RICARDO

rQ Ricardo Quarterly Review

Tug of war

The US-European technology split that's dividing the global truck industry

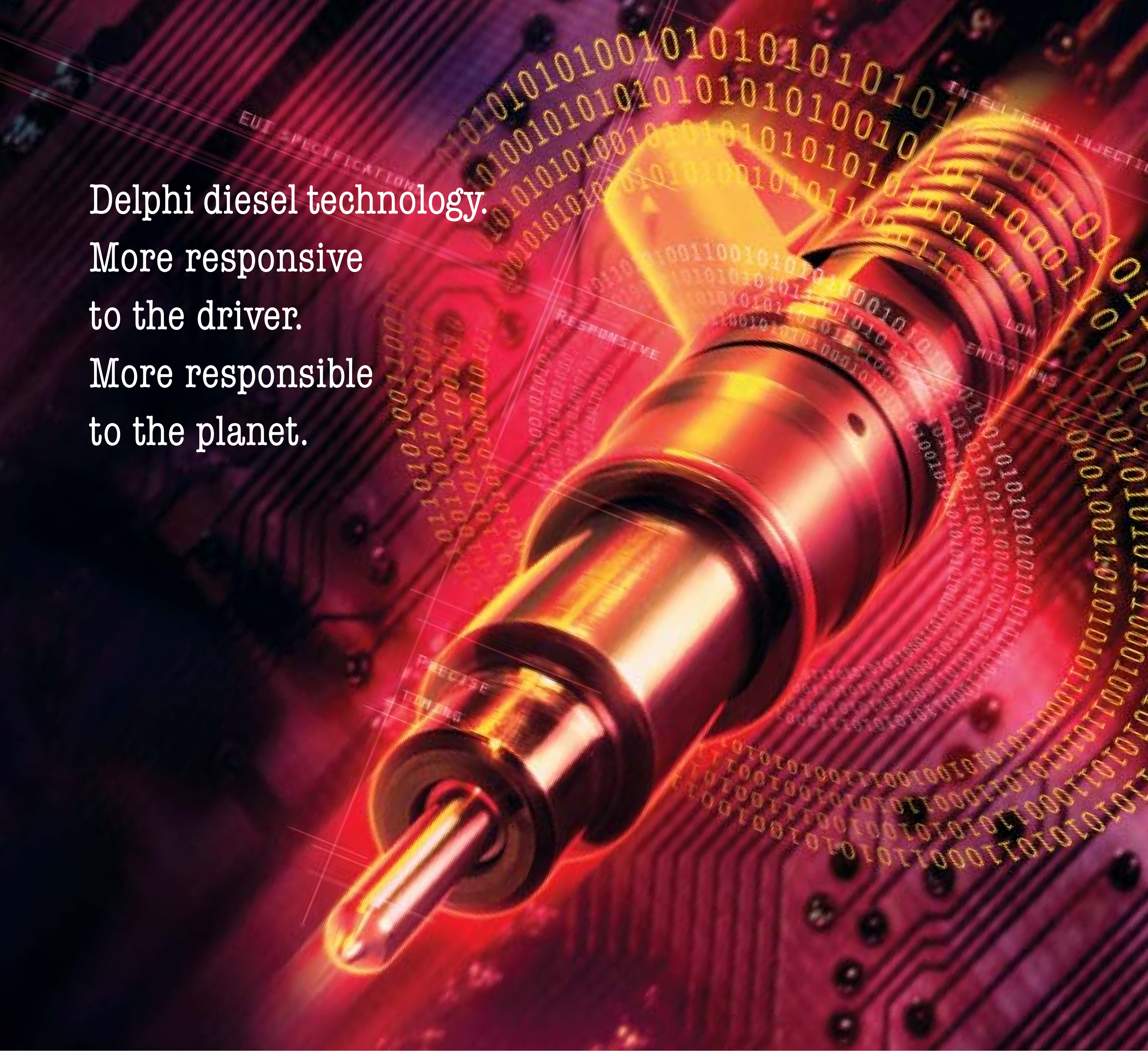
Interviews

Giuseppe Greco, Lamborghini
Leif Johansson, AB Volvo

Reducing time to market

Ricardo offers the automotive industry key competitive advantage

Autumn 2002



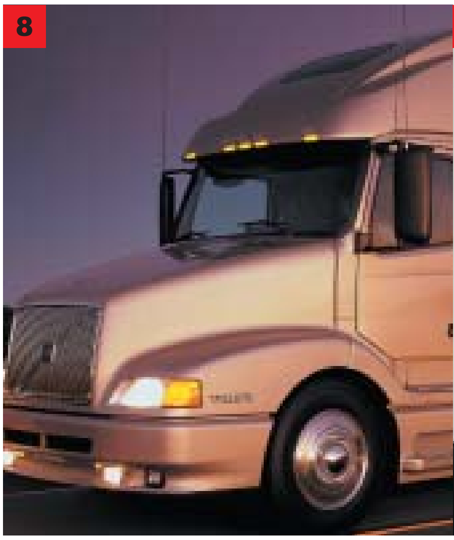
Delphi's EUI and EUP products are sophisticated, electronically controlled high-pressure systems that can help everyone breathe a little easier. By managing the precise timing and fuel quantity required for each cylinder, these intelligent injection systems provide immediate responsiveness for drivers while lowering emissions and helping improve fuel economy — for all of us. Let's work together to clear the air. Visit www.delphi.com.

DELPHI

Driving Tomorrow's Technology

contents

Autumn 2002



Ricardo Quarterly Review

Ricardo enquiries: UK: +44 (0) 1273 455611
USA: +1 (734) 397 6666
Germany: +49 (0) 711 806082-20
Czech Republic: +42 0296331150

Business development: busdev@ricardo.com
Head office: Ricardo plc, Bridge Works, Shoreham-by-Sea, West Sussex BN43 5FG, United Kingdom

Conceived and produced for Ricardo by TwoTone Media Ltd
Editor: Tony Lewin
Contributors: Richard Feast, Alan Bunting, Lucienne Brown, Anthony Smith, Mats Ekelund

TwoTone Media Ltd contacts:
Anthony Smith AVSmith@2tmedia.com
Tony Lewin tonylewin@2tmedia.com

● in brief

Huge production rise forecast

More motor vehicles will be produced in the world in the next 20 years than in the last 100 years of the motor industry's existence, according to Professor Garel Rhys, director of the Centre for Automotive Industry Research at Cardiff Business School. "Nearly 180 new production plants, each capable of making 300,000 vehicles a year, will be required to make these new vehicles, most in new manufacturing locations," he told an audience of steel executives.

Jaguar goes aluminium

Jaguar has opted for aluminium construction for its new XJ luxury sedan series, following the example set by Audi with its pioneering A8 in 1994 and renewed this autumn. Jaguar claims a kerb weight of "up to 200kg less than the outgoing XJ" – which makes the new car the lightest in its class.

Hybrid Honda for Europe

Honda is to market its Civic Hybrid in Europe as well as in the US and Japan. The four-door sedan, which uses a 1.3 litre four-cylinder gasoline engine teamed with a 10kW electric motor-generator, will be Europe's first mainstream hybrid.

SUV warning

Large SUVs are not as safe as their owners believe, according to a recent study by the University of Michigan and the Lawrence Berkeley National Laboratory. "Some of the higher risk in SUVs relative to cars is due to the tendency of SUVs to roll over," the report said. Overall, the report concluded, design, rather than size, appeared to be the critical safety factor for vehicles.

Industry news written and edited by Tony Lewin

GM Hy-wire brings fuel-cell cars a step closer

When the head of the world's largest carmaker describes a concept car as "a complete new paradigm in automotive technology", it is a development that deserves to be treated very seriously indeed. For these are the words used by GM CEO Rick Wagoner at the Paris show launch of the GM Hy-wire, the world's first fully-driveable vehicle combining both fuel-cell propulsion and drive-by-wire control systems.

Hy-wire was developed in eight months using the innovative, skateboard-like Autonomy fuel cell powered platform first shown earlier this year in Detroit. The body is by Italy's Stile Bertone and is fixed to the chassis – just 28cm thick at its widest point – by ten attachment points. All the hardware is positioned within the chassis sandwich, leaving a completely flat floor without even a bulkhead between the cabin and the glass front of the body.

"Autonomy was a true reinvention of the automobile," said GM vice president of R&D and planning, Larry Burns. "Hy-wire takes it a big stage further – and it represents GM's willingness to take a risk."

On the vexed issue of cost, Burns was surprisingly bullish. "We need to be cheaper by a factor of ten – but I'm confident we can do that.

"We see huge business potential for the Hy-wire concept and fuel-cell propulsion in general," added Burns. "This could come as soon as 2010."

Like its competitors, GM expects to introduce its fuel cell vehicles gradually through captive fleets and public service fleets. Honda, Toyota and more recently Nissan have brought forward their fuel-cell vehicle availability dates from 2004 to next year or even late this year; all agree that lease agreements with official and academic bodies will be the most likely means of introduction.

DCX picks ambitious emissions strategy

At last month's IAA show in Hanover, Europe's truck and bus manufacturers revealed more plans to meet Euro 4 and 5, the next two phases of emissions legislation affecting over 3.5 tonne vehicles.

As Germany's and the world's largest commercial vehicle producer, Daimler-Chrysler surprised many by declaring its intention to adopt SCR (selective catalytic reduction) aftertreatment technology for Euro 4, in 2005/6, on all Mercedes models powered by its 900 Series in-line and 500 Series V6 and V8 diesels.

Urea reductant-fed SCR was, admitted DCX, initially a good deal more costly than the most obvious Euro 4 alternative of cooled EGR; in addition, it brought the challenge of getting a Europe-wide urea supply infrastructure established. But in return for the higher on-cost, SCR would bring fuel savings of around 5 to 6 per cent compared with today's Euro 3 trucks. Dealing with NOx emissions downstream, instead of inside the engine, enabled lost fuel efficiency to be restored.

Fiat's Iveco truck division supports DCX's strategy of adopting SCR for Euro 4, adding that only minor system programme changes would be needed to meet Euro 5 requirements in October 2008, when the NOx limit comes down from 3.5 to 2g/kWh.

In any case, environmentally driven tax incentive schemes being implemented unilaterally by the German government will encourage early compliance with Euro 4 and,

Renault's blueprint for mild hybrid small car

There may be a shock value to its style and its unusual interior may be impractical for production, but in many key respects the Renault Ellypse concept presented at the Paris auto show is a strong pointer to the future shape of small car engineering.

The 3.9 metre hatchback weighs just 980kg and uses an advanced, downsized four-cylinder, 16-valve turbo diesel engine of 1.2 litres. Fitted with 10-hole piezoelectric injectors giving 2000 bar injection pressure, the 16-valve unit claims 100 horsepower and 200Nm torque.

The engine is linked to the five-speed shift-by wire gearbox via a 12kW starter-alternator, which also provides 42 volts for the electric air conditioning, the Delphi electric brakes and the electrically actuated steering.

A bank of photocells on the roof helps reduce the energy demand imposed by the climate control system.

