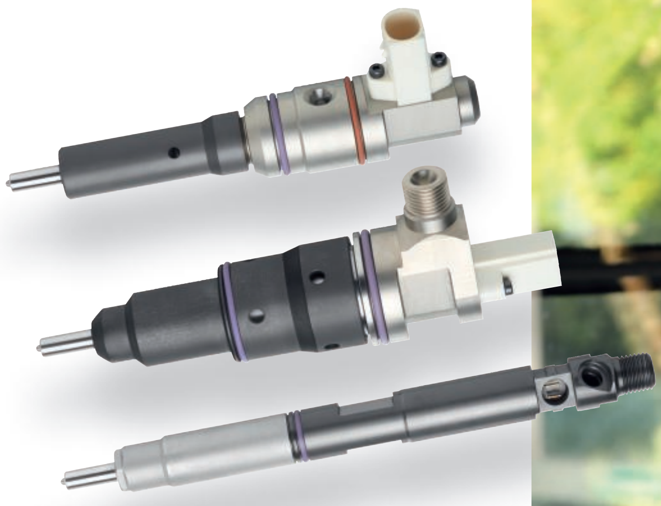


As truck and engine OEMs look to a future regulated by Euro 7, their supply chains are thinking about innovative fuel injection and combustion strategies, and how to deliver them. Brian Tinham reports

Injecting intelligence

Late last year, Delphi Automotive pre-launched its next generation ultra-high precision common rail fuel injection systems for heavy- and medium-duty engines (anything from 0.7–3.0 litres per cylinder). That's not all. The technology specialist also announced "revolutionary" electronic truck controllers, which, it said, will transform not only engine ECU speed and responsiveness, but also functionality.

What does all that mean? James Kewley (above), chief engineer for fuel injection systems at Delphi Powertrain, says it's about anticipating the direction of future drivetrain developments. No one disputes that those will be driven primarily by further draconian emissions cuts mandated under EC legislation, with long-term policing through OBD (on-board diagnostics). And Brexit or not, compliance won't be optional. But it's equally clear that manufacturers must respond to the opposing demands of operators – around everything from fuel efficiency to reliability and also uptime.

So truck and engine manufacturers are heading for a period of yet more serious innovation, particularly in terms of fuel injection, thermal management and combustion strategies, but ultimately also driveline sophistication and integration. That, in turn, has clear implications for system management and, again, diagnostics. And overarching all of this will be the OEMs' obvious desire to maximise their returns from proven engine designs and existing production facilities.

Hence Delphi's claims for its next-gen F3 fuel injection systems and truck controllers as being critical to future engine and driveline developments.

Looking first at its new injection systems, top line features include: an ultra-fast injector, allowing up to nine fuel events per cycle; lightweight 1mm ID three-way control valves; and a closed-loop controller. Delphi says the latter will, for the first time, enable 'as-new' injector performance from cradle to grave – at least 1.6 million km. What's more, all of that will be offered within the current (F2) Euro 6 modular package dimensions.

There will also be ongoing support for all common architectures: traditional common rail with a remote pump; EUI-style with a cam-driven pump in selected injectors; and EUP-style with separate pumps driven by a cam in the engine block. And there will be a new family of higher-efficiency and smaller pumps, designed to integrate into the injector housing or engine block.

Kewley states that, as a result, engine designers will be able to deliver "substantial improvements" in emissions, as well as fuel economy and refinement, while harnessing existing engines.

"Our F2 injectors were based on 2mm control valves, but taking the technology down to 1mm brings real advantages," he explains. "Specifically, it means they're faster mechanically and hydraulically, so we can initiate more injections, closer together and in smaller quantities."

DIGITAL RATE SHAPING

This alone amounts to a major step in the fundamentals of injector functionality. "We're talking about enabling digital rate shaping: controlling the rate of heat release during combustion cycles to maximise engine efficiency, while minimising in-cylinder NOx and PM [particulate matter]," says Kewley.

"Combine that with closed-loop control, via sensors and electronics mounted on the injectors themselves, and we can also allow the engine ECU to compensate for changes in injector performance due, for example, to wear as the vehicle ages," he adds.

