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ricardo quarterly review

Interview
William Clay Ford Jnr

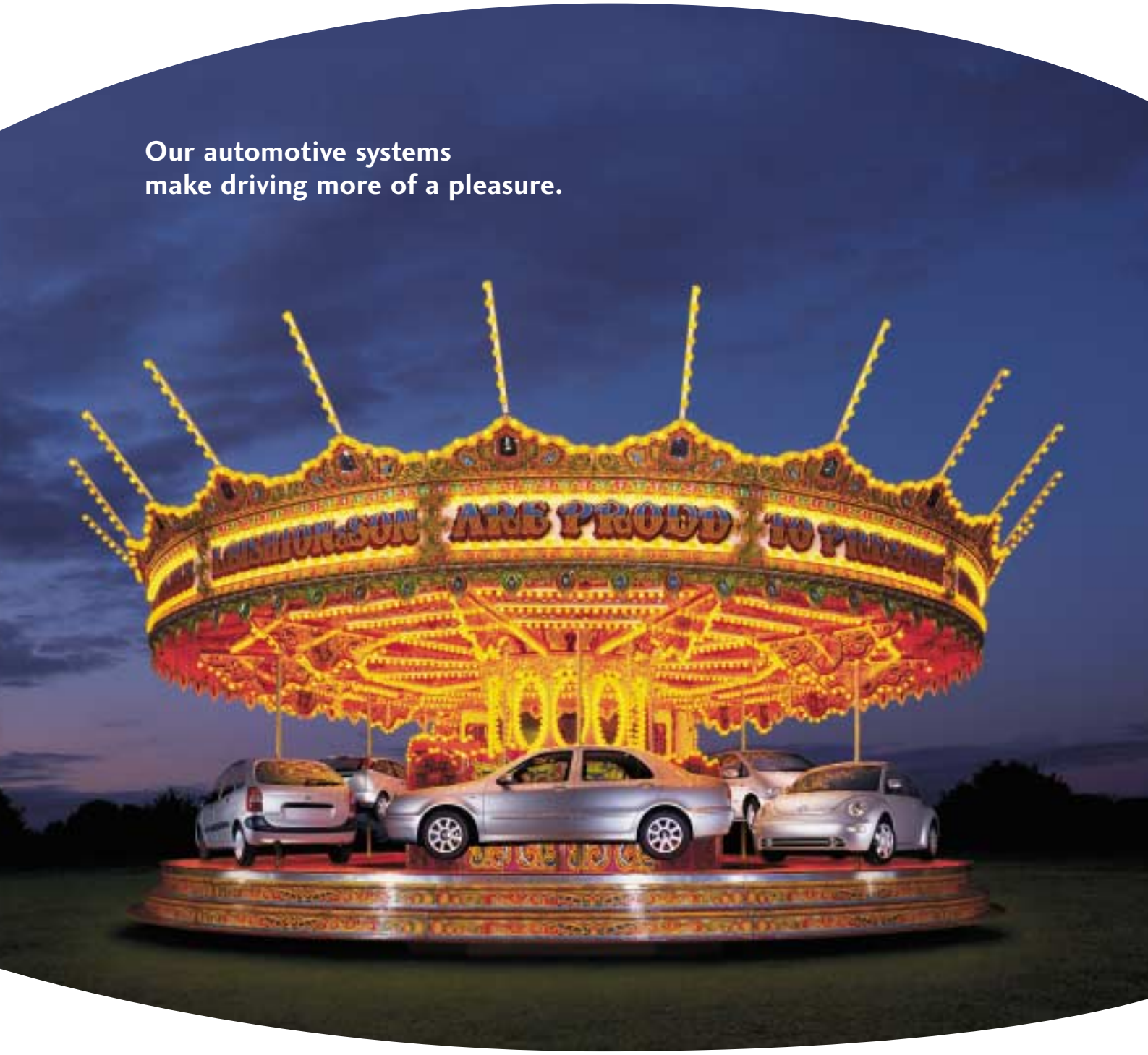
Race transmissions
Improving on the very best

Lean Boost Direct Injection
New route to engine downsizing

Spring 2002

Volvo D5

The world's first all-aluminium five-cylinder diesel engine was developed in record time – with the help of Ricardo know-how



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● in brief

US Army goes hybrid
Heavy duty hybrid trucks will be widespread in the US Army by the middle of the decade, improving both environmental performance and "energy security". Fuel currently accounts for 70 per cent of the bulk tonnage transported by army vehicles during combat, but the army plans a 75 per cent cut in its fleet fuel consumption by 2010.

Massachusetts slow to follow California
Following Texas and New York, with Vermont also likely to do likewise, Massachusetts has decided not to adopt strict Californian emissions standards yet. The main concern is the target of 10 per cent ZEVs in new car sales, which is thought unachievable by the original 2003 adoption date. The new proposal is 2007.

Netherlands proposes distance charging
The Dutch government is planning to charge all vehicles according to how far they are driven from 2004, using satellite technology. The idea is to make the scheme revenue-neutral, so those driving over 18,000km a year pay more than now, others pay less thanks to reduced fuel, car and purchase taxes.

US carmakers exhorted to use aluminium
The Aluminum Association championed the lightweight metal's use at January's Detroit Auto Show, giving awards to Nissan for the Altima and Chevrolet for the Trailblazer SUV. Both vehicles use much aluminium, helping to reverse the trend towards ever-greater weight.

Sulphur-free diesel in Europe from 2009?
EU environment ministers have set 2009 as the target date for sulphur-free diesel. This would enable vehicle manufacturers to develop cleaner engine technology, currently inhibited by high levels of sulphur.

AW Knowledge (AWK)
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Cooper S raises MINI game

The highly successful MINI range now has a Cooper S flagship, reviving the model name of the ultimate original-style Mini launched in 1963. The new car has a supercharged version of the 1.6-litre engine already seen in the MINI One and MINI Cooper: the unit is built in Brazil by Tritec Motors Ltda, a joint venture between the BMW Group and DaimlerChrysler. It represents the next stage in a programme with which Ricardo has been intimately involved for the past two years – as reported in *RQ* Autumn 2001.

With 163bhp, achieved with the help of an Eaton supercharger, the Cooper S has a 48bhp power advantage over the regular Cooper. "Of course, the S name refers to the shape of the intake path from the airflow meter through the supercharger and then the intercooler," says MINI powertrain leader Johannes Guggenmos, not entirely seriously. He points out that the installation is a very tight package, with the water pump ingeniously moved to the rear of the supercharger.

External changes include a large hood scoop to feed the intercooler, and the suspension has been stiffened to handle the extra performance. The other major change is a six-speed gearbox with three shafts and two final-drive pinions, a configuration chosen for its compactness which suits the MINI's restricted width.

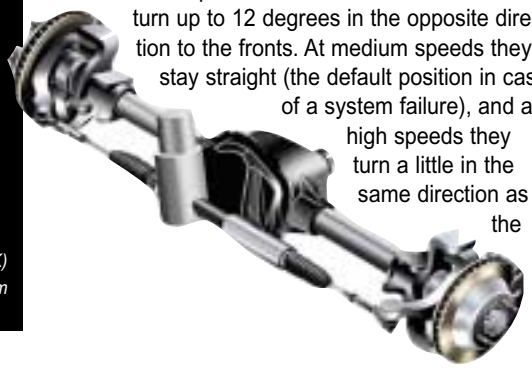
The Cooper S marks the launch of the MINI brand in the US, where sales began in mid March. Japan was next, at the the end of March, while European buyers must wait until June (UK) and summer 2002 (other EU countries). It will be worth the wait, as first press reports suggest that the Cooper S may be the most entertaining hot hatchback since the mid-1980s Peugeot 205 GTI. "It even sounds like an original Cooper S," said one journalist, "because it has a deep exhaust note and the supercharger whine mimics the old car's transfer-gear noise."

JOHN SIMISTER

Delphi launches rear steer-by-wire

GM's Sierra Denali luxury pick-up has become the first truck to be fitted with four-wheel steering, although several cars have been so equipped during the last decade. And, for the rear wheels, it is a steer-by-wire system. Delphi's QuadraSteer uses signals from steering wheel angle and front wheel position sensors, computes them with road speed information and decides which way the rear wheels should turn.

In low-speed manoeuvres the rear wheels turn up to 12 degrees in the opposite direction to the fronts. At medium speeds they stay straight (the default position in case of a system failure), and at high speeds they turn a little in the same direction as the fronts which, says Delphi, greatly enhances stability, especially when towing.



This is possibly the first time rear-wheel steering has been applied to a solid rear axle. Actuation is by electric motor and a rack-and-pinion.

Delphi is among the components manufacturers developing steer-by-wire for the front wheels, but as yet it is not legislated for by the European Commission. Legislation is expected to be in place by 2004, with low-volume production by 2005. Driving enthusiasts need not worry: Dr Ulrich Eichhorn, Volkswagen's executive director for research, environment and transportation, says that with the right feedback sensors such a system can give excellent steering feel to the vehicle.

AWK

Eaton previews hydraulic energy storage

HYDRAULIC Launch Assist (HLA) is the name of a new device, developed by Eaton, which can store and release kinetic energy in the form of hydraulic fluid pressure. Revealed at the Detroit Auto Show in January, the device works by recovering some of the energy normally lost during braking and using it to pressurise a fluid, which is held in an on-board accumulator.

The stored pressure is then released briskly through hydraulic pumps to assist the vehicle as it pulls away. Used in a large SUV, or a pick-up such as Ford's Mighty F350 Tonka concept which previewed HLA at Detroit, the device could produce fuel economy improvements "as high as 25 or 30 per cent", significantly higher than claims made for electrical integrated starter/alternator devices.

The concept, patented by the US Environmental Protection Agency, has been developed jointly by Eaton and Ford. Eaton has already invested "millions of dollars" in HLA-related work, but predicts that the business could be worth more than US$500m across the motor industry by the end of the decade. As shown at Detroit, the F350 concept also used an electrically-driven turbocharger to banish lag in the turbo's response. *AWK*

PNGV out, Freedom CAR in

THE Bush administration in the US has axed the PNGV (Partnership for a New Generation Vehicle) project, started by the Clinton administration in 1993, in favour of a new initiative called Freedom CAR (Co-operative Automotive Research).

Whereas PNGV aimed to develop an internal-combustion family car capable of 80mpg in normal use, Freedom CAR is embracing the hydrogen-powered fuel cell option.

