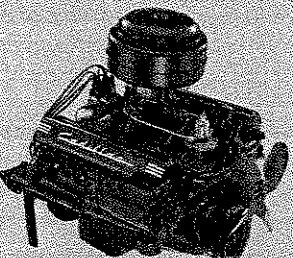
- 1903 Single-cylinder engine produces 10 hp (7.5 kW). The liquid-cooled engine uses variable valve lift in lieu of a throttle. It powers the Model A Runabout—the first model-year Cadillac.
- 1905 The 297-in³ (4.9 L) four-cylinder engine is introduced and eventually powers most of Cadillac's touring cars.
- 1912 Cadillac introduces a self-starter.
- 1915 World's first mass-produced V8 with a thermostatically controlled cooling system becomes the standard Cadillac engine.
- 1928 Cadillac's synchromesh transmission eliminates gear clash during shifting.
- 1930 World's first V16 engine for a passenger car. Its hydraulic lash adjusters silence valvetrain clatter.
- 1941 One year after Oldsmobile, Cadillac offers an automatic transmission as a \$125 option.
- 1949 Cadillac introduces the world's first high-compression, short-stroke V8.
- 1968 First Cadillac V8 with exhaust emission controls introduced.
- 1970 V8 displacement on a Cadillac peaks at 500 in³ (8.2 L).
- 1975 Cadillac introduces electronic fuel injection and catalytic converter.
- 1981 Displacement-on-demand technology used on Cadillac V8-6-4 engines.
- 1985 Introduction by Cadillac of world's first car with transverse-mounted V8 and front-wheel drive.
- 1993 At its introduction, the Northstar engine claims 16 patents.
- 2002 Northstar XV12 concept engine debuts in the 2002 Cadillac Cien concept car. The all-aluminum 7.5-L V12 engine delivers 750 hp (559 kW).