Plainly, the latter would be useful in achieving today's OBD conformity requirements, as per Euro 6c, but Kewley makes the point that future legislation will be even more demanding. "We expect the regulations to extend the operating envelope over which emission limits must be managed. So our new systems will allow the OEMs to fully exploit

Filter functionality

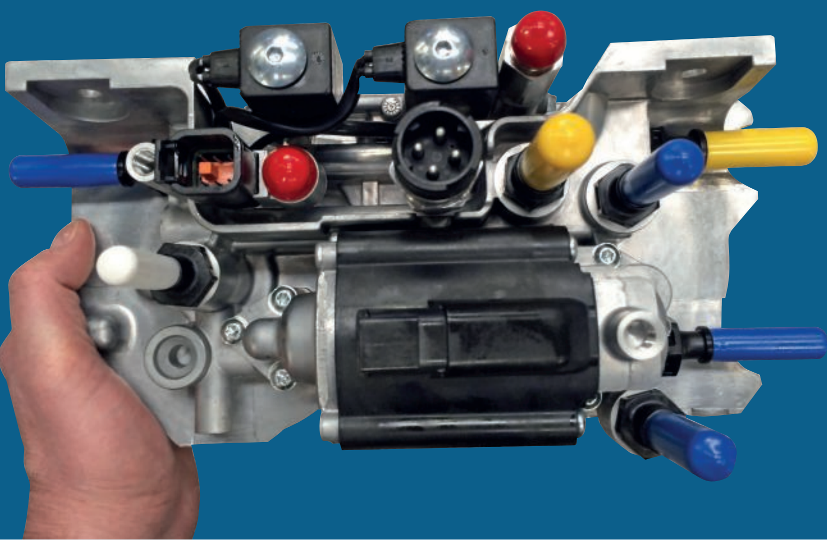
Fuel filters are simple enough, aren't they? Well, yes and no. With Euro 6 now and Euro 7 yet to come, they're rapidly becoming precision components, argues manufacturer Parker Racor. Indeed, product manager Adam Pearce, who looks after the fuel filtration side of the business, says technicians need to understand the near surgical level of cleanliness required for any intervention.

He also says they should be aware of increasingly complex filter systems as a result, for example, of DPF (diesel particulate filter) fuel dosing systems, but also smart pumps for start-stop pressurised fuel delivery. And they ought to know about the newer range of ultra-fine filters built into fuel line water separation systems, as well as those integrated into increasingly popular thermal fuel recirculation systems – and not just in cold countries.

"Operators will increasingly see more complex systems on the fuel side so one thing their technicians need to be wary of is maintenance in a world that requires higher levels of cleanliness," advises Pearce. "They also need to stick with OE filters to prevent blockages and eventual damage to the dosing systems and related subsystems."

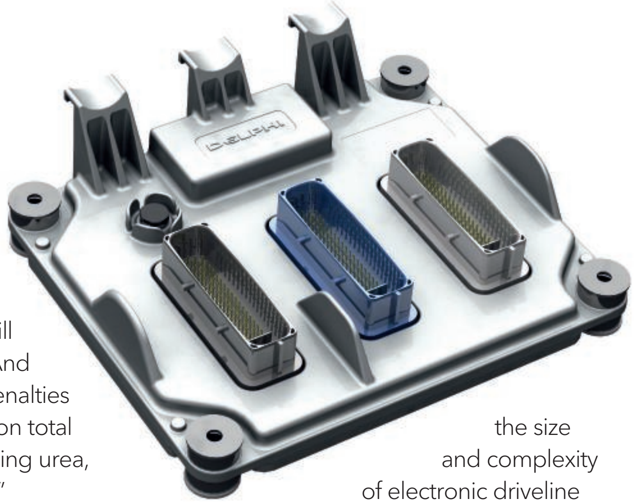
And he adds another warning. Filters themselves – particularly those for water separation – are becoming more sophisticated in order to achieve 'as-new' performance for as long as possible. "Instead of gradually becoming less efficient, these filters now work well much closer to point of blockage, with negligible parasitic losses due to degradation. There's virtually no change in pressure drop for 80% of their life, but then in the last 20% the back pressure can increase by 80%."

On the one hand, that results in trucks running fuel-efficiently for far longer. It also means simple service swap-out against a prescribed period or mileage. But on the other, if maintenance is solely against diagnostics, workshops could fall foul of trucks breaking down before their next service interval is due.