Part of the plan is thought to be a desire to reduce the US dependence on imported energy. The partners – the US Department of Energy, GM, Ford, DaimlerChrysler and the US Council for Automotive Research – will work together to bring down the cost of the hydrogen fuel cell to an economically acceptable level.

According to an editorial in *Automotive Environment Analyst*, the Bush administration has been criticised for failing to address shorter-term solutions, given that fuel cell cars are 10-15 years away from widescale production. The critics forget that manufacturers have already invested much time and money in fuel cell cars, says the newsletter, and that hybrids – the likely products of the PNGV programme – are already available. *AWK*

Visteon develops one-piece facia unit

NEW plastics technologies are driving some innovative interior developments. Visteon has devised a laminate insert moulding process which inserts a preformed laminate skin into a conventional moulding press before the injection-moulding cycle to form a complete facia panel. The fully-recyclable result is a one-piece moulded polypropylene panel with selective soft-touch zones. It can have a two-tone appearance if required, without the use of paint, and seam lines are consistent.

The company has also refined its "negative thermoforming" process, in which a complete instrument panel made from a TPO skin is produced in much the same way as a styrofoam cup. It is an alternative to powder slush moulding.

Developments such as these have won Visteon, originally a Ford subsidiary, a contract to manage the production of entire interiors for the next generation of GM's small cars. *AWK*

A message from the Chief Executive

THE new all-aluminium D5 engine is the first ever diesel to be produced by Volvo Car and was one of the highlights of last year's new engine product introductions. It is particularly pleasing therefore that in this issue of *RQ* we are able to bring to you the story of the Ricardo involvement in this D5 engine project, drawn from interviews with both the Volvo and Ricardo teams.

This was a highly complex programme carried out to a challenging time-scale, but one which has delivered a state-of-the-art product worthy of the Volvo Car brand. In the news section I am also pleased to see that the latest addition to the MINI family, the MINI Cooper S, has now been launched. Those of you who read the Autumn 2001 issue of *RQ* will know how much pride Ricardo shares with BMW in this excellent new family of premium small cars. As ever, the value and innovation of Ricardo technology is only truly measured in the quality of products of our customers.

Rodney Westhead

Ford to the rescue

Photo: PA

These are tough times for the Ford Motor Company. Chairman (and, since the departure of Jac Nasser in November, chief executive officer) William Clay Ford Jnr has shuffled his management pack and announced several restructuring actions as part of his company's Revitalisation Plan, a product-focused programme designed to strengthen Ford's position in the marketplace and improve its financial results.

These actions are aimed at enhancing the company's ability to produce the highest level of quality cars and trucks while reducing the cost structure.

Between now and mid-decade the automaker plans a reduction of North American plant manufacturing operating capacity by about one million units. This will mean the loss of around 12,000 hourly employees in North America, plus an additional 1,500 salaried personnel, to reach a goal of 5,000.

A material cost reduction programme has been initiated with North American suppliers which, along with other material cost reduction efforts, should improve ongoing annual pre-tax profits by $3 billion by mid-decade. Ford's new CEO spoke to Anthony Lewis and Chris Wright at the North American International Auto Show in Detroit earlier this year.

The turn of the century has proved difficult for the Ford Motor Company. What is the overriding message that you have got to get across to both company workers and car buyers?
We are not a nameless, faceless corporation. We are global, but we are also local and a family firm. We must re-polish the blue oval and get it shining brightly again.

Right now we are in the middle of a painful but necessary transformation of our company. We've made some progress but we are not finished yet. Our Revitalisation Plan is based on executing the fundamentals of our business to build great products. What we are outlining is a comprehensive plan that builds for the future. It's going to take everyone in the extended Ford family – employees, suppliers and dealers – working together, over

time, to make it work. Although the actions we have outlined are difficult, they are necessary steps to lead Ford back to a strong financial and competitive position.

You have talked of plant closures. Where will these be?
We are looking at closing five plants in the United States: Edison Assembly, Ontario Truck Plant, St. Louis Assembly, Cleveland Aluminum Casting and Vulcan Forge. In addition no new products have been identified for two plants: Ohio Assembly and Cuautitlan Assembly. We are pursuing the sale of Woodhaven Forging Plant and major downsizing and shift reductions at 11 plants. We are also looking at line speed reductions and changes to operating patterns at nine plants. In order to remain competitive and profitable, we must make some hard decisions to align capacity with our anticipated sales. At the same time, the company is continuing its commitment to North American manufacturing operations with investments of about $20 billion over the next five years in new product programmes and spending. This will add flexibility and increase our ability to respond quickly to changes in market demand.

This is obviously not good news for North America, but what effect is there likely to be in Europe and the rest of the world?
Beyond North America Ford will continue the implementation of the European Transformation Strategy, the Premier Automotive Group strategy, the turnaround in South America and a revised direction for Ford Financial. I don't see any fallout in Europe; Ford of Europe is absolutely on track. Jaguar, Land Rover, Volvo and Aston Martin – which together form part of Premier Automotive Group – are central to the company's future success and profitability. I don't ever envisage selling them off. I believe we can be extremely profitable again – and we will be.

Ford is building a new plant in St Petersburg to serve the Russian market. Is it possible there could be more new factories in Europe?
I would not rule out opening new Ford factories, even in Britain, even though it has been said following the ending of car production at Dagenham that Ford-badged cars would never again be built in the UK. Yes, I'd consider it. But the conditions would have to be right. It would have to be a modern factory. But I have a very open mind on that. Britain has been a great place to do business.

Would Britain have to join the Euro before you would consider such a move?
I would prefer the UK to be in the Euro-zone in terms of all of the company's business in the country, but it is not a critical factor.

What effect will the Revitalisation Plan have on Ford vehicles in the short term? There do not seem to be very many new models scheduled.
Low-margin models such as the Mercury Cougar, Mercury Villager, Lincoln Continental and Ford Escort will be discontinued this year. North America is not as fortunate in having new product coming through as Europe but we still have some significant vehicles in the next two model years. This spring we will launch the redesigned Ford Expedition and Lincoln Navigator. Later this year we will introduce the Lincoln Aviator, an upscale version of the Explorer. In 2003 we will launch a restyled F-series pick-up plus a replacement for the Mercury Villager. We plan to invest $20 billion to roll out 20 new or freshened models in the United States by 2005.

The new vehicles you mentioned are niche or variations of existing models which will not expand Ford's market share. What other plans do you have for new models?
We are looking at several projects including a subcompact sport utility and a mid-size sport wagon. I think we can maintain our current market share over the next two years with what we have available and the new products planned.

Can you tell us a little more about the shared savings programme you plan with suppliers?
Ford spends about $50 billion annually on outside purchasing and we believe suppliers can find $3 billion on cost savings if given an incentive to share in them. We will dedicate 300 engineers to work with the supply base on cost-reduction targets, and suppliers will get 35 percent of any savings. We want co-operation with suppliers to get their best ideas, and I believe this shared approach will not jeopardise quality as across-the-board demands can.

Now that Jac Nasser has gone, you have made several new management appointments – including a number of British executives such as Nick Scheele as chief operating officer and David Thursfield as president of Ford of Europe. What is the significance of that?
These are people who have earned their stripes. I have seen the way in which they have restructured Ford's operations in Britain and Europe – including the transformation at Dagenham from a car factory to an engine plant. This will form the blueprint for bringing American operations back on track. You can't take the hill if no one follows you. This company is way too big for one person to manage alone. I'm under no illusions; the next year is going to be very tough. There will be bumps along the road, but I've got good people around me. And I'll let them do the job.

At this year's Detroit Show you invited employees as well as the media to the unveiling of the GT40 concept. What message are you giving out there?
I wanted to use the success the original GT40 achieved at Le Mans in the 1960s to remind everyone that this company has ways of emerging as a winner after tough times. Our heritage brings perspective to what we do now. We've had tough times before and come through them – and we will do it again.

You have a big challenge ahead. Are you looking forward to it?
Yes I am. I feel like a football coach before a big game and I actually felt more pressure when I was outside looking in. Now I'm calling the shots I've got my game plan in place. We've got to get our business structure right – and we will. Our business model is not as robust as it should be, but we are fixing it. We have had issues with quality and warranties. Costs will have to be cut but we won't be penny wise and pound foolish. Sometimes cost-cutting with a meat cleaver looks easy to do – but [it] costs you more in the long run. You can't cost-cut your way to prosperity. ■

Five alive

Volvo Car Corporation had traditionally relied on buying off-the-shelf engines from its competitors to stay in the diesel market. Then it realised the premium diesel segment was about to take off, and turned to Ricardo for expertise. Just 24 months later, it began building what could well be the most advanced diesel engine in the world, the five-cylinder D5. Tony Lewin reports

It's rare to find a company with the courage to switch its policies while in the full rush of success. It is rarer still to find a major and highly respected international player who will go public about the change and concede that, perhaps, what it was doing before was less than perfect.

But that's just what Volvo Car did in 1998 when it decided to build its own diesel engines, after many years of insisting that buying in diesels from other carmakers was the best strategy.

"Knowing what we know now, I must admit that we should have focused on our own diesel engines earlier. Now we are going to concentrate on a really powerful entry that will quickly establish a sound basis for success and large volumes," explained Volvo CEO Hans-Olov Olsson at the launch of the D5 in the summer of 2001.

"Early next year [2002], our Cross Country range will be expanded with a newcomer to the SUV segment, the XC90. It is extremely important to have a good diesel engine in this category. By the time this new model is unveiled, our latest diesel engine will have convinced the market that we belong among the very elite in diesel technology," Olsson concluded.

It was a decision prompted by the already-accelerating pace of diesel car sales in Europe, itself triggered by rising fuel prices and the advent of CO_2 emissions-linked vehicle taxation in several European Union member states. Yet Volvo Car faced a thorny problem, as powertrain director Derek Crabb explains:

"We've always had the desire to go into diesels, and when we designed our petrol engines we put the capacity into the bottom end to accommodate a diesel. But there's always only so much resource in a company [to do the job] and we therefore continued to buy in diesel engines — from Volkswagen, for example."

However, looking further ahead it was clear that, as well as being costly to buy and upgrade, the five-cylinder inline diesel from Audi was also approaching the limits of its development. More important still, says Crabb, it was commercially dangerous to be dependent on a competitor for engines in a market that was clearly poised for such massive growth.