These energy-saving measures are rewarded by a European drive cycle CO_2 emission figure of just 85g/km, corresponding to diesel consumption of 3.2 litres per 100km.

Renault Ellypse: Paris show concept incorporates all the latest small-car thinking

A message from the Chief Executive

The international heavy truck market is an extremely demanding commercial environment. While production volumes are generally far smaller than those for automotive products, pressures for improved emissions performance and reduced total operating costs are arguably more intense than for any other vehicle type. At the same time there are significant differences between the critical North American and European markets, both in the type of products that customers demand and the technical solutions – particularly with respect to emissions – that those products must embody. In this issue of RQ we focus upon the heavy truck sector, outlining the advanced technology that Ricardo offers to the industry in all parts of the world. I am particularly pleased that we can include the perspective of the world's largest producer of truck engines in an interview with Leif Johansson, chief executive of AB Volvo.

Rodney Westhead

later, Euro 5 limits. Most still agree SCR is the only route to Euro 5 compliance.

EGR, already adopted – uniquely on heavy-duty diesels – by MAN, will also be available from Scania as well as from Volvo, whose 12.0-litre diesel has anyway needed EGR in achieving US EPA certification to tougher emission standards applied this October.

Alan Bunting

CO_2 bill worries US industry

Automakers in the US have reacted strongly to a new California bill empowering the state to demand "maximum feasible cuts in greenhouse gas emissions" from the transport industry, which accounts for 60 per cent of the state's CO_2 output.

Bill 1493 seeks to adopt regulations by 2005 for implementation by 2009; a two-year consultation process is already underway to develop the regulatory package, and next autumn will see a series of workshops to explore the technical options.

The leaders of thirteen of the world's top car and truck makers met at the Paris show to discuss how the global industry should meet future issues of public concern. Called by ACEA president Jean-Martin Folz, CEO of PSA, the meeting resolved to campaign for a greater uptake of diesel engines in preference to gasoline; the company heads also agreed to press for the speedier introduction of green fuels and to harmonise emissions rules worldwide.

Renaissance man

Giuseppe Greco was appointed President of Automobili Lamborghini in 1998, shortly after it was bought by Audi. At 55, he has spent most of his career working for Fiat around the world, including spells as general manager of Ferrari and Alfa Romeo operations in North America. Here, he talks to **Richard Feast** about his plans for revitalising this prestgious Italian marque

It has been four years since Audi bought Lamborghini. What have been the highlights so far?
The launch of the Murcielago. It's the first part of a planning process that began in 1998, when Audi bought the company. The final objective of this planning process is the independence of Lamborghini in terms of financing its future models. The shareholders – the Audi group – funded this project by making possible the development of the Murcielago first, and the second car which is going to be launched next year. Once these two launches are complete, Lamborghini will be in a position to generate positive cashflow to the extent that future models will be financed by Lamborghini itself, without any increase in capital from the shareholders. This probably means we will never send a dividend to the shareholders, but we will employ the cash for the future.

Never send a dividend?
In the short term. In the long term, the shareholders will get their benefit from the increased value of the company. When they bought us, the company was producing roughly 200 cars a year, it was losing money and had no plans to finance any product plans for the future. Now, the company will produce 400 cars this year [and aims to increase this] to more than 1600 cars in 2004 – at a profit.

So, as Audi sees it, Lamborghini's value is as an asset rather than as an income? But don't you have to return the famous six per cent set by the VW group?
Yes, I have to return it, but six per cent is what I have to invest for the future models. That's the first time Lamborghini has been in a position to do that.

How long will this strategy be in place?
It's a medium term strategy. Let's say we work in lifecycles of products. A company like ours cannot have very short lifecycles. Let's say eight to ten years, with new versions in between. I would say the lifecycle of the Murcielago and the second car is the lifecycle that is going to finance the lifecycle of the [subsequent] cars. Beyond that, you're going into 20 years, so it's a little foggy for me to look at. I hope I will be sitting on a bench in a park by then.

Did Audi ever say how much it paid for Lamborghini?
No. I have absolutely no idea. But I know how much has been invested – about 130 million from 1999 to 2003.

The second model is the one known internally as the L140. What will it be like?
It's a smaller Lamborghini. It will be based on aluminium technology as far as the space frame and body are concerned. It will have a 10-cylinder engine. It's close to five litres and we hope to be close to 500 horsepower, so it's certainly not a small car in terms of performance.

Can we expect four-wheel-drive?
Yes. It's a typical Lamborghini set-up.

When will the car be on sale?
Next year.

Audi has invested in two products. What about the production facilities?
That's the least of the investment. Of the 130 million, we probably have not invested more than 10 million in facilities. The big investment has been in research and development.

So, with your facilities, you can produce the 1600 vehicles you talked about?
Yes. We'll probably be at 80 per cent of our production capacity next year when we produce 1600 units.

Does that mean employing more people?
When Audi bought Lamborghini there were fewer than 300 people. We are at 540 today [and] should hire 80 to 100 more. That would be an appropriate level for the production we are talking about.

How does a Lamborghini differ from a Ferrari?
Kandinsky and Picasso are in the same category, but they are totally different from each other. It's the same between ourselves and Ferrari. First of all, we are younger than Ferrari. We were born only in 1963. And we were born out of a maverick's idea of showing Ferrari what to do. We don't have anything in the field of racing competition, which for Ferrari is big time. We could go racing if we had the factory producing profits and so on. But it's not in our DNA, because the founder, Ferruccio Lamborghini, saw Ferrari put all the profits of the passenger cars into racing and didn't want to do that. It was a wise decision at that time and still is today. But, longer term, maybe things will change.

Why did this area of Italy, Emilia Romagna, create so many vehicle manufacturers?
This is very typical of Italy, and not only for automobiles. You find it in other merchandise. Eighty or ninety per cent of spectacle frames are made in north-east Italy – Padua, Venice, Treviso. In Florence you'll find most of the produce is leather handbags and shoes. The first pioneer will start doing something – engines in our case. Then there is a proliferation of small suppliers that will start working with him. And if you want to do something in the same field, you go to the same suppliers. There is already a small network of people to help you. All this proliferates [and] after 40 years, you find you have Ferrari, Lamborghini, Maserati, deTomaso and for a brief period Bugatti when they started again. There is Pagani – Pagani was one of our employees, and for a period

was one of our suppliers. It's a small circle of expertise, a virtuous circle if you like, that starts building up on its own. And people in this area have always been extremely interested in cars. Ferrari, before forming his own company, was a racing driver for Alfa Romeo. As long as the automobile has been with us, there's been something relating to automobiles in this area.

How many dealers do you have worldwide?
We have about 43 to 45. We're going to grow, but not to the point where we double. We'll probably add another 10 or 15 dealers around the world. We want to make sure that our business is significant for the dealers. We put dealers only in a market areas that have enough potential to make the investment on the part of the dealers credible.

In terms of national markets, which are your most important?
United States is the most important market that we have – it is about 30 per cent of our sales. Then we have Germany, which is about 20 per cent. The UK is coming on extremely strong once we changed the dealer. Then we have Switzerland and Japan.

You didn't mention Italy.
Italy is probably less than four per cent of sales. We export 95 to 96 per cent of our product.

Why is it that in comparison with customers in other markets, so few Italians buy your cars?
Basically, because Lamborghini never offered an entry-level sports car. Ferrari has all the time. Since the Countach times, we have produced only 12 cylinders, which is the past 30 years. And Italy has never been strong even for Ferrari. I hope once we have the second car on line, which is going to be more in the 360 Modena segment, then we will increase our sales in Italy too. In the end, it's a question of per capita disposable income, and the United States is richer than Italy.

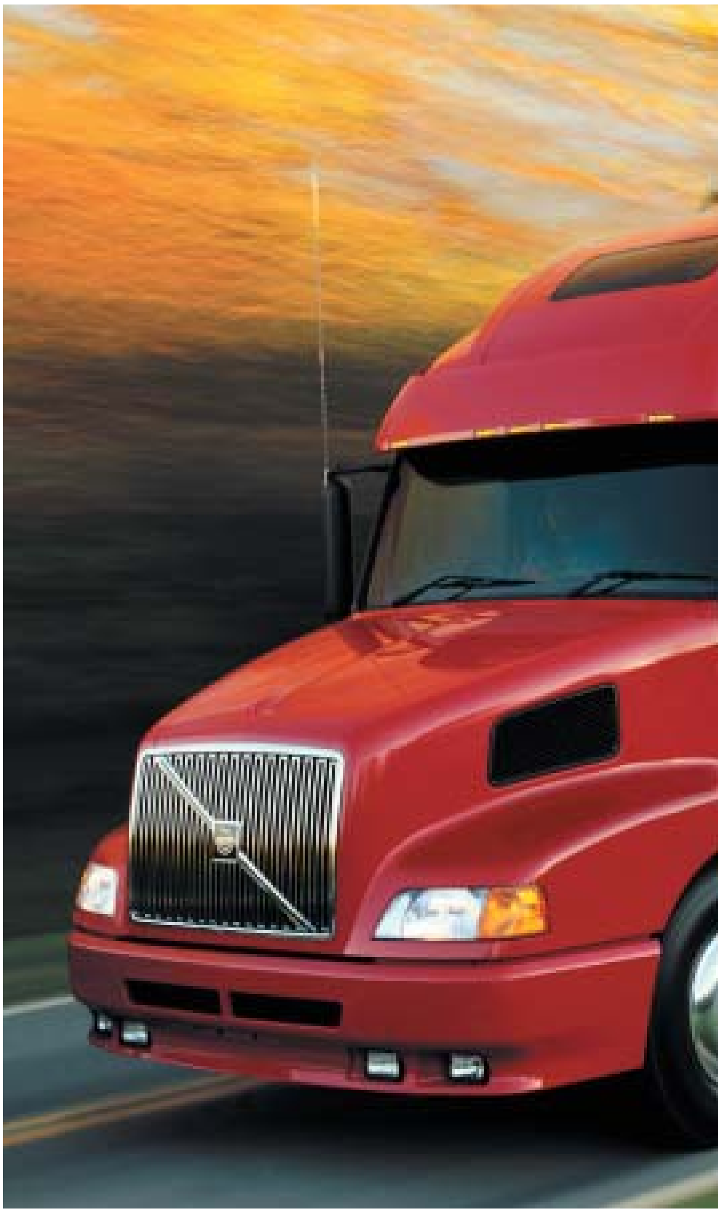
Long term, after your first phase, is it appropriate for Lamborghini to make a sports-utility vehicle?
We have two other genes in our DNA. One is sport-utility vehicles, and the second is the four-seater, the Espada. Right now, we are too busy to get the first step – which is self-financing. But among ourselves we have already started assessing which one of these two genes we want to wake up first. Credibly, it will have to be only one. When we are producing 1600 cars, if you dropped a pin in this factory, it wouldn't touch the floor. It will be really crowded. We would have to expand the factory, so it's a major, major step into another direction. In both cases, you would probably have to change your mechanical strategy. You can't have a mid-engined SUV or a mid-engined four-seater. It will take much more digesting before we can step in that direction.

