JON LAWSON, *iVT International*

ENGINES

E-MISSION IMPOSSIBLE?

EM:i-T4

Your mission, and you are compelled to accept it, is to integrate Tier 4 engines into your vehicles. Part One of our investigation into the array of potential technologies reveals the strong favourites

Next year, Tier 4 emissions regulations will come into force. No one could accuse the EPA of keeping the details of the new legislation a secret. The relevant page of the EPA's website runs to over 50,000 words, with a summary that reads: "Beginning in 2008, the new Tier 4 engine standards for five power categories for engines from under 25 horsepower to above 750 horsepower will be phased in. New engine emissions test procedures will be phased in along with these new standards to better ensure emissions control over real-world engine operation and to help provide for effective compliance determination."

This can be broken down into specifics. For sulphur compounds, the EPA seems to be looking more to the fuel suppliers than the engine makers. Diesel fuel now has to contain a maximum of 500ppm sulphur, with a target of just 15ppm by June 2010.

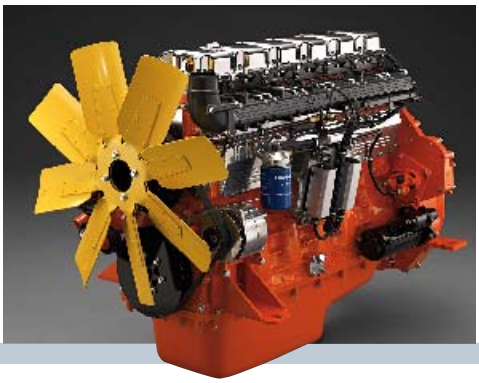
For NOx, Tier 4 ultimately demands a 90% reduction, and particulate matter

MAN has invested in a 'future-proof' platform

Swept volume increase?

Scania assures us it will also be ready for the new regulations. Robert Sobocki, from its Industrial and Marine wing, says: "We are still in the preparation phase and, of course, the more severe the emission regulations become, the more difficult it is to achieve. We are aiming to achieve Tier 4 without aftertreatment. Maybe urea (SCR) will be used in some applications."

Sobocki acknowledges that with targets as tough as these, it is difficult to isolate which particular problem is the most complex to overcome. He will not be drawn on exactly which methods the company is planning to use, but he muses: "EGR is a simple solution for the end user – just add diesel. But SCR will make it easier to achieve high outputs. Now, with EGR, a bigger cooling capacity is required, but with SCR an extra tank and rather complicated urea-injection systems are required."



Sobocki does predict more commercial vehicle-style onboard diagnostics, especially where NOx reduction is concerned, and he will admit that Scania is aiming for a closed crankcase ventilation system.

"Scania's target is to achieve every new emission stage without ruining our existing good fuel economy. Maybe a bigger swept volume will be required to achieve the same output."

a 95% reduction. Fuel quality will have a bearing on this, but the onus is also on engine manufacturers to do their bit. The EPA states: "This change in fuel quality will directly lead to important health and welfare benefits associated with the reduced generation of sulfate, PM and SOx. Even more important, introduction of 15ppm sulfur nonroad diesel fuel facilitates the introduction of advanced aftertreatment devices for nonroad engines."

So that covers what has to happen and when. The targets are ambitious – however, technology is available now that will help. It is perhaps just a question of deciding which is the most appropriate for your needs.

A future-proof platform

MAN is prepared for the new regulations. The company has an engine range ready from 110kW to 885kW. Reiner Roessner, of the company's Commercial Vehicles and Industrial Engines division, says, "We have spent a lot of money over the last few years to get a 'future-proof' engine platform. We have developed the all new D20/D26 series as well as the new V-series D2868 (eight cylinder) and D2862 (12 cylinder). Together with the D08 Common Rail series, we now have a unique range of engines.

"MAN is using and advancing the latest technologies such as external EGR, two-stage turbocharging, common rail, MAN PM-Kat and MAN AdBlue SCR to realise better consumption and to make a cleaner environment."

The company is also pondering the use of multiple-pilot injection to help keep HC emissions down.

Economy has also been considered. Roessner: "We always aim for best-in-class economy, so we are careful to develop these systems with no penalty in fuel consumption. In the future, we expect there to be more emphasis on cutting CO_2 emissions, as well as discussions on oil resources."

Engine internals have been scrutinised. A new crack process is used for con rods and main bearing cap manufacture, while materials such as monosteel for the pistons and vermicular cast iron for the crankcase are employed to cope with high combustion pressures. On the subject of crankcases, their ventilation is now part of the Tier 4 rules. Roessner says: "MAN

has used closed crankcase ventilation for many years. Over time, these systems have been improved to produce a maintenance-free solution on most applications."