"That's why we decided to go for a better business case, bring the technology in house and commit to a programme internally."

This, remember, all took place well before the dramatic moment in early 1999 when a beaming Ford CEO, Jac Nasser, announced that the American giant had bought Volvo's passenger car business. Pre-Ford, Volvo certainly did not have the muscle to go it completely alone in developing its own diesels, though its highly flexible Skövde engine plant had always had provision for expansion into diesel manufacture.

Derek Crabb and his colleagues at Volvo Car were nothing but realistic about the challenge they faced in bringing a new generation of diesel engines into production in record time and with limited resources. "We had a team of diesel engineers inside – about 25 people – who were capable of

Volvo D5 innovations

- First all-aluminium five-cylinder diesel
- First in-house diesel from Volvo
- Developed in 24 months from concept to manufacture
- Weight of 186 kg vs gasoline engine at 168 kg
- First use of second-generation Bosch common-rail fuelling
- Electronically controlled 1600 bar injection pressure
- Electronically controlled variable nozzle turbocharger
- Electronically controlled EGR to reduce combustion temperatures
- Cooling of EGR for further seven per cent NO_X reduction
- Roller finger cam followers for reduced friction
- Machined on same lines as gasoline versions

applying engines," he remembers. "And to launch our engine from concept to industrialisation in just over two years with only 25 people needed a lot of support. We didn't have the right knowledge or the right numbers of people."

"So," continues Crabb, "we had to find a way of lifting the project off very quickly and moving the experience in-house, so we could support the engine fully internally at the start of production."

Brian Taylor, Ricardo lead designer for the D5

The answer, not unnaturally, was to tap the broader engineering community for support. Volvo Car had already worked with both Ricardo and AVL of Austria. Each of these organisations was considered competent to deliver the programme in its own right but, given the work Volvo had already undertaken with each of them, the company took the highly unusual step of bringing both suppliers into the D5 programme.

The agreement broke new ground in many ways, not least because it brought together Ricardo and a direct competitor to work on the same engines at the same time. Pretty soon the partners had established who would be responsible for which systems, the engine being metaphorically divided halfway up, with AVL taking everything above the cylinder head gasket and Ricardo handling the lower half. Nevertheless, remembers Crabb, several grey areas remained – notably the belt drive systems, which spanned the dividing line, and components such as the pistons, piston rings and the head gasket itself.

"We judged from our side," says Crabb, "that this was a wonderful combination. We tried to put a deal together that was fair to both of them, but without infringing on this competitiveness [between Ricardo and AVL] which does exist. It enabled all three of us to come out of it with a decent amount of business and a good engine at the end. For us it was very successful."

At Ricardo, any initial apprehension at working alongside the company's closest competitor was soon dispelled. "At the end of the day we are all professional engineers with a job to do," says Steve Cox, Ricardo programme manager for the D5 project. "When you're all sitting round a table with an engineering problem to solve, you quickly forget you're supposed to be competitors."

Steven Cox, Ricardo D5 programme manager

Cox's sentiments are echoed from the Volvo side by Crabb: "If there was a problem like a cylinder head gasket failure, it wasn't a question of whose fault it was – it was simply a question of who was going to lead the work. The problem can come from many different sources." Common sense prevailed along the way, says Crabb, though clearly there were some tricky moments.

A tough timetable

One of the factors prompting Volvo Cars to place the diesel engine development contract with Ricardo was undoubtedly the Shoreham-based firm's pre-existing expertise with the Volvo engine family. Back in January 1996, recalls Brian Taylor, Ricardo lead designer for the D5, Ricardo had been approached with a view to assessing the viability of diesel derivatives.

"Volvo needed support in the area of diesel," remembers Taylor. "They came with an outline specification for a 2.5-litre diesel and wanted a concept study from us. Our early study had an 84mm cylinder bore and a 91mm stroke."

The programme was frozen in mid-96, but in January the following year Volvo came back wanting a study of the aluminium cylinder block. This was a crucial factor in the programme's viability and also in the performance of the final vehicle, for no other manufacturer had ever succeeded in building an all-aluminium inline diesel with more than four cylinders.

The work with the existing gasoline and prototype diesel engine blocks gave Ricardo the chance to exploit its sophisticated Hydrapulse machine to analyse how the components performed under huge stresses, way beyond those encountered in even the severest road conditions. The results of these tests were encouraging, says Tim Yates, Ricardo chief engineer for the project: "The validation provided by this physical test gave additional confidence to the predictive CAE methods that were used extensively to analyse almost all aspects of the design."

The fact that each supplier used its own software tool set for the programme might on the face of it be considered a source of potential discrepancies. Yates is reassuring in his views in this respect: "However complex they may be, the CAE software codes we use are essentially just mathematical

'The final delivery of the economy target versus the NO_x requirements was very, very hard'

Derek Crabb, Volvo Car Corporation

The Volvo D5 engine in figures

- Maximum power 163bhp at 4000 rpm
- Specific power 67.9bhp per litre
- Peak torque of 340Nm from 1750rpm
- Weight of dressed engine (as shipped) 186kg
- EU combined cycle consumption of 6.0 litres/100km in S60 application
- 0-100km/h acceleration in 9.5 seconds for S60
- 80 – 120km/h acceleration in fifth gear in under 10 seconds for S60
- Maximum speed of 210km/h in all three applications
- Operating range of 1170km for S60
- Regulated toxic emissions outputs for Volvo S60 D5 (163bhp) with manual transmission:
  CO_2 171g/km
  NO_x 0.443g/km
  $HC+NO_x$ 0.483g/km
  CO 0.348g/km
  Particulate 0.032g/km

'We are confident that our new diesel engines will give us a major upswing in European sales'
Hans-Olov Olsson, CEO, Volvo Car Corporation

models of physical engineering phenomena. If the phenomena represented are the same in two codes and an equal level of attention is paid to modelling, the results should be compatible – which is what we found."

With all the factors pointing in the desired direction – that diesel versions of Volvo's existing gasoline engines were the best way to go – the formal decision to go was finally taken in December 1998, though the split of responsibilities had been agreed before this.

"It had to be a very rapid programme," recalls Derek Crabb. "Though we had built the concept engines, the final decision to go with this concept was taken very late, and we were targeting early 2001 for completion."

The partners agreed on a gradual transfer of responsibility to Volvo Car as the programme progressed. To start with, says Crabb, "It was them doing 100 percent of the work for us". However, by the start of production Volvo were 100 percent responsible for the build process with Ricardo and AVL providing support.

The partners faced a tough set of targets – and not only those imposed by the exceptionally tight 24-month programme timetable. Derek Crabb again: "We very much said to Ricardo: 'This is the block and crank we've got – we think it can go into a diesel of this capacity and we think we can get this number of horsepower and this much torque. Please can you validate this.'"

Further targets were set in terms of fuel consumption, emissions, NVH, packaging and of course durability. At this stage the programme was for a family of three engines based on the inline four, five and six-cylinder gasoline units: Volvo's overriding priority of crash safety had always meant that broader V-configuration designs, which reduce the available impact absorbing crumple zones, were out of the question.

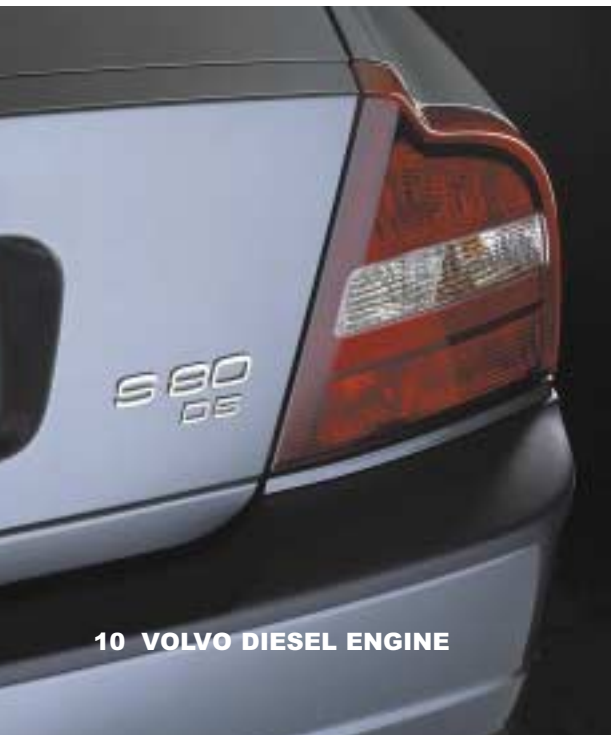
Of the three diesels it was the 2.5 litre five-cylinder, designed to power the as-yet unrevealed new-shape V70 and S60 models, that was singled out as the top priority. Yet even this suddenly appeared up in the air when Ford announced its takeover of Volvo in February 1999: the concern was that Volvo would be encouraged to utilise the existing Ford diesel range rather than continue developing its own product. In the event these fears proved largely unfounded, and only the four-cylinder (which clashed directly with the PSA-Ford co-operative unit of similar capacity) was dropped from the programme.

Derek Crabb doubts whether the decision to go ahead with the diesel programme would have been any different under Ford than in the pre-Ford era: "The business case was sound, and Ford accepts sound business cases."

What did change under Ford, however, were the horizons and the ambitions encompassed by the programme. Derek Crabb takes up the story once more:

"By this time Dr Reitzle had entered the scene. He basically said that we should aim upwards. He urged us to 'go for the BMW six-cylinder – use that as your benchmark … I accept that we've only got a five-cylinder, but the BMW is the car that we're competing with, and that's what we must use on all our test drives.'"

Dr Reitzle's exhortation to take on the very best only added to the challenges faced by Ricardo. Yet there was an important trump card: Volvo had the promise of being the lead customer for Bosch's very latest, second-generation common rail injection system with its attendant major potential benefits in emissions, consumption and NVH control. This, coupled with the pioneering use of an all-aluminium cylinder block and electronically-controlled cooled exhaust gas recirculation, promised to make the Volvo D5 the most advanced passenger car diesel engine in the world as well as a highly effective motor for Volvo's advance into the premium executive segment.



Design solutions

With Volvo's forthcoming range of cars already at an advanced stage of development, it was clear from the outset that any diesel solutions would involve the engines being made to fit the vehicle, rather than vice versa. "We were limited in what we could do," says Crabb, "so we had to optimise the small degrees of freedom we did have."