How much of your production is done inside the company?
We still do more things than just assembling. We manufacture all the trim and upholstery for the Murcielago. We have a very important portion of the composite material done in-house. All the machine tooling for the engine is done in-house; we get the castings from outside. We do all the machining and assembly and testing. In terms of value-added, we still own 70 to 75 per cent of the value of the car. Don't forget, we put more than 500 hours in manpower into the Murcielago. Actually, it takes a little bit more – 500 hours is our objective. Then you think of the thousands of hours we put into research and development, before we can even produce car No.1... you're talking about 140 engineers in our research and development department. And they cost more than the people on our assembly line.

Does Lamborghini have the facilities to develop a car from scratch?
Of course. Out of the 540 people, we have 140 in research and development. That's a little bit more than 25 per cent, and in terms of our costs it's probably 50 per cent. Otherwise, you wouldn't have a Lamborghini.

Richard Feast is an international commentator and a contributor to Automotive News Europe

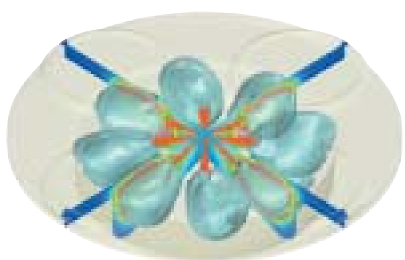
Worlds apart



The heavy truck industry has long been a fiercely competitive environment. With global production running at 1.6 million units, product development costs are spread over volumes extremely small by automotive standards. The primary technology driver for heavy trucks has traditionally been that of reduced total operating costs: now, the marked divergence between the US and Europe on emissions has placed even greater demands on truck manufacturers. **Alan Bunting** looks at the trends in each market, technologies under development, and the tools and techniques that Ricardo heavy duty teams in the US and Europe are applying to the benefit of truck manufacturers

Today's trucks and buses are environmentally cleaner than their predecessors, to an extent that barely a decade ago would have been thought impossible. A current Euro 3-compliant truck running at 44 tonnes, for example, emits around a third of the oxides of Nitrogen (NOx) and a tenth of the particulate matter compared with a typical 38-tonner built in the early 1990s. Driven primarily by environmental legislation, this trend has been overlaid with much greater fuel efficiency constraints than are present in the automotive sector.

For today's hard-pressed transport operators, especially those in the long-haul sector, everyday costs are dominated by expenditure on fuel and percentage savings can make all the difference between continuing profit and a doubtful future. Thanks mainly to diesel injection system refinements and associated engine combustion process improvements, heavy commercial vehicles have, as well as being markedly cleaner than their forebears, also become up to 20 per cent more fuel efficient.



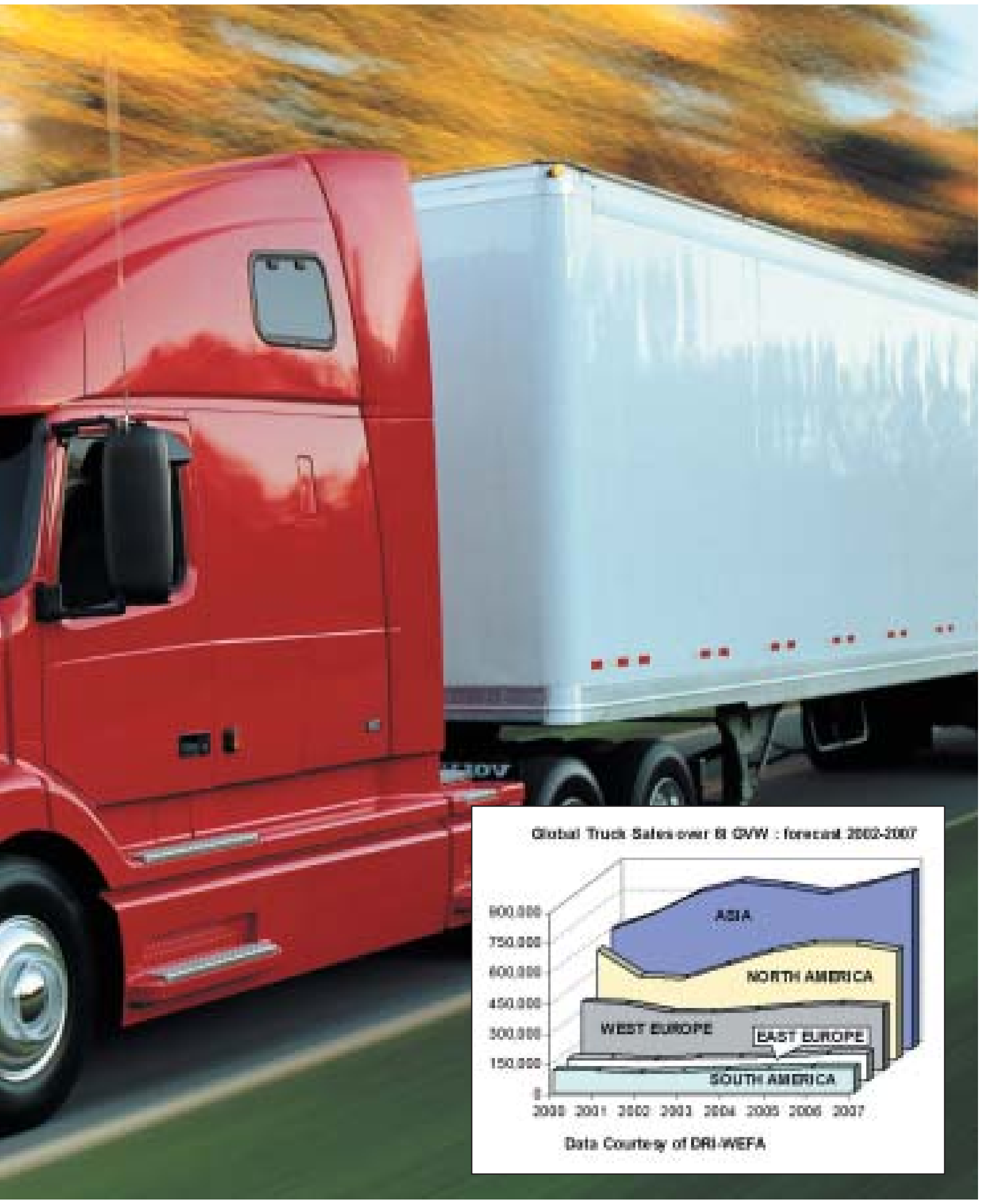
Ricardo VECTIS CFD analysis of a DI diesel truck combustion system provides a detailed time-history of fuel spray structure, distribution and flame development

On particulate emissions, legislative requirements that take account of particle size and number as well as total mass are now being discussed at a global level, though the practical challenges of enforcement mean that they are unlikely to be implemented before 2010. By that time, it is anticipated that the relationship between the size and number of particles and their effects on health will be more positively established. Between now and then it is also hoped that diesel engine test bed instrumentation will be developed which is able to measure accurately, and repeatably, the size and number of the whole range of potentially harmful particles, from the smallest nucleation mode to the largest accumulation mode species. In-cylinder refinements designed to cut particulate emissions, especially higher injection pressures and better fuel-air mixing, have brought accompanying fuel economy benefits.

But, alas, measures to reduce NOx bring no such fuel bonus. On the contrary, steps taken in recent years to curb NOx formation, most obviously retardation in injection timing, have an adverse effect on both fuel economy and in some instances particulate levels.

Because NOx levels are related to peak cylinder temperature and pressure, an injection – and hence combustion – delay reduces the cumulative effect of the two influences on maximum cylinder pressure, namely combustion of the fuel-air mixture and the compression of the rising piston. Advanced computer modelling of the diesel combustion process, using the Ricardo WAVE engine performance simulation program and VECTIS computational fluid dynamics (CFD) package, has been able to quantify the key fuel consumption trade-off consequences of injection timing and, more recently, rate shaping.

Rate shaping, that is regulation of fuel delivery through the injector nozzle, is being accomplished ever more precisely with common-rail and now some unit-injector



systems, through multiple spray/cut-off injection events.

So-called pre-injection enables combustion to be initiated more gradually, so that during the subsequent main injection phase the surge in combustion chamber pressure and temperature is more contained, thereby holding down the critical peak values which determine NOx levels. There are also important spin-off benefits from pre-injection in terms of reduced noise and harshness.

A further post-injection event is now being implemented on some experimental fuel system and aftertreatment installations. It is a means of adding another brief combustion phase, in order literally to burn off some of the soot which is formed in the cylinder. An additional benefit of post injection is that it can be used to reduce the NOx which is stored in a lean NOx trap (LNT), yielding harmless oxygen and nitrogen gas to the exhaust stream.

Associated validation work has come from the Ricardo spray research activity. Through the use of a range of visual and laser imaging techniques, the dynamic behaviour of the air and fuel can be studied in detail as each enters the diesel combustion chamber. The precise nature of the subsequent fuel-air mixing process can be analysed. So too can the flame advance after combustion is initiated, through luminosity visualisation and the resulting formation of particulate matter, using laser-induced incandescence.

It is however now acknowledged that with the implementation of Euro 4 and 5 emission limits in Europe in 2005/2006 and 2008, and the yet more demanding requirements of EPA 07 in North America, fuel system and combustion refinements – even augmented by EGR – may not be sufficient to ensure legislative compliance, at least not for heavy duty automotive diesels in volume production. Downstream aftertreatment built into truck and bus exhaust systems could therefore become unavoidable.

Latest unit injector shown to reduce particulate-NOx trade-off

The results of a test programme carried out by the Ricardo heavy duty diesel engine team are to be presented at the Fuel Injection Systems conference of the I.Mech.E., London, in November 2002.

They will show that on an engine complying with the 3.5g/kWh Euro 4 NOx limit, the latest Delphi E3 two valve electronic unit injector (EUI) is capable of cutting particulate emissions significantly. They suggest that the accompanying 0.02/0.03g/kWh particulate limit could be met without the need for a costly soot filter.

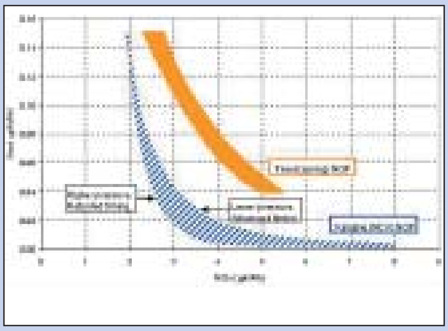
In addition to the normal EUI spill valve, the E3 injector has a second valve to control needle opening and closing. It provides for multi-event injection rate shaping of the kind only achievable hitherto with a common-rail system – while retaining the EUI's higher maximum injection pressure advantage.

Ricardo's recently developed stochastic process modelling (SPM) technique was used to model the test data, gathered on a single-cylinder test engine.

The technique, the latest in a series of DoE (design of experiments) methods used in company projects, is capable of undertaking multi-variable analyses in an unusually flexible way.

The E3 injector in combination with cooled EGR (exhaust gas recirculation) – as a means of controlling NOx level – enabled the historical trade-off between NOx and particulate to be substantially improved.

