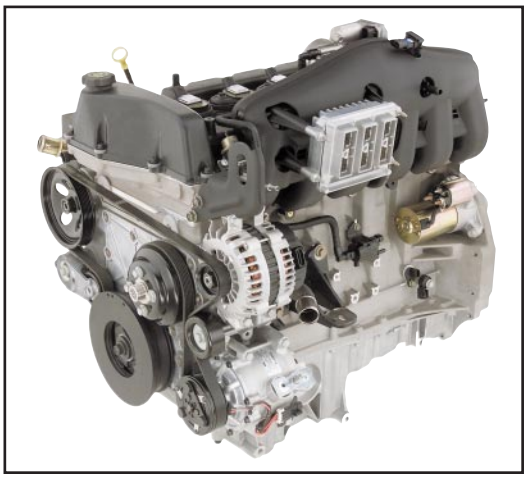
ALL-NEW HIGH-TECH GM VORTEC 4200 ENGINE TO SET BENCHMARK IN SUV MARKET

VORTEC I6 PROVIDES V8 PERFORMANCE AND 6-CYLINDER EFFICIENCY

For the first time in nearly two decades, three new General Motors vehicles will feature an inline six-cylinder engine, called Vortec 4200. The all-new high-tech I6 will provide the power, capability and smoothness of a premium V8 and the fuel efficiency of a six-cylinder engine. The Vortec 4200 will be standard in the 2002 Oldsmobile Bravada, GMC Envoy and Chevrolet TrailBlazer.

The all-aluminum 4.2-liter engine features dual overhead camshafts (first-use in a GM truck engine) and four-valves-per-cylinder technology. It will produce an outstanding 270 horsepower and 275 lb-ft of torque. The Vortec 4200 will be mated to a Hydra-Matic 4L60-E 4-speed automatic transmission.



"When we began evaluating engine possibilities for the new midsize sport-utilities, we were attracted to an inline-six configuration," said Ron Kociba, GM Powertrain chief engineer for the I6 engine. "Its clean and elegant design provides an inherent balance that results in smooth operation. We are thrilled to offer customers the power of a V8 with the fuel efficiency of a six-cylinder."

Additional engine features include a high compression ratio of 10:1, electronic throttle control, variable valve timing and coil-on-plug ignition. Multec II fuel injectors, an advanced Powertrain Control Module (PCM), direct-mount accessories and easy-maintenance features are also part of the package.

Back to the Future

GM's first mass-produced inline six-cylinder engine debuted in 1929 on Chevrolet cars and trucks. It displaced 194 cubic inches and produced 50 horsepower. The last time a new GM vehicle rolled off the assembly line with an inline six was in 1985, in a Chevrolet truck. The engine delivered 115 horsepower and 215 lb-ft of torque. In the 1970s, inline six-cylinder engines last appeared in Oldsmobile, Buick, Pontiac and GMC models.

"If you're going to make a different engine configuration choice like going from a V to an inline, your only real opportunity is with an all-new vehicle," said Kociba. "You have to factor in all the various requirements, and if you start with an all-new engine there's an opportunity to put it right into the design criteria."

The redesign of the GM midsize SUVs offered just such an opportunity and GM Powertrain engineers took full advantage. The program began in 1995, with earnest development work underway in 1997. The results are outstanding – this engine is the most comprehensively developed, tested and evaluated in GM's history.

The Development Story

"We insisted on giving the customer the best balance of performance, fuel economy, quietness, mass efficiency and emissions all at once," said Kociba. "We knew that an inline configuration, by nature of its simplicity, was the very best solution. You get one cylinder head rather than two, two cams rather than four if you're doing dual overhead cams, one cam drive system rather than two, and so on. The inline configuration allows us to offer customers more value and more content."

At the outset of development, GM Powertrain engineers made a list of all the requirements for a new engine: class-leading power, smoothness, quietness, improved towing capacity, fuel economy and emissions, and technologies, including dual overhead camshafts, 4-valves-per-cylinder and variable valve timing.

"When you make a list like that, you're like a kid in a candy store – you want everything," said Kociba. "I believe that in the end we came as close to getting every piece of candy we wanted as I've ever seen and without any compromises."