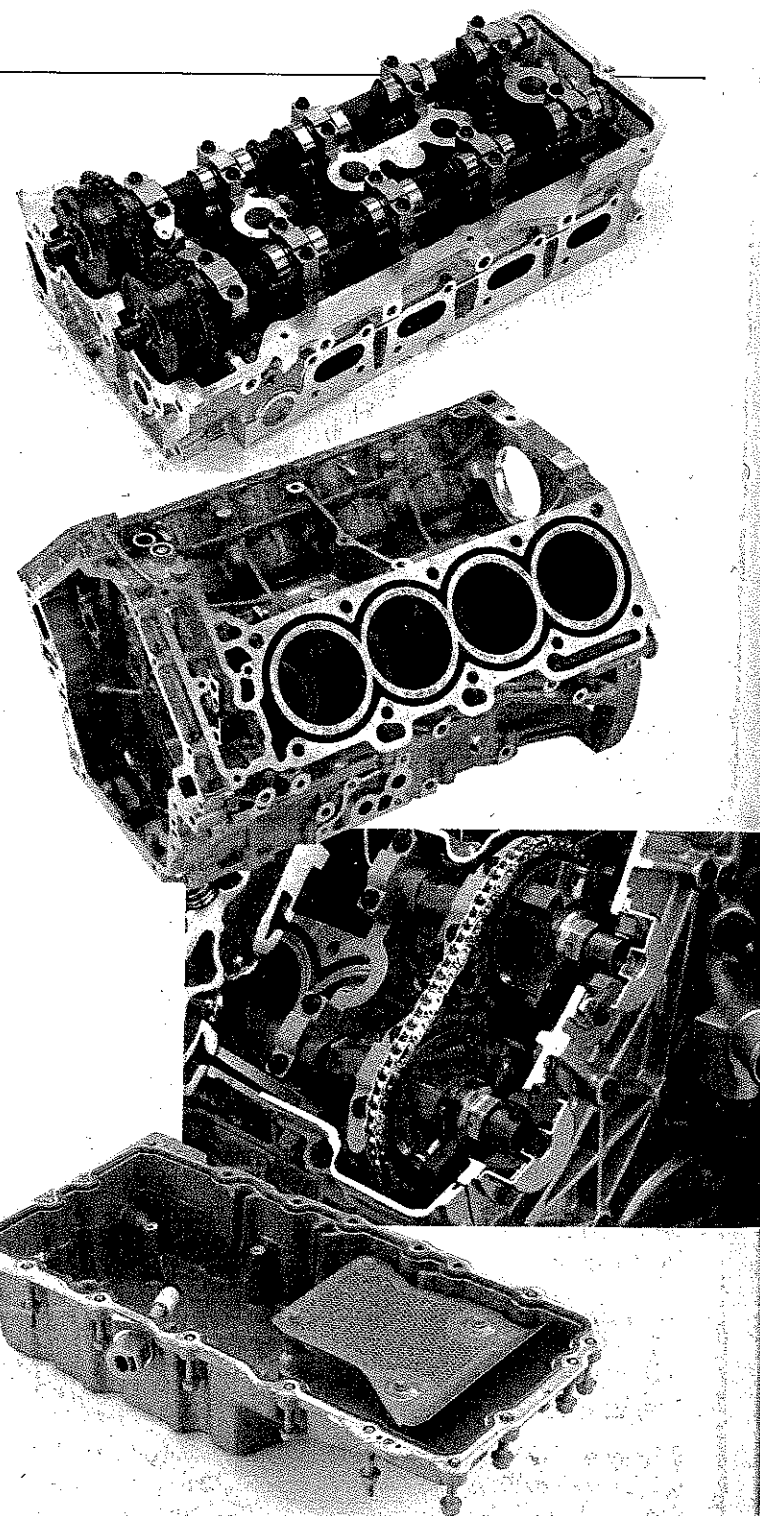
1903 single-cylinder



1930 V16



1949 V8 OHV



Next-generation rear-wheel-drive Northstar engine details: exhaust-side cylinder head; block assembly; exhaust and intake cam phasers; and top front of (XLR) oil pan.

maintaining engine braking—following the initiation of continuous performance driving periods. Performance algorithm shifting modifies automatic gear selection during high-lateral-acceleration maneuvers.

The XLR engine will mate to a torque-tube bell housing rather than directly to the transmission. A transmission case extension to the rear differential uses a dual-seal arrangement to separate transmission fluid from rear differential fluid. With the transmission in the rear, the XLR achieves close to a 50/50 weight distribution. The SRX engine will mount to the transmission in a conventional manner. The driveline on the SRX consists of a transfer case, front and rear differential, front and rear propshafts, and four half-shafts. Design of the 5L50-E entailed the first use

of a virtual transmission software program developed by GM that allows engineers to analyze shift metrics based on various clutch sizes and capacities.

The next-generation Northstar will be produced at GM's engine plant in Livonia, MI, which employs new engine assembly and cylinder head subassembly lines as well as upgraded machining operations. The new transmission will be produced in Strasbourg, France. Transmissions are hand-assembled in a clean room, with components delivered through sliding Plexiglass windows without handlers entering the area. **aei**

Cylinder deactivation for the Hemi

Several technologies are being developed to help reduce the fuel consumption of gasoline engines, perhaps none more talked about in recent years than cylinder deactivation. But **Chrysler** Group engineers purposely kept quiet about their plans to introduce the technology until it was close to production—the reason being that action speaks louder than words, said Burke Brown, Chief Engineer of the Chrysler 300 and **Dodge** Magnum vehicles.

The automaker's Multi-Displacement System (MDS) is standard equipment on the new Hemi-powered 2005 300C and Magnum RT. According to the Chrysler Group, these are the first "modern, high-volume" production vehicles in North America to feature fully functioning cylinder deactivation.

"The MDS seamlessly alternates between high-fuel-economy four-cylinder mode when less power is needed, and V8 mode when more power from the 5.7-L Hemi engine is in demand," said Eric Ridenour, Executive Vice President of Product Development, Chrysler Group. "This [transition] optimizes fuel economy...without sacrificing vehicle performance."

The system deactivates eight of the valve lifters—supplied by **INA**—stopping

combustion and loss of energy due to pumping air through these cylinders. The transition from eight to four cylinders is said to take just 40 ms. Some of the significant technologies enabling the MDS, according to Chrysler, are the sophistication of the algorithms controlling the system and the use of Electronic Throttle Control.