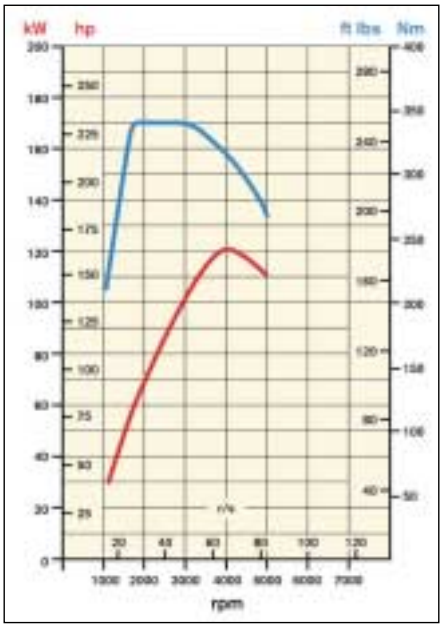
It went without saying that, as an engine from one of the world's most environmentally conscious car makers, the new Volvo diesel had to be one of the cleanest as well as lightest and best performing. Early on it was decided to use sophisticated injection and combustion systems to minimise raw engine-out emissions, rather than employ complex after-treatment mechanisms to clean up the exhaust afterwards. In particular, says Crabb, Volvo did not want to go into technologies such as particulate filters or traps.

So the approach chosen was one of simple, clean combustion driven by electronic control not only of the injection timing but also of injection volume and pressure, as well as VNT turbo configuration and additional pre-injection pulses to manage NVH and emissions. The provision of electronically regulated and cooled EGR would help limit combustion temperatures and therefore NO_X emissions, while a tandem catalyst arrangement would look after the remaining emissions under both cold-start and operating temperature conditions. The cooled EGR alone helps cut NO_X emissions by seven per cent compared with non-cooled systems.

The ability to manipulate these many degrees of freedom – especially the injection pressures up to 1600 bar available with the Bosch common rail system – proved to be the key to the achieving of the tough targets imposed on the D5 programme. For obvious reasons the three partners are still coy about the actual numerical values put forward in the original specification, though Crabb is willing to confirm that the 6.0 litres per 100km consumption so spectacularly attained by the middleweight S60 sedan was indeed one of those original targets.

What is also evident is that, even setting aside the whole issue of the compressed two-year timeframe, this was a very demanding programme that demanded maximum effort and co-operation from all concerned in order to meet its tough objectives.

"Clearly," says Crabb, "the final delivery of the economy target versus the NO_X requirements was very, very hard. The final calibration work was done by a combination of people from all three partners."



Power and torque of the 2.5 litre Volvo D5 are among the the best in the class

Evidence of the success of the programme comes in many forms. The engine's light weight, for instance, is crucial to performance, emissions, economy and vehicle handling. At 186kg the finished unit is just 18kg heavier than its gasoline counterpart.

The final power and torque values of 163 horsepower and 340 Newton metres from just 1750 rpm speak for themselves. The torque figure is greater even than that of the prodigiously powerful, gasoline-fuelled T5 turbo from Volvo's fastest sports sedans; it more than amply fulfils CEO Hans-Olov Olsson's stipulation that driving enjoyment should be "top of the list of priorities in the development of the D5" and that the driver should feel that the engine has more power than it actually has.

Tim Yates, D5 chief engineer at Ricardo

At 67.9 bhp per litre the D5 also has one of the highest specific power ratings of any diesel on the market – yet its emissions values, way below the current Euro 3 norms, are also among the very best. As an instance, the D5 performs well on NO_X, with certified values of 0.443g/km. Even in the sensitive area of particulate emissions the D5 scores highly, with a grams per kilometre rating of 0.032.

The market

Anyone in any doubt about the potential of diesel engines for large cars need look no further than the registration statistics in the premium segment. It is hard to be a serious player in the executive car business without a top-notch diesel engine, particularly in southern and western Europe.

Yet even France, with a diesel share of 82 per cent in the premium sector, cannot boast quite the highest penetration: that honour belongs to Belgium, where 87 out of every 100 premium buyers opt for diesel. Both Austria and Italy run at 70 per cent or more, and new CO_2 -related business-car taxation in the UK has swung the whole company car market dramatically round towards diesels. The pan-European figure for diesels in the premium sector stood at 44 per cent in the summer of 2001 when the D5 engine first appeared on the market – and since then Volvo's sales forecasts of 33,000 diesel-powered S60s and S80s in 2001 have proved if anything rather conservative. In Germany alone, 14,000 units were allocated for 2001. In 2002, with the V70 station wagon also brought into the diesel portfolio, the overall target is in excess of 50,000 units.

"We are confident that our new diesel engines will give us a major upswing in European sales," says Volvo Car CEO Hans-Olov Olsson, while Lars-Gustaf Hauptmann, project manager of the D5 pro-ject, points out that the D5 will put Volvo on the shopping list of an entirely new customer category in several key European markets.

"The new D5 is poised to play a central role in reaching the Volvo Car sales targets for Europe," he says. "It has a very efficient combination of power and torque, meaning high performance with low weight and very low emissions. The starting point was that the new Volvo diesel should be both sporty and cultivated, and offer absolutely world-leading qualities in a number of key areas: performance, fuel economy, noise level, weight and emissions. It is these criteria that customers in the premium segment prioritise when they specify a diesel engine."

Derek Crabb, for his part, can see the day when the Skövde plant produces more diesel than gasoline engines. "The way it is evolving, it is not that hard to see diesel being the ideal engine for a Volvo – not an R-line high performance Volvo with 300 bhp, but the average type of luxury saloon [and wagon] Volvo. The diesel engine is an ideal match – for me it is natural to expect diesel engine sales to keep on going up." ■

'Dr Reitzle's exhortation to take on the very best in the diesel market only added to the challenges faced by Ricardo'

Derek Crabb, Volvo Car Corporation

That final two per cent

How do you squeeze yet more from a transmission that is already the best? That was the challenge faced by Ricardo Motorsport, whose high-performance transmissions have been central to Audi's dominance of long-distance sportscar racing. William Kimberley reports

William Kimberley (left), editor of *Automotive Engineer*, presents the magazine's award for Best Engineered Product of the Year to Mark Barge of Ricardo Motorsport

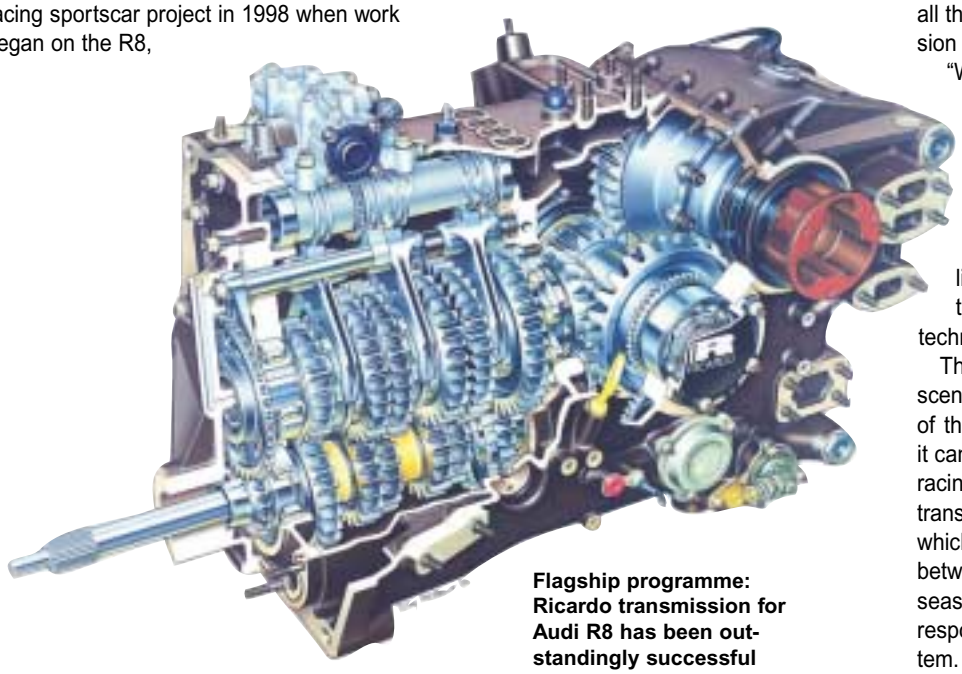
For the last two seasons the Audi R8 has been the class of the field, whether it be at the classic Le Mans 24 Hour race or the gruelling American Le Mans Series (ALMS). Its victories at the Sarthe circuit proved its domination with a 1-2-3 result in 2000 followed by a first and second last year, and in ALMS it has been beaten only three times in the last two years. So now Audi comes into its third season as the team to beat – a track record which brings its own pressures.

Ricardo first became involved in Audi's racing sportscar project in 1998 when work began on the R8, although the relationship between the two companies went back long before then. "Ricardo had been working with Audi on the German Touring Car and rally programmes for around 10 years, and I think they recognised our capability and were happy with the work we had done," says Mark Barge, motorsport director at the Ricardo Midlands Technical Centre at Leamington Spa. For the sportscar programme, though, the level of responsibility placed on Ricardo was to be considerably greater than just the supply of differentials.

"From supplying individual components," says Barge, "it was an order of magnitude switching to delivering a gearbox." However, this programme being Audi's first foray into sportscar racing, the Ingolstadt manufacturer still needed a high level of control and so decided on a division of labour. While Audi took responsibility for the casing and its transmission department acted as the interface with all the other vehicle architecture within the company, Ricardo concentrated on all the internal components of the transmission system.

"We already had a good way of working," Barge continues, "so off we went. What we really benefited from is the fact that Ricardo puts a great deal of effort into both its research programmes and the development of its tools and technologies, and the two lines converged. We were therefore able to demonstrate our ability to use these techniques on a new gearbox."

Three years and many victories later, the scenario has changed greatly. The success of the R8 has been truly outstanding. In fact it can claim to be one of the most successful racing cars ever produced. Of course, the transmission has played a vital role – a role which has led to mutual trust and respect between the two companies. So after the first season's racing in 1999, Ricardo took responsibility for the entire transmission system. In effect, this meant a new gearbox for



Flagship programme: Ricardo transmission for Audi R8 has been outstandingly successful

the 2000 season.