The biggest step forward over a standard EUI in terms of soot emissions is the ability to increase initial injection pressure through use of the new needle control valve. That in turn could mean multi-event injection not being needed under European emissions legislation until the NOx limit comes down to 2g/kWh in 2008.



Effect of nozzle opening pressure on NOx/soot emissions trade-off

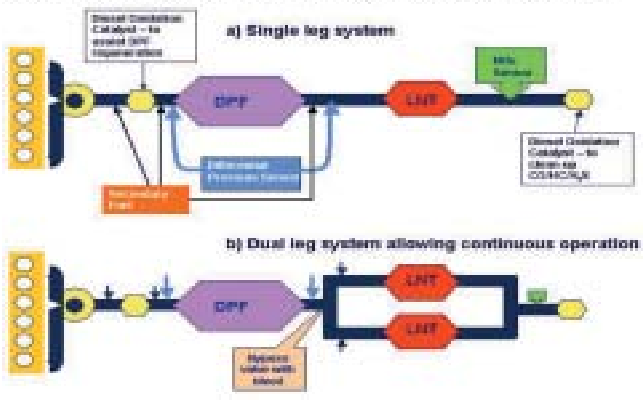
US concerns with SCR make LNT an interesting option

Graham Weller, VP Engineering, Ricardo Inc.: "US operators tend to favour the 'fit and forget' solution provided by LNT"

With a few notable exceptions, the engines in most new heavy trucks in North America built from October 2002 onwards to comply with the EPA 04 limit for NOx + NMHC (non-methane hydrocarbons) of 2.5g/hp-hr will feature cooled EGR.

The next step-down in allowable emission levels announced by the EPA, scheduled for phased implementation between 2007 and 2010, is based on a NOx limit of just 0.2g/hp-hr (with a separate 0.14g/hp-hr limit for NMHC). That is a reduction from the EPA '04 limit of over 85 per cent. This additional NOx reduction is beyond the capability of EGR alone or any other in-cylinder solution and some form of NOx aftertreatment seems to be unavoidable. While acknowledging the efficiency of SCR which is, after all, proven technology, having been used on stationary applications for many years, the US EPA has approached its adoption as a deNOx system for on-highway diesel vehicles with little enthusiasm. Although the 2007 date would appear to give adequate time for SCR systems to be developed for the US market, the EPA is concerned about several aspects of the use of SCR as an industry-wide solution. Ensuring that operators replenish their urea tanks is considered an impractical piece of law enforcement, notwithstanding proposed US federal legislation requiring on-board diagnostic systems to verify legal compliance. The EPA also recognises that setting up adequate urea replenishment facilities is a much greater challenge, geographically, than in Europe.

Schematic of a typical LNT aftertreatment system



The US authorities, while maintaining a position of being technology neutral, are encouraging the development of lean NOx traps (LNT) as an alternative deNOx aftertreatment technology. This technology should be closer to the dictum of 'fit and forget' and would certainly not be reliant upon a nationwide infrastructure such as that for urea that would be required with an SCR solution.

In principle, the operation of an LNT is quite simple. When the engine is running on its usual lean fuel-air mixture, oxides of nitrogen in the exhaust are adsorbed onto the surface of the LNT catalyst. At an appropriate level of trap fill a controlled richening of the air/fuel ratio (to a sub-stoichiometric value) produces a combination of a high exhaust gas temperature and a stream of CO and un-combusted hydrocarbons which enables the catalyst to regenerate, thereby converting the stored NOx to N_2 and releasing it along with CO_2 and H_2O.

Ricardo's Chicago-based engineering team is participating in a US Department of Energy initiative intended to investigate the viability of LNT technology for a heavy duty truck engine and in particular the interaction between the LNT and sulphur in the diesel fuel. The work is being conducted in collaboration with Cummins, which has supplied the latest version of its 15 litre ISX engine which incorporates an EGR system enabling the base engine to meet the 2002 emissions legislation. The Ricardo team have modified the engine to incorporate both in-cylinder and in-pipe secondary fuel injection and have worked closely with the Cummins engineers to develop a system that manages the complexities of the engine operation during the transitions to the rich operating regimes. The test programme will include fuels with sulphur levels of both 8ppm and 15ppm, the latter being the new standard for introduction in 2005 and will compare both a single leg LNT system, where all of the exhaust gas passes through one catalyst, and a dual leg system, where the exhaust gas is alternatively directed through one of two LNT systems connected in parallel. In the dual leg system, the trap in one leg is being regenerated while the other leg is in an adsorbing mode.

The long-term durability of the aftertreatment devices is of particular interest for a product sector that requires emissions certification after an equivalent of 435,000 miles and where trucks are frequently kept in service for a million miles or more. The durability of the LNT catalysts is dependent upon several factors, with the fuel sulphur level being a very significant one. From 2005, automotive diesel fuel in the US will be required to contain no more than 15ppm of sulphur. But even at this level, SO_2 in the exhaust will become deposited on the surface of the catalysts as sulphates, inevitably marring their NOx conversion performance. The higher the sulphur level, the more rapid the sulphate build-up and hence the more frequent the need for its removal in a second and longer form of regeneration process, again achieved through a rich-running phase where temperatures of 550°C and greater must be maintained for several minutes in order to achieve the desulfation of the catalyst.

The periodic rich mixture required for both the NOx and sulphate phase regeneration can be achieved by a variety of techniques including a controlled late injection of additional fuel (sometimes called post-injection) using EGR or an intake throttle to reduce the fuel-air ratio or an additional fuel injection into the exhaust system. The additional post-injection needed for LNT regeneration will, of course, bring its own fuel consumption penalty; early projections of this impact are that it could be in the 3 to 5 per cent range for a well optimised system. For LNT efficiency to be maximised, the installation must be maintained within an operating temperature window typically between 250°C and 450°C during the NOx adsorption and desorption phases; this raises thermal management issues as normal truck operation will result in exhaust gas temperatures outside both ends of this range.

markets show a clear divergence in strategy

Europe favours SCR as its reduction solution

Europe has – at least for heavy duty, higher-mileage trucks and buses/coaches – now chosen selective catalytic reduction technology as the preferred deNOx solution. SCR uses consumable liquid urea to provide the ammonia-rich conditions required to activate the system's main deNOx catalyst, and has been shown to achieve NOx conversion rates as high as 80 per cent.

However, in a study undertaken by Ricardo in Germany together with DaimlerChrysler AG and reported at the SAE Truck and Bus meeting in 2000, a fine cost balance emerged when considering SCR and EGR based solutions, the two most well proven deNOx technology alternatives. Ricardo chief engineer, Simon Edwards, explains that while EGR has less absolute potential to cut NOx emissions than SCR, its initial vehicle on-cost (for the additional engine air/gas management plumbing and control hardware) is likely to be lower. Recirculation of the exhaust gases requires no direct vehicle operator intervention and should require only minimal additional maintenance effort and cost.

In contrast, the more effective SCR downstream aftertreatment technology carries initial installation and on-going consumable running costs, but these may be off-set by improved fuel efficiency. Throughout the vehicle's life the system consumes a finite amount of reductant (in practice, urea), held as a benign liquid in a secondary on-board tank. Trials indicate a typical 1:20 ratio of urea solution to fuel consumption. In cost calculations made during the Ricardo-DaimlerChrysler study, a pump price for urea of 50 per cent of fuel price was assumed. However, Edwards points out that the investment needed to put a urea supply infrastructure in place across Europe is unknown at this time, which leads to uncertainty about the likely final reductant price per litre.

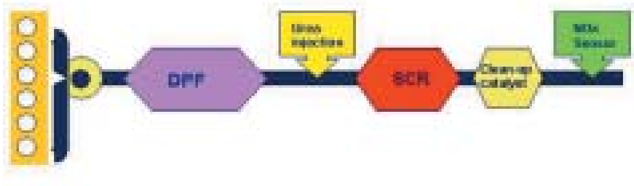
But the SCR system on-costs, while significant, could be recouped through the fuel savings which come with it, and clearly those are greatest on the inherently thirstier, heavier-duty trucks and coaches which cover the highest mileages.

How does SCR bring fuel consumption benefits? The now familiar NOx, particulate and fuel consumption trade-off curves, published by numerous manufacturers, provide the answer. They highlight the fact that fuel system and in-cylinder measures taken in order to reduce NOx are prone to increase particulates and fuel consumption.

An alteration in net injection timing is the most obvious and pertinent example. Through the 1990s, with successive tightening of European and EPA emission limits, injection timing of automotive diesel engines has been steadily retarded in order to reduce NOx levels. In consequence, both fuel consumption and particulate emissions have suffered. In practice, the effects have been minimised, thanks to the adoption of electronic injection control which has been accompanied by higher nozzle pressures and associated improvements in fuel-air mixing.

Because SCR is capable of cutting tailpipe NOx levels by 80 per cent or more, it offers the opportunity for injection timing to be re-advanced. This may yield significant fuel consumption benefits potentially off-setting both the initial cost of the SCR installation and its on-going urea consumption. At the same time particulate emissions can be reduced through the

Schematic of a typical SCR aftertreatment system



"SCR is a technology which will enable us to adhere to future exhaust emission standards going beyond Euro 4 through a systematic process of further development, while at the same time optimising fuel consumption"
– Eckhard Cordes, DaimlerChrysler

advanced injection timing, which may in itself avoid the need for a soot filter in order to meet Euro 4 legislated limits.

Based on lifetime vehicle operating costs and the fact that in general, the heavier the truck, the greater its annual mileage and working life, the Ricardo-DaimlerChrysler study concluded that EGR was the more cost-effective deNOx solution on diesel vehicles up to about 8 tonnes gross vehicle weight. The fuel-saving potential of SCR made it the preferred alternative on heavier trucks. In the light of the study's findings DaimlerChrysler announced at the end of July that, ahead of the October 2005 deadline for Euro 4 compliance on new vehicle models, Mercedes-Benz would be incorporating SCR on to its heavier trucks and buses.

Eckhard Cordes, Member of the Board of Management of the Commercial Vehicle Business Division of DaimlerChrysler AG, said of this strategic move: "SCR is a technology which will enable us to adhere to future exhaust emission standards going beyond Euro 4 through a systematic process of further development, while at the same time optimising fuel consumption".

Looking beyond Euro 4, the combination of an SCR system and a particulate filter, which clearly increases the initial vehicle cost considerably, offers the potential of NOx levels down to 1.0g/kWh and particulate levels as low as 0.01g/kWh (each respectively half of Euro 5). Ricardo has carried out a project on behalf of the Association of Emissions Control by Catalyst (AECC) which indicated that such low levels could be achieved not only with fresh catalysts but also when the catalysts were aged for 1000 hours on the test bench over a severe ageing cycle, including periods of operation on relatively high sulphur fuel.