After compiling a comprehensive list of requirements and vehicle technical specifications, the engineering team set out to prioritize, analyze and evaluate all of the various options. During this "concept selection" process, the engineers put out a call for technologies from all the systems groups.

"That's where we get everybody's proposals for the entire basic system including the cylinder block, crankshaft, bearings and control system," said Kociba. "You end up with a lot of input, then you sort through all of it, and finally, select the content and put together a bill of materials – basically a parts list."

As each set of systems was added to the engine design process, the design itself changed several times. Each version was evaluated using the very latest in math-based design processes. The Vortec 4200 was designed with the most extensive use of math-based data analysis, more than any other GM engine to date.

Computerized math-based tools enhance, and in some cases eliminate, traditional physical tests, from structural component analysis to engine simulation. Development time decreases significantly as a result. This also helps with engine simulation for sizing and determining camshaft profiles. Moreover, computational fluid dynamics can be measured for designing the cooling system and the intake and exhaust manifolds. Software was used to develop manufacturing aspects of the engine, including determining optimum conditions for casting the block and head.

Specific examples of math-based tools include:

- Powertrain system modeling, which use simulation tools and product requirements to predict many performance variables.
- Dyna-Tools – Computer-aided calibration math methods that provide a process for model-based powertrain control algorithms, resulting in the optimal calibration methods for all powertrains.
- Virtual Transmission – A math-based toolbox for developing faster, high-quality transmission controls.

Testing, Testing… and More Testing

During its development and testing stages, the Vortec 4200 was benchmarked against the very best engines, including competitor domestic truck engines and the quietest and most fuel-efficient of the import passenger car engines. Once the engine was built, it was tested thoroughly. GM Powertrain built more than 800 engines during the testing process – 540 of those went into vehicles to support vehicle development.

On the dynamometer, 24 engines were tested and met the 150,000-mile target. Five of those were kept on the dynamometer, running wide-open, until they hit 300,000 miles – a test of astounding durability.

"They were still running very well at 300,000 miles," said Kociba, "I'm confident they could have gone many more miles, but we had to move on to other development testing."

Overall, the I6 reached more than 4 million miles of testing on the dynamometer. Outside the lab and in the real world, the engines also were tested extensively for durability, hot- and cold-weather performance, emissions and fuel economy. The Vortec 4200 fared particularly well in Death Valley's hot-weather, trailer-towing testing. Hauling a 5,000-pound trailer, the Vortec 4200 consumed 20 percent less fuel than the competing engines it was tested against.

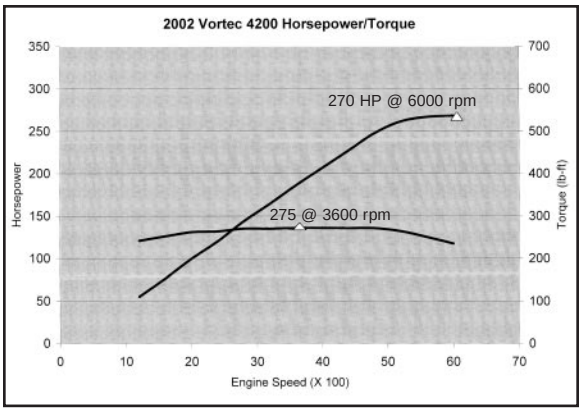
In addition to the Vortec 4200 production engine, GM's racing Vortec inline engine has been proving that an I6-equipped truck can beat V8 competitors, even in the grueling off-road racing environment. The Vortec-powered Chevrolet TrailBlazer won this year's SCORE Baja 500 in Mexico and the Nevada 2000 race. The same Vortec inline engine also powered a GMC Envoy to an overall victory at this year's Pikes Peak International Hill Climb in Colorado Springs, Colo.

Program Targets Met

The power requirement was simply to be best in class, a significant accomplishment for a new inline-six playing in a field dominated by V8s.

"I'm proud to say that when all was said and done," said Kociba, "we achieved every one of the technical targets we set. Given our considerable stretch targets, that is a notable success."