"In designing the ultimate race car," says Barge, "Audi wanted to capitalise on what it had learnt for itself – things like the aerodynamics, suspension system, general packaging and so on – while it felt confident in asking Ricardo to design and develop the new transmission. This was necessary as the transmission was subject to the same aggressive design targets as the rest of the car, particularly for weight, overall stiffness and shift time."

For 2001, the gearbox was further refined. "The package was set in terms of vehicle dynamics, the aerodynamics package and suspension points," explains Barge, "so we centred all our attention on the critical details such as further increasing stiffness, reducing the shift times and improving data integrity. The transmission carries a number of sensors for shift performance, and an amount of work was involved in the continuing development and optimisation of the shift system itself in terms of strategy and hardware." That the transmission was one of the cornerstones of the car's reliability, enabling it to notch up so many victories, has been well documented – so how do you improve upon the best if you are not to let the competition catch up?

"It's the classic case of the 80:20 scenario where 80 per cent of effort is put into achieving 20 per cent of gain, except that in this case it's more like a 98:2," says Barge. "Because both Audi and Ricardo believe the R8 is already truly optimised within the regulations, it was not worth our while starting with a clean sheet of paper. The most important thing is that the gearbox is already extraordinarily compact, it is very stiff and hopefully it is extremely reliable. So all our efforts are about minute performance gains.

"This means that we are now focusing more on traditional risk aversion," he continues. "We feel the pressure, as there is such a high expectation on the car to win. This means that we must now be more vigilant than we've ever been on schedules, components, sub-assembly performance, sign-off checks, the re-testing work, and our overall performance."

Barge is hyper-aware of the dangers of complacency. "There is almost a risk in the familiarity of this programme. We know what we're doing, we've been doing it for a few years, everyone knows everybody, we're off to Sebring, then the American Le Mans Series, then the Le Mans 24 Hour race – everything is now much more of a routine. The risk is that you lose focus and you turn your attention to other things, assuming that it's going to be all right on its own.

'Improving the race-car transmission is the classic case of the 80:20 scenario where 80 per cent is put into achieving 20 per cent of gain, except that in this case it's more like a 98:2'

Mark Barge, Ricardo Motorsport

"It means that we're just working in a small band – is it possible to reduce shift time or is it possible to continue to increase stiffness? We have been focusing all our efforts on making sure that every technical decision we make is a gain, rather than any form of risk or loss."

And just to concentrate the works Audi team's efforts all the more, it has last year's cars – now entered by the privateer Champion team – to compete with, as well as potent rivals from Cadillac and Panoz.

While the Audi programme has given Ricardo a great deal of exposure, it is not its only one in the motorsport arena. Less well known but nevertheless very significant, Ricardo is working with Italian constructor Dallara, which is providing cars for one-make series both in Spain and in the US.

"Over the last six months or so Ricardo has put more emphasis on its motorsport business in its entirety, and we have now created Ricardo Motorsport as a group-wide business stream," says Barge, with his eye on the lookout for more projects. Given his organisation's background of working on highly confidential programmes, undertaking projects in the motorsport world – where nothing is given away except on a need-to-know basis – is not a problem at all, he contends. "We have all the tools and experience to succeed, but from a commercial sense it's vital that we win new projects, break into new markets and expand our customer base."

That customer base already includes PK Sport, which will be fielding a private Porsche entry at Le Mans this year the team having benefited from Ricardo expertise in improving the torsional stiffness of the 911's body shell.

"The Dallara project is a good contract," Barge says, "as it provides a good volume of transmissions that is unusual in this business. Another good thing is that it is a manual gearbox rather than semi-automatic, so we can prove that our technology and expertise work in all areas of the market. It's also a chance for Ricardo to take another project into the public domain and make sure that we're not remembered only for the Audi one – because if you're not careful, success can be counter-productive. The very next question is 'And then what did you do?' "

However, all eyes are still fixed on Audi. This is the flagship, the one that is the centre of attention on both sides of the Atlantic. The first ALMS race – the Sebring 12 Hours – has already taken place, with Audi finishing first and second. This has got the team off to a flying start, even though the second place car was the privateer Champion R8 driven by Jan Lammers, Andy Wallace and Stefan Johansson, behind the works car driven by Johnny Herbert, Rinaldo Capello and Christian Pescatori.

The works team will probably opt to miss the second round of the 10-race series at Sears Point in California, as it is held between the Le Mans test days and the race itself. That means the countdown has already begun to the main event in June, in which Audi expects… ■

William Kimberley is editor of Automotive Engineer magazine

Adept adaptor

With peace-keeping operations an increasingly significant role for the British Army, a practical means of deploying its vehicle assets is needed. The Rapid Deployment Vehicle (RDV), based on a Land Rover conversion, is a Ricardo development whose mettle has now been tested in some very demanding environments. Anthony Smith reports

The ability to move rapidly, and across difficult and potentially hostile terrain, is increasingly important to the British Army. In addition to their more long-standing commitments, British forces have in the past year alone been deployed on peace-keeping missions in Europe, Africa and Asia.

Traditionally the Land Rover has been the backbone of general military transportation, but in its adapted form – the Rapid Deployment Vehicle, or RDV – it occupies a leading role in peace-keeping situations requiring rapid deployment.

The success of the RDV is based on work carried out at the Shoreham facility of Ricardo Vehicle Engineering over the last ten years. John Lake, general manager for Special Vehicles, takes up the story: "The original concept on which the RDV is based was developed in 1993. We developed a conversion kit which could turn a standard Land Rover Defender into a multi-role combat vehicle incorporating a robust roll cage and weapons mounting.

"A small number of these initial kits were sold, predominantly to overseas forces. However, the idea attracted the attention of the British Army for use in a potentially much larger programme, and in 1997 Ricardo was asked to develop the concept on a more robust scale.

"The most immediate area for further development was the roll cage, which had to meet the extremely stringent military roll-over specifications. In addition to this, it needed to be single-hoop in configuration to free the upper structure for more high-calibre weapons mountings than the previous design could handle. A series of finite element analyses were carried out to develop and optimise the new design, which was subjected to physical roll-over crash testing in a prototype vehicle."

But rapid deployment of forces in most situations requires the use of aircraft to transport equipment to the theatre of operations. For this reason the design of the RDV also had to be made sufficiently robust for air-portability. As such it can be carried internally in a C130 Lockheed Hercules, and either internally or under-slung in standard helicopter transports such as the Chinook.

While the roll cage is the most immediately striking feature of the RDV Land Rover, it is the flexibility of this concept

which is truly remarkable. In peace-time, an army requires basic utility vehicle transport more than it requires peace-keeping vehicles, and this is reflected in the large number of standard Land Rover Defenders in military service. But when peace-keeping vehicles are needed, they are generally needed quickly and for deployment in almost any environment. The RDV concept is based on a "weapons mounting installation kit" or WMIK, comprising the roll-cage and associated components, which can be fitted to an army Land Rover to convert it from a standard transport into an implementation-ready peace-keeping vehicle in under four hours.

"The base vehicle fleet which is used for RDV conversion naturally requires a minor one-off modification to enable it to accept the WMIK system," says Lake. "This involves the provision of fixings for the roll-cage structure and the addition of chassis outriggers". The concept enables the army to optimise its vehicle assets – it can turn standard transports into peace-keeping vehicles extremely quickly when the need arises, and then covert them back when the job is done.

The RDV-converted Land Rover is a truly versatile vehicle, with a range of around 500 miles and a payload of up to 1400kg. Its standard crew is three – a commander, a driver and a rear gunner – although numerous alternative configurations are possible.

The Land Rover RDV entered service with the British Army in 1999. Many vehicles have been converted, and similar numbers of WMIK systems have been supplied. While it may not have received the media profile that was given to the similar-looking vehicle used by the fictional character Lara Croft in the movie *Tomb Raider*, the real-world and highly practical Ricardo-developed RDV has now seen active service in many parts of the world. It has become standard equipment for British forces, and its success has not gone unnoticed elsewhere. As well as further orders for the British Army, a number of vehicles have been supplied to the forces of several NATO member states. ■

'The design of the RDV had to be made sufficiently robust for air portability – either in a C130 or underslung below a helicopter'

Main pictures: PA

Finite element analysis (far left) was employed to develop a roll-cage to meet the extremely stringent military roll-over and air-drop specifications

Lean Boost Direct Injection Gasoline – a big idea about downsizing

Manufacturers are developing direct injection gasoline engines in the search for improved fuel efficiency. Lean boosted direct injection gasoline combustion may bring even greater benefits, as Anthony Smith explains

Whatever the ultimate fate of the Kyoto protocol, the pressure on manufacturers to reduce vehicle CO_2 emissions is likely to continue to increase in the coming years.

In Europe, through an agreement by the representative body ACEA, manufacturers are committed to a new vehicle fleet average CO_2 emissions level of 140g/km by 2008 (against an average of 185g/km in 1995 and 174g/km in 1999). Similarly in the US the prospect of bringing SUVs into the passenger car CAFE standard is refocusing attention on fuel economy. But while gasoline engine fuel efficiency improvements over the last three decades have been impressive, to say the least, much of the benefit derived from this has been swallowed up in the increasing kerb weight of today's typical passenger cars.

The impending fuel efficiency challenge is all the greater therefore. Greater, that is, unless customers are to be weaned off their taste for increasingly higher specification (and hence higher weight) vehicles – a prospect which few manufacturers regard as a likely one.

For Tim Lake and his gasoline research team at Ricardo Consulting Engineers, this challenge of pushing the boundaries of fuel efficiency is extremely familiar. They are responsible for the company's gasoline research programmes and are pursuing a range of new technologies for improved fuel economy. One such initiative is the development of a new Lean Boost Direct Injection (LBDI) gasoline combustion concept.

"If you examine the typical sources of energy loss in a gasoline engine, it becomes immediately apparent that there are four areas in which you can address efficiency improvements" says Lake (see figure 1).

"First of all you can attempt to reduce the thermal energy being lost through the exhaust gases. Secondly there is the heat lost from the engine to its coolant and oil. Thirdly there is the energy consumed in mechanical friction, and finally there are the losses associated with the processes of gas exchange. In developing the LBDI concept we are seeking to address improvements in all of these areas simultaneously."