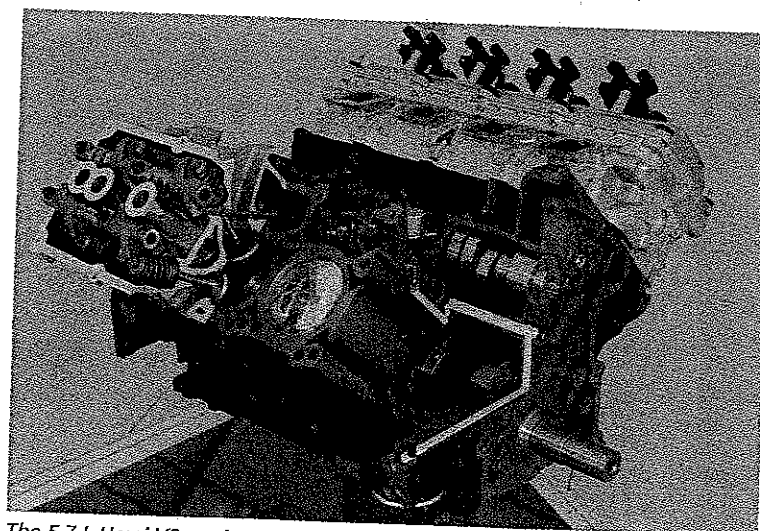
Fuel economy gains are estimated at up to 20% under certain driving conditions, with a projected 10% aggregate improvement. "The MDS has a very simple design that allows an engine with 390 lb•ft of torque [at 4000 rpm] and 340 hp [at 5000 rpm], but with the fuel economy of a large V6 or smaller V8 engine," said Brown.

Any time the vehicle is cruising on level ground from about 18 to 80 mph (29 to 130 km/h), the engine will likely be in four-cylinder mode, according to Brown. "We thought about putting a telltale on the instrument panel to let the driver know [when cylinder deactivation is occurring], but it works so often that it would be a flashing light," said Brown. The frequent transitioning is worthwhile, he added, because "if you put a lot of hysteresis in the system so it didn't kick in until held at a steady throttle for awhile, then some of its benefit is lost."

"We planned it all along," said Brown, noting that the Hemi was originally designed to accommodate MDS. "Because we started with a clean sheet, we were able to design the best system without constraints of an existing design or manufacturing process." This approach resulted in a cylinder-deactivation system that is completely integrated into the engine design with fewer parts, he added.

The modifications necessary to convert the engine are replacing eight of the valve lifters with deactivating lifters; adding four solenoids—supplied by **Saturn Electronics** from its manufacturing plant in Coopersville, MI—into the engine block and connecting them with a wiring harness; and replacing the camshaft.

As a result of the integration, the base and MDS engines have the same performance characteristics, except for fuel economy. And easy assembly of those few



The 5.7-L Hemi V8 engine was originally designed to accommodate the Multi-Displacement System, allowing the technology to be integrated into the engine design with few modifications.

Briefs

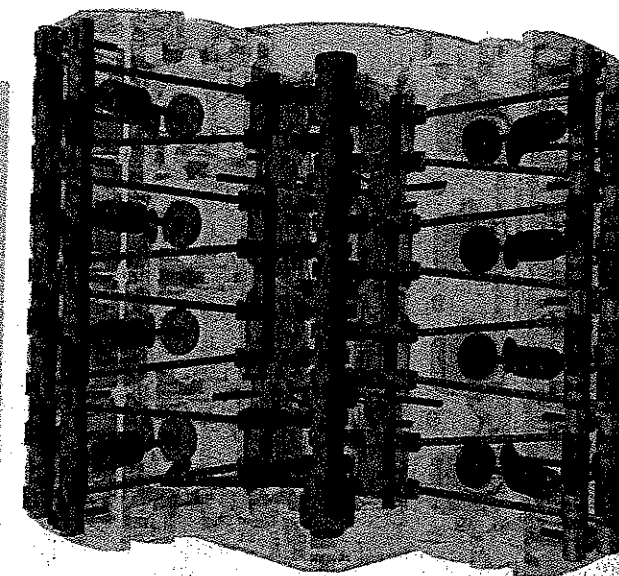
Ford will license key **Toyota** patents for the hybrid system it is currently developing for the Escape. In addition, Ford and Toyota will license a variety of each others' emissions-purification technology patents for lean-burn engines including Toyota's NOx storage reduction three-way catalytic converter system and Ford's NOx-control and Direct Injection Spark Ignition technology.

