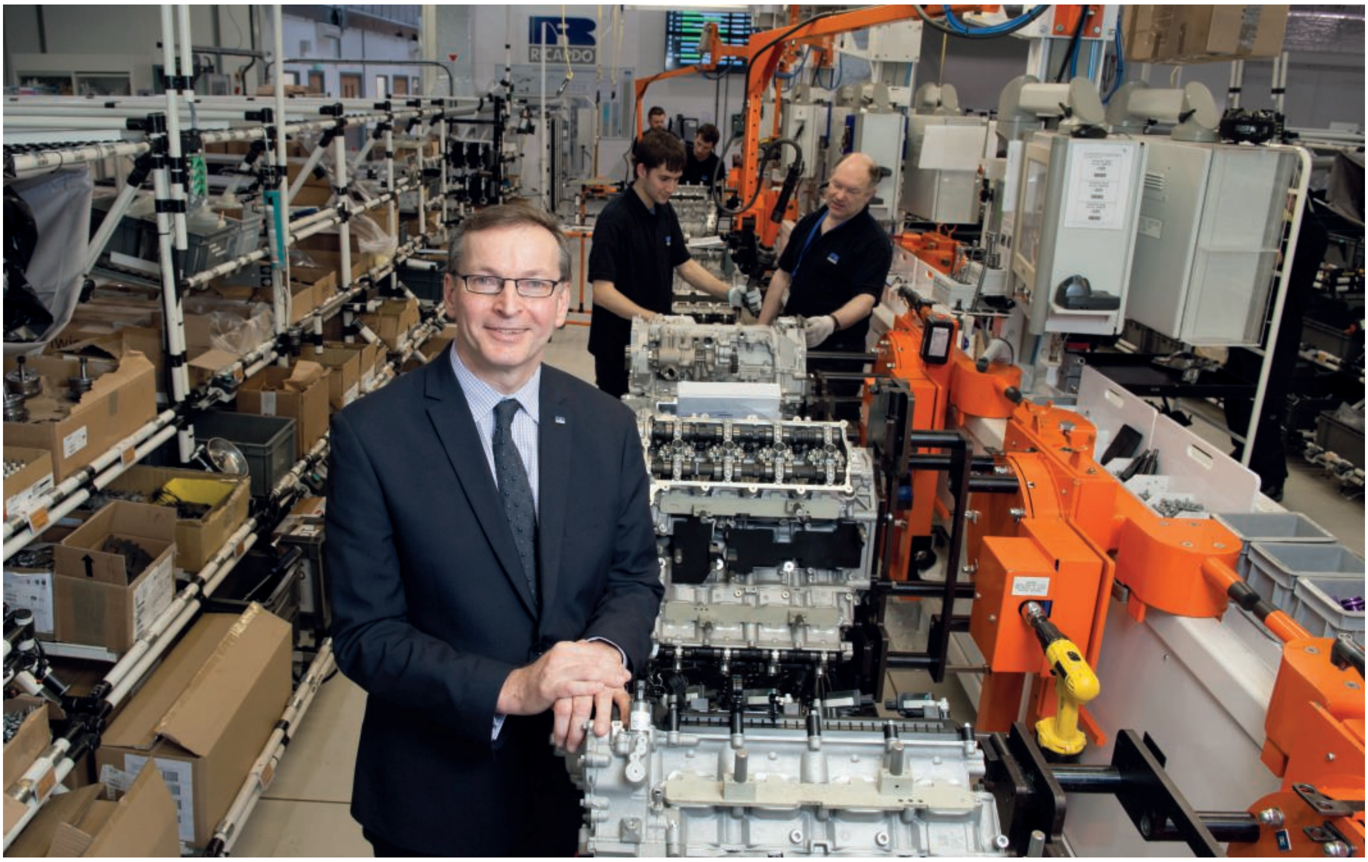


# Next generation

**As OEMs and operators come to terms with Euro 6c and the certainty of Euro 6d just around the corner, Brian Tinham examines the likely impacts of Euro 7 in the early 2020s**

Split-cycle diesels – with their promise of truly revolutionary engine brake efficiency – may still be more than a decade away, but Euro 7 is likely to be upon us much sooner. And, while best estimates for this next heavy-duty engine emissions legislation are the early 2020s, OEMs must now be working on revisions of everything from powertrains to the aftertreatment packages if they hope to meet the anticipated requirements.

So what exactly do those look like? Nothing is yet cast in concrete, but Andy Noble, head of heavy-duty vehicles at world-renowned Ricardo, foresees more than just the predicted curtailment of $CO_2$. "We expect to see NOx limits halved from Euro 6, while $NO_2$ is regulated for the first time, because of its known impact on human health. So NOx may be limited to 200mg/kWh for the WHSC [world harmonised stationary cycle] and 230mg/kWh for the WHTC [world harmonised transient cycle]. Then for $NO_2$, we expect 100mg/kWh on WHSC and 110mg/kWh on the WHTC."