One of the most promising avenues for these improvements in both gasoline and diesel engines is 'downsizing': the development of engines of increased specific output and reduced swept volume. The LBDI gasoline engine is an example of this, combining direct injection, lean operation and pressure charging to enable a smaller engine – with consequently fewer losses and hence greater fuel efficiency – to take the place of larger and less efficient current production engines.

A fundamental concern with the operation of a pressure charged gasoline engine is the minimum octane requirement of the fuel. Typically, manufacturers seek to reduce the compression ratio in a boosted engine to avoid combustion knock. Unfortunately, while knock may be avoided, this reduction of compression ratio has the unwanted side effect of reducing thermal efficiency. However, the LBDI concept's combination of direct injection and homogenous lean operation both act to reduce the octane requirement, which in turn enables a higher compression ratio with its associated improved thermal efficiency (see figure 2).

The theoretical basis of the LBDI concept can be explained in terms of the effect of boost pressure on the operating band of air-fuel ratio of the engine. As the intake air pressure is increased, so the achievable indicated mean effective pressure (IMEP) also increases. At the rich limit of air-fuel mixture for a given boost pressure (the minimum practical excess air factor), combustion stability is hindered by ignition retardation due to knock. So with increasing boost pressure, the rich limit becomes more lean. Similarly, at the lean limit of air-fuel mixture for a given level of boost, combustion stability is limited by spark initiation and flame propagation.

As this limit improves with boost, the overall operating band becomes leaner with increasing boost. At any given boost pressure, as the air-fuel ratio moves from the rich to the lean limit, engine output will decrease. The objective in developing an LBDI engine is therefore to boost to the desired level of IMEP for the downsized engine – typically significantly higher than that achieved at stoichiometric operation of the equivalent naturally aspirated engine – while maintaining a homogenous lean mixture of between 1.4 and 1.6 excess air factor. To minimise the airflow demand on the engine (and hence gas exchange losses) the richest mixture that allows stable operation at the desired IMEP is selected (see figure 3).

So much for the theory. What about the practical validation?

"There is a range of tools available to us in assessing a concept such as this," explains Lake. "Most of the development work is typically carried out on a single-cylinder research engine, and the Ricardo Hydra is an obvious choice for this. For the initial development work a 74mm bore, 75.5mm stroke configuration was used, giving a swept volume of 324.7cc. In parallel with the single-cylinder test programme we also conduct a significant amount of CAE work using software tools such as WAVE and VECTIS".

One application of CAE is to assess the likely multi-cylinder performance based on the test results from the Hydra. It is well

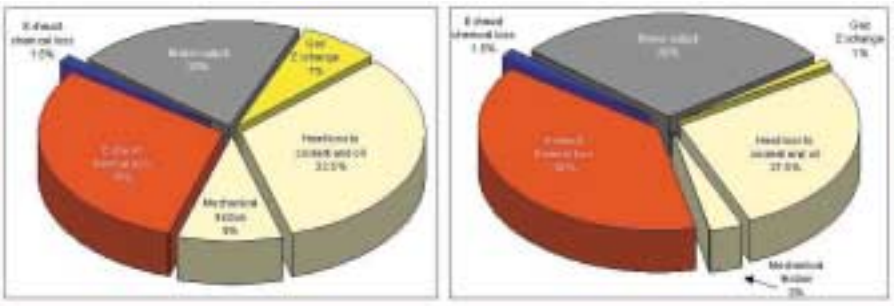


Figure 1: Typical brake output and energy losses at part load (left) and full load (right)

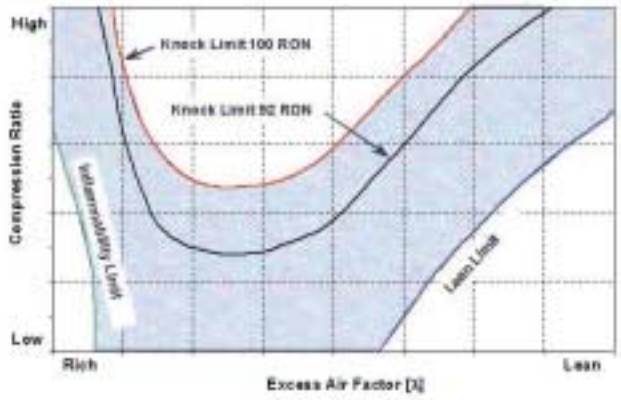


Figure 2: Octane requirement versus air-fuel ratio

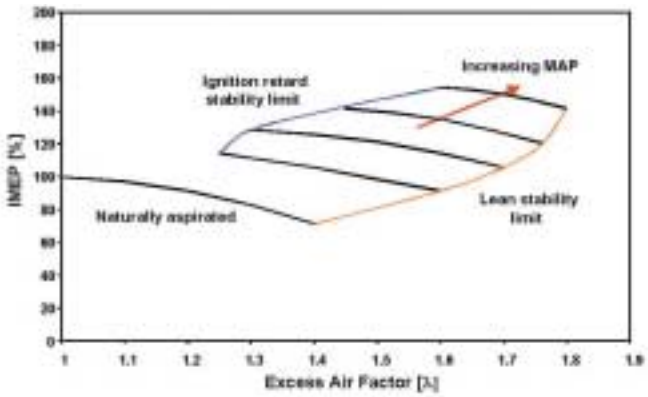


Figure 3: Theoretical basis of LBDI concept

established that the volumetric efficiency of single-cylinder research engines is often lower than their production multi-cylinder counterparts. For this reason a higher boost pressure is applied in single-cylinder test work in order to match and correlate the likely performance of the multi-cylinder application.

Combustion stability is widely accepted as presenting perhaps the most significant challenge to the development of LBDI gasoline engines. "We knew in advance that cycle-to-cycle variations in IMEP were likely to arise from a number of contributory factors such as air-fuel ratio, ignition timing, injection timing and boost pressure," commented Lake. "However, we found that by far the greatest impact on stability came from the ignition system used."

The team found that through incrementally optimising the ignition system during the development programme, they were able to increase significantly the maximum combustion-stable level of IMEP. The final ignition system comprising a coil-in-plug unit with high-ignitability platinum electrodes achieved an increase of over 15 per cent in combustion-stable IMEP compared with the standard baseline system. But if the ignition system offered a clear means of improving combustion stability, so too did the opportunity to develop a dual-injection strategy. A second injection pulse is used late in the cycle: this, together with the associated partial stratification of the charge, was found to reduce cycle-to-cycle variations significantly.

The full impact of the LBDI concept can be appreciated when comparing torque curves. The similarity of the curves for a 1.2-litre LBDI engine with variable nozzle turbocharger (VNT) against a typical current-production 1.6-litre port-fuel-injected (PFI) gasoline engine demonstrates that downsizing of 25 per cent on swept volume is clearly a very practical proposition. However, in common with all downsized turbocharged engines, torque at low speed remains the limiting factor rather than maximum power. To move beyond this level of downsizing and achieve even greater fuel efficiency benefits would be possible, but it would require the addition of more advanced boosting concepts such as an electrically-assisted turbocharger or, alternatively, mild hybridisation.

In order to evaluate the LBDI concept in a European vehicle application, a simulation model was created to represent a generic lower-medium C-segment car typical of current production and powered by 1.6-litre PFI naturally-aspirated engine. This was compared with two further models powered by a 1.2-litre LBDI gasoline engine with VNT turbocharger and intercooler, respectively calibrated for optimal fuel economy and for low NO_x. Over the NEDC drive cycle the LBDI vehicle with maximum fuel economy calibration was predicted as delivering a 17.5 per cent improvement in fuel consumption with a similar improvement in CO_2 emissions. Against this, the low NO_x calibration of the lean-boost engine showed a 17-20 per cent reduction of engine-out NO_x for a 2-3 percent fuel economy penalty over the economy-optimised version – clearly a price worth paying given that aftertreatment for NO_x is a crucial aspect of this concept.

The concept was also evaluated based on a 4000 lb (1800kg) sports utility vehicle intended for the US market, incorporating a 4.0-litre PFI naturally-aspirated engine as a comparator for a 3.0-litre LBDI unit with the same alternative calibrations as the European example. In this case the vehicle was evaluated against the FTP drive cycle. Fuel economy improvement for the LBDI compared with the PFI engine was greatest (up to 13 per cent) for the city cycle where operation at part load gives maximum advantage. The overall combined EPA fuel economy benefit was 10 per cent for the optimal fuel economy calibration and seven per cent for the low NO_x calibration.

The results so far look very promising, but where next for LBDI research and development? "The LBDI concept shows considerable potential and has attracted a lot of interest from the OEMs," says Lake. "We have already started on the next stage of the research in collaboration with a number of engineering partners including Ford and Johnson Matthey."

This project will involve development of the concept in a C-segment demonstrator vehicle, and will include a much more rigorous evaluation of in-vehicle performance and feel. The eagerly-anticipated results of this work should be revealed in mid-2002. ■

The Ricardo gasoline research team: the next stage for LBDI will also involve Ford and Johnson Matthey

Renault's bold vision

Maxime Boniteau has been director of product planning for upper range models at Renault since August 2001. Before that he spent five years in China with Magneti Marelli. He spoke to Tony Lewin in Renault's plush *Atelier* on the Champs Elysées in Paris as the company prepared to launch the Vel Satis, its radical bid for a share of the high-image luxury car market dominated by Mercedes-Benz, BMW, Audi and Jaguar

Why is it necessary for Renault to compete in the E-segment?
We believe we need to be present in the segment because it is also a very good way to be sure that all our vehicles have the same quality. We want to exist as a global player in the car industry: for us, the E1 segment is a big part of the car world.

Is it a question of the prestige of the whole brand, or the technical filter-down to lower priced models?
Probably both. We want to be sure we are recognised as a carmaker who is able to make the right car with all the right fundamentals. To be recognised as an E1 or E2 segment player shows that we are in complete control of all the fundamentals of the car. The second point concerns the smaller models in the Renault range: if we are not in the E segment we may lose out in terms of image and appeal. We see that our German competitors are moving down towards smaller car segments, and we don't want to leave them an open space.

You say you are a global player, yet you are not in the USA. Why not?
We are there in some ways, because Renault is not a single company. We are part of the Alliance, and the Alliance is a place where Nissan and Renault have their own territory – and I don't mean this strictly geographically. Nissan is recognised as a real player with its Infiniti brand. Today it is not on the agenda to restart the Renault brand in the US, so we are leaving North America for the Nissan group.

Would you rebrand the Vel Satis as an Infiniti for the US?
It is not in the plan, but we have considered this possibility.