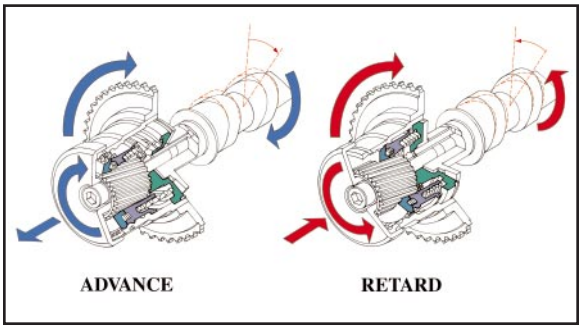
Targets met:



- Specific power output – 64.9 horsepower per liter, best in class and exceeding the target of 62.5 horsepower per liter.
- Torque – can be overwhelmed by sheer displacement, putting the 4.2-liter I6 at a disadvantage against the larger engines of the competition. The engine delivers 275 lb-ft of torque, 10 more torque than our target. The torque also is a significant improvement over the current 4.3-liter V6. The Vortec 4200's torque curve extends through the majority of the speed range. Ninety percent of the peak torque is available from 1,600 to 5,600 rpm.
- Noise/vibration/harshness (NVH) – NVH is among the best in the world for any truck. Its rigid structure is designed to meet or exceed the standards set by some of the world's best engines, and its solid power at idle and at passing speeds rivals world-class passenger cars.
- Emissions – The I6 will be among the first truck engines to meet National Low Emissions standards (NLEV). In addition, the use of lost-foam casting, pioneered by GM, for the aluminum block and head significantly reduces emissions and waste during manufacturing.
- Smoothness and balance – The Vortec I6 is inherently balanced, eliminating all forces and vertical shake associated with V6 engines. The engine is smooth through the whole operating range—a smoothness that is very noticeable to the driver and passengers. Vibration is virtually eliminated from the steering wheel, seats, floor pan and instrument panel.
- Mass reduction – Due to the Vortec 4200's aluminum construction and parts reduction, the I6 engine is more than 40 pounds lighter than the 4.3-liter V6, and more than 100 pounds lighter than a typical V8 offering.
- Fuel efficiency – The engine's fuel efficiency is best in class, thanks to its lighter weight, the use of advanced technologies such as electronic throttle control and variable valve timing, combustion system design, and low-friction components.

Variable Valve Timing

Featured for the first time in a GM truck engine, variable valve timing (VVT) is a unique technology that is accomplished by cam-phasing. On the Vortec 4200, the technology is used on the exhaust cam, which allows adjustment of overlap in the intake and closing event timing of the exhaust cam.



The valve timing is electronically controlled and solenoid actuated by advancing the exhaust cam relative to the intake. Very little exhaust gas is allowed into the intake charge. The result is a smooth and clean combustion that enables good torque and power throughout the speed range and reduced emissions.

By increasing the overlap of the cams (in essence, retarding the exhaust cam), internal exhaust gas recirculation (EGR) is achieved and distributed

to all cylinders. Whatever is residual simply goes into the next burning cycle – a big enabler for emissions control while providing high output and smooth idle.

"It helps performance, fuel economy, emissions and 'pleasibility' all at once," Kociba said.

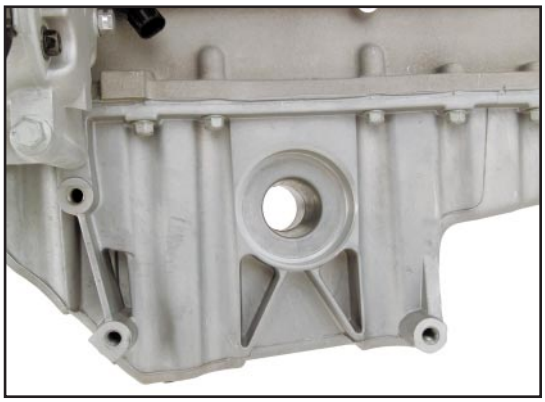
Electronic Throttle Control

Electronic throttle control (ETC) consists of an accelerator control module containing sensors that relay driver acceleration-intent information to the powertrain control module (PCM). The PCM is engine-mounted and supplies force feedback (pedal feel) to the driver.