Another aspect of the new legislation is cold-start performance. Always a tricky thing to master, MAN's solution is to tailor the design to the load. As Roessner explains: "We have a close look at the engine application and, depending on the parasitic load, we check if the installation fulfils the customer's requirements. Also, we use different compression ratios to manage special applications, such as snow groomers or portable air compressors (low ambient conditions and high parasitic load). If it's necessary, we do cold-start tests together with the customer on the complete machine."

The trend for more electronics across all areas of engine design has been mirrored in the off-highway sector. For MAN, this meant a new custom Bosch ECU to oversee proceedings. In the future, Roessner sees more and more sensors monitoring more and more parameters, such as exhaust temperature and back pressure. "To keep emissions low and the engine's lifespan under control, an increased number of sensors will become mandatory" he believes. "Also, the control systems will have to improve, with more features in the software to manage the low emissions."

Of course, all of this complicates engine installation for the OEM. The worst offender is the aftertreatment system, which puts severe limits on the design of the exhaust, especially where space is already an issue. The SCR urea container doesn't help; neither do increases in sensor wiring.

Cooling could become increasingly important as aftertreatments proliferate

These elements all mix together to create a jumble of pros and cons. "When using the EGR-MAN PM-Kat system, no SCR AdBlue is necessary, which has to be an advantage. However, the cooling system needs to be expanded, which is the down side," Roessner observes.

Cool front

Cooling is a subject close to the heart of Jon Aitchison. His employer, Comesys Europe Ltd, and its North American partner Engineered Machine Products Inc, are developing modular electronic cooling systems with the aim of using better economy to reduce emissions. Discussions are taking place between the partners and several, as yet undisclosed, industrial vehicle OEMs.

The view from China

China's burgeoning economic growth has led to a great demand for engines to work in off-highway applications. One organisation with its finger on the local pulse is Wuxi Cummins Turbo Technologies Co Ltd. Based in the New Development Zone in Wuxi, near Shanghai, the company is a 55:45 partnership between Cummins Turbo Technologies and Wuxi Power Engineering Co Ltd. As well as OEM customers that include leading Chinese truck manufacturers DFM and FAW, the company services a thriving aftermarket.

Wuxi CTT chief engineer Alan Parkes says: "China started its nationwide on-road Stage I in January 2000, which is equivalent to Euro 1; followed by nationwide Stage II in September 2003. Now there will be emission standards for off-road mobile diesels (Limits and Measurement Methods for Pollutants from Diesel Engines of Non-Road Mobile Machinery (I, II) GB 20891-2007), which will be enforced from 1 October 2007. This standard is equivalent to European Stage I and Stage II/EPA Tier 1 and Tier 2, excluding those engines over 560kW. China does not have anything close to Tier 4 yet."

China does seem to go its own way, loosely basing its emission regulations on the system that operates in the EU. Regarding potential exports, Parkes says, "With new off-road emission standards in place, local engine makers will have more incentives to invest in emission-compliant, off-road engine technology. In the long run, this will help increase local makers' competitiveness in the global market. It's a bit early to talk about specifics like EGR or catalyst design as the country is still at Stage I, but the West's proven technology paths will surely be a good reference for local manufacturers."

The system works by replacing the water pump and radiator fan with new, electronically controlled items. "The principle is to remove the parasitic loads that come with a mechanical drive, belt, viscous clutch or hydraulic system. For OEM fit, we'd do a complete bespoke design to create a thermal kit, and propose a cooling pack to fit," Aitchison explains.

To get rid of the single large fan design, a battery of smaller, electric motor-powered fans is used. These could run at the optimum speed for the engine's requirements, instead of just matching its revs. Also, not all the fans would come on together so, for example, the oil cooler could be allowed to stay at its operating temperature, while the water in the radiator could be cooled. This allows the oil to stay at its ideal viscosity, and not thicken during unnecessary cooling.

"We could retrofit separate sensors if it was an aftermarket job, but for most of the OEM applications all the sensor information we need is available on the J1939 CANbus. This enables us to precisely control all the different elements of the engine, instead of just cooling everything," says Aitchison.

It is the changes brought about by Tier 4 – specifically EGR and catalysts – that Aitchison believes will accelerate the use of the electronic system: "The additional heat problems will need managing more carefully." As for the electronic water pumps, the conventional thermostat is removed and the pump only works when necessary. Also, working independent of the engine could be important for regenerative braking on hybrid systems.

