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Diesel hybrid hope
Can the optimum solution for emissions reduction be made cost-effective?

Price war
Toyota and Honda go head-to-head in the hybrid stakes

Engines revisited
The gas turbine

INTERVIEWS

Malcolm Sandford
chief engine engineer, Jaguar

Dick Elsy
chief executive officer, Torotrak

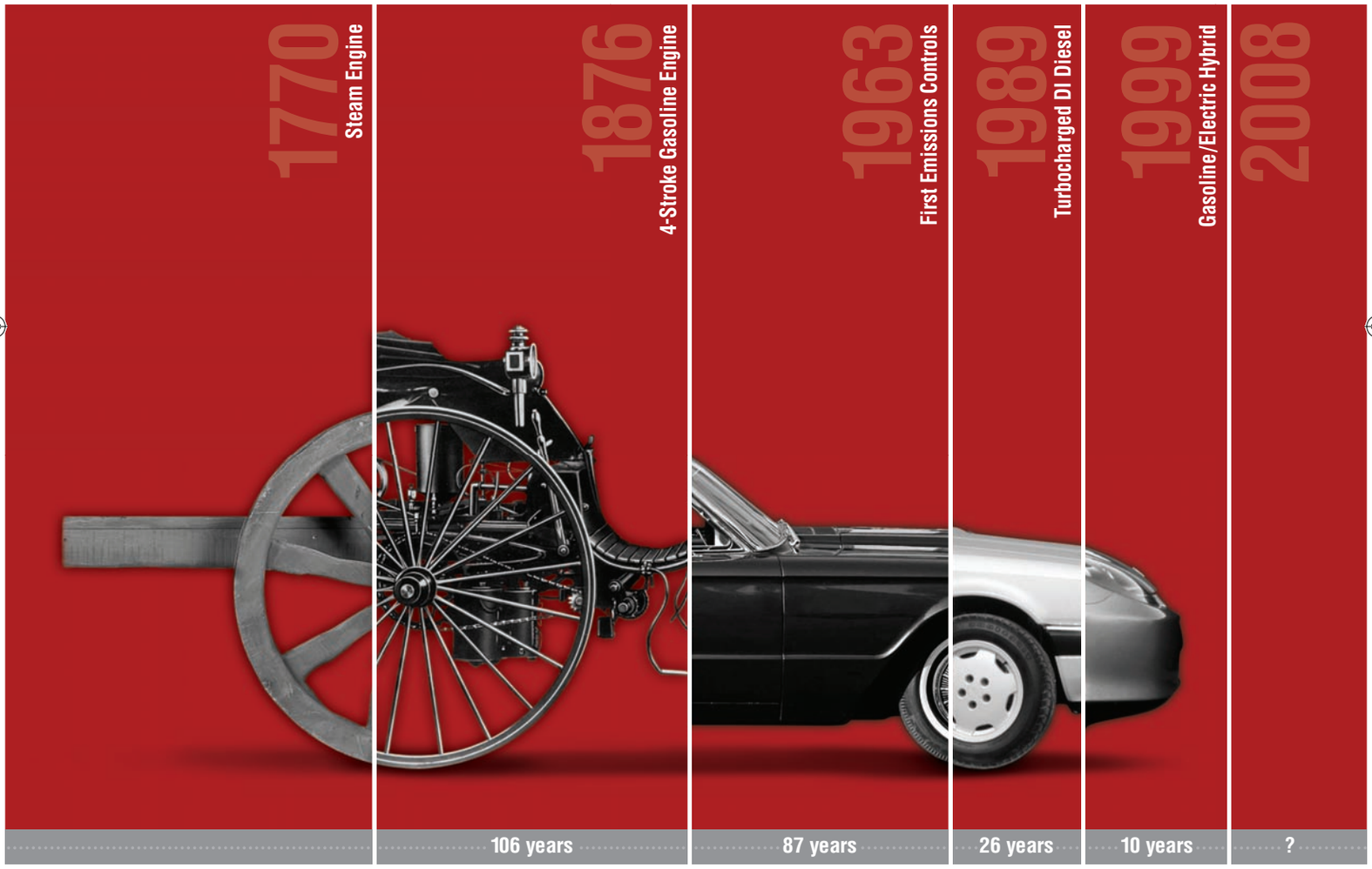


V Power
Jaguar hits back with all-new V powertrains

Reaction time

What next in the evolution of emissions technology?