The PCM then determines and optimally positions the throttle body air valve through the use of an electronic motor. ETC helps achieve optimal fuel efficiency with high output while ensuring a clean burn.

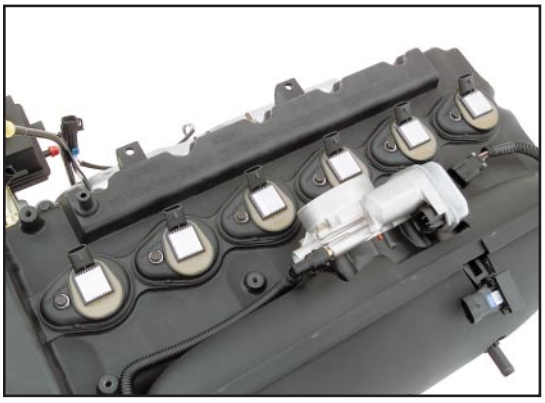
Oil Pan Axle Configuration

In a unique design that saves undercarriage space while reducing interior noise, the four-wheel drive differential is bolted directly to the engine's oil pan (rather than the frame) and a half-shaft passes through the pan via a cast-in passage. The new midsize SUVs are the first in GM to incorporate this configuration. Typically, the differential shaft crosses underneath the pan, and in turn, the engine must be raised.



In this application, the shaft is designed to pass through the oil pan, which helps in engine packaging, serviceability, styling, visibility and noise reduction. In addition, there's no longer a noise transmission path going directly into the vehicle compartment.

Innovations Abound



In addition to VVT, ETC and the pan axle, the Vortec 4200 is equipped with other advanced technologies. For example, a coil-on-plug ignition system is employed. It's an electronic engine sensing and spark control system that has no moving parts and doesn't require timing adjustments. The coil-on-plug system delivers a high-energy spark, which results in clean and consistent combustion for meeting onboard diagnostic misfire requirements. The system also contributes to improvements in fuel economy, the elimination of spark wires, improved high-speed performance and increased engine efficiency.

Roller follower valve train and a state-of-the-art PCM also improve the engine's performance, efficiency and noise levels.

"The engine is so quiet," Kociba said, "that during testing people kept turning the key at idle when the engine was already running. To prevent that, we added an algorithm programmed into the PCM to keep the starter from engaging once the engine has already been started."

Future Applications: The Sky's the Limit

"Part of GM Powertrain's success is to creating flexible architectures for global applications," Kociba said. "Once we got started with the Vortec I6, it wasn't long before we started thinking about a four and a five to add to the family. Incorporating them on largely the same manufacturing equipment is a real enabler for GM, providing excellent flexibility to respond quickly to market conditions."

The new engine family will allow GM to respond to market shifts with minimal manufacturing changes because inline engines of four, five and six cylinders can be built in the same manufacturing environment. Between 75 and 80 percent of the parts will be common between the family of engines, and they can be machined on the same equipment. Shared systems and components may include rods, pistons, piston rings, bore liners, valves, valvesprings, bearings, sensors, coil-on-plug ignition system, fasteners, roller followers, cam drive systems and a host of other components.

"Even beyond the solid platform from which to expand the engine family, the Vortec 4200 gives us a good, strong foundation from which to add other technologies, such as twin turbocharging or direct injection-gasoline," said Kociba. "We see a long life for this engine family. We want to demonstrate that we can accept more output and better emissions, and that we've designed an architecture that's ready for all those add-ons if we determine there's a market for them."

Expect the "brothers" of the Vortec 4200 to appear in the marketplace soon on future GM trucks. Twin turbo applications and direct injection-gasoline applications are under study.

Could've Had a V8; Should've Had an I6

The Vortec 4200 clearly demonstrates the versatility of an inline-six configuration, which has come a long way since its days in the 1980s.

"We're applying technology that allows us to take advantage of the inherent strengths in the I6 and overcome its past weaknesses, such as the length of the intake manifold and even fuel delivery," said Kociba. What we have accomplished is a world-class engine."