On a design and manufacturing level, what are the changes that entry into this class has forced on Renault?
All our upper segment cars are built in one plant – the Laguna, this Vel Satis, and soon the new Espace. Building this car forced us to be very careful on all the details because in this sector all the fundamentals have absolutely to be there. We already have the fundamentals: the Laguna is the only car to score five EuroNCAP stars. In terms of safety we have done a good job; in terms of engines, the Alliance gives us access to a range of power units which we have not had in the past.

Is that enough to allow Renault to compete at this level?
We have worked hard to offer these upper range customers something they don't get in other cars. We offer our customers space and roominess, for instance, and small details well thought through. We started by designing the interior, and after that we made a car around it: we started with the customer's needs.

How will you know when you have succeeded?
When customers buy the car. We have a reasonable target in terms of volumes, and we hope that we will convince even more people than we have targeted. Right now, we hope that the vision we have shared and the choices we have made will be accepted by the customer.

Will there be an external sign of success, maybe the French president riding in the back?
Our best success will be when we have an individual saying "I've bought this car and I am very happy with it". Or when a normal customer [for a German car] says "I've changed my mind and I have decided to move to you because of the way you take care of me and my family."

So is the Vel Satis a different way of doing a normal job, like a B&O hi-fi or an iMac computer?
Yes, we admire those products. Some of our customers want to have the technology, and we have to have technology in this car. But the technology has to be discreet and presented in a way that's friendly . We don't want lots of plastic buttons – we want a more French touch.

What is the benchmark for quality you use?
We use all our best competitors: the German products and also North Europeans such as Volvo and Saab.

How do you see the evolution of the E-segment in terms of body shape?
We have established that the normal three-box sedan car is continuing to decline as a percentage of the market – it's now below 50 per cent in Europe. North America is something different because all the SUVs and trucks are part of the picture, something that is not the case so much in Europe. We believe that not being three-box, traditional, German or North European gives us plenty of space to grow. This car is different, and we see that more and more people want something different.

At the Detroit show, crossover vehicles were strongly in evidence. You recently showed the Koleos concept: does this mean crossovers will join the Renault range?
Yes, the Koleos was a nice concept car. I cannot say too much about it, but we are definitely considering it as an E-segment contender. There are plenty of approaches to this segment, and we can see some very interesting things.

Is diesel power essential in this segment?
Definitely yes. With the Vel Satis the proportion of diesels will be 60 to 70 per cent, and for this we have two diesel engines – a three-litre V6 which comes from Isuzu and is linked to an automatic gearbox, and either automatic or manual gearboxes with the 2.2 DCi common rail four-cylinder engine.

You offer five-speed automatics and six-speed manual gearboxes, but competitors such as BMW and Jaguar have moved to six-speed automatics. Will Renault follow?
It's a possibility. Today, we have a five-speed; yesterday we had four-speed. These days, the way you handle and manage the speeds is more important than the number of speeds you have. Electronic management is the key: our gearbox is auto-adaptive – it learns the way you like to drive so that it can move the car in the most appropriate way. We know the six-speed has better consumption, but we have a good five-speed right now.

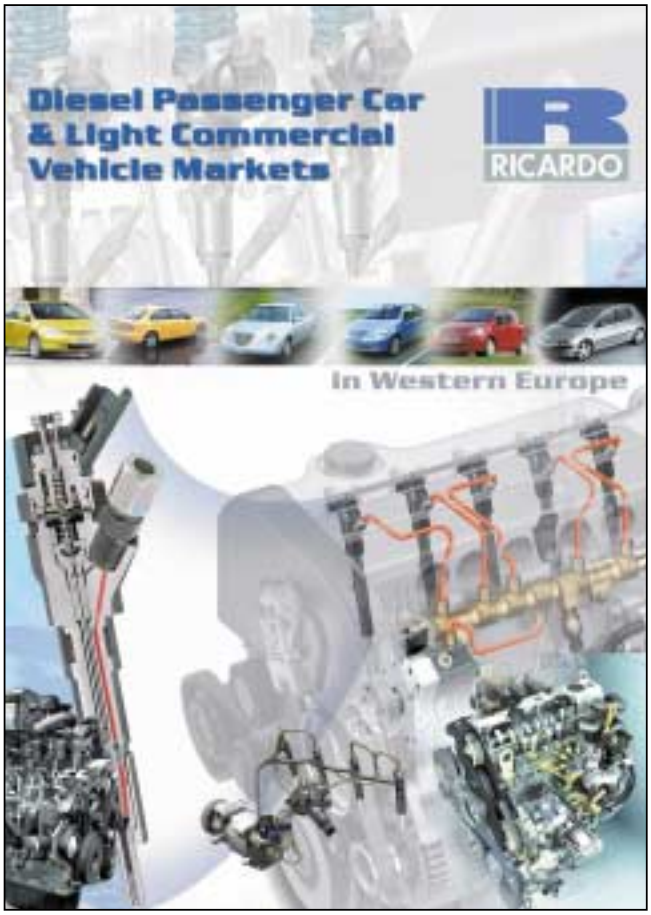
Electronics is rising fast as a proportion of the cost of the car. What are your thoughts on how this will evolve in the next four or five years?
That's a tough question. In fact, in terms of the value content [of the vehicle] the next big frontier to cross is the implementation of drive-by-wire. This is where electronics will be present in significantly greater proportions. Today we are close to that frontier and we still keep both mechanical and electronic control, but drive-by-wire will definitely be implemented as soon as we can guarantee completely that it is safe enough. It gives us extra flexibility in design of the engine and other components inside the vehicle. We're working on it just like everyone else is – and we've already made a move with the automatic [parking] brake, which is both electronic and mechanical. We have to move step by step so as to avoid any trouble for the customer.

Are you working with any particular suppliers on drive-by-wire?
Different Tier 1 suppliers have different solutions: we are working closely with all our suppliers in partnership. This kind of new technology really does need to be tackled with the vision of a partnership. This is what we have done with the keyless [entry] system; it's what we have done with the automatic [parking] brake. Partnership is the main theme of our purchasing vision.

You have got a lot more content in this vehicle than in, say, the Laguna. How do you manage it on the same production line? Does it not slow down the other cars?
These two vehicles – and, soon, the new Espace – are produced on the same flexible line at the Sandouville plant. They share plenty of sub-assemblies and the plant is designed around a platform vision. However, some of the actions for the Vel Satis and Espace which are not on the Laguna are done away from the main line. An example of this is the chrome strip which runs above the doors on the Vel Satis.

Has Renault's relationship with Nissan changed through this programme?
We have a close relationship with Nissan, which also involves cross-company teams. Plenty of our components used in the Laguna are also used in Nissan cars, and we are sharing the 3.5-litre [gasoline V6] engine for use in the Vel Satis. But we will always respect the brand identity of Nissan and the brand identity of Renault – we are completely open in terms of using components as long as it does not mix the brand identities of the companies. This is the right way to save investment and reduce costs.

The European End of Life Vehicles (ELV) directive will soon come into effect. Have you built into the Vel Satis a provision for the cost of scrapping and recycling?
It is certainly a strong concern, and all the parts [in the car] are designed to be dismantled in an easy way. We can recycle a very very high percentage: to have the right materials is one thing, but to ensure easy dismantling is quite another. When it comes to the responsibility for the cost of the final scrapping, we don't know yet exactly what the law will be. We have designed this vehicle for minimum dismantling cost, either by ourselves or a third party, but I cannot say whether we have made any financial provision. This is the first stage: it is for the law to decide who's going to pay and how. ■



2002 Diesel Report links new technology to rising sales

Fuel economy demands and lower CO_2 emissions are driving manufacturers towards more advanced diesel engine technology, helping to fuel the continued rise in diesel passenger car sales across Europe, according to the latest Ricardo Diesel Report. Record sales, up by 12 per cent to over five million vehicles, gave a market penetration of almost 36 per cent. At this rate, Ricardo estimates that diesel sales will reach 40 per cent within a few years and 50 per cent by the end of the decade.

France and Germany saw the most rapid sales growth, and the UK saw a massive turnaround with a 39 per cent rise in diesel sales (to give 18 per cent market penetration) after six years of steady decline. Sales of diesel cars in France, Spain, Austria, Belgium and Luxembourg already exceed those for gasoline cars. All leading manufacturers reported rises in diesel sales, with the VW Group retaining overall leadership of the market.

Improvements in diesel engine performance, driving characteristics and refinement are helping to drive this sales growth across Europe. "In order to meet consumer demands for better fuel economy and EU CO_2 emission targets of 140g/km by 2008, carmakers are directing a lot of effort towards diesel engine technology," says Ian Penny, Director of Diesel Engineering.

"We have now reached a stage where the technological development of the diesel engine has caught up with gasoline and helped eradicate traditional disadvantages associated with diesel engines. Many potential car buyers today actually prefer the performance and refinement of modern diesel engines."

France has the largest share of the West European diesel market, achieving almost 24 per cent of total diesel car sales in 2001. Its 21 per cent sales rise gave a diesel sales total of 1.27 million units – representing over 56 per cent domestic market penetration. Germany, the second largest market for diesel cars, had a 12.6 per cent sales increase to reach almost 25 per cent market penetration, and Germany remains Europe's largest exporter and producer of diesel cars. Austria once again enjoyed the largest overall diesel penetration at 65.7 per cent, a new record for the major European markets.

In the UK, business car drivers trying to reduce CO_2 levels in the run-up to the new emissions-based company car tax, which started in April 2002, helped fuel last year's rapid rise of diesel sales.

Throughout Europe, increased development effort has brought rapid advances in refinement and performance. Common rail fuel injection systems are used on most new diesel engine designs. Better cooling strategies, improved fuel injection and more advanced turbocharger technology have led to production diesel engines of up to 180kW (240bhp). The report also highlights the trend towards smaller-capacity diesels of around 1.4 litres.