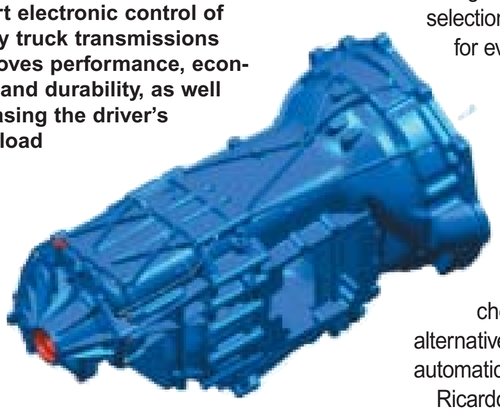
Transmissions offer great potential

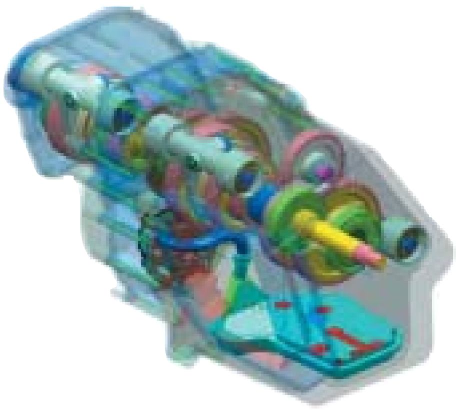
Heavy vehicle transmission technology has undergone a quiet revolution in the last 20 years. Most heavy truck manufacturers now offer semi- or fully-automatic shifting. The systems, which were developed first for trucks but have since found their way on to some passenger cars, crucially come without the fuel consumption, cost and weight penalty of traditional torque converter based automatics. Most of today's AMTs (automated manual transmissions) are derived from standard, volume produced manual-shift countershaft gearboxes, but using compressed air or electric motor servos to replace the driver's arm muscle. The need for such gear-shift assistance had grown in line with ever rising concerns about fuel consumption, protecting the driveline from damage, driver workload and repetitive strain injuries.

Electronic controls have from the outset been a necessary integral feature of all AMTs, in order to prevent potentially damaging forced gear engagements. It was not long before those electronic controls were made 'smarter' so that they could optimise shift timings in the interests of maximising acceleration performance and fuel economy.

At Ricardo transmission system development for trucks and buses and even off-highway machines has become an important area of activity in recent years. Team leader Mike Savage says AMT refinement projects have involved the evolution of improved electronic algorithms and associated calibrations. They are typically built into total powertrain management strategies, where transmission and engine controls are interactive so that, in everyday vehicle service, every gear shift is triggered at the correct instant to make best use of the engine's power, torque and/or specific fuel consumption or even emission mappings. In its most advanced form, the control system can goal-seek to provide the best combination of engine and transmission performance to suit driving conditions.

Smart electronic control of heavy truck transmissions improves performance, economy and durability, as well as easing the driver's workload





Today's production AMTs are well suited to the majority of heavy duty truck and inter city bus applications. However, there are a wide range of applications which endure frequent stop-starts and creep, such as urban buses, urban delivery and garbage collection trucks, which are currently best served by torque converter automatic transmissions. Although these large torque converter automatic transmissions deliver good durability (because there is no dry clutch to slip and damage every time the vehicle moves) in these tough applications the efficiency and hence fuel consumption tends to suffer.

Ricardo engineers have undertaken several car application projects to design and develop second-generation AMTs known as 'dual clutch' transmissions, whose pre-selected shifts maintain a continuous (ie uninterrupted) drive and whose wet clutches provide durability and creep if used in conjunction with adequate cooling flow. One clutch is disengaged for the selection of odd-numbered gears, the other for even-numbered ratios. The aim is to match, as nearly as possible, the launch and shift smoothness of a torque converter automatic. This makes the system acceptable for urban bus use while, in heavy truck applications (including urban delivery, garbage collection, and fire appliance vehicles), providing a cheaper, lighter, more fuel efficient alternative to the large torque converter automatics.

Ricardo's work on hybrid drivelines has also been extended into truck and bus applications, with the development of a novel series hybrid diesel-electric transmission. Aimed initially at North American urban delivery applications, the installation is based on a 240kW traction motor. It draws its electrical power either from a generator, driven by the vehicle's diesel engine, or – in silent, emission-free mode, for making city centre or night-time freight deliveries – from batteries kept charged from the same generator.

Prototype units are already running in the USA, and Ricardo sees particular commercial vehicles as the most likely applications of hybrid powertrains in the near future.

Legislators becoming more particular – about particles

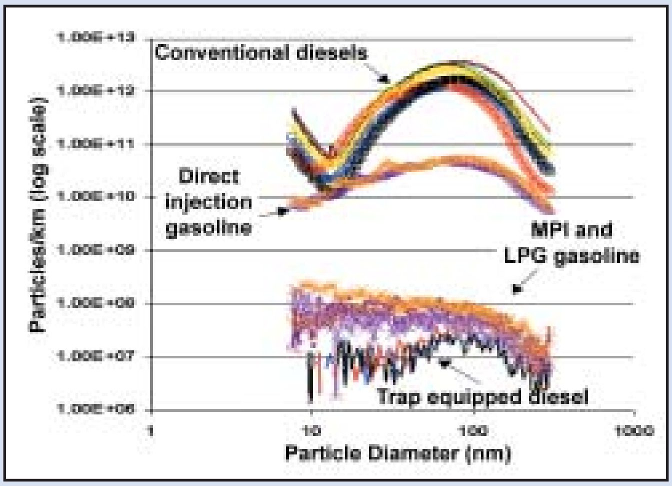
Jon Andersson, Chief Engineer, Ricardo Chemistry Department

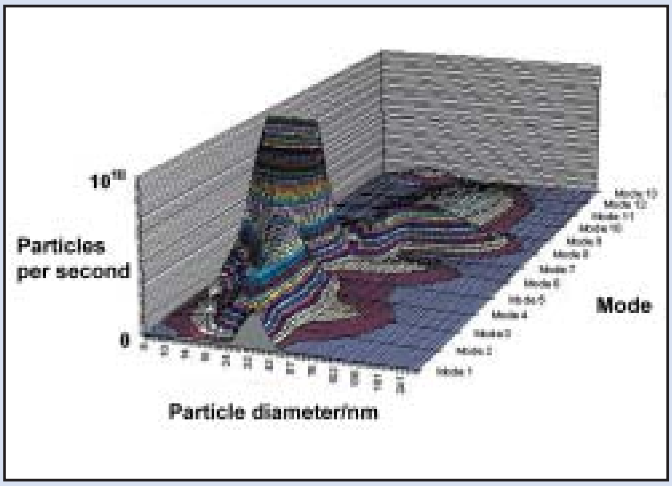
The first on-highway diesel emissions legislation in Europe in the early 1970s addressed visible exhaust smoke in a somewhat arbitrary manner, through smoke opacity. The test was seen as lacking accuracy and took little account of near transparent non-gaseous hydrocarbon and inorganic exhaust constituents.

It was not until the mid 1990s that legislators in Europe and North America added a quantitative limit for particulate matter to those established a few years earlier for pollutant gaseous emissions, and measured in the same units of mass related to engine power. Permitted particulate levels have since been progressively reduced on both sides of the Atlantic and further tightening of emission laws later in this decade will impose yet lower particulate mass limits.

Meanwhile, even more demanding controls – either mandatory or incentivised – on exhaust particulates have been imposed by individual urban authorities in Sweden and elsewhere. Without setting specific limits, some cities require the

Jon Andersson: "Advances in engine technology have tended to reduce overall particulate mass largely through a reduction of larger acccumulation mode particles"





Particle size and number distribution for a range of vehicles at 50kph (left), and in detail for an R49 test on a heavy duty diesel (right)

exhaust systems of buses and municipal vehicles to be fitted with DPFs. The most commonly used retrofit DPFs are based on catalysed (NO_2 based) oxidation of carbon, enabling continuous passive regeneration of the DPF under most duty cycles. However, careful matching of DPF type against duty cycle is necessary.

The extent and the nature of the harm done by ingested vehicle exhaust particles on the respiratory system remains a contentious subject among medical researchers, with each newly published scientific paper tending to throw up as many questions as conclusions. It is now evident, however, that not only the total mass of particles entering the respiratory system, but also their total number and distribution of sizes, are of significance in the health effects debate.

The importance of the issue led to Ricardo being commissioned in 1998 by the UK government, CONCAWE (the Oil Companies European Organisation for Environment, Health and Safety) and the Society of Motor Manufacturers and Traders to undertake the three-year particulate research programme into the effects of light duty vehicle engine and fuel specification on the nature of exhaust particulate matter. Gasoline, CNG and bi-fuel (LPG/gasoline) as well as diesel exhaust samples were analysed.

In the research programme, particle number and size were measured using two different SMPS (scanning mobility particle sizer) instruments, while mass and size within a wider size range were measured with MOUDI (micro orifice uniform deposit impactor) equipment. Measured particles were categorised into accumulation and nucleation mode, respectively larger and smaller than 50 nanometres.

The results indicated that advances in engine technology driven by stricter emission standards have tended to reduce overall particulate mass largely through a reduction of larger, accumulation mode particles. However, the study also showed that no fuel or engine refinement was able to reduce both large and small particles, as well as total particulate mass, under all load/speed operating conditions.

Fitting a DPF to the exhaust system of both light and heavy duty diesel vehicles was found to cut both particulate mass and number, though at high exhaust temperatures there was a significant increase in the level of smaller, nucleation mode particles emitted. They were suggested to comprise mainly condensed HC (hydrocarbon) droplets formed downstream of the DPF.

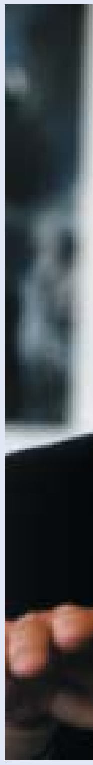
Inclusion of Swedish Class 1 diesel fuel in some of the programme tests showed that fuel sulphur content – uniquely low within the programme at no more than 10ppm – had a small but significant reducing effect on both particle mass and number.

Being able to measure the size and count the number of all accumulation and nucleation exhaust particles accurately and repeatably, under engine test bed conditions as opposed to laboratory conditions, is an obvious prerequisite for eventual legislated limits. The fact that permitted particulate mass will be reduced to a mere 0.02g/kWh by 2008 in Europe (and even less in the US) will make accurate measurement an even tougher challenge than at current levels. Nevertheless Ricardo is also investigating new methods of accurately measuring very low masses. New techniques being evaluated include transient mass measurement where the particles collected on a special vibrating crystal can be weighed in real time to an accuracy of nanogrammes.

To that end Ricardo has been contracted by the UK government to assess the feasibility of such future quantitative particle measurements – specifically in heavy duty diesel exhaust. The work is part of a wider study being undertaken by the Particulate Measurement Programme working group formed by the ECE (the Economic Commission for Europe, a United Nations body).