Innovation at the speed of change



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COVER STORY
JAGUAR V ENGINES

What's all this fuss about engine downsizing? Jaguar has put the finishing touches to two new V units. Read exclusive details here

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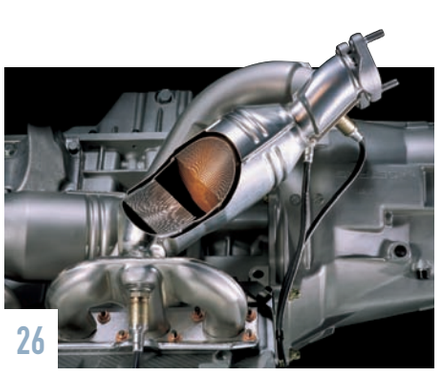


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Often referred to as the optimum eco-friendly powertrain solution, the first mass-market diesel hybrid vehicle is yet to be realized. But will such a technology ever make the leap from the R&D lab into the real world?



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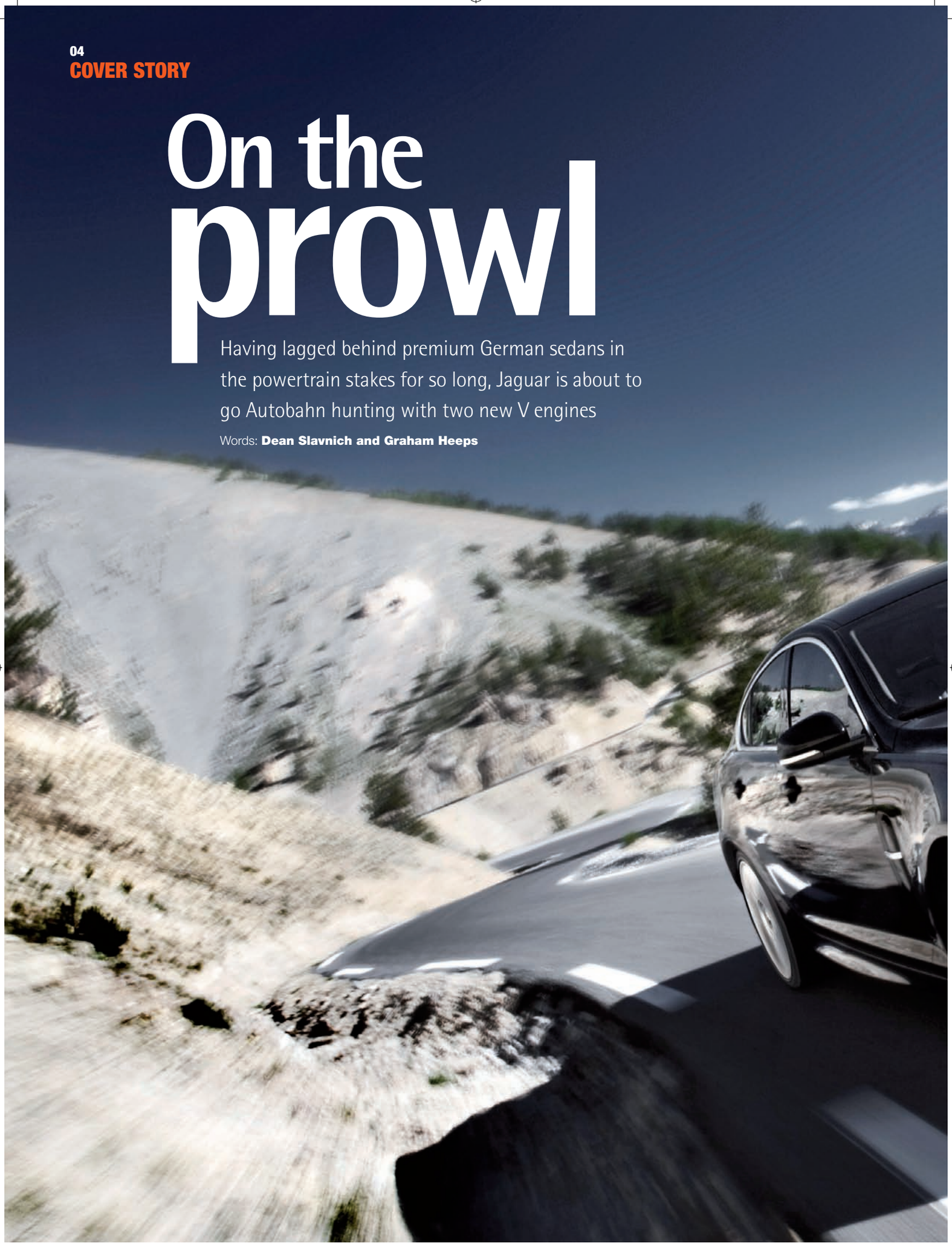