Rheinmetall AG has sold **Hirschmann Electronics GmbH** to a European private equity investor, **HgCapital**. Following the sale of the **Preh Group** to **Deutsche Beteiligungs AG**, the Hirschmann transfer is the final step in the divestment of Rheinmetall's electronics group, allowing it to focus on its core businesses: Automotive (**Kolbenschmidt Pierburg**) and Defence (**Rheinmetall DeTec**).

The **Timken Co.** has signed an agreement to supply steel gear components for the new six-speed automatic transmission currently under development by **General Motors Corp.** Timken will provide precision-machined preforms that GM will use as the material for 20 transmission components, including sun ring, and pinion gears. The new transmissions will be installed in a number of GM vehicles beginning in 2006.

Delphi Corp. has been awarded significant electrical/electronic distribution system content on the next-generation **Mercedes C-Class** vehicles scheduled for introduction in 2007. Delphi's Packard Electric division will assist Mercedes in designing customized technology that incorporates flexible printed circuits and flat cable. Delphi will be responsible for component management, in-line sequencing, and just-in-time delivery.

Compuware Corp. has agreed to acquire the products and technology of **Covisint**, the company set up to connect the global automotive industry. Covisint has more than 135,000 users in more than 96 countries, helping companies communicate and collaborate through a common infrastructure.



MDS transitions the Hemi engine from eight to four cylinders in just 40 ms, thanks to sophisticated algorithms and Electronic Throttle Control. The deactivating lifters are illustrated in transparent purple, the solenoids in green.

additional components reduces engine plant complexity; both engines are built simultaneously on the same line.

Cylinder deactivation is being introduced on the passenger cars first, said Brown, because that is where the biggest opportunity is in terms of fuel-economy

gains while maintaining performance. "If you put it in a bigger vehicle, it's still going to work well," he said when asked of the possibility of adding the MDS-equipped Hemi to the Dodge Ram pickup and Durango sport utility vehicle.

Ryan Gehm

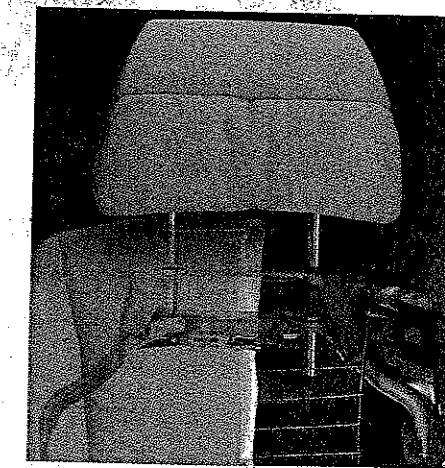
Active headrests for U.S. market

"We're here in the U.S. to start selling to American customers with components built in Mexico or the U.S.," said Ervin Jahic, Senior Project Manager for the Automotive Division of **Grammer Industries, Inc.**, from the company's first U.S. application engineering and sales office in Troy, MI. The first application of an active headrest system for the U.S. market is likely to be in MY2006.

Grammer's active headrest system—comprising two coil springs, a plastic headrest housing unit, electro-magnetic activated plate, and wiring—was done in Europe, but any necessary application-specific work will be done in Michigan.

"Development of this product was done without an order from a customer," said Jahic. "Everything is built within the headrest. The two coil springs push the headrest forward once there's a signal from the vehicle's control unit, and with this design we're not so dependent on the seatback frame."

Grammer AG-Automotive is now supplying an electronically triggered, pyrotechnically actuated head restraint system to **BMW** in Europe for 7-Series and 5-Series vehicles sold in the U.S. and Europe with the optional comfort



Grammer's in-production mechanism integrates into the seat's upper backrest. If a critical force is reached, the electronic system triggers the head restraint mechanism at a defined point, actuating a piston to move the headrest and reduce the head-to-headrest space.

seat package. The pyrotechnic mechanism, having a mass of 0.65 kg (1.4 lb), is integrated into the upper section of the seat frame. Grammer's active headrest system has a mass of approximately 300 g (10.6 oz) less and requires no extra parts in the seat frame.

Kami Buchholz