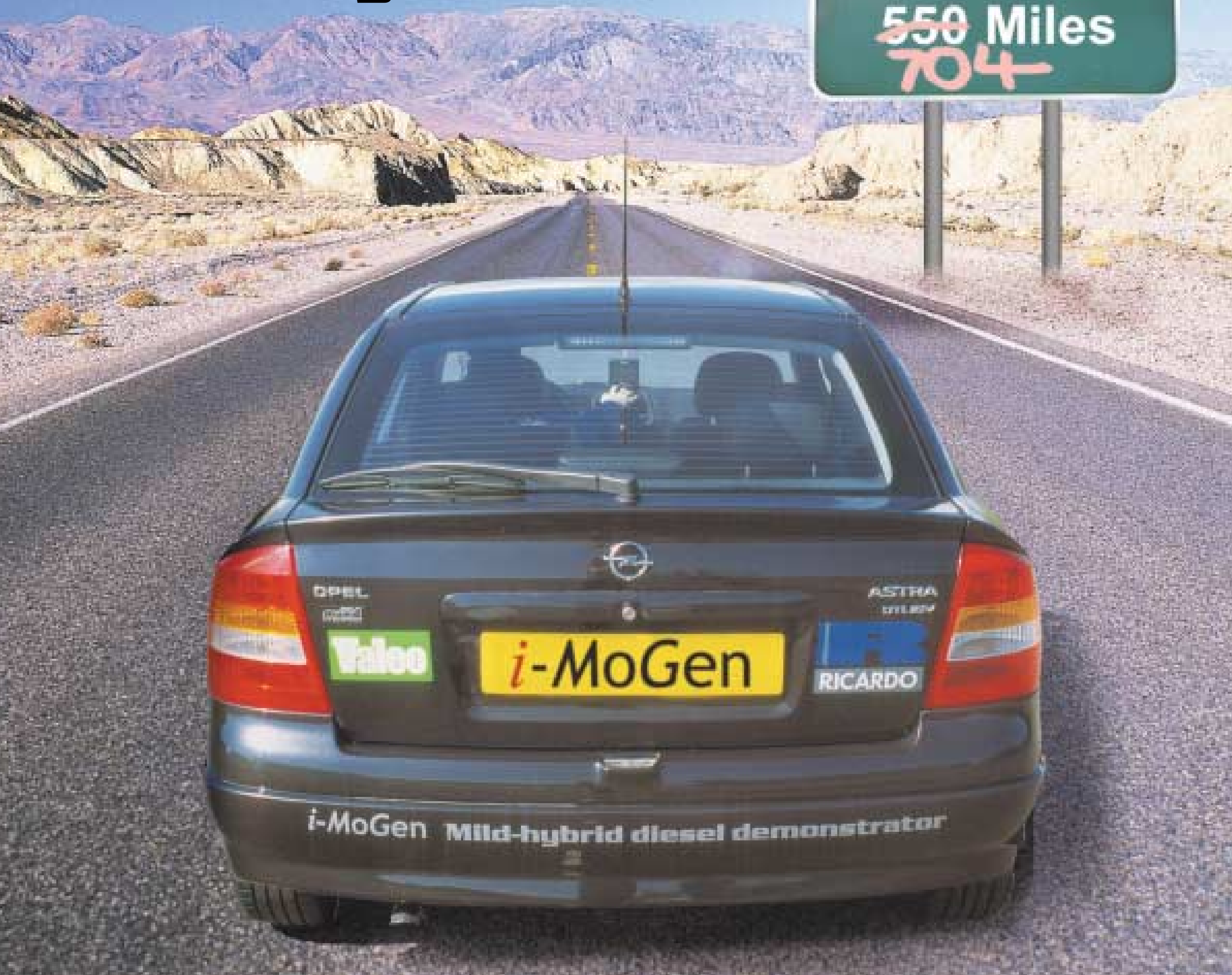
RICARDO

rQ
ricardo quarterly review

New horizons in powertrain efficiency



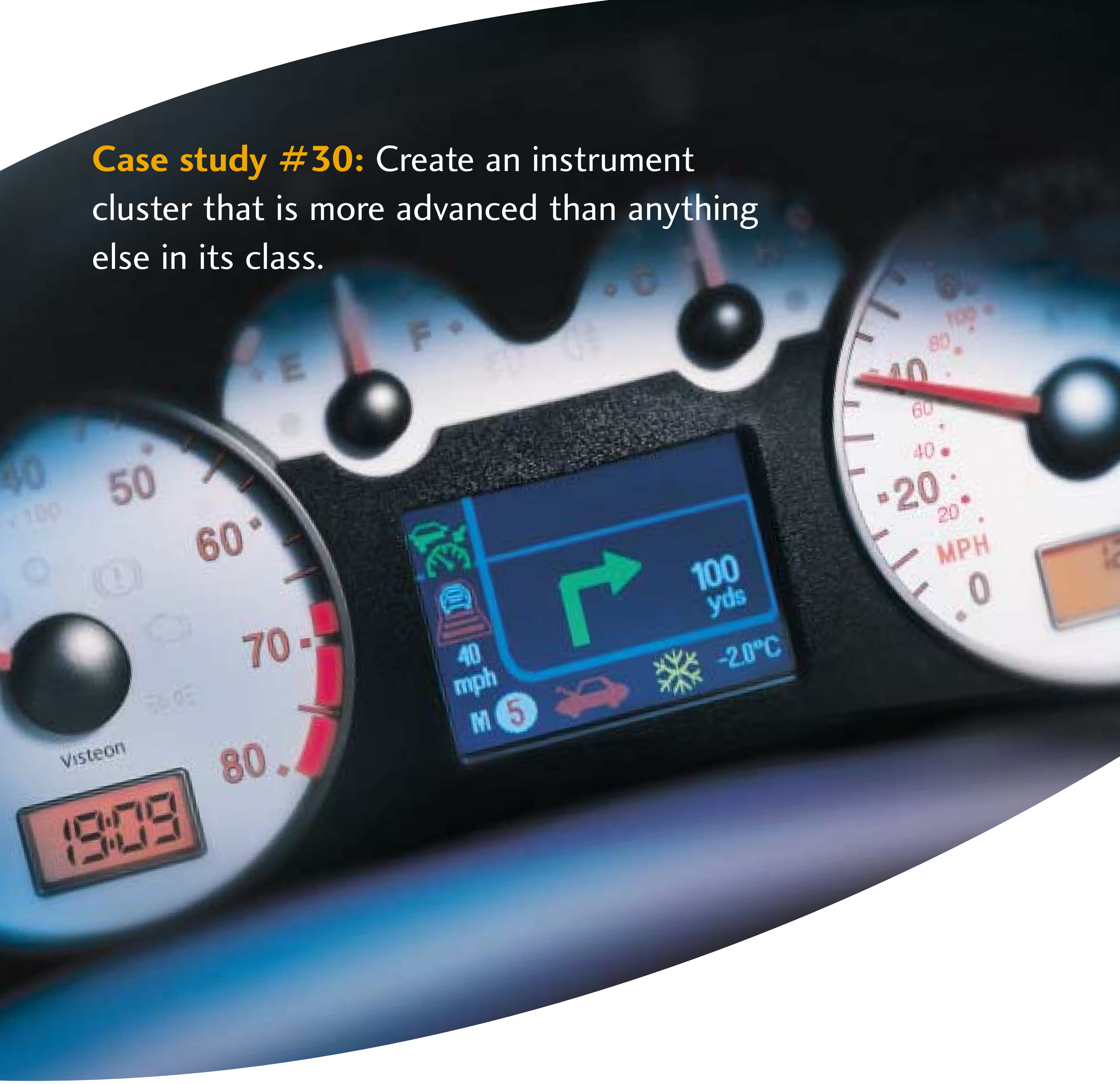
4 litres/100km and Euro 5: How the Ricardo mild hybrid re-writes the C-sector fuel economy rules

Interviews

Wilfried Bockelmann, Skoda
Thierry Morin, Valeo

Summer 2002

Case study #30: Create an instrument cluster that is more advanced than anything else in its class.



Challenge:

How can we design an instrument cluster with all the information a driver needs in one place for a C-category car?