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On the prowl

Having lagged behind premium German sedans in the powertrain stakes for so long, Jaguar is about to go Autobahn hunting with two new V engines

Words: **Dean Slavnich and Graham Heeps**





The XF range has been rejuvenated with the XFR shown here and the XFD

Jaguar waited for so long to introduce a diesel into its range – just six years ago the British car maker was a purely gasoline-driven brand – but it has now brought to market its third diesel engine, and it is packed with innovative features.

The centerpiece to the powertrain is a unique, parallel sequential turbocharger system – the first of its type to be fitted to any V-powertrain. The Honeywell-Garrett turbos work sequentially to deliver best-in-class torque at low engine speeds, while packing a punch and a half at higher revs. A variable-geometry primary turbo does all the work on a daily basis, while the second turbo remains dormant and saves energy. When the diesel climbs above 2,800rpm, the second turbo is brought in line with the first turbo within 300ms, boosting engine output and eliminating turbo-lag. In an effort to minimize pumping losses, valves controlled by the engine management system isolate the secondary turbo from the exhaust stream and the engine inlet tract.

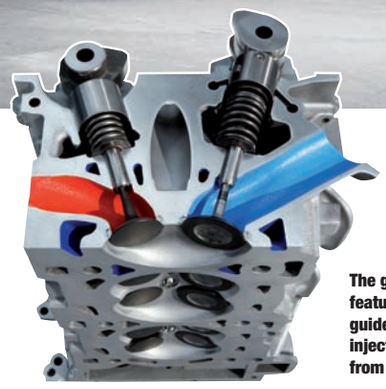
There's no denying that Jaguar engineers are proud of the turbocharger system. Waxing lyrical about the setup is Alan Jones, manager of diesel applications: "This technology is really innovative for a diesel. We assessed the BMW system before opting for this setup and we didn't use it for three reasons: the BMW setup did not quite deliver the dynamic performance of our system because we have a VNT



Jaguar's answer to AMG and M, XKR and XFR get a supercharged 5-liter V8 developing 503bhp

"We focused on reducing the parasitic losses during the warm-up period, and our specialists for the lubrication system came up with a new pressure relief valve concept"

MALCOLM SANDFORD, CHIEF ENGINE ENGINEER, JAGUAR LAND ROVER



The gasoline V8 features a spray-guided direct-injection system from Bosch

on the primary side and they have fixed geometry. The second reason is cost, but the biggest factor for not adopting the BMW system is because it really is too hard to package that system in our engine bay. It's great for an inline engine where the turbos are right next to each other, but not so good for our V engine."

Project AJ-V6D Gen III will spawn two diesel units: one pumping out 235bhp and 500Nm of torque; the other developing 270bhp and 600Nm of torque. Premium diesel sedans from Bavaria, Ingolstadt, and Stuttgart have been warned!