But that's not all. Noble suggests that, although there is unlikely to be any change in the PM/PN (particle mass/number) restrictions at Euro 7, it is possible that the size of particles counted will come under pressure. "We're talking about a reduction from the current 23 nanometres down to 10 nanometres."

Noble agrees that Euro 7's tighter limits may well present challenges to the sensors and instrumentation community. He's not too concerned about NOx and $NO_2$. They can be measured by advanced versions of today's dynamometer laboratory and PEMS (portable emissions measurement systems) equipment. The problem arises with detecting and counting vanishingly small particles.

"Ten nanometres is very small, but at that size particles are also unstable," he explains. "And it's not just about diesel engines either, but also petrol and potentially natural gas engines, too – due, for example, to oil escaping past the valve guides and the turbo oil seals. So, if this new size regime is enforced, the entire market will be affected and the EC will be pushing the limits of what is currently feasible with measurement technology."

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Andy Noble

And there could be another challenge: preventing emissions of such small soot particles will likely mean finer DPF (diesel particulate filter) pores and potentially new substrate materials. These may, in turn, demand further engine technology alterations. "Using larger DPFs might prevent back-pressure increases," muses Noble. "But these, too, are not without their implications, particularly in terms of penalising space and weight. Hopefully, the OEMs will learn from their Euro 6 experiences and avoid such issues."

What about $CO_2$? Noble makes the very valid point that the issue for global warming is not just $CO_2$, but all greenhouse gas (GHG) emissions. He points to European legislation that next year will require all heavy-duty engine manufacturers to plug their dynamometer emissions data into the EC's VECTO simulation tool to reveal trucks' estimated $CO_2$ emissions. "That should also be indicative – although no more than that – of their fuel consumption, so there will be incentives to bear down on emissions."

## GREENHOUSE TOTAL

However, that's just the start. For Euro 7, the expectation is that all GHGs will need to be reported – particularly methane ($CH_4$: 25 times $CO_2$ global warming potential) and nitrous oxide ($N_2O$: 298 times $CO_2$ equivalent). "Only very small amounts of methane result from diesel combustion – although more for natural gas – while nitrous oxide is a by-product of the SCR [selective catalytic reduction] process," explains Noble.

So under Euro 7, the likelihood is that VECTO may be further developed to take in dynamometer data for each gas to reveal a total GHG picture for any truck.

So far, so good. But the next stage of existing emissions legislation (Euro 6d, which will be enforced from 2019) reveals a potential for further challenges. "Under Euro 6d, manufacturers will be required to achieve emissions limits at lower average powers, down to 10% [currently 20% at Euro 6c], to recognise typical inner city running cycles. Operating at lower powers makes the engine more fuel efficient, but it also means lower exhaust temperatures – possibly as low as 100–150°C in slow urban traffic."

Unfortunately, that has an adverse impact on the efficiency not only of the SCR for NOx conversion, but also of the DOC [diesel oxidation catalyst] for hydrocarbon conversion, both of which require in excess of 200°C. Additionally, regenerating the DPF requires much higher temperatures, generally around 600°C at the DPF. "So manufacturers will need to turn the wick up on existing thermal management techniques to raise exhaust temperatures," suggests Noble.

He points to exhaust and/or intake throttling, additional injectors in the exhaust and possibly VVT [variable valve timing] as per Mercedes' OM934 and 936 5.1- and 7.7-litre engines. "On common rail systems, the OEMs could also go for late injections, although fuel washing through the bores would risk cylinder wear. So that won't be a popular choice for heavy-duty engine manufacturers."

Whichever combination they choose, all of these options are going to cost OEMs and operators alike, in terms of increased fuel consumed (and hence also $CO_2$ emissions) without producing torque. That's effectively an own-goal – but something has to give in the name of improving air quality.

And complications arising from a likely Euro 7 continue. Already at Euro 6c, engine dynamometer and on-road PEMS data are collected, the latter based on a representative driver, trucks carrying 10–100% payload and a prescribed mix of urban, suburban and motorway style driving. These are required for Type Approval, but also for seven years of in-service truck operating life – with similar periodic testing of older trucks to ensure ongoing conformity.

Presently, the EC allows a maximum factor of 1.5 increase against the original dynamometer emissions measurements. However, for Euro 7, Noble believes that conformity factor may shrink to 1.25, putting further pressure on long-term engine and exhaust aftertreatment efficiency. Furthermore, PM and PN are likely to fall into the PEMS testing regime – again to ensure long-term emissions limit compliance, in this case for the DPF.