Volvo's three-axle rig

With the acquisitions of Renault Véhicules Industriels and Mack, Volvo has now become the largest engine manufacturer in the global truck market. Volvo CEO Leif Johansson spoke to **Mats Ekelund** about the strategy of AB Volvo, its future growth plans, and the synergy rewards that it intends to reap from its recent mergers



Can the Volvo, Renault and Mack truck businesses complement each other without risk of losing their former total market share?
The three companies each represent different markets. RVI mainly produce light and medium duty trucks, while Volvo produce larger units – like class 8 trucks – and Mack is extremely strong in the segments where vocational vehicles are sold. We have very few geographical or market overlaps. Volvo will keep the brands apart and make sure they live their own lives; this will inevitably mean that they will compete here and there, but this can be managed. Volume-related savings in purchasing, the ability to spread development costs, and the presence in the market of three strong and individual brand names are the main benefits as we see it.

AB Volvo's global strategy sees Mack (top) strong on vocational trucks, Volvo (centre) concentrating on heavies, and RVI focusing on light and medium applications

Have there been any unexpected benefits arising from the acquisition of RVI?
Possibly the size of the savings – they may well exceed some of our initial expectations. We found that all three manufacturers were involved in producing natural gas engines for buses and trucks. Even though we had prepared for this merger thoroughly, we had not expected that so much work in this area was being carried out by RVI and Mack.

And unexpected difficulties? Is integration progressing at a satisfactory rate?
We were well prepared for the cultural challenges. Volvo and Renault had worked together previously and we have each been active in the North American market before. Positive things happened too. The differences have created openings and new methods of co-operation that we had not expected. Purchasing has gone extremely well. For example, we reduced the number of forklift suppliers from 11 to three and we have saved 8 million in establishing a unified NPA (Non Automotive Purchasing) function.

Does the disparity between technical standards in Europe and the United States represent a problem or an opportunity for the Volvo trucks group?
The European and US markets look more and more like each other and after EPA 2002/2004 and Euro 4, 2006, we will probably see much more integration between the two. We had a major advantage in meeting EPA 2002. We are very happy about the working group that has started the task of examining where US, European and Japanese legislation as well as test methods may eventually be harmonised – but that will probably not happen until beyond 2010. We would also want to see more harmonisation on fuels and fuel qualities. This will enable us to develop more dedicated and low emission engines. The work done in Europe has been more extensive but the need to meet EPA 02 emissions has helped us significantly in preparing for Euro 4. Our vehicle projects 2280 and 2285 on cabs mean that the same construction may be used in all markets even though the detail design may vary from market to market.

When do you expect to see an upturn in the global truck business? Volvo has not shown nearly as good results as Scania and Paccar. What will be the factors that enable the recovery?
We are expecting a major growth in China and, following this, several of the new Asian markets. US emission legislation will limit the growth but we normally do not comment publicly on our predictions. Clearly, though, the demand for transportation in North America will continue to increase and they have the oldest fleet of trucks compared with other western markets. The US market will have to start to invest soon, but we cannot foresee the time where the market will turn up again.

Which markets do you think will lead the recovery?
No comment..., but we will be there.

Will all European Renault as well as Volvo heavy trucks be powered by Volvo D9, D12 and D16 engines by 2006 (when Euro 4 emission limits come fully into force)?
We are moving away from the current 18 platforms on which we now build our engines; there will be two only in the near future. We will have a "shared technology and common architecture", allowing for larger volumes and more efficient purchasing. However, we will not give up on the engine characteristics that the drivers of the different brands are used to and expect.

Will engines continue to be built at Mack's

Hagerstown, Maryland plant? If so, what will they be?
Yes, the plant is modern enough and still offers opportunities for development and good efficiency. We have no other plans.

Given the now much larger combined Volvo and Renault middleweight truck volumes, does the Volvo-Deutz mid-range diesel joint venture still make commercial sense? (One assumes that, starting again today, an all-new family of mid-range diesels would be developed and produced in house).
The volume at Deutz is growing continuously and we will continue operations there. It makes economic sense. They live better with us than without us and we live better with them than without them. We would have trouble living without each other.

Is Volvo confident that the percentage of Volvo VN trucks sold in the US and Canada powered by in house engines will grow significantly, beyond the present 20 per cent or so?
We are convinced that we have a concept strong enough to gain market share.
We are presently powering some 35-40 per cent of the Class 8 Volvo trucks sold in the North Americas with in house engines. We are confident that we will increase that share significantly. We have noticed that the American market increasingly purchases from companies that can offer the complete vehicle. Volvo is in a strong position to take advantage of this trend. We will continue to develop the VN engine and all the others too. The expected loss in thermal efficiency for EPA 02 engines will be very small: if anything, we expect to increase the fuel efficiency during the next couple of years. At some point the limit to where the efficiency can be further increased will be reached, but it seems we are not there yet.

The CEOs of the Volvo, Renault and Mack truck businesses report direct to you, Mr Johansson (following the Volvo Global Trucks layer of management being ditched, a few months after the merger/takeover). Clearly that gives Renault and Mack people a stronger voice in policy making. Does it also mean that you want Volvo to compete as vigorously with Renault (and with Mack in North America) as it did before the merger?
Volvo Global Trucks has fulfilled its mission and we have now integrated the purchasing operation. The three companies are now focusing on developing their brand names and continue to develop the integrated purchasing and development process. In the first two quarters of 2002, the savings have been in the range of 225 million on an annual basis. We expect next year to be close to 300 million. Beyond the purchasing operation, we expect a total saving on development costs and reduced overheads of another 300 million or more.

Volvo lost its truck links with Mitsubishi (to DaimlerChrysler). We now see your Swedish rival Scania establishing a link with Hino. Is there still an opportunity for Volvo in Japan – possibly via Nissan Diesel?
Volvo does not have or plan to have any co-operation with Nissan Diesel. We made a 50m profit from selling the share in Mitsubishi. Scania is a smaller but very skilled manufacturer and we do assume that they have a need, just like anybody else, to increase their volumes. We have no specific comments on other companies inside our industry. Our market position, though, is of interest, because we will not be able – or even allowed – to grow substantially in our traditionally strong markets like Europe and the Americas. At one point, the authorities will limit our growth for reasons of competition. However, we do foresee substantial growth in South East Asia, China, Japan and South America.

'The differences have created openings and new methods of co-operation that we had not expected '

Born in 1951, Leif Johansson trained as an engineer at Chalmers University of Technology. Before joining Volvo in 1997 he was CEO of Electrolux.

Time is money

Getting the right model to market at the right time has never been more critical: delays can mean the difference between success and disaster, profit and loss. Yet marketing pressures demand ever more niche derivatives, brought to market faster and faster in order to maximise commercial opportunities. The result is immense strain on product development resources, budgets and schedules. Ricardo has responded to the challenge with a product development template that can save time and money – and help guarantee that all-important start-of-production date.
Tony Lewin reports

Though history does not record who first coined that now-universal adage, one thing is for certain: it could have been invented especially for the automotive industry. In the car game, time is more than just money: it's big-time money and can often mean the difference between profit and loss, success and failure – or even survival and extinction.

Slip up by a few weeks – or, heaven forbid, a couple of months – and a big programme could lose all its meticulously-calculated financial viability; planned connections go out of the window, marketing slots will be missed, other teams and programmes are kept waiting and, worst of all, the final customer will get fed up with the delay and may defect to a competitor. All the time, the dollar-clock is counting the cost – and the fast-disappearing profits.

Nowhere is this more critical than in the launch of a new model. Just as no one is interested in yesterday's newspapers or last season's fashions, few are keen on buying last year's car when the showroom up the street already has next year's shiny new model in stock. And not only does the innovative new model have the potential to pull in the customer from another marque, it will also earn its manufacturer monopoly profits for that all-important honeymoon period when it is the only contender in a brand new, must-buy, vehicle category.

Renault demonstrated the point perfectly with its first-generation Scenic, launched as a Mégane derivative in autumn 1996. At the time Renault knew it was on to a good thing, but estimated that it had perhaps 18 months to exploit the new niche before competitors got in on the act. In the event, it was well into 1999 before GM began producing substantial numbers of its rival Zafira, and it was longer still before the Citroen Xsara Picasso entered production. Had Opel and PSA been able to respond more quickly and get their designs to market faster, the Scenic would not have been such a profitable model for Renault – and it certainly would not be in the fortunate position it enjoys today when demand is still strong, even though its replacement is imminent.

A lot has changed since 1996, of course: consolidation has seen individual producers polarise into large, competitive, multi-brand blocs; vehicle types and configurations have proliferated as manufacturing processes have allowed more flexibility, and in the saturated western markets carmakers must now seize on every design and fashion trend as fast as possible in order to steal crucial competitive advantage over their opponents and keep their plants working at full capacity.

Time to market – the critical measure

Each one of these developments points towards what has now become the single most important measure of an automaker's ability to survive on the world stage: its capacity to respond to trends and bring new models to market faster than its competitors can.

Again, Renault provides a graphic illustration of how this all-important Time to Market (or T2M) measure has

accelerated. The 1995/6 Mégane range, encompassing six different body styles, took 47 months from styling freeze to start of production: its 2003 successor, with seven styles, reached the same stage in just 29 months. And once again Renault will be able to boast a potentially profitable market exclusive in the shape of the long-wheelbase derivative, the only one in the C-sector and due early in 2004.

Delays – everyone's worst nightmare

No matter how ambitious a vehicle programme is in its time-to-market goals, it will fail in its objectives if it falls behind schedule along the way. In fact there is mounting evidence that the more compressed a programme is, the harder it is for programme managers to ensure that the schedule is adhered to. Delays here can be even more financially damaging than those

Accelerating development: Renault's 2003 Mégane series (left) was developed in 29 months from styling freeze, while its predecessor (above) took 47 months

Time to Market – some examples

BMW 7 Series	34 months
Citroen C3	34 months
Fiat Stilo	24 months
Ford Fiesta	36 months
Honda Jazz	36 months
Nissan Primera	24 months
Opel Vectra	30 months
Renault Avantime	41 months
Renault Mégane 1995	47 months
Renault Mégane 2003	29 months
Seat Ibiza/Cordoba	36 months
Toyota Corolla	32 months
Volkswagen Polo	36 months
Volvo XC90	27 months

Source: *Automotive News Europe*, 15/7/2002
Note: different carmakers may define start of development period differently, so timings are not strictly comparable

resulting from slow development processes for the vehicle itself.

With the loss in profit and recovery racking up at well in excess of £1.5 million per day for late entry – even more for high volume product leading segments – this substantial sum is only part of the story. Delays to the new model will mean the existing vehicle will have to be given costly extra marketing support to boost its flagging appeal to consumers and prevent the factories having to go on to uneconomic short time. Not only that, but the planned replacement for the new model will itself have to be speeded up if the same downward spiral is not to be repeated for the next model generation.

And to add insult to injury, a model launched late may not sell as well as expected, needing support throughout its life – yet also needing to stay in production longer, with still more support, to amortise the extra cost of its extended development period.

A further risk is that customers will migrate to other brands that are able to offer fresher, newer models. Two major internationally owned brands have been particularly hard hit in Europe, losing market share throughout the 1990s because of their inability to regain lost development time to bring their model replacement cycles back into synch with those of their competitors.