Although it's based on the outgoing 2.7-liter V6 that was developed with partners PSA Peugeot Citroën and Ford, the new 3-liter diesel can almost be counted as a new engine, says engineer Jones, who adds, "Pretty much every single part has been optimized in one way or the other." Major parts such as cylinder heads and blocks have been plucked from the 2.7-liter, but they've both been heavily reworked. The heads, for example, have had the porting modified, and the blocks have been touched to help cope with the increase in torque. Baffling has also been changed. Fully new parts include pistons, con rods and crank.

Having been benchmarked against the outgoing 2.7-liter engine, the 3-liter BMW unit that drives the 535d and Audi's V engines, AJ-V6D Gen III, needed to be packed with technology. As a result, the V6 uses a new, common rail fuel-injection system supplied by Bosch that delivers up to five diesel injections on each cycle at a pressure of 2,000 bar. Described as a "superb system", by Jones, Bosch's technology enables each injector tip to be perforated by seven holes through which finely atomized fuel is sprayed into the cylinders. New, third-generation high-speed piezo injectors enable up to five precise injection events during each combustion cycle, minimizing combustion noise. Unlike other piezo packs, the crystals in Jaguar's new injectors are fitted nearer to the tip, which means they are mounted deeper inside the engine, providing better sound insulation and quieter operation.

Compact graphite iron is used for the engine block, with the high tensile strength allowing for an 80mm reduction in block size compared to conventional gray cast-iron. An aluminum ladder-frame is used for boost stiffness, and baffles in the sump body maintain oil flow during high-G maneuvers.

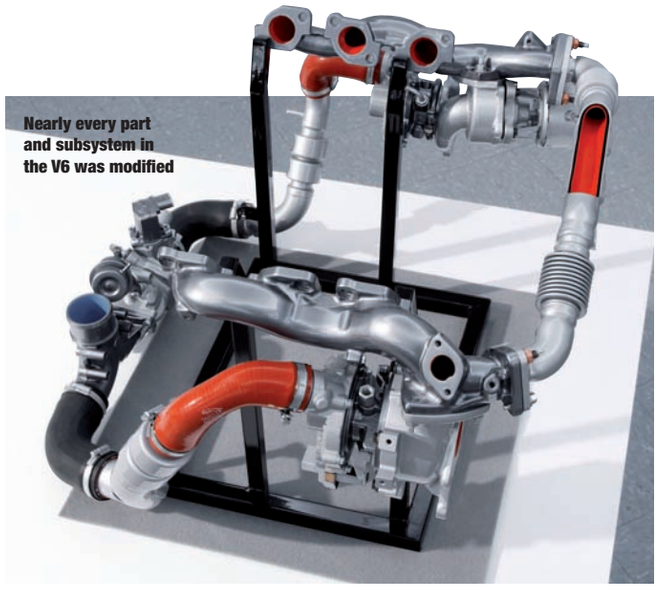
The two cylinder heads are constructed from aluminum alloy, with four valves per cylinder. The intake ports have been designed to optimize airflow and fuel/air mixing due mainly to the new helical ports delivering swirl air motion. Also new is a tangential port design for enhanced high-speed flow. A new, water-cooled EGR helps to ensure that V6D Gen III is more



PSA had very little input during the development of the new diesel unit

THIRD TIME LUCKY

Much has changed since Jaguar worked with PSA Peugeot Citroën and Ford to develop the 2.7-liter V6. "This project is very different to the development of the previous diesel," says Jones. "The last one was obviously a combined project and was a collaboration with PSA. This time it's quite different because it is very much driven by ourselves." Part of the reason for this – although Jones denies it – is because originally Jaguar wanted a 3-liter diesel heart while PSA senior engineers were looking for a 2.5-liter unit. In the end the two partners, with help from Ford, agreed to meet in the middle and develop a 2.7-liter unit. Jones continues, "We initiated this project and very much pushed the technology, such as the turbocharger system, which won't find its way to Peugeot applications."


Nearly every part and subsystem in the V6 was modified

efficient than the 2.7-liter unit in terms of pumping losses and NOx output. Compression ratio has been reduced from 17.3:1 to 16:1, while bore/stroke has been increased to 84mm x 90mm. There's also a new glow-plug system from Bosch.