"Specifically, it means they're faster mechanically and hydraulically, so we can initiate more injections, closer together and in smaller quantities"

James Kewley



more complex combustion strategies while closed-loop control gives them confidence that they will be precisely maintained over the life of the vehicle."

Incidentally, Delphi also points out that closed-loop control will eliminate any compromise in calibration currently required to allow for drift over the injector lifetime. And it adds that the new system will remove the need to scan characterisation codes when fitting new injectors. This information will be held in the injector's memory and transmitted directly to the ECU.

Talking of combustion strategies, though, the firm sees two main competitors continuing to emerge – not just SCR (selective catalytic reduction). It won't be just about low- or no-EGR (exhaust gas recirculation) with low-pressure injection and high-efficiency SCR to absorb emissions, says Kewley. The future may well see a resurgence of EGR with high-pressure digital injection at the front end. Hence the firm's investment in fully flexible injection control that accommodates both.

"Given the very low NOx limits in upcoming US regulations, SCR alone will have limited scope," he suggests. "So the future may well see a trend back to high-rate EGR backed by high-efficiency SCR. The question is to what extent in-cylinder NOx will have to be controlled… And remember, one of the penalties of SCR-only is its impact on total fluid consumption including urea, particularly on long haul."

Either way, Delphi accepts that a release date for the new F3 common rail system depends largely on OEM engine programmes. Currently, the firm anticipates first applications entering production around 2021.

SOPHISTICATED CONTROL

Much the same is likely to be the case for its new truck controllers, which represent the remaining piece of this high-tech jigsaw. "ETC7 [electronic truck control – for engine mounting] and DCM7 [diesel control module – for chassis mounting] are our first 'multi-core' CV ECUs," says Kewley. "They derive from our passenger car systems," he adds, indicating that there is now a single common controller architecture Delphi-wide.

Essentially, the company has turned to advanced, multi-core processor-based devices that massively expand computational power, memory and functionality. The result is an opportunity for OEMs to significantly reduce both the size and complexity of electronic driveline infrastructures. For example, the new controller will include after-treatment control as well as powertrain- and vehicle-related management, such as cruise control and other cab features.

So we're looking at a re-centralisation of the currently distributed – and therefore necessarily sluggish and complex – CANbus-connected truck ECU layout. This matters. If we want faster inter-system bus communications, in order to improve responsiveness, then CANbus latency has to go – and improved integration is the only way.

OEMs will need that because, with more injection events and a greater range of temperatures, calibration maps grow and algorithm complexity increases. Also, closed-loop systems require faster sampling, with quicker responses to enable more sophisticated control strategies. Furthermore, increased numbers of sensors and actuators throughout powertrains – for example, to respond to ammonia slip and PM formation – require more inputs, fault storage capacity and access.

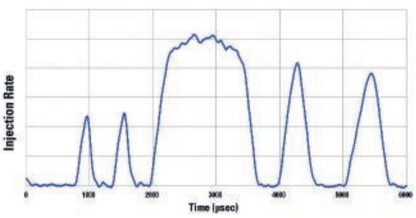
But enabling all that hasn't been trivial. Beyond the new processor, Delphi had to design bespoke ASIC (application specific integrated circuit) technology to deliver the size reduction, increased I/O (inputs/outputs) and extra control.

"For example, one of our ASICs now manages the injector drive waveforms. That alone replaces hundreds of components." And he adds that ETC7 and DCM7 also cover cyber security and open the door to managing extra technology. We're looking at an ECU capable of handling anything from mild hybrid and safety systems, right up to autonomous driving.

DELPHI'S DFI 21 INJECTOR CLOSED-LOOP

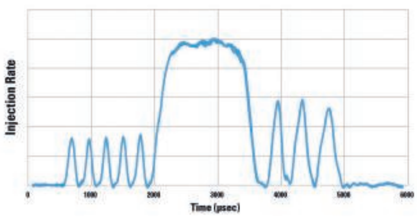
Control for Lifetime Performance of Medium Duty and Heavy Duty Vehicles

Without closed-loop



Up to **five** injection events per cycle
Pilot / post injections **4** mg / **10** mg
Separation **300** µsec

With closed-loop



Up to **nine** injection events per cycle
Smaller pilot and post injections **2** mg / **5** mg
Smaller separation **100** µsec