The fourth-generation SisuTronic is under test

More SCR and less EGR for Sisu Diesel

Sisu Diesel satisfied the emission levels contained within Stage IIIa by using second-generation Bosch common-rail injection, an electronic fuel-flow control on the high-pressure fuel pump, and splitting one injection period into five different phases. The software in control is the in-house developed SisuTronic.

All engines with outputs above 56kW are turbocharged and intercooled. All six-cylinder engines have a standard turbocharger, and only for 80kW and above do four-cylinder engines have a wastegate fitted. Special variable geometry turbochargers (VGTs) are not used for cost and reliability reasons. Four-valve cylinder heads are commonly used in high-power applications.

Mauno Ylivakeri, director R&D, says, "Aftertreatments are not necessary in Stage IIIa engines at all. We have not used external cooled EGR (cooled exhaust gas recirculation) because it increases heat rejection and for some agri-tractors there is limited room to install efficient cooling packages, and an effective fan will create a big power loss. Also, cEGR is a rather complicated and expensive system requiring special turbo matching to get the positive pressure ratio so that EGR really happens in the right way and quantity."

For Tier 4, Ylivakeri continues, "Because the production period for Stage IIIb is only three years away, we need to focus on that Stage and final Stage IV at the same time. Sisu Diesel will utilise SCR. That will offer the possibility of improving fuel economy and reducing the amount of heat release. Less heat release allows a reduced cooling package. SCR will require an AdBlue injection at about 5%, but the price of AdBlue is about half that of diesel. cEGR will be at least partly needed too, but the amount of EGR will be minimised to avoid increasing heat release." Development work and preliminary field tests are underway with a system, working in tandem with the new fourth-generation EEM4 SisuTronic software.

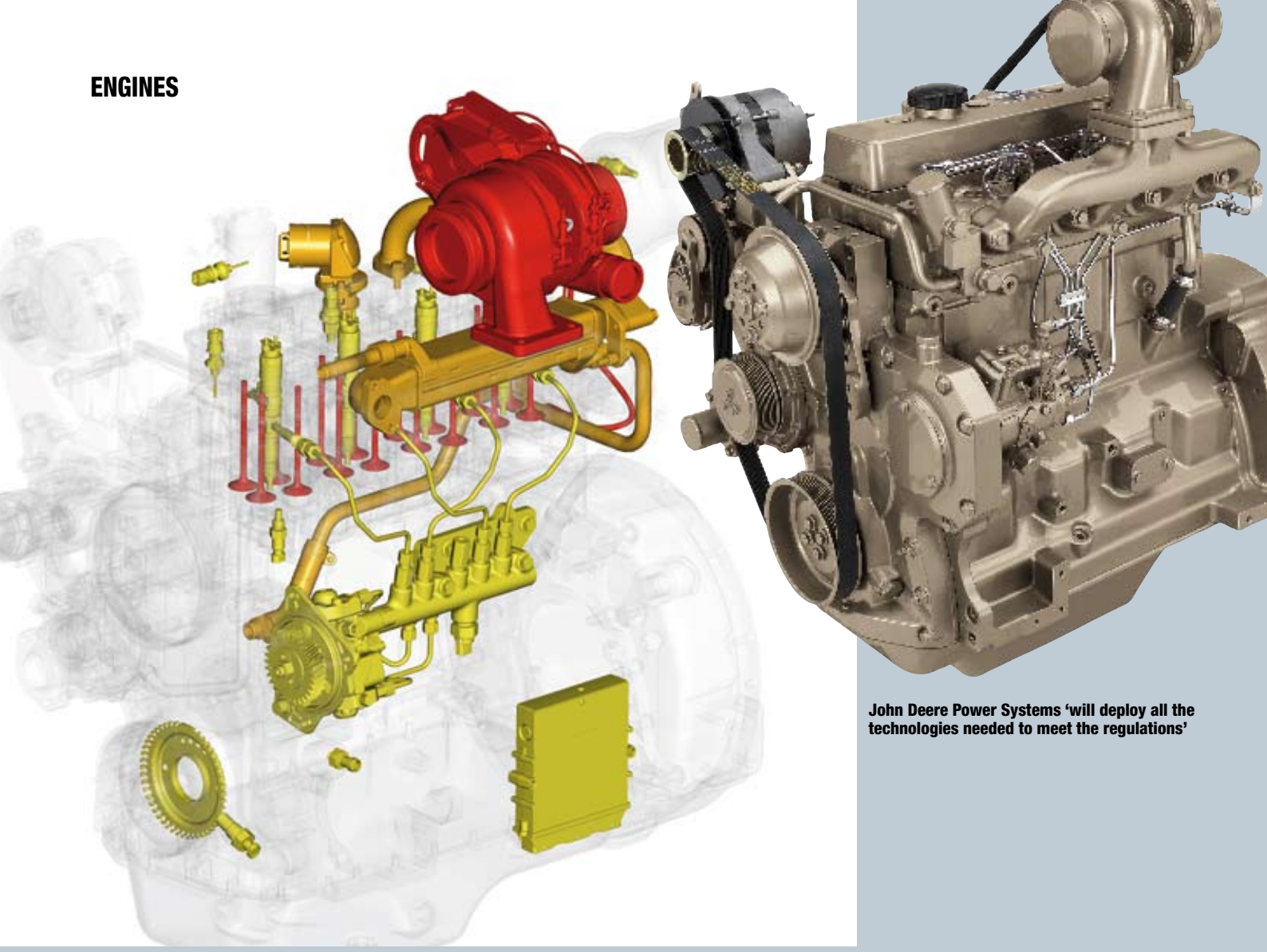
As well as reduced noise, Comesys reckons that the reduction in parasitic losses could lead to between 10-35% increases in economy.