Carmakers are understandably reluctant to admit to delays, let alone quantify the cost of those delays. However, *Automotive News Europe* recently reported Renault conceding that its 2000 Laguna programme did slip four or five months due to problems with computer tools. Based on Ricardo estimates of the typical cost of delayed SOP, at a notional monthly volume of 25,000 and a showroom price of $20,000, this hold-up could have cost the French firm as much as $1.25 billion in lost revenue and market position on the new car.

Avoiding delays

The enormous penalties of failing to hit start of production dates are plain for all to see. Unfortunately the problem in meeting SOP targets is compounded not only by the need to develop cars more quickly, but also by the fact that there are now far more cars being developed at any given moment. Where five years ago a typical model range used to comprise two or perhaps three body derivatives, three or four engines and a couple of transmissions, today's equivalents can run to twice as many permutations – each of which has to have its own development programme.

The proliferation of niche models is placing a major strain on carmakers' resources – in terms of both time, facilities and cash. The pressure is further intensified by the need to check, double-check and check again every safety-critical system on the vehicle: mistakes here could lead to expensive in-service recalls and damage to brand image.

More than ever, vehicle development is an area where outside specialists can share some of the load – especially when it comes to applying techniques which not only help shorten time to market, but which also ensure those time-scales are adhered to.

Even the most straightforward of development programmes can tie up many hundreds of engineers for long periods of time in order to carry out essential calibration, testing and durability work. This is in addition to development tasks further upstream. Ricardo is partner to many major automakers on a wide

Ford's Racing Puma: calibration for this special-version programme took just twelve months, thanks to Ricardo development expertise

variety of programmes, but to give a feel for the scale of the task involved, principal control and electronics engineer Dr Robert Dorey provides an idea of a typical programme. "A typical programme of, say, two to three powertrain variants on a single vehicle body style, might require in the region of 160 weeks of steady state tests and 1200 emissions tests. It might call for a fleet of 50 development vehicles and perhaps 50 more for durability testing. Over a period of three years all of this might keep an in-house team of between 50 and 100 people busy, together with similar numbers drawn from the customer organisation".

Yet, says Dr Dorey, the use of the Ricardo VCOT development process – see panel, right – and other advanced development tools allows at least six months to be slashed from the programme time. It also allows big savings to be made in the size of the vehicle fleet: these largely handmade prototypes are notoriously time-consuming and expensive to build, to track and to manage. Industry experts estimate that they cost between 20 and 30 times the price of the eventual production car – so the financial benefit of needing just 65 rather than 100 prototypes can be dramatically quantified at around $15 million for the programme.

The secret of VCOT is not just the fact that it automates many of the tedious but vital testing functions that used to be carried out on the road or track with human drivers. It feeds test data back into the simulation models used in the CAE design processes, speeding up the determination of the key trade-offs between parameters such as fuel consumption and emissions. And by taking engine testing out of the vehicle and into a test cell environment, the engine work can begin at a much earlier stage than it would if it depended on the transmission and chassis having been completed beforehand.

"In essence what we are doing is to simulate the whole vehicle, the drive cycle and the driver," explains Dorey. "We simulate all the components and test the engine in an environment that it would expect to see, yet without having to have a transmission, a fleet vehicle or a driver available. You can also take out all the driver-to-driver variables."

Outlook

The pressures on carmakers and their development teams have never been greater. More products have to be developed in less time and on a shorter product lifecycle as the next new derivative is primed to grab its momentary market initiative.

Yet all this pressure is overlaid by the need also to cut back on costs and resources. As model niches grow ever more numerous it is plain that even the best-placed companies will find it helpful to call on external resources to achieve those all-important start-of-production dates.

VCOT – the intelligent template that reduces both the time and the cost of car development

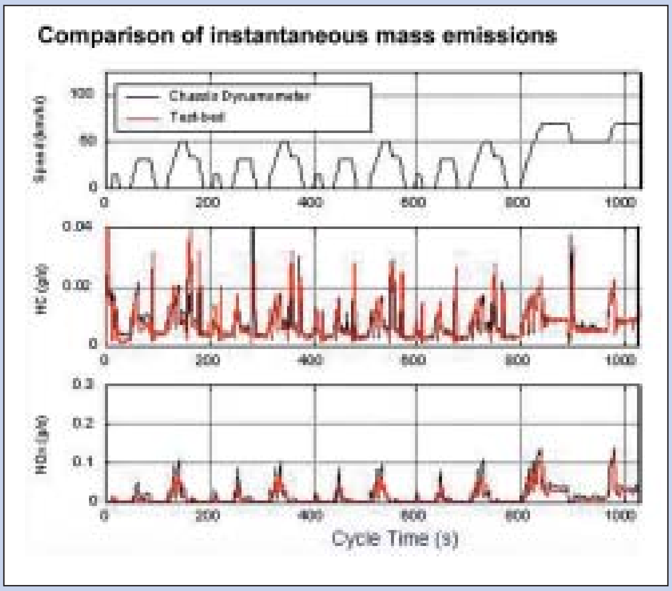
For anyone not fully up to speed with the complexities of modern engines and the even greater complexities of official legislation that today governs those engines, the precise nature and scope of the VCOT system is at first hard to grasp. Even spelling out the acronym as Vehicle Calibration on Test bed undersells the significance of this valuable tool.

Principal control and electronics engineer Dr Robert Dorey is one of the architects behind the system and defines it as follows: "VCOT is all about bringing transient engine and powertrain testing into the test cell. It replaces that part of the development process which has traditionally taken place in the vehicle."

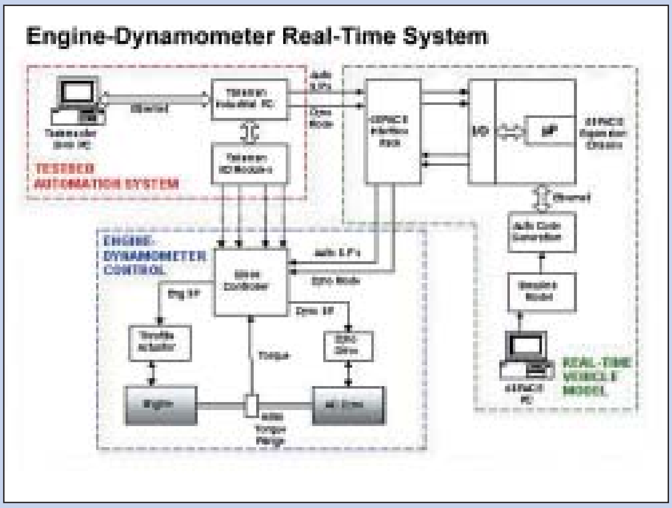
"However," continues Dorey, "in a much broader sense it encompasses all the upfront processes associated with design and development leading into steady-state test bed calibration, automated mapping and automated testing, into transient testing and then the subsequent handoff to vehicle. It needs to be seen in that very broad frame in order to see the true benefits that we talk about."

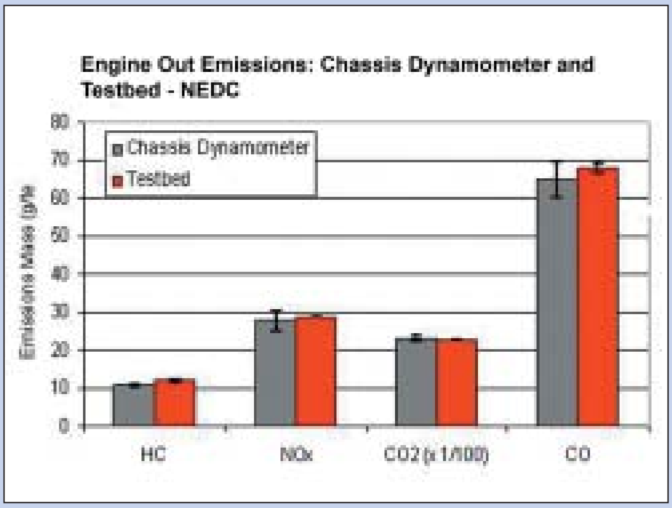
Stated more simply, what VCOT does is to take care of the final phase of engine development, when the powertrain has to be mapped in order to provide data for the engine management and On Board Diagnostics (OBD) system, and calibrated in order to confirm compliance with legislative standards for emissions, consumption and other parameters.

Some of this involves steady state testing; other phases, such as official drive cycles, would normally require a driver and a complete vehicle but are done under VCOT in the test cell using accurately simulated loads for transmission, ancillaries and



VCOT-managed test bed results (left, top right) correlate closely with figures achieved with full chassis dynamometer





cooling pack configurations.

Again, this might seem relatively straightforward – until it is realised that to get a single engine/transmission/body combination through the requisite European and Federal tests requires around 200 separate tests.

"As the market moves towards more niche derivatives and less base powertrains," explains Dorey, "it becomes increasingly important to be able to do calibrations with different vehicles, even though the concept definition is the same.

"It is important to be able to do quick calibrations," he continues, "to get your product out onto the market. The vehicle type (saloon, cabriolet, people carrier), its features (size, weight, payload, gear ratios, power output) and intended market all impact the calibration and multiply out to make a huge amount of work."

For carmakers the attraction of a programme such as this is that it enables them to bring derivatives – and even main models – to market much faster, at less cost and with less of a drain on resources. Ricardo was able to re-calibrate the Ford Racing Puma within 12 months, for example.

More recently, major strides have been made in in-cell development of driveability, a notoriously time-consuming and subjective activity normally carried out by teams of drivers in expensive prototypes on the open road. Climatic testing, another well-known cash burner, can be tackled, too:

"Instead of sending the engine – or rather the complete vehicle – to Arizona, we put the engine into our climatic test bed," Dorey explains.

Though companies tend to like climatic trips because they are able to take a whole range of vehicles, the expeditions tend to be awkward hard points in the development calendar, forcing engineers to pull out all the stops to hit the dates; all too often, too, the trips are used for development work that could have been done earlier.

"If you could reduce your dependence on these trips it would be very beneficial," adds Ricardo project director Mark Garret. "Under our system we would use them more for validation [of what we had already developed through simulation] – the one thing you can never get around is validation in the full vehicle."

Again, the virtuous circle is clear. Quicker development, because test results are fed back into the CAE design loop; quicker calibration, because in contrast to the traditional human test operations of two a day, automated tests can take place in parallel and round the clock, achieving as many as 12 per 24 hours. Ricardo even has rapid cool-down techniques so that these tests can be run back-to-back with cold or ambient-temperature starts. Big savings can be made in the number of people, and there are fewer costly prototypes to build and manage.

The logical extension of this thinking would be to move to zero prototypes, where the correlation between simulation and reality was so precise that only pre-series validation vehicles would be required.

Such a position may be closer than many people think, but for the moment Garret likens the process to that used in crash testing.

Body structures are designed in the computer and subject to repeated virtual crash tests to fine-tune their performance. Only when the computer model's impact performance is satisfactory is a full-size car built and impact-tested – hopefully validating the computer's predictions.

And as powertrains become yet more elaborate, with countless extra degrees of freedom such as variable valve timing and turbo nozzle angle, pre-, post- and main injection, EGR and lean NOx trap regeneration – not to mention the effects of hybrid operation and regen braking, – calibration, like safety, will cease to be an art. More and more it is becoming a science – and one that demands effective tools if it is not to be the bottleneck preventing urgently-needed new models from reaching the market in time.