## ENGINE IMPLICATIONS

Improving the $CO_2$ picture ultimately requires higher peak cylinder pressures and compression ratios to drive faster, cleaner combustion. "We're certainly seeing these trending upwards," confirms Noble. "Not so long ago compression ratios were typically 17:1 for larger engines. But we're now working on 19:1 and even north of 20:1 on new engines, because those values yield improved thermodynamic efficiency."

However, one obvious impact of both these engineering inevitabilities is a requirement for stronger cylinder heads, pistons and indeed whole crank trains. But these, in turn, imply greater engine weight and/or the use of more expensive materials. They also demand more R&D, especially where ensuring durability and longevity are concerned. So getting Euro 7-ready isn't going to happen overnight.

Beyond such generalisations, though, there are several opportunities for increasing power and torque while also cutting fuel consumption. Turbocharging is right up there, although – surprising maybe for some – not now so much mechanical turbo-compounding.

The latter is well established, so the best the industry might hope for is incremental improvements, and at significant cost. Furthermore, although mechanical turbo-compounding undoubtedly delivers significant benefits in some parts of the operating map, it doesn't across the board. As Noble puts it: "The benefits are in high torque and high load. But at lower loads, these reduce and can even become negative


because of all the work done in rotating the extra transmission and gears."

Instead, the future for turbocharging to achieve Euro 7 lies in hybridisation and electrification, mirroring strides taken in the automotive sector with electronic control and electric machines. "Suppliers are already developing the technologies and offering them to manufacturers for trials. So, although there is nothing yet in wide-scale production for heavy-duty applications, the supplier base is out there and many are already at alpha and beta prototype stages."

Another opportunity involves electrically-operated, electronically-controlled auxiliaries. Noble gives the example of variable-speed pumps for oil and coolant that deliver only the flows the engine needs. Some are already present in latest truck variants from the main OEMs; others are now close to production. Certainly, these are entering the mainstream and proving their positive impacts on reducing parasitic losses.

What about the roles of engine downsizing and down-speeding? Well that trend continues, and is likely to accelerate in the face of Euro 7 emission limits, as described. In the not too distant future, says Noble, medium haul 40-tonne artics may no longer require 12–13 litre engine prime movers. More modest 7–8 litre alternatives could well be adequate.

The fuel advantages there aren't difficult to work out. But they're also available from down-speeding, with Noble advising that, as a rule of thumb, every percentage point of down-speeding delivers an equivalent fuel economy improvement.

"That's quite a lot," he insists, citing R&D by Daimler and others under the EC-funded four-year CORE ($CO_2$ Reduction) project, which reported last year. In that trial, a Daimler OM936 medium-duty 350bhp 7.7-litre engine was subject to 18% down-speeding (by 400 rpm to 1,800 rpm). Peak torque had to be increased from 1,400 to 1,700Nm, but the net result was a 2% fuel improvement for a simulated mix of regional and long-distance driving.

## DOWNSIZING ENGINES

"So work is being done on downsizing and down-speeding with both medium and larger heavy-duty engines," confirms Noble. And he adds that reducing engine displacements also holds promise for aftertreatment effectiveness because powertrains have to work harder. Add in improvements that can be achieved with engine and auxiliary electrification plus hybridisation, and the result is further assistance in meeting Euro 7.

"For example, stop-start is common in cars and that could soon migrate right up the power ranges." Likewise, 48V is already well on the way in the automotive sector and that, too, could be interesting for commercial vehicles, not least because of the technology's ability to electrify parts of existing powertrains, so enabling mild hybrid approaches.

"Adding a 48V electric machine into a powertrain delivers an order of magnitude more power than a conventional alternator. Feeding it indirectly with KERS [kinetic energy recovery system] to capture braking energy then enables you to provide some kind of zero-emission driving, engine torque assist and/or reduced emissions drive for the ancillaries."

It all helps. And, while on electric machines, all eyes are currently on Mercedes-Benz's 26-tonne full-electric, zero-emission rigids, which are now undergoing pre-production trials across Europe (page 15). Noble and indeed most other pundits, don't see such vehicles becoming mainstream any time soon – simply because of the price and payload penalties – but that development goes to show there are other ways of achieving Euro 7.

Talking of which, what about the future for that split-cycle diesel engine concept, which Noble describes as a game changer? "The best engines now deliver typically 45–46% brake thermal efficiency. By the mid-2020s, we might reasonably expect to break the 50% barrier.

"But our forecast is that split-cycle engines could achieve 55–60% brake thermal efficiency. That's huge. It's going to take a massive development effort, but we believe that's essential if we want to keep on using internal combustion engines but make further improvements in terms of emissions."

How massive? "The technical challenges are immense. Our work to date with the University of Sussex is showing temperatures and pressures way above what we currently deal with… For example, charge air at 750°C and 100bar into the combustion cylinder. Compare that to the typically 50°C and 2–2.5bar in today's diesel engines."

Formidable indeed. TE

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