A cultured approach

John Deere Power Systems is also well on top of the emissions situation. Kevin Resch, who is manager, Product Planning, Tier 4 at John Deere Power Systems in Waterloo, Iowa, says confidently, "John Deere will be ready. Delivering compliant products that meet or exceed our customer expectations becomes increasingly difficult with each new phase of regulations, and Tier 4 is no exception. However, we are committed to delivering compliant product on time."

Resch concedes some work will still need to be done. "One of the most difficult challenges is the program objective of maintaining or improving engine performance while meeting these ever-stricter emission regulations. What we are doing is looking at advanced fuel-injection systems, optimised combustion systems, improvements in air-induction systems and reductions in engine friction. We will also continue to improve the performance of these adopted technologies and our strengths in electronic controls."

At this year's bauma, John Deere announced Interim Tier 4/Stage IIIa compliant engines for ratings 74hp (56kW) and below. These engines require no aftertreatment. Tier 3-compliant PowerTech Plus engines already use cooled exhaust gas recirculation. It is also anticipated that this technology will be used in Tier 4/Stage IV product.



John Deere Power Systems 'will deploy all the technologies needed to meet the regulations'

Fuel is a vital part of the equation. Increased sulphur levels can impair or completely block aftertreatment devices, such as diesel oxidation catalysts and particulate filters

As stated earlier, the new rules require an approximate 90% reduction in PM. John Deere will utilise various technologies to meet these regulations – however achieving this level of reduction without resorting to aftertreatment looks unlikely for engines above 74hp (56kW).

Resch is realistic about the benefits and drawbacks. "Each technology offers different 'tools' for achieving emissions compliance. EGR is effective at reducing NOx emissions, however it can increase PM, fuel consumption and heat rejection. Diesel Particulate Filter (DPF) technology is effective at controlling PM emissions, but may not be effective at controlling non-solid particulate fractions. SCR is a proven technology that can effectively reduce NOx, however, it requires operator intervention and a supporting infrastructure so that the urea solution can be replenished."

Materials are also vital in the battle to reduce emissions. John Deere adopted a new single-piece steel piston in its 9.0-litre and 13.5-litre Tier 3 products. This has reduced friction and increased the durability.

Fuel is a vital part of the equation. Increased sulphur levels can impair or completely block aftertreatment devices such as diesel oxidation catalysts and particulate filters (DOCs and DPFs). Perhaps this is why the company was an early champion of biodiesel: it approved B5 biodiesel blend for general use way back in December 2001.

"The performance of the final Tier 4 product is still being determined. John Deere will deploy all the technologies needed to achieve these program objectives," concludes Resch.

Perhaps this brief review should finish where it started – with comments from the EPA: "We believe these standards are technically feasible in the lead time provided given the availability of 15ppm sulphur fuel and the rapid progress to develop the needed emission control technologies. We acknowledge that these standards will be challenging for industry to meet, in part due to differences in operating conditions and duty cycles for nonroad equipment and the diesel engines used in that equipment. We have carefully weighed the desire to have clean engines sooner, with the challenges yet to be overcome in applying the technologies to nonroad engines and equipment, in determining the appropriate timing and emission levels for the standards finalised today."

As we have seen, the technology does exist to tackle the emissions problem. However, should the discussion about carbon dioxide emissions intensify, along with concerns over the reliance on mineral oil, perhaps the biofuels option will take the industry in a whole new direction. ***iVT***

Part Two will appear in the Oct/Nov issue of *iVT International*