The cost of delays

	C-segment derivative	D-segment main model
Vehicles per month	6000	25,000
Revenue per vehicle	$15,000	$20,000
Material per vehicle	$7500	$10,000
Loss of recovery/profit per vehicle	$7500	$10,000
Cost per month of delay	$45 million	$250 million

Base calibration: traditional versus intelligent development

	Traditional	Modern	Saving
Duration	24-36 months	18-30 months	6 months for approx. 140 engineers
Engineering	$1.5m-4.5m	Approx. 15% less	Approx $0.5m
Project costs	100 prototypes; 5 trips	65 prototypes; 3 trips	Approx. $30m

Source: Ricardo

Renault chooses Ricardo to launch diesel range

Renault has chosen Ricardo once again - but for something very different to engineering services. In August this year Renault GB Ltd chose Ricardo as a venue for the press launch of a range of new model derivatives, including diesel versions and the high-performance Clio Cup hot hatch.

"Ricardo is seen as leader in its field, an independent company to hold the launch at," said Graeme Holt, press relations manager for Renault GB. "We were happy to showcase an English company that Renault entrusts its work to. And besides, it was a good opportunity to educate people about diesel: there is still quite a lack of awareness on the subject."

Shortly after the event, Renault GB managing director Philippe Talou-Derible also expressed his thanks: "The journalists and fleet customers who attended the event were impressed by your facility at Shoreham," he wrote, "and they were fascinated to get an insider's view of how a number of your testing cells operate. In addition, the expert's view of how the diesel market is evolving, provided by Ian Penny, was greatly appreciated."

i-MoGen hybrid receives global acclaim

The Ricardo programme to develop a C-segment mild hybrid vehicle, i-MoGen, has been one of the biggest internally-funded projects ever undertaken by the company. And after two years of development, the demonstrator vehicle has been released to great acclaim, with presentations and ride-and-drives by the world's leading automotive executives and media.

Such has been the level of interest in the automotive media about i-MoGen's innovative technology that the development vehicle took a rare day off from its exhaustive global ride-and-drive schedule to return to Shoreham and face the analysis of the international press.

Two dozen journalists congregated at Shoreham to hear presentations given by Michel Lifermann of Valeo and Neville Jackson from Ricardo – and to take a turn in the i-MoGen vehicle itself, along with a standard Opel Astra diesel as a comparator. This was the first time i-MoGen had been assessed by the media, many of whom had never driven development prototypes. Reaction to the vehicle was overwhelmingly positive, with special praise for the vigorous and refined performance of the tiny 1.2 litre diesel engine at medium and high rev/min. Many found it hard to believe the engine was that small – until the accompanying Ricardo engineer switched off the electric torque assist at low revs.

A special seminar on hybrid vehicles further reinforced the message that combining a downsized internal combustion and electric power is the most effective solution to achieving the low $C0_2$ emissions soon to be targeted by the world's legislators.

To provide information to a wider audience, Ricardo has created a dedicated i-MoGen website within the Ricardo site. Its purpose is to act as a one-stop shop not only for the OEM users but also for the media and for investors.

"It is important that they know just how significant this project is," said Ricardo new media marketing officer Andrew Kennedy. "It's a highly technical programme, so the website has a high degree of technical information too."

The thinking behind the microsite is to offer a general overview area, where users can access information on five key areas of i-MoGen technology. Beyond this point is an added value section where users who register can dive deeper into the technologies developed under the programme: this second level of access is divided into channels for engineers and for media and investors. Much of the information can be downloaded in PDF form, and there is even access to technical papers presented at conferences but not yet fully in the public domain.

The i-MoGen microsite can be reached at http://www.ricardo.com/i-mogen/.

Ford chief delivers keynote address at Ricardo-sponsored conference

Statistical methods are now an essential element of the automotive design process, according to Professor Richard Parry-Jones, group chief technical officer and vice president of global product development at Ford Motor Company. Providing the keynote address at the Ricardo-sponsored international conference on Statistics and Analytical Methods in Automotive Engineering, Parry-Jones stated that statistics should be best used in conjunction with engineering deductive skills in order to solve problems. In a wide ranging address he drew upon Ford experience in areas such as product planning and target setting, reliability optimisation and prove-out, and fixing problems in the field – the latter including the recent and very challenging Firestone tyre crisis in the USA.

While the unique context of automotive engineering applications needs to be recognised, Parry-Jones stated that industry should look to examples in the medical industry for future guidance on the application of statistical science. He also underlined his personal belief that more statistical engineering should be embedded in the curricula of engineering courses, citing the success of Ford Motor Company, Loughborough University and the Royal Statistical Society in this area.

Statistics and Analytical Methods in Automotive Engineering was held on September 23rd and 24th at the headquarters of the Institution of Mechanical Engineers, London. The conference was chaired by Simon Edwards of Ricardo and included presentations and exhibitions from a wide range of participants including Ford, Jaguar, PSA/Peugeot-Citroen and Fiat, as well as research institutes and software developers. In addition to papers describing the use of Design of Experiment techniques for engine development, a range of other applications were also addressed, including statistically based driveability analysis and optimisation of vehicle structures for crashworthiness. Design for Six Sigma was a significant theme of the second day, where the integration of product development and manufacturing engineering is making reliability and durability estimation a more objective process.

The conference was organised following the highly successful 1999 Statistics in Engine Design seminar, which was also sponsored by Ricardo. Commenting on the Ricardo involvement, Edwards said, "Ricardo has a long history of using statistical techniques in the development of engines and we have had many successes in expanding their application to drivelines, transmissions and vehicles." More information on Ricardo work in this area is available via the Ricardo website.

Richard Parry-Jones: "Modern automotive design requires the integration of statistical science into the engineering tasks"

Ricardo rides again

For Mike Monaghan, former Ricardo technology director, this 1922 Vauxhall two-wheeler has a special significance – beyond the fact that it is the only example of its kind. Mike takes up the story:

"In 1921, Ricardo was doing engine work on Vauxhall cars, and Vauxhall approached Ricardo to design the engine for a motorcycle – a luxury motorcycle for the top of the market. The bike was to have lots of power and be capable of lugging a sidecar."

Harry Ricardo said he was too busy to handle the work himself, but that a certain Major Halford would take on the task - which he duly did, and designed the complete motorcycle for good measure. But soon after Vauxhall had made up components for twelve prototypes of the four-cylinder, 944cc machine, a boardroom split at the carmaker resulted in the departure of the directors who supported the motorcycle project, and the cancellation of the programme.

"The two prototypes that had been made up were auctioned off, and one was later broken up for scrap," explains Mike. "But it was through various twists of fate that Ricardo came to hear that a motorcycle enthusiast, Bob Thomas, had found the machine and restored it."

Ricardo and Thomas agreed that the machine should enter as many historic motorcycle events as possible, with Ricardo looking after it in the winter months. And as Ricardo's resident motorcycle enthusiast, Mike had the privilege of doing most of the rides.

"We thought we would do this year's Banbury run – just for the sake of history," recalls Mike. "It's tricky, as you don't get told the course until the start, and you have to maintain a 20mph average – which is far too slow for that bike. I could feel the bike wasn't really happy, so I opened it up properly. Much to my surprise I got second in class for timing – as well as the cup for the machine of greatest technical interest."

Product development of a Stirling Cycle engine for STM

When Michigan-based STM Power needed a development partner for a new product range, it turned to Ricardo

STM Power, Inc. is a privately held Michigan company that is the world's leading developer of external combustion (Stirling cycle) engines for electric power generation in the 20kW to 500kW size range. Unlike gasoline or diesel internal combustion engines that burn their fuel within the cylinder, Stirling cycle engines use an external combustion source or heat supply to provide energy to the working fluid of the engine.

Combustion can thus be a continual process and may be optimised for a wide range of fuel types. Interest in the use of this form of power unit for distributed and mobile electrical power applications has grown considerably in recent years due to the potential that it holds for improved fuel efficiency, the ability to use a wide variety of fuels or heat sources (including solar) and reduced operating costs, emissions, and noise.

In May 2001 STM Power announced that it had selected Ricardo, Inc. as technical partner for the product development process of the STM 4-120 25kW Stirling cycle engine, which is to form the basis for STM Power's products used in a variety of stationary and mobile power applications. Within this programme, Ricardo led the detailed design and release of the beta version of the engine and its auxiliary drive systems. Ricardo played a central role, with responsibilities ranging from the specification of comprehensive durability and reliability targets appropriate to the numerous intended applications of the engine, through to the development of the detailed design to meet these targets.

Starting from what was essentially a product in concept form, an overall objective for the Ricardo team was to develop the design to meet the requirements of volume manufacture. In doing so, Ricardo has helped STM Power to move their product from a research environment to one of structured development and production, conforming to appropriate automotive industry standards and disciplines. This has included the specification and implementation of rigorous product development and design release processes for use by STM Power on all future product engineering programmes.

The Ricardo team on the STM 4-120 engine comprised approximately 20 engineers and support staff, including specialists in the areas of CAE simulation, design, manufacturing and programme management.

Working in partnership with STM Power, the Ricardo team was able to develop the design from concept form to that of a production-ready product ready for final validation testing. As a result of the support provided by Ricardo, STM Power has been able to bring their first production Stirling engine concept to market-readiness within a highly competitive time scale. The company will also benefit in the longer term as it develops its future products using the product development and design release processes implemented at STM Power by Ricardo.

Transmission Trends: Ricardo technology seminar

Tightening emissions legislation and ever-rising customer expectations for smoothness and comfort have led to a heightened level of innovation and activity in the transmissions sector. Already, many innovative types have appeared on the market.

Increasingly, transmission is being seen as a key market differentiator and, with several more new designs awaiting launch, Ricardo believes this process has only just begun.

Significant advantages are being claimed by each of the new designs competing for automakers' and customers' attention. The aim of this latest Ricardo themed seminar is to help auto industry engineers and executives make sense of these new technologies and their competing claims.

Transmission Trends and Technologies is a compact and intensive one-day seminar to be laid on by Ricardo Driveline and Transmission Systems at the Midlands Technical Centre near Leamington Spa on Wednesday, 5 February 2003.

Whilst focusing predominantly on the European market, the seminar will also take into account the structural differences in the North American and Japanese markets.

Ricardo will give a detailed presentation of the technology drivers, the relative merits of each technology and the timing of their likely introduction and eventual obsolescence. Delegates will be given a likely market forecast for 2010 and beyond.

The whole spectrum of technologies will be included, from five-speed manual transmissions through to hybrid transmissions. Dual clutch transmissions will be highlighted in particular.

Leamington Spa is 30 minutes from Birmingham Airport, and Ricardo suggests that delegates should arrive on the evening of Tuesday, 4 February: hotel accommodation can be arranged on your behalf. Specific information will be available in November: however, if you wish to pre-register for the limited number of places available, please contact Emma Bushell, email Ebushell@MTC.ricardo.com.

The charge for this seminar, per delegate, is £500 (plus VAT).

We hope you can join us for this exciting event.