Petrol power

In mid-2008, a 503bhp supercharged V8 looked like just about the worst new engine any OEM could introduce, but the fall in fuel costs will have come as a relief to Jaguar as it brings just such an engine to market. Together with its 380bhp normally-aspirated sister, with which it shares about 85% of its parts, the two engines constitute the Tata-owned marque's first all-new V8s since 1996.

Central to both is a Bosch-supplied, spray-guided direct injection system delivering fuel at 150 bar. "The injector is located in the center of the cylinder, like a diesel," explains Malcolm Sandford, chief engine engineer at Jaguar. "It's a solenoid-operated, multihole injector giving six sprays to the 3-liter diesel's seven. We've chosen that technology and put the injector close to the spark plug in order to put the fuel exactly where we need it, specifically in the cold start period when we're trying to generate as much heat as possible to light the catalysts, and at the same time trying to achieve low engine-out emissions. It has been very effective – we've had a 2.5-fold increase in heat to catalyst during cold start spark retard, which has enabled us to achieve about a 50% reduction in hydrocarbons while keeping NOx at tailpipe levels."

Also appearing on both gasoline powertrains is a VCT system activated by the torque generated through the opening and closing of the intake and exhaust valves. Supplied by BorgWarner, this is the second application of the technology after Ford's US-market 3-liter V6, with whom the Jag team worked before Ford sold the company. "Not being oil-pressure actuated, it's got very low oil consumption, which has allowed us to design a small oil pump on the engine, smaller than a conventional vane-type VCT design would have allowed us," says Sandford. "It has very high actuation rates, more than 150°/sec. There's a three-fold increase in the rate at which we can actuate the VCT, which in turn has enabled us to run what we feel is a very aggressive cam timing strategy. We have a very fast change in inlet and exhaust cam timing to maximize internal EGR and get the best fuel efficiency improvement possible."

As for the smaller oil pump, it has been changed from a round-the-crank design to a separate unit attached to the windage tray, shortening the engines by 24mm. "It was an interesting choice early in the program as to whether we needed a variable-geometry oil pump or not," he recalls. "Because it's a small unit the benefit of a variable-geometry oil pump was minimal. We focused on reducing the parasitic losses during the warm-up period, and our specialists for the lubrication system came up with a new pressure relief valve concept. Using feedback on oil pressure from deep in the oil galleries, we've been able to reduce the pumping work all the way through the warm-up period."

On the NA engine, the VCT is coupled with a cam profile switching system. The inner hydraulic tappet is used to switch between 5.5mm lift and 10.5mm lift. "The benefit is twofold: an enhancement in low-speed torque, between 1,000 and 3,000rpm, which was one of the prime objectives for the NA; and a 1% friction efficiency gain through running lower lift at lower engine speeds."

Also variable is the geometry of the inlet manifold, the length of whose eight inlet tracts switch from 680mm at low speeds to 350mm above 4,700rpm. "By combining this with the cam profile-switching system, you get a three-phase torque curve," Sandford enthuses. "At low speeds it's short cams, long runner; at medium speeds it's high lift and long runner; and at high speeds it's high lift and short runner. You break the compromise you normally have to achieve as an engine designer to optimize the valve lift and runner length somewhere in the middle. I'm very proud of the torque curve, and specifically at 1,500rpm/11.1 bar is good by any benchmark.

"I'm also proud of the transient response. Our measurements show that we've improved on the previous benchmark, the 4.8-liter BMW. That's down to the great low-speed torque, reduced transport delays as a result of the DI system, and the very high actuation rates we got on the VCT. Those three combine to deliver the torque in a really immediate fashion."

Although the NA V8 achieves 515Nm torque at 3,500rpm, the supercharged unit makes 625Nm from 2,500-5,500rpm. Key to that is the supercharger itself, which is from Eaton's Twin Vortices Series. The engines' other high-tech components are an all-new, high-pressure die-cast block that has cast-in iron liners, deep skirts, and cross-bolted main bearing caps. *ETi*

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