A major future technology is 'mild hybrid' diesel engines. Ricardo is collaborating with Valeo on the i-MoGen (Intelligent Motor Generator) research project, based on an Opel/Vauxhall Astra, which can return a fuel consumption under four litres/100km. The electric motor accounts for no more than 10 per cent of the engine's power output, and the 1.2-litre high-output four-cylinder diesel

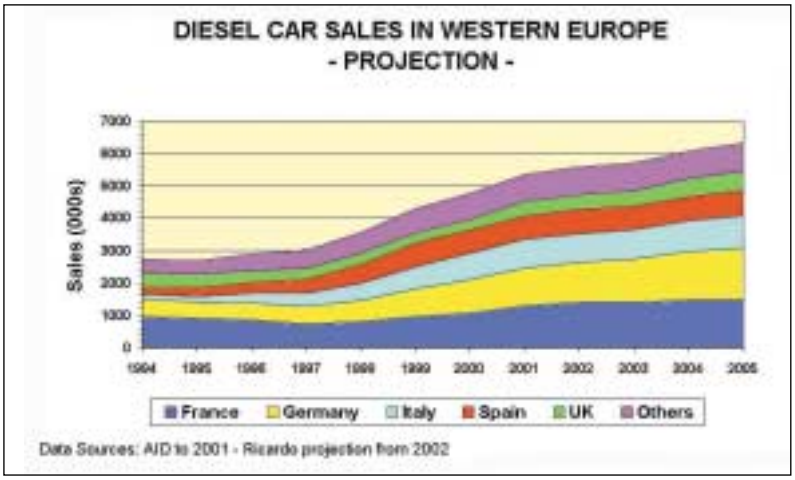
Interim results show growth and profits

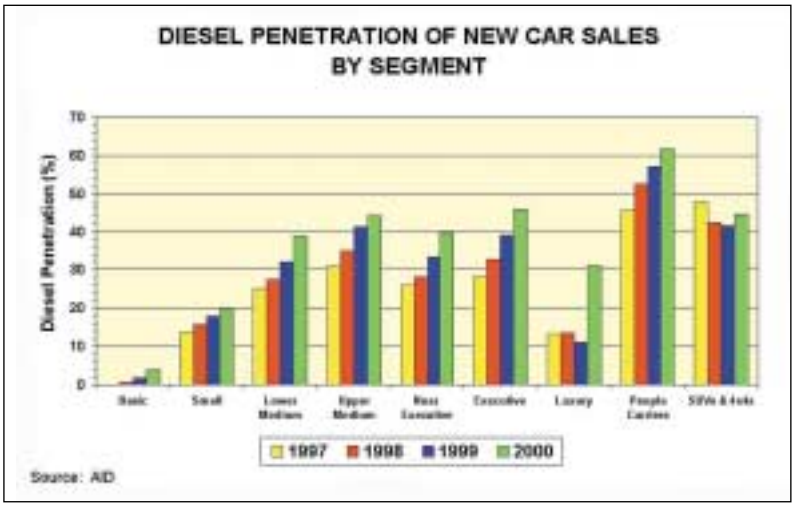
Ricardo has published its results for the six months ended December 2001. Its highlights include:

- Profit before tax up 12 per cent to £7.6m (2000: £6.8m)
- Order book up 15 per cent to over £57m
- Earnings per share up 13 per cent to 11.1p (2000: 9.8p)
- Interim dividend 2.6p (2000: 2.5p)
- Trend to outsourcing by OEMs and emissions legislation continue to support growth
- Exciting opportunities in newly created Motorsport division

"The new calendar year has started with a record opening January order book and a record January order intake across all of the business," said chief executive Rodney Westhead. "Despite some pressure on margins, we expect performance for the full year 2002 to be on track. Looking forward, there is greater uncertainty given the current difficult market conditions in the automotive industry but the group is well placed to exploit long-term trends in our key markets."

Mr Westhead described the pricing pressures applied by major customers in a competitive marketplace, but cited the growing importance of electronics as a rapidly developing area of expertise for Ricardo. The company sees further significant growth here in the future.





engine produces 83bhp per litre.

The report reviews sales and production data, analysing trends by vehicle type, by manufacturer and by individual major markets as well as covering Western Europe as a whole. It forecasts future marketing and technical trends and includes detailed engine performance tables.

The electronic report, which costs £400 for a single user licence, can be obtained from Ricardo Information Services at Shoreham in the UK on +44 (0) 1273 794230.

Ricardo diesel seminar

A Ricardo Technical Seminar in May can help you find out why more and more Europeans are opting for diesel cars. Entitled Passenger Car Diesel Engines in Europe, it takes place on 23 May 2002 at the Ricardo head office in Shoreham, UK.

The traditional belief is that Europeans buy diesel cars because they are cheap to run. The presentation challenges this assumption and explores the technical achievements that have fuelled the diesel market.

Ricardo will give a high-level forecast of how the market will change between now and 2010.

In recent years Ricardo has put much effort into technology roadmaps. The seminar will present the technology roadmap for passenger car diesel engines, taking a considered look into the future, and predicting not only the new technologies that will appear but also the time-scales of their appearance in the market place, their rise to pre-eminence, and their replacement with new technologies. Downsizing will be considered, along with boosting techniques and emission control systems. Also covered will be system integration and mild hybrids.

Ricardo suggests arrival in Brighton on the evening of 22 May, and can obtain hotel rooms at a special rate. The company will host a dinner in the evening at a restaurant in Brighton.

The charge for this seminar, per delegate, will be £500 (plus VAT for UK companies)/825 Euro/96,000 Yen, including the dinner, and the closing date for registrations is 8 May. Further details from Rob Thring at Ricardo, email address RHThring@ricardo.com.

Ricardo calibrates Focus rally kit

It looks like a Focus World Rally car, but at a starting price of £15,000 Ford Rallye Sport's Group A Focus kit is considerably cheaper.

Designed as a low-cost route towards a competitive car, the kit includes a fully-prepared bodyshell, suspension, brakes and a 165bhp engine, all in either asphalt or gravel specification. An extensive testing programme has been carried out at Ford's Boreham test track, and a prototype competed on the Ypres rally in Belgium driven by Patrick Magaud.

A very compressed development time scale led Ford to Ricardo for engine calibration development, including optimising power and torque figures while ensuring the Focus meets emission standards. "Rally cars are not exempt from these," says Terry Bradley, the project leader at Ford Rallye Sport, "as they are driven on public roads between stages."

The output of the 2.0 Zetec engine is raised from 130 PS to 165 PS, with new camshafts, a four-branch exhaust manifold and a revised air intake system. The exhaust system incorporates a racing catalyst. The flywheel is lightened to 5.5kg, carries a modified clutch cover and a six-paddle cerrametallic disc, and transmits the engine's output to a modified MTX 75 transaxle with a lower final drive ratio and a limited-slip differential.

The three-door bodyshell is fitted with a welded safety cage in T45 high strength steel, incorporating full side impact protection and suspension turret extensions. Seat mounting rails are welded to the floor pan. A full body kit includes front and rear wheel arch extensions in plastic, an RS front bumper and a unique rear tailgate spoiler.

The suspension uses Bilstein dampers with adjustable spring platforms, and braking modifications include larger-diameter discs, four-piston front calipers, twin-piston rear ones and a hydraulic handbrake. Two championships will be contested in Europe this year.

Engineering support for the **Maserati Spyder**

Maserati is committed to a strategy of producing high class and top performance vehicles with high technical content, but well refined and suitable for daily use. The new Maserati Spyder is a fine example of this strategy. It has been conceived as a car representing a synthesis of state-of-the-art technology, satisfying stringent crash and emission requirements and, meanwhile, featuring excellent performance and driveability.

A completely new V8 engine has been developed, and a driveline architecture with gearbox at the back was adopted for optimum weight distribution. The gearbox/differential unit is rigidly connected to the engine with a torque tube externally wrapping the propshaft. Transmission is available in both manual (GT version) and Cambiocorsa versions, the latter featuring four different shift strategies.

Refinement is a significant engineering challenge for this class of vehicle, as technical solutions aimed at optimising performance and dynamics often run counter to the interests of excellent refinement. Because of its enviable reputation in this field of work, Ricardo was chosen as engineering partner for this aspect of the vehicle.

Ricardo activities included NVH target setting, risk analysis and tracking. Where NVH concerns were identified, analysis and appropriate testing were carried out to identify countermeasures to be implemented rapidly and effectively. Close and effective communications were critical to the success of the programme, and for this reason Ricardo placed one of its Italian-speaking engineers as resident at Maserati.

The Spyder is an exceptional vehicle product and it is a great credit to both Ferrari/Maserati and Ricardo as engineering partner. As a consequence of the success of this programme, the partnership will be continued on existing and future programmes.

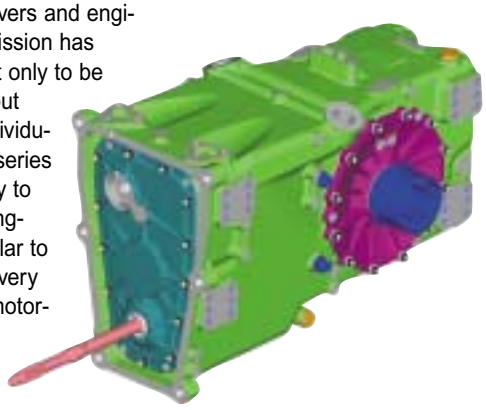
Dallara opts for Ricardo transmissions

Ricardo Motorsport has announced a three-year contract to supply Dallara, one of the world's leading motorsport chassis manufacturers, with transmissions for two new chassis for use in international single-seat race series.

Ricardo will design and manufacture 40 transmissions for Spain's Open Telefonica Formula Nissan series, similar in concept to Formula 3000, and the American-based IRL Infiniti Pro Series, the support series for the Indy Racing League. Both series will use fundamentally the same longitudinal transaxle, a six-speed sequential-shift unit with a 500Nm torque capacity.

"We're delighted to be supplying and supporting Dallara in Spain and America," said Mark Barge, director of Ricardo motorsport transmissions. "Both race series are important stepping-stones for many talented up-and-coming drivers and engineers. Our transmission has been designed not only to be cost competitive, but also to provide individuals racing in both series with an opportunity to experience a cutting-edge gearbox similar to those used at the very highest levels of motorsport."

The Dallara transmissions are being engineered, manufactured and hand-assembled at the Ricardo Midlands Technical Centre.



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Working together with our customers - the world's leading vehicle manufacturers and race teams - Ricardo leads the way in providing engine, vehicle, driveline and transmission engineering services and technology. Our people are our greatest asset. Their team spirit and their commitment to excellent quality of service is the very essence of our success and defines the culture of our technical centres in North America, the United Kingdom, Germany and the Czech Republic. Its what makes us Ricardo and its what moves the automotive industry.