GM engineers are rightfully enthusiastic about the new engine. "This engine stands out in three areas – smoothness, power with even torque delivery and better fuel efficiency," said Tom Sutter, GM Powertrain assistant chief engineer for the I6 engine. "It's an excellent engine for trucks, with the technical sophistication of a premium passenger car engine."

The engine is nothing short of a giant leap forward, with its emphasis on advanced technology while not sacrificing any of its robustness. "There was a heavy focus on robustness," Kociba says. "For example, the crankshaft has large 70-mm journals to make sure it's very quiet. We focused

on an industrial strength approach, with direct-mount accessories – the alignment of all the accessories is better, quieter, and lighter."

GM has a rich history of lasting benchmark engines and the Vortec 4200 is another example of GM Powertrain asserting its leadership in the industry.

"Conventional wisdom says go do another V8, but we've done that for many years. Now we're stepping out and doing something different, something we are very proud to offer customers. The Vortec 4200 is a great engine and we can't wait for our customers to experience it."

WINNING VORTEC-POWERED CHEVROLET TRAILBLAZER SEEKS CHALLENGE AT BAJA 2000 RACE

WITH THREE VICTORIES, VORTEC I6 ENGINE DEMONSTRATES POWER AND DURABILITY

General Motors' off-road racing Vortec inline six-cylinder engine will once again demonstrate its outstanding capabilities against V8 competitors in its final event of the season at the SCORE Baja 2000 on November 9-16 in Ensenada, Baja California, Mexico. The race-specific Vortec inline six-cylinder engine captured first place finishes at the SCORE Baja 500, Pikes Peak International Hill Climb and Best in the Desert Nevada 2000 races.

The SCORE Baja 2000 features an 1,800-mile course, which begins in Ensenada, 65 miles south of San Diego, and finishes in Cabo San Lucas in Baja California Sur, the southern tip of Baja, Mexico.

The SCORE Baja 2000 is the final of three off-road races GM decided to compete in this year with the Vortec-powered TrailBlazer. The SUV won its debut race at the Baja 500 on June 2-4 in Mexico. Veteran-racer Larry Ragland captured both the overall four-wheel vehicle win and the Trophy-Truck divisional title. Ragland completed the grueling 440.6-mile loop-style trek with a time of 8:56.43. He collected his third overall win (1982, '84, '00) and fourth class title (1982, '84, '91, '00) in the history of the race.

Ragland also drove a Vortec-powered GMC Envoy with the inline six-cylinder engine to victory at the Pikes Peak International Hill Climb on July 4 in Colorado Springs, Colo. Ragland completed the 156-turn, 12.42-mile gravel course with a time of 11:17.66. His time earned top billing in the High Tech Truck and Sport Utility Vehicle class and the overall race victory.

The off-road racing Chevrolet TrailBlazer won its second consecutive race at the Best In The Desert Nevada 2000 on July 14 in Las Vegas. Six days and nearly 2000 miles of some of Nevada's toughest terrain was a great test for the Chevy TrailBlazer. It won the Trick Truck class with an overall time of 26:28:36 and beat the next entry by more than 30 minutes. It was the second best overall time out of the 66 truck and car-based entries. The Herzog Motorsports team of Brian Stewart, Mark Miller, Bekki Freeman and Ryan Arciero traded responsibilities behind the wheel.

The Chevrolet TrailBlazer features a computer-designed carbon-fiber body mounted on a tube frame chassis. It is powered by a race-specific all-aluminum 5.0-liter I6 engine featuring dual overhead camshafts and a Hydra-Matic three-speed automatic transmission. The Vortec I6 engine produces 600 horsepower at 7500 rpm and 450 lb-ft of torque at 6000 rpm. The same engine powered the GMC Envoy to victory at Pikes Peak.

“The Baja 2000 race provides a great opportunity for GM to cap an outstanding season with the Vortec-Powered Chevy TrailBlazer,” said Brian Miller, GM Racing off-road program manager. “The Vortec inline six-cylinder has demonstrated its power, durability and efficiency against all of the V8 competitors. We are confident that our new Vortec-powered TrailBlazer and team of acclaimed drivers will continue our commitment to racing a winning combination at the Baja 2000.”