Solution:

By integrating all the vehicle's data display into the main cluster incorporating an eight-colour screen that is easily visible to the driver. Not only that, the driver can personalise the display and it can, for example, remind him of birthdays or appointments. Visteon has also integrated safety related displays alerting the driver of adverse conditions or if he is exceeding the speed limit. This advanced technology, which you would normally expect to find only in higher vehicle categories, was in fact designed by Visteon for the new Fiat Stilo. You may not expect to find an instrument cluster like this in any other C-category car – but now your customers probably will.

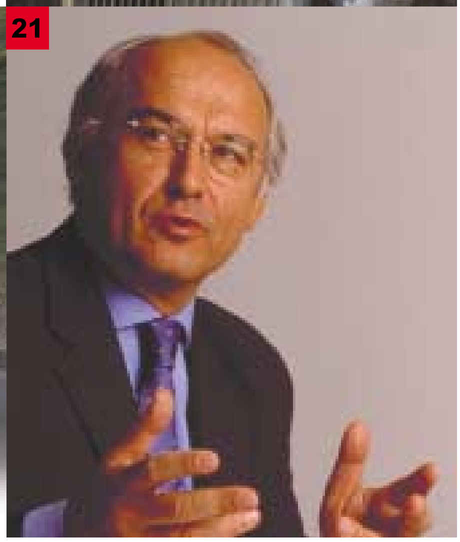
For more information visit:
www.visteon.com

Visteon

See the possibilities™

contents

Summer 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, Jeff Daniels, Paul Bale
Anthony Smith, Jesse Crosse, William Kimberley

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

● in brief

When is a truck not a truck?
This paradoxical question is fast becoming a headache for automakers in the US, especially the Big Three. Light trucks have always enjoyed much more lenient treatment than cars under Federal Corporate Average Fuel Economy (CAFÉ) rules, and for many years automakers have been openly bending the already flexible definitions to gain classification for a startling variety of vehicles as trucks.

So with the NHTSA starting talking about reclassifying borderline trucks as cars, the automakers are beginning to get worried about having to hit a 27.5 mpg average instead of just 20.5. At present all pickups and minivans are classed as trucks, as are SUVs – and even the Chrysler PT Cruiser. All that is needed to gain classification as a truck is one or more characteristics from the NHTSA list, which includes four wheel drive, a flat load floor, removable rear seats or an open load deck.

London black cab comes clean at last
What promises to be the cleanest – as well as smoothest and quietest – black cab has been developed by Powertrain Ltd, part of the MG Rover group. Substituting an LPG-fuelled version of Rover's K-Series engine for the cab's traditional rattly diesel has cut NO_x by 95 per cent, particulates by 92 per cent, CO_2 by 29 per cent and noise by 50 per cent. The cab will begin service in Birmingham, but it is hoped that the initiative – which attracts a government grant – will soon spread to London and other cities with black cab fleets.

Honda's micro-motor
Honda has developed the world's lightest four-stroke motor. Weighing just 2.8kg, the tiny 25cc GX25 develops 1.25Nm torque at 5000 rpm and is aimed at the market for hand-held garden equipment.

The Japanese company has also come up with a next-generation solar cell which does not require high-energy silicon in its manufacture. Instead, Honda employs copper, indium, gallium and selenium in a thin film cell that is easy to produce and which claims high levels of photoelectric transfer efficiency.

Industry news written and edited by Tony Lewin

Clean fuels field trial

A CONSORTIUM of German companies has announced it is to embark on an ambitious real-world trial of clean-energy vehicles, including hydrogen-powered fuel cell models.

The programme will be based in the German capital Berlin and brings together carmakers DaimlerChrysler, BMW, Ford and Opel, as well as MAN from the truck side, engineering firm Linde and fuel supplier Aral. One of the first moves in the five-year project will be the establishment of a hydrogen filling station in Berlin to serve the fuel cell vehicles in the 30-strong test fleet.

The Berlin trial shares several parallels with the California Fuel Cell Partnership. However, it also acknowledges the importance of diesel in Europe by including other fuels such as synthetic diesel and methanol in its remit.

In early June the Mercedes-Benz Necar 5 became the first fuel cell vehicle to complete a coast-to-coast crossing of the US when it was welcomed into Washington DC by Senate Auto Caucus Chairmen Carl Levin of Michigan and George Voinovich of Ohio.

The 3000-mile (5000km) journey is the most demanding so far undertaken by a fuel cell powered vehicle, especially as the itinerary included mountains and extreme weather conditions. The Necar 5, based on the Mercedes A-Class compact, can travel over 300 miles on a tank of methanol.

"Our goal was to make it to Washington DC to deliver the message that fuel cell technology is moving forward, but that there is still a much work to do. Whether we made it or not, it is critical for the development of fuel cell technology to try," said Dr Ferdinand Panik, head of DaimlerChrysler's fuel cell project group and outgoing chairman of the California Fuel Cell Partnership.

Meanwhile, President Bush has reaffirmed his opposition to the Kyoto treaty and dismissed as 'bureaucracy' a new report into global warming by the US EPA. The EPA report predicts among other things that total US greenhouse gas emissions will increase 43 per cent between 2000 and 2020.

DaimlerChrysler group launches global engine

Mitsubishi Airtrek: Likely home for new DCX global engine

KOREA'S Hyundai is to take the lead in the development and implementation of a new family of global engines which will power future generations of DaimlerChrysler group vehicles. Up to 1.5 million units of the new engine family will be produced annually, making it one of the world's most widely applied engines.

Mitsubishi and Chrysler group are equal partners in the Global Engine Alliance joint venture, which will be headquartered in the US but with each of the companies producing engines locally for its own model ranges. The Alliance has stated that the engine will be a state-of-the-art aluminium design with displacements of between 1.8 and 2.4 litres and power outputs ranging between 120 and 165 horsepower. It gave no indication of cylinder configuration or the types of injection and fuelling likely to be employed.

The company began operations in May 2002. Initial production of engines is expected by Hyundai in March 2004, and Chrysler and Mitsubishi output is scheduled to begin the following year. Mercedes-Benz brand passenger cars are unlikely to use the new engine.

Chrysler CEO Dieter Zetsche said that for Chrysler group the project represented the "tangible fruits of the alliance with Mitsubishi and Hyundai", hinting that the ventures like this could lead to even greater co-operation. The companies have already agreed to study the possibility of joint production of the engine in the NAFTA region in the immediate future.

At the Vienna Motor Symposium in April, reported *Automotive News Europe*, speakers including new Volkswagen CEO Berndt Pischetsrieder stressed the influence of developing markets in determining global engine design policy. Improved gasoline and diesel engines were realistic and cost-effective alternatives to hybrids, they concluded.

Big diesel raises Ford's pickup game

FORD has upped the stakes in the thriving US heavy pickup market with the adoption of Navistar's new six-litre direct injection Power Stroke V8 by the big-selling F-Series Super Duty. The engine was first shown in the mighty F350 Tonka concept truck at the Detroit Show in January and, with a rated output of 325 bhp, puts Ford to the head of a class where power and torque are key selling points.

The rival 6.6 litre General Motors Duramax, designed by Isuzu, gives 300 bhp and has contributed to the strong success of the Chevrolet Silverado and GMC Sierra. The equivalent Chrysler product, the Dodge Ram, features a 305 bhp 5.9 litre straight six diesel from Cummins.

Although the new Power Stroke is a structurally relatively conventional all-iron V8 and overhead valve, rather than overhead camshaft in its configuration, it incorporates modern features new to big diesels such as direct injection, common rail fuelling and four valves per cylinder. Also included are EGR and electronic control of turbocharger geometry. Peak power of 325 bhp is produced at 3300 rpm and maximum torque of 525 lb ft (746 Nm) occurs at just 2000 rpm. The engine is mated to a new five-speed TorqShift automatic transmission.

GM overtakes Ford in productivity

THE steady advance in productivity of General Motors' US plants has at last allowed the American giant to overtake Ford, the long standing leader among the Big Three, according to the 2002 edition of the influential Harbour report on manufacturing productivity.

GM's 4.5 per cent overall gain in plant productivity outpaced all other manufacturers, and its assembly facilities came best overall in six of the 13 assembly plant categories. GM also had the best V8 engine plant, at 4.55 hours per engine.

Nevertheless, the Big Three still have a long way to go to catch up with, let alone overhaul, the super-efficient Japanese transplants in North America. Nissan is still top, followed by Honda, Toyota and Mitsubishi. The report, which measures the labour hours absorbed in the production of each vehicle, still shows the Japanese plants way ahead: Nissan has an overall hours-per-vehicle figure of 17.92, while even with its rapid improvement shaving some four hours off its average vehicle assembly time, GM still takes a lot longer to do the same job. With labour accounting for some 20 per cent of the cost of the vehicle, says Harbour, the Japanese firms are enjoying a price advantage of between $500 and $700 per vehicle in the showroom.

GM has also become the best-performing domestic automaker in the respected 2002 JD Power and Associates Initial Quality Study, which showed vehicle quality at the 90-day mark to have improved 10 per cent over the 2001 result. Toyota group models topped nine out of the 16 categories – a record – but the Chevrolet Malibu and Buick Century took the Entry and Premium Midsize segments respectively.

A message from the Chief Executive

THE impact of global warming is perhaps one of the greatest issues facing mankind at the start of the twenty-first century. While some question the precise triggers for the greenhouse process, there can be few who deny its existence as a phenomenon or question the dire impact that it may have if it continues unchecked. There is also something of a growing consensus amongst scientists, environmentalists, engineers and legislators that reducing emissions of CO_2 - particularly from motor vehicles – will have a positive effect in slowing the process of global warming.

Hydrogen powered combustion engines and fuel cells are held in many quarters as the panacea that will lead straight to the goal of zero CO_2 emissions from vehicles. However, to be truly sustainable and effective in reducing global CO_2 emissions, this approach would require the synthesis of the hydrogen fuel to be based on renewable and CO_2-neutral sources of electrical power generation – something that might be considered a long way off given the current electricity generating mix of most of the industrialised nations.

While the automotive industry must of course prepare itself for such long-term challenges, it is perhaps of greater immediate importance for us to explore more pragmatic, near-market and production-ready solutions; solutions which aim to push forward the boundaries of fuel efficiency and thus maximise the amount of energy derived from each gramme of CO_2 released. Completed in early 2002, the Ricardo mild hybrid demonstration programme (i-MoGen) is an excellent example of this type of development and, as such, it forms the central focus of this specially extended issue of RQ.

Starting from a production 2.0-litre diesel Opel Astra car, the i-MoGen engineering team have delivered a demonstrator vehicle which realises a fuel consumption improvement of nearly 30 per cent without any loss in performance or refinement and without compromising the interior or exterior packaging of the vehicle. I have found it personally extremely rewarding to accompany the i-MoGen team to presentations at a number of European vehicle manufacturer locations. The response of the auto industry executives who have driven the demonstrator vehicle at these events speaks for itself – almost without exception they have been highly impressed with the quality of the drive and the practical and production-ready engineering solution that it represents.

Over the coming months we will be taking the i-MoGen demonstrator vehicle to our customers in North America and Japan. Nevertheless, particularly for those unable to attend one of our presentations, I am pleased that we have been able to produce this special issue of RQ so that the achievements of the programme can be appreciated by a wider audience.

Rodney Westhead

Engineering an astonishing turnaround

Professor Wilfried Bockelmann was recently put in charge of technical development at the Volkswagen group's newly created 'conservative division', where he has overall responsibility for future VW, Skoda and Bentley products. The development makes him one of the world's top automotive engineers.

A career Volkswagen man, Bockelmann joined Skoda board four years after its acquisition by VW in 1991 and was given responsibility for technical development. Skoda was then making around 200,000 cars a year. Today it is a half-a-million producer with an all-new product line whose quality has transformed Skoda's once-poor reputation. Shortly before taking up his new appointment, Professor Bockelmann talked to Richard Feast about the metamorphosis of his old firm.

What were the highlights for Skoda since it came under Volkswagen's ownership?
I guess we have three areas where you could say it was crucial. Let me compare Skoda with the other Eastern Bloc manufacturers. In the old times, behind the Iron Curtain, Skoda was always the technology leader. If you compare a Skoda at that time with a Trabant or Wartburg with their two-stroke engines, it was the high class car. So we already had a very high image in that region, because we used to be the high-tech manufacturer. This was completely different to Britain or the rest of Western Europe, where Skoda was known as the cheap car.

There was a tradition and there were engineers [at Skoda] who were capable of making cars – if you let them. That was not always the case in the socialist times. Up to the mid-1960s, Skoda still had good cars. Look at the old Felicia, the convertible, the old Octavia. Then came the rear-engined era, and the whole thing broke down, basically because they had no money to invest.

You need to spend a lot of money to develop a new car, to invest in new production technologies for a new car. And if you were in a socialist area, you had no money. At that time, maybe you could compare Skoda with companies like Polski-Fiat, with Lada. Now you can't.

Then, if you think of mergers like Daimler with Chrysler, how could you imagine a small company like Skoda could survive without [such synergies]? There's no chance. We had good engineers, and we could maybe develop a new gasoline engine and a new manual gearbox, but where do we get the diesels? Where do we get the automatic gearboxes? Where do we get all the ABS systems? For example, before Volvo joined the Premier Automotive Group, they bought their diesel engines from outside – and Volvo had more money. With a limited number of development engineers, you can't do everything. You have to buy some things from outside.

And that was the help [to Skoda] of the VW group. Then you could buy from inside the group. You know, access to automatic gearboxes, the best diesel engines in the world, technologies, processes and platforms. That helps a lot. Without the VW strategy, there was no chance to survive.

Have you ever added up how much VW has invested in Skoda?
Yes, there are numbers, but you cannot say what VW has invested in Skoda. I know if VW hadn't been there, we [Skoda] would have had no chance to invest. In the past four or five years, we have invested roughly 10 per cent of our turnover, which is very much higher than the average. Typically, you have four, five, maybe six per cent. We have always had two-digit numbers.

That's because we had to do everything from new. New paint shop. New press shop, New production assembly plant. That's all new (at Mlada Boleslav). We call it the brownfield, because you can use some of the buildings.

Some of the production output is used by the VW group, presumably?
Some, but not very much. We are still building up our company in several areas. For example, we invested in an engine and gearbox plant. The gearboxes started at the beginning of 2001, and we supply them to the group. The engine plant has just started with components, so we make blocks and heads, con rods. Complete assembly starts this year, so we are now supplying these parts to other parts of VW, where they are assembled as real engines. We have a capacity of 500,000 engines and gearboxes a year.

Does that make Mlada Boleslav a 500,000 cars a year unit?
Yes, Skoda is [a half-milliion unit]. Mlada Boleslav makes most of the cars, all of the engines, all of the gearboxes, but not every

car. We have three plants producing cars – Kvasiny, Vrchlabi and Mlada Boleslav.

Vrchlabi does every speciality version of the Octavia, for example. Every 4x4, the RS, most of the Laurin & Klements – the special things that disturb the big line. Kvasiny does the Superb. We have a completely new paint shop there, a new assembly line and body welding line. They do some of the Fabias [sedan versions], so we have some balance. Mlada Boleslav does everything else.

How many vehicles did you sell last year?
Roughly 462,000. The previous year we had about 450,000.

It sounds as though Skoda is reaching the limits of its manufacturing capacity?
I have a different point of view. You need a minimum sales volume to be a complete car manufacturer. If you do not sell more than 500,000 you are always very flimsy. You will not stand the storms and showers and so on. You need a certain volume. Otherwise, you must be a high-image maker, like Porsche or Ferrari. But if you are a volume manufacturer – as Skoda is – then you need a certain minimum output of cars, and that is 500,000. Look around the world, and you see lots of companies on that volume.

Then you can lean back and say, What are we doing? Do we need a million? No. We have reached this crucial point now.

Is it now a matter of debate about where Skoda goes from here?
Now it's a matter of quality of money. Now, if we have a certain volume of manufacturing, then we have to decide. Do we have to go to Liberia? Is there a better market than that? Is it better, for example, to increase in Great Britain instead of going to South America?

What are the answers?
Britain.

Does that mean Skoda will remain an essentially European phenomenon?
Not really. We are intercontinental, but we are not a global player.

Where else in the world can one buy a Skoda?
To the east side, we are the spearhead of the VW group.

In Asia?
No. We do not go to Japan. China is where we sell a little bit, but that is the home country of VW. In India, for example, we have started assembly. We are the biggest importer in Russia. Poland, we are No.1 in the VW group. So, if you look to central and eastern Europe, there we have a very strong foothold. This was typically Skoda, even before VW.

So, if you can make a better profit in the UK or Germany, forget Paraguay?
Something like that. We are not pressing cars into Paraguay just to reach volume. If you have reached this crucial point [500,000], then you can say, okay, now we can decide for the quality of the sales.

At 500,000, do you make VW's target of 6.5 per cent return on sales?
No, because we have lots of trouble with the value of the crown. The crown is very much over-valued because the euro is so weak. You know in Britain what happens. It's the same story. We have a very strong crown. That's our problem. We are exporting, so we get fewer crowns for the cars we sell in Europe at present. There we are suffering right now. We are not losing money, but we are not earning the money we would like to have.

The crown is very stable and very hard. The typical small company (in the Czech Republic) is going bankrupt because it can't compete with Poland, with Croatia and so on because the crown is priced so high. If you sell to the EU countries, you have this 10 per cent penalty.

In five years' time, presumably the Czech Republic will be a member of the EU?
Yes, I would say so.

What about Skoda as a company?
500,000 to 600,000 a year. A model range basically [the same as] what we have now. The big change is done.

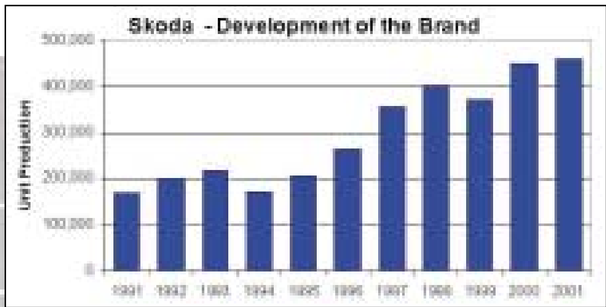
So it's a question of changing the quality of the sales?
Yes. And of the engineering and of production. We have to keep the model range that we have modern. We have to change the Octavia some time, but I don't think we will have another model range, and not the type of sales explosion of the past decade. Dr Piech [former VW group chairman], because he was engine-driven, always asked me: "why aren't you putting six-cylinder engines into the Octavia?" We could have done that three years ago. My typical answer was, "let's not run faster than the customer can follow us."

That was the point on which I convinced him. We don't have six cylinders in the Octavia. That's why we don't have eight cylinders in the Superb.

When I did my first drive in a Skoda, I was driving the biggest, most powerful, most luxurious car [in the range], from Mlada Boleslav to Ingolstadt. Do you remember at that time, in June 1995, what was the biggest, fastest, most luxurious car from Skoda? It was the newly launched Felicia. There was no Felicia Combi [wagon]. It had a 1.3-litre 68 horsepower engine, with pushrods, because the 75 horsepower 1.6-litre came later. Without air conditioning and without power steering.

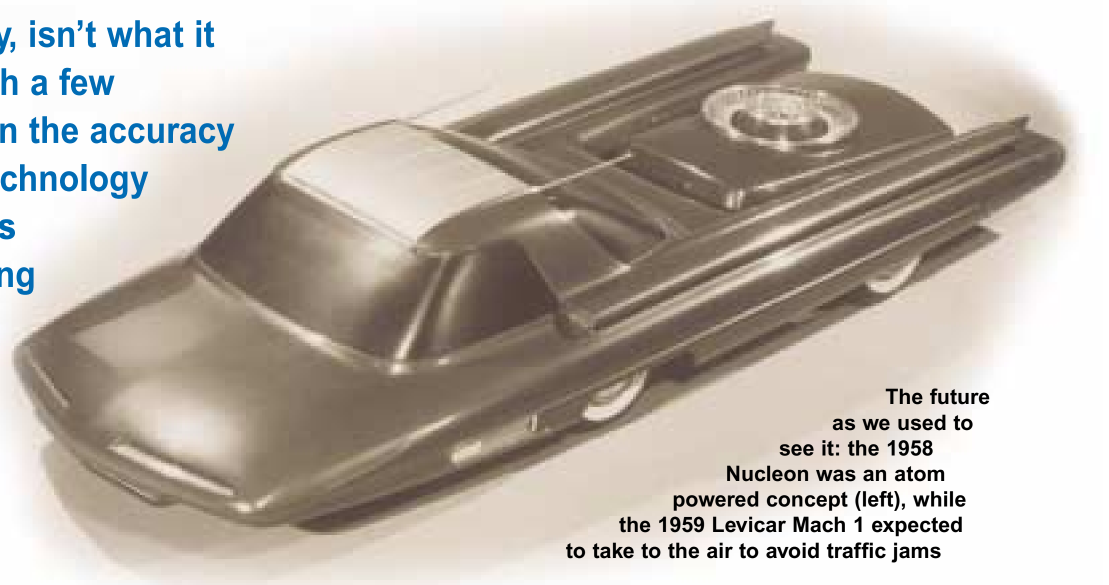
That was seven years ago. Now people ask,"why has the Superb not got an eight cylinder engine?" We would be running too fast for the customers. You could [always] say 'No' to Piech if you had [the right] arguments. ■

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



Motoring into the Future

The future, as they say, isn't what it used to be. Armed with a few sobering reflections on the accuracy of past predictions, technology specialist Jeff Daniels makes some fascinating predictions about the next half-century of automotive evolution



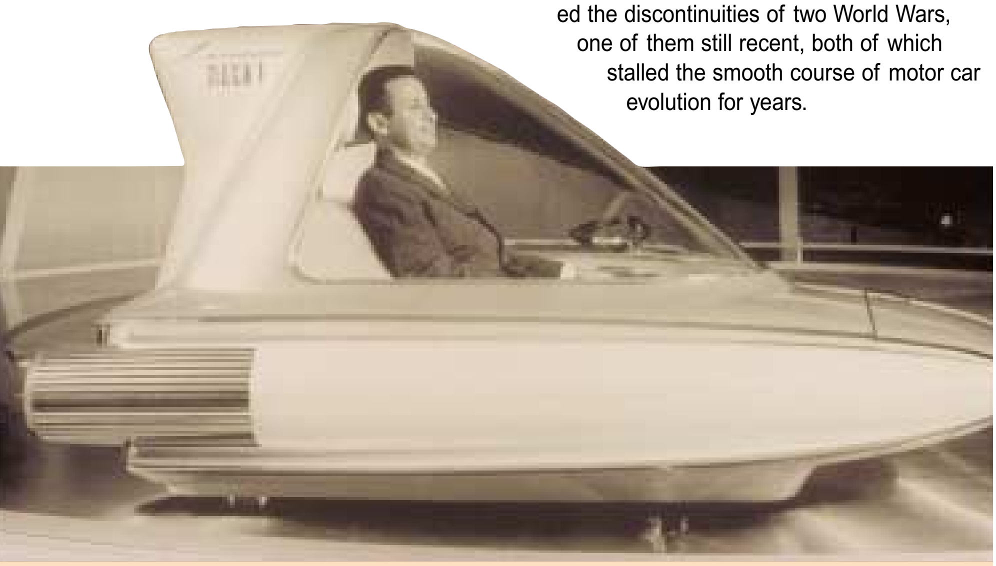
The future as we used to see it: the 1958 Nucleon was an atom powered concept (left), while the 1959 Levicar Mach 1 expected to take to the air to avoid traffic jams

The temptation when predicting the future of the motor car is to overdo it. The truth is that if you look back from 2002 to the motor car of 50 years ago, to Alec Issigonis' British motoring icon the Morris Minor, for example, you find no great fundamental change.

An engineer would probably walk around the Minor and, say, a 2002 Ford Focus, and list the major changes: a body with a hatchback, unheard-of in 1952; a shift from rear to front-wheel drive, from live rear axle to independent rear suspension, from cross-ply to radial-ply tyres; the engine itself with twin overhead camshafts instead of one side camshaft and pushrods to overhead valves (even by 1952, the Minor had abandoned its original side-valve engine in favour of the first A-series).

Given a little more time to explore in depth, the engineer would also point to the 2002 car having a complex and highly effective system of exhaust emission control, and an equally complex series of interlinked features to improve passive safety. And eventually, he would come to appreciate how far electronics had come to influence so much of what happens inside the modern car.

Yet if you had asked some young enthusiast of 1952 to predict what the 2002 car would be like, his answers would surely have been much more exciting and far-reaching: a car which could take off and fly when necessary, or equipped with a nuclear power unit such as the Ford Nucleon concept car of 1958. So when this now old enthusiast of 2002 tries to look ahead, he does so with a lot more caution – and also with the benefit of being able to look back over 50 years of continuous evolution. This gives me an advantage over the 1952 crystal-gazer, whose rearward perspective – reaching back to some extremely crude cars, of course, close to the very dawn of motoring – included the discontinuities of two World Wars, one of them still recent, both of which stalled the smooth course of motor car evolution for years.



Starting points

If the typical modern car provides one starting point, others are provided by the anxieties of our modern age. The future of the car is clouded, in many eyes, by sheer traffic congestion – what is the point of owning a car if it takes you ages to drive it anywhere? – and the related questions of greenhouse emissions and the inevitable exhaustion of crude oil reserves. In fifty years' time, by most reckoning, the oil may not have run out but will certainly have become much scarcer and more expensive. What does that imply for the future car?

If it is to survive – and I'm sure it will – the car will have to come up with answers to those questions. Probably the clearest conclusion is that cars will use much less energy. We have already seen it happen. Today's engines are not only cleaner, they are more economical. Europe's car manufacturers have undertaken to bring their fleet average CO_2 emissions down to 140g/km by 2008, and the process is not going to stop there. The last few years have seen new technologies evolve for both gasoline and diesel engines – direct injection for both, common-rail systems for diesels, developments like BMW's Valvetronic for gasoline engines.

Nor is there any sign of this development stream drying up. Twenty years ago one might have looked at any of them and reckoned it too expensive and complicated ever to reach production. Today any development which promises to reduce CO_2 emissions and energy consumption is a potential runner. Waiting in the wings we have the camless engine, with valves individually operated under electronic control; we have variable compression ratio; we have further advances in mixture preparation and the direct sensing of real-time conditions inside the combustion chamber. Once it would have been a brave engineer who predicted such things would ever find production application: today it is braver (not to say unwise) to predict they will not.

Some of these developments, especially the camless engine, will be made practical by a revolution which is almost upon us – a change from 14V to 42V electrical systems, making practical the idea of automatic engine stop-start operation in heavy traffic, and enabling things like valve-actuating solenoids to be made sufficiently powerful and far more compact. The voltage step-up will equally enable concepts like brake by wire and steer by wire, with electrical linkages replacing mechanical ones. Such moves may sound rather alarming at first, but the signals passing along electrical linkages can be shaped and tuned far more easily to produce safe and progressive response. This, surely, is the path to the chassis of the future.

As for the transmission, it rather depends how you view the future. Ultra-efficient internal combustion engines demand gearboxes that will not squander hard-won economy. In this connection some of the robotised manual transmissions now emerging in Europe, fulfilling at last with the aid of electronics the 1920s dream of reproducing the actions of the most skilled of drivers in clutch and gearchange operation, are well worth a look and a side-bet for the small car market at least. Luxury cars will continue to depend on the traditional automatic, with the CVT slowly winning more friends as engineers learn how to make best use of it.

All this, however, depends on the growth (or otherwise) of other trends. It may well be that the car of the future will use electric traction, and thus will need no clutch, and probably no gearbox, at all. By electric traction I do not mean battery-powered vehicles, which have now been written-off by serious engineers for the saddest and most conclusive of reasons: the batteries cost too much and do not last long enough, and much hard work over the last 20 years has scarcely dented this drawback. Instead we may find ourselves driving cars in which the electric power comes either from an internal combustion engine driving an efficient high-voltage generator – the so-called hybrid – or from a fuel cell, that pinnacle of future promise, the device which electro-chemically combines hydrogen and oxygen to produce nothing but electric power and water.

Fuel cell questions

Most motor industry engineers now assume that in the long term, say by 2050, nearly all new cars will be powered by fuel cells. Some do not agree: BMW in particular still insists the better option is to retain the internal combustion engine but switch over to running it on hydrogen. But the fuel cell is the favoured solution of most, and so far it has justified their confidence with a speed of development which the battery lobby has long since given up hoping for. However, fulfilling the promise needs answers to at least two difficult questions. The first is how get from here to there, so to speak; how we move from an industry building millions of internal combustion engines every year, to one which builds an even larger number of fuel cell power units per year – bearing in mind that a fuel cell power unit consists not only of the cell stack, but all the peripheral units needed to make it operate. The second question, quite simply, is which fuel we use.

Ultimately, the answer to the second question is hydrogen – because at some stage the supply of fossil hydrocarbon fuel will indeed run out. But there is no hydrogen supply infrastructure, nor the ability to make either ultra-high-pressure gas storage tanks or super-insulated liquid hydrogen tanks in the numbers the industry will eventually require. So, in the meantime, do we feed fuel cell cars with a liquid fuel – petroleum or alcohol based – and reform it to extract the hydrogen? So long as the hydrocarbons are there, this makes more sense in that it is easier, and the infrastructure already exists.

‘In the longer term there is another argument in favour of the hybrid. It may form a convenient stepping-stone to fuel cell vehicles’

British Motor Industry Heritage Trust Archive

The British 1950s equivalent of today’s Ford Focus was the Morris Minor (right). The basic mechanical principles may be similar but the modern car has performance, refinement and safety unheard of even ten years ago

Thus it would make the introduction of fuel cell cars that much easier. In the end, however, we have to address the hydrogen question because unless we go to the trouble of synthesising liquid hydrocarbon fuel, or take a development path into biomass derived alcohols and natural gas, there will be no alternative – and at least we shall have arrived at a situation where we have taken the carbon out of the vehicle-fuelling process altogether. Just how we make enough hydrogen is another matter: for the time being it seems that we shall have to use large-scale electrolysis using electric power from renewable resources. That in itself is a major challenge but eventually the answers will be found, out of necessity.

The Honda Insight (above), together with the Toyota Prius, are the world's only production hybrids; Toyota has built over 100,000

A hybrid bridge?

The hybrid internal combustion/electric vehicle sits in the middle of all these arguments. Not so very long ago, the most frequent argument was that hybrids would never see production because they would always be too expensive, needing more (and more expensive) components than a car with a conventional transmission. This remains largely true, although ingenious ways have been found of whittling away the cost. Yet we have seen two hybrid cars, the Honda Insight and the Toyota Prius, enter at least limited production, and more are planned for the near future.

The argument which has begun tipping the balance in the hybrid's favour is efficiency, thus lower fuel consumption and very low exhaust emissions. In a hybrid car, not only can you make the internal combustion engine more efficient – and run it mainly at its most efficient load point – but you can also manage the use of energy, reclaiming it when braking or running downhill, feeding it back from a storage battery (with other, lighter, highly efficient energy storage devices such as capacitor banks on the horizon) when accelerating or climbing hills.

It is this aspect of the hybrid which has suddenly awakened great interest in a seemingly unlikely product area – that of the huge and heavy SUVs and light trucks (many of which serve in fact as personal transport) in the USA. Consumers in that market like these vehicles simply because they are so big, high and spacious, but they consume fuel at a frightening rate to European eyes. Frightening also to Americans, whenever fuel prices rise sharply, and worrying when debate turns to whether these vehicles should be included in passenger car CAFE fuel consumption limits.

One solution is to make such vehicles much more fuel efficient by adopting hybrid technology. The most widely studied approach, and one which is likely to see production very soon, is to leave the internal combustion engine driving one pair of wheels, while installing an electric drivetrain to the other pair. Much then depends on the way the system is controlled overall, something which has been the subject of close study; but the economy and emissions benefits can be considerable, especially if the internal combustion engine is downsized, allowing for the ability of the electric drivetrain to maintain the same level of performance when required. One positive point is that the extra weight of the electrical system components is barely significant in vehicles which can weigh up to three tonnes in conventional internal combustion form.

While hybrid technology has its part to play in enabling North America to achieve better fuel efficiency, it is clearly also attractive in Europe where fuel costs (including a heavy tax element) are so high. You may have to pay more for the vehicle to begin with, but its substantially better economy begins to make up the difference the first time you fill the tank. Therefore we can expect to see more hybrids in the major European markets.

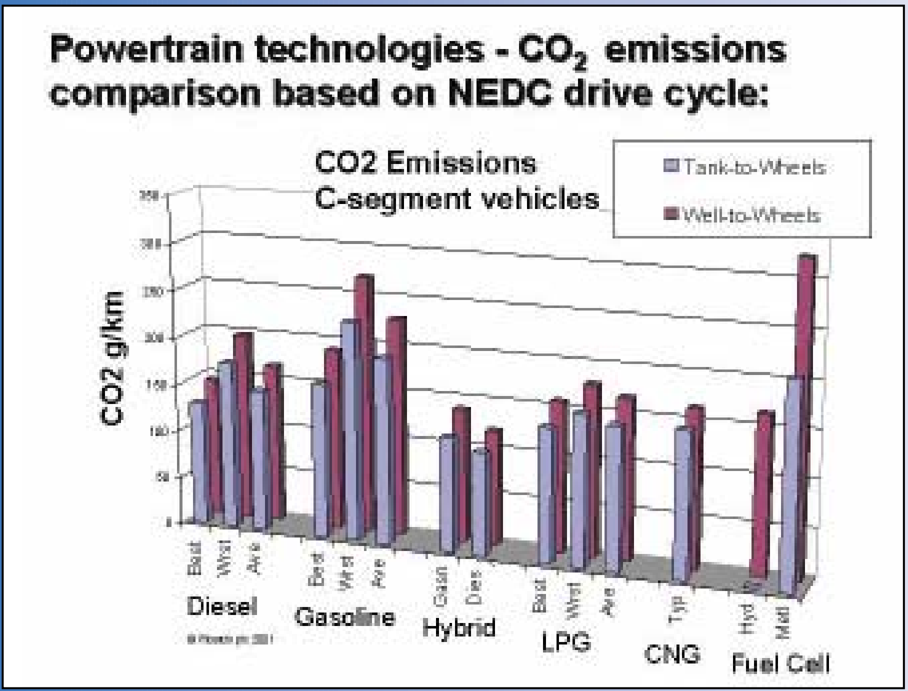
In the longer term, though, there is another argument in favour of the hybrid. It may form a convenient stepping-stone to fuel cell vehicles. In principle, if you have a parallel hybrid – one in which the drive can be entirely electric, with no connection between the engine and the wheels – you can wait until you have developed a satisfactory fuel cell package and use this to substitute for the internal combustion engine. Certainly this is a simplistic way of looking at things: in practice, a great deal of work would need to be done in the systems integration and control areas. But from the consumer's point of view, what would be the difference between an internal combustion engine based hybrid with an electric drivetrain, and one powered by a fuel cell stack? There would be one difference, certainly: the ability to draw near-silent, non-polluting electric power from the fuel cell for as long as the fuel lasted. Imagine the difference that might make to a camping expedition – something which is already being pitched as a major advantage in the American market.

Heavy SUVs have awakened great interest in hybrid powertrains

Thus we may proceed, over a period of many years, from cars powered by essentially conventional but ever more efficient drivetrains, through internal combustion hybrids, and eventually to hydrogen-consuming fuel cell vehicles. However, there is still that other challenge to overcome: the nightmare scenario of a motoring world brought to a stop by congestion. The engineers have answers for this too. The truth is that even in crowded northern Europe and Japan, there is enough road space for everyone. The problems arise when too many people try to use a few strategic stretches of road at the same time.

Eventually the answer will be provided by systems which will be able to advise drivers of the best route to take, and indeed the best speed at which to drive, in order to reach their destinations smoothly, safely and without conflict in the sense of jostling for possession of the same ten square metres of road space. Full implementation will involve some interesting concepts: vehicles running on main roads in close convoy, and cross-roads where vehicles will be electronically shepherded through without stopping.

The problem with road space today is not a lack of it, but rather that we use it with hideous lack of efficiency. Future vehicles will be equipped to overcome that deficiency, just as they will be provided with drivetrains that enable them to complete journeys consuming amazingly small amounts of energy. It may not sound much fun to today's enthusiasts, but by 2050 our descendants may view it differently – and confine their "fun" motoring activities to driving internal combustion engine powered cars on closed tracks, just as steam railway buffs today exercise their beloved, beautiful but anachronistic machinery. ■



Ricardo well-to-wheels analysis of CO_2 emissions shows diesel hybrid as the best performer – undercutting even the fuel cell running on hydrogen produced from non-renewable sources

The Ricardo view

Nick Owen and Peter Brown provide their perspective

Jeff Daniels provides a useful and thought-provoking view of the future of the car, and emphasises the importance of examining past changes as a sanity check to temper any future predictions. We would perhaps make a few additions to the observations of Jeff's imaginary 1952 engineer: first and foremost if he or she stepped into a current production car and drove it, the biggest surprise of all would be the improvements in performance and refinement. In addition to this, the advances in both electronics and safety equipment in the last 50 years – and their highly accessible cost – would be truly amazing.

Naturally for Ricardo it is imperative that we have a view of the future direction of automotive technology so that we can bring the requisite expert knowledge and resource to our customers' programmes. We put significant resource into developing our Technology Roadmaps: this is important in steering the future direction of our research and development efforts, of which the i-MoGen programme featured in this issue of RQ is just one example. The major drivers for change are CO_2, safety and road congestion.

There are significant global differences in the perceived importance of CO_2 reduction, which is difficult to equate to global component commonality. Many CO_2 -reducing technologies have a cost associated with them, and the acceptable level of cost per unit benefit differs regionally. When looking at the impact of new technologies on CO_2 emissions it is vital to consider their respective 'well-to-wheels' impact. Daniels rightly points out the technical challenges of hydrogen transportation and storage, but there is in our view a more fundamental concern. In simple terms, the hydrogen has to come from somewhere. A fuel cell vehicle using hydrogen made from existing hydrocarbon fuels is not so attractive on the well-to-wheels metric. The emergence of the so-called hydrogen economy, based on large-scale generation of electrical power from completely renewable sources, is perhaps the most significant obstacle to the mass take-up of hydrogen fuel cell vehicles: it is certainly more of a challenge than the engineering of the fuel cell vehicles themselves. As such, we see an increasing number of fuel cell demonstrator vehicles in the coming years for the purposes of technological development, but few products, if any, reaching commercially viable volumes within the next ten to twenty years.

The hybrid is the most pragmatic automotive powertrain solution for this time frame as it enables the stepwise approach to sustainability which Daniels describes. In effect this form of powertrain attempts to squeeze the maximum fuel efficiency out of the combustion engine – whatever its fuel – through optimising and managing the internal energy flows of the vehicle. Less well understood is the way in which hybridisation also enables significant engine downsizing without sacrificing the driveability of a larger unit; this delivers the most significant economy gain in the case of 'mild' hybrids such as i-MoGen. Systems integration and sophisticated supervisory control are the key to a good hybrid powertrain, especially when future elements of the system, like advanced boosting systems, feedback combustion control and dual-clutch transmissions are so ideal for control integration.

And it is integrated control which offers the answer to our other drivers, safety and the avoidance of congestion. In the absence of continual new road building, the alternatives seem to fall into two categories – road pricing to discourage travel at times of congestion, and telematics-based technologies aimed at improving the utilisation of road space. If vehicles are within themselves already rich in highly networked electronics, it seems reasonable that with the advent of new telecoms developments this networking could be extended externally, enabling the vehicle to communicate with the outside world for everything from fault diagnosis and maintenance management to route planning, congestion avoidance and on-board entertainments.

This type of whole-vehicle supervisory control will also be at the heart of a new generation of so-called 'X-by-wire' technologies, in which steering, braking, torque vectoring and other driving functions will first become electronically linked to the standard driver inputs, then progressively influenced by intervention strategies to make driving easier and to avert disasters. And here could be the big change for the car of 2052: while the Morris Minor and Ford Focus both have a steering wheel and three pedals, it is entirely possible that the car of 2052 will require no more control input than the words "take me home". Despite being car enthusiasts, we at Ricardo think that type of capability has a great deal of real world appeal. It certainly isn't just wishful thinking. ■

Nick Owen is Manager of the Technology Department at Ricardo Consulting Engineers Ltd, Shoreham

Peter Brown is Vice President, Powertrain Projects & Design Engineering at Ricardo Inc, Detroit

Joined-up thinking

The Ricardo-Valeo i-MoGen programme to develop a mild hybrid powertrain for mainstream vehicles marks a new era in collaboration between leading industry players. Michel Lifermann of Valeo and Neville Jackson of Ricardo talk to Jesse Crosse about the synergies which have allowed their two companies to show the auto industry the way forward

In more than 100 years of automotive development it is unlikely that the industry has ever been under greater pressure than it faces today. That pressure is not only to push sales up and costs down, but also to bring down both fuel consumption and emissions.

All this pressure is being brought to bear from a number of different directions. In the US, toxic emissions dominate the agenda, while in Europe CO_2 has become equally important. Fuel price in both Europe and the US has become a major issue for consumers and businesses, both directly at the pump and, in some places, indirectly through carbon taxation.

Against that background and the recognition that 'miracle cures' like the fuel cell are still a long way off, Ricardo and Valeo, two of the industry's biggest names, decided to pool their very different skills and collaborate on a project which could have far-reaching implications in the field of both emissions and fuel consumption. When, in 2000, work started on the mild hybrid, high economy demonstrator programme (i-MoGen), it did so without the backing of a car maker, but instead was completely self-funded by the two partners.

The i-MoGen project was started in recognition of the fact that providing a concept is not always enough. "Ricardo doesn't manufacture anything, apart from some specialised transmissions," explains technology director, Neville Jackson. "We go to a customer and offer them a new concept but we're not offering them a product. If we have a collaboration, as we now have with Valeo, we have a route to manufacturing and we can say, 'here is a real product,' a complete delivered system and not just a concept."

i-MoGen was born out of a natural synergy between two specialists whose abilities are so complementary it would have seemed almost sacrilegious not to have brought them together. "We were all aware of the growth in power electronics," recalls Jackson, "and the efficiencies of electric motors outside of the automotive industry. The Ricardo point of view was that combining the best features of power electronic engineering with our ICE technology looked interesting. The main question was whether we could combine the technologies to arrive at a powertrain that was better than the sum of the parts."

"We have a big drive at Ricardo for system engineering," Jackson continues. "How do you put subsystems together to make them work better as a whole? And how do we combine technologies to show significant benefits in fuel economy and in performance, by taking what is essentially a cost effective route? Ricardo has worked extensively on downsizing engines but there are problems in doing that. Specifically, you can have a small engine with high power, but its driveability is compromised by the lack of low-speed torque. By combining it with an electrical machine you can overcome those handicaps."

But i-MoGen goes much further than simply investigating the viability of a concept. Despite the undoubted value of simulation, there comes a point in some circumstances where a project needs to be taken to a more advanced stage. "The implementation of advanced control systems is very different to the simulation, "Jackson continues. "Hardware implementation is the real challenge. Understanding communications systems, CAN issues, the kinds of day-to-day things that can cause real problems in practice." Ricardo is of course known for preaching the gospel according to simulation, yet this is no contradiction. "Our overall philosophy is to move more to virtual powertrain and virtual vehicle. Our approach is to identify the right concept and to prove the concept; not to build 15 different concepts first."

> **'Our overall philosophy is to move more to virtual powertrain and virtual vehicle. Our approach is to identify the right concept and to prove the concept; not to build 15 different concepts first.'**
> **Neville Jackson, Ricardo**

Ricardo and Valeo fitted together neatly like two pieces in a jigsaw, each party's skills complementing the other. "The idea of collaboration is not new," says Michel Lifermann, who is Valeo's transversal vehicle projects director, corporate R&D. "But this is the first time we have done something like this on such a wide basis; a multi-branch collaboration involving a partner to really enhance our systems expertise. And our future does rely on being able to develop systems rather than individual components.

‘With i-MoGen we felt we had a really exceptional opportunity to integrate our systems in an advanced powertrain technology, and we have learned a lot of lessons. All the deliverables, evaluations and test performances of the demonstrator are available to us.’

Michel Lifermann, Valeo

In this case, we felt we had a really exceptional opportunity to integrate our systems in an advanced powertrain technology, and we have learned a lot of lessons. All the deliverables, evaluations and test performances of the demonstrator are available to us and we will use them to further develop our future technologies related to powertrain.”

When it comes to fighting emissions and fuel consumption, the industry as a whole is well aware of the plethora of technologies available to it. But choosing the right course of action is not so easy. “My view is that auto makers are working very hard to improve fuel economy and they see that as a major challenge,” says Jackson. “The big question is, what strategy to follow? Which technology to employ? What is the most cost-effective route? There are many choices to be made with many combinations of technologies, and it is a difficult time for technology planning. What we’re trying to do is provide a leading light and we think i-MoGen is a good approach to take for the most cost-effective economy improvements.”

“Also OEMs have to focus their resources,” adds Lifermann, “and [they] cannot explore all the solutions and combinations by themselves. They appreciate that large engineering concerns like Ricardo and Valeo have their own individual research activities and are able to propose solutions.” But however limited an OEM’s resources, in most cases they are still substantial and there is a danger for anyone contemplating a self-funded programme that a potential customer might prefer to develop its own solution. “It is a point,” says Jackson, “and one we needed to address before we made this investment. Ricardo is a people business. It’s about the engineers we have. One of the reasons we do R&D is to actually investigate future technologies that we think will be important to the industry. But then we have to train our people to be able to offer those technologies to customers.”

“We decided to join the programme,” adds Lifermann, “because we thought the car manufacturers would appreciate this initiative and recognise Valeo’s track record in systems responsibility. The first customer demonstrations have already proven that this was a sound choice.” So given that both partners had the soundest of reasons for both collaboration and also for self-funding a major project like this one, why a C-segment car and why a diesel? “We didn’t want to offer a niche vehicle but wanted a mass market vehicle,” explains Jackson. “And C-D segment cars dominate the mass market. The C-segment was chosen ultimately, because we had already developed a downsized, 1.2-litre engine that would be particularly applicable to that class of 1200kg-1300kg vehicle, and produced the right kind of power for good performance. We also had a proposal to do a six-cylinder 1.8 litre version for a C/D-segment vehicle designed to improve the perception of diesel engines in that sector of the market. In the end, we decided on the smaller vehicle because it was more cost-effective.”

But while the i-MoGen demonstrator incorporates a diesel engine, gasoline could be just as appropriate in markets outside Europe – and almost as effective. “The standard HSDI engine emits about 25 per cent less CO_2 than a stoichiometric, MPI gasoline engine. What we’ve done through downsizing and mild hybridisation is to improve HSDI CO_2 emissions by 30 to 35 per cent. You could also take a boosted downsized gasoline engine, using similar hybridisation to i-MoGen, and deliver a very driveable vehicle with similar CO_2 emissions to a conventional diesel vehicle. A downsized gasoline engine of this type would have a particular advantage in the US where NO_x from a diesel engine presents more of a problem.”

In more radical technologies, like fuel cells, the potential for a change in fundamental vehicle architecture is very real but, contends Lifermann, i-MoGen deliberately sets out to achieve the opposite. “We concentrate on systems which can be installed in the classical layout. We want to improve the performance, with proven technologies which will also allow to keep a high level of standardisation in order to control cost.”

Flexibility of packaging is key, agrees Jackson. “It’s important the manufacturer can offer a vehicle with the option of a standard powertrain or the hybrid powertrain.” System costs remain an important part of the equation. “Although i-MoGen has an additional battery pack and related control systems, a primary objective was to minimise the battery size from a weight and cost perspective; even so the battery remains the single most expensive part of the system.”

Both partners have found the collaboration to be a rewarding one and although it has principally been a relationship between the two companies, Jackson sees no reason why, in theory, such arrangements should not be extended if necessary. “On this particular project the partnership is between Valeo and Ricardo,” he explains. “But in my view there is no limit to the number of partners you can have in order to deliver the product to the customer. The issues are how you manage it, how you control it and how you direct it.”

Lifermann agrees that successful collaboration is as much about how you do it, as what you do. “One of the partners must be selected to take the lead as the integrator.”

“Yes,” agrees Jackson. “In this case Ricardo is the integrator for the total vehicle. But, for instance, Valeo will have responsibility for some of the systems while Ricardo will take responsibility for others. The project is organised to deliver the whole vehicle as a series of sub-systems and each sub-system may in turn contain many components. If two or more companies are involved, one of them has to be nominated to pull the whole thing together.”

Both the partners are confident that hybridisation of mass market vehicles is the way to

go. With CAFE regulations tightening in the US and manufacturers already taking steps to dramatically improve fuel consumption on a global scale, the timing has never been better.

"Obviously fuel prices will carry on rising," says Jackson, who believes energy security will also play a part in driving fuel consumption down. Of the US, he says, "even if the prices remain low, the pressure will come from the US government and from auto manufacturers who want to be seen to be taking a responsible view."

But Jackson insists niche vehicles are not the way forward when it comes to reducing fleet averages. "Niche vehicles do not have an impact on fleet average fuel economy – full stop. If you want to have an impact on fleet averages, you have to introduce product to the mass market. You cannot provide a 2-litre car that seats three people because no one will buy it." Despite the high profile of hybrids like the Honda Insight and Toyota Prius, Jackson still believes that mass market applications will be drip fed into the market.

"The hybrid will not become part of some big revolution," he says. "It's going to be an evolutionary process with small levels of battery capacity and stop-start. It's going to move towards motor-assist systems still driven by a belt and then fitted to the crankshaft as the manufacturing structure evolves, the investment comes and we get the integrity we want from the electronic systems. It's one thing doing a prototype vehicle but it's another to lay down the investment to build several hundred thousand units a year with the level of durability and reliability which modern vehicles demand."

And as that evolution takes place, Ricardo and Valeo will be ready and waiting with a unique proposition, the ability to deliver a fully developed and packaged, hybridised powertrain capable of substantially reducing the fuel consumption and emissions on a series production vehicle. Not so much a miracle cure but, in the context of current automotive and environmental trends, one which is perhaps even more convincing. ■

Jesse Crosse is editor of Automotive Environment Analyst

The i-MoGen mission

Over the next seven pages we interview key Ricardo and Valeo engineers about the remarkable achievement this mild hybrid demonstrator represents

THE CHALLENGE

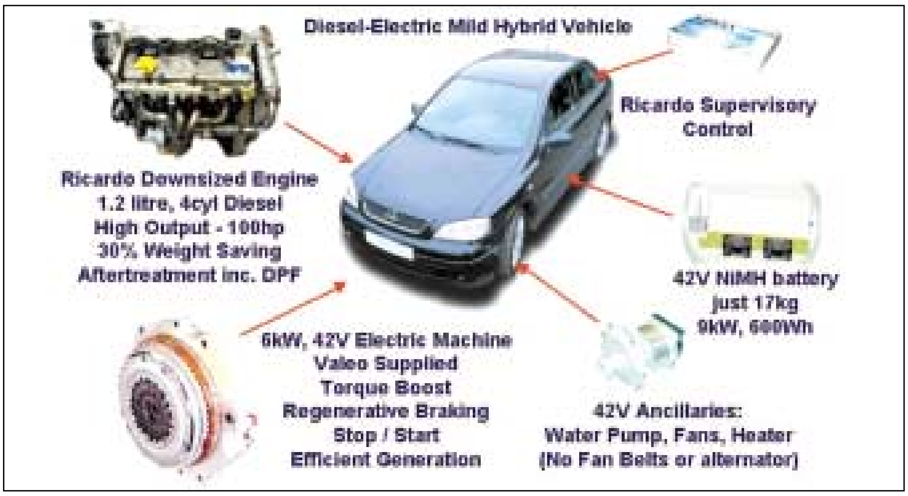
To use a mild hybridisation systems approach to develop a C-segment car capable of achieving 4.0 litres/100km over the complete NEDC, as well as half Euro 4 emissions – yet maintaining the driveability characteristics of a modern 2.0 litre diesel

THE DESIGN

The combination of a downsized 1.2 litre diesel engine and flywheel mounted electric motor/generator with an advanced 42 volt electric system with minimised battery mass and a Ricardo supervisory control system. In addition, 42 volt ancillaries and 42 volt air conditioning allow the removal of the engine's front end accessory drive

THE RESULT

An Opel Astra with uncompromised five-seat accommodation, handling and driveability, yet achieving 3.98 litres/100km NEDC economy and capable of the tailpipe emission targets of half 2005 Euro 4 standards



i-MoGen elements fit standard production car platform

PROJECT OVERVIEW

Interview with Richard Gordon, i-MoGen programme chief engineer, Ricardo

What in your view is the most important overall achievement of the i-MoGen programme?
The biggest achievement is to have shown a 28 per cent reduction in fuel consumption whilst retaining the same driveability as the original car. It is very easy to reduce the fuel consumption of vehicles, but you invariably also reduce how nice they are to drive, how well they accelerate and how they feel on the road. We've beaten this.

So does i-MoGen feel exactly like an ordinary car to drive?
Yes. Of the hundred people that have driven it so far, about 80 said exactly that. They said that if they had not been told, they would have thought that it was a much bigger engine. The other 20 per cent were more used to things like V8 luxury sedans rather than diesels. That feedback has been useful, as has the response to the stop and go strategy.

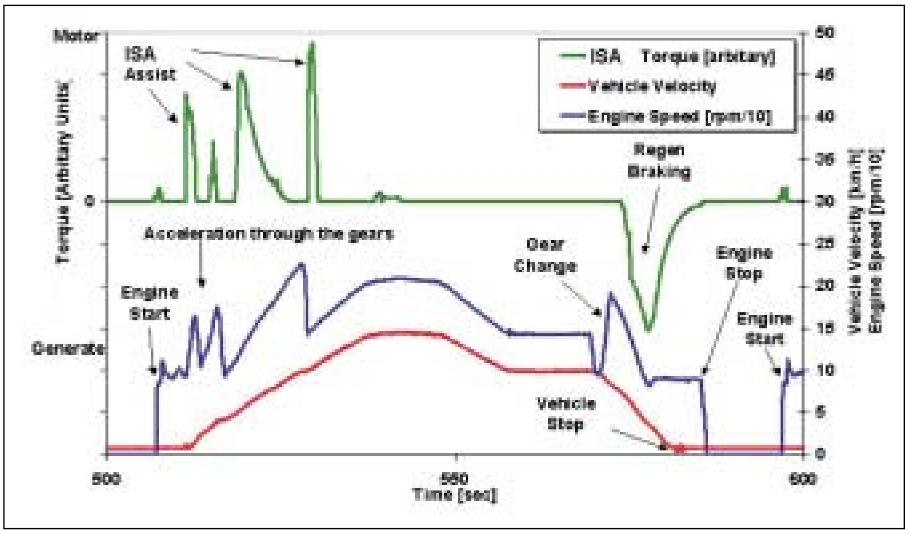
And how about the engine itself?
The engine is very special. It's 1.2 litres, delivering the same peak power and peak torque as the 2-litre [Opel] engine – and this has been perhaps the most amazing thing when people have driven it. A number of them had expressed concern and disbelief in our numbers – until they drove it. They would then come out with a smile on their face. One particular executive was extremely sceptical – but in the end wouldn't stop driving it. It's a remarkable little engine, and it's achieving two-thirds of our fuel saving. We have been able to show that extreme downsizing is possible and that we are able to assist clients to find the most appropriate downsizing approach for them. This includes all the influences of refinement, turbo lag minimisation and packaging improvements. It is also important to say that what we have shown from downsizing the diesel engine is also applicable to gasoline engines too – so this could just as easily have been a small gasoline engine. We are working just as hard on small, highly efficient gasoline engine technologies.

Were there any areas new to Ricardo?
42 volt technologies in this particular type of application were new to us, and i-MoGen was a very good way of getting that experience. Judging the size of the electrical machine and the battery with Valeo was not easy, nor was the actual physical putting it all together – it's more than just bulbs and batteries. It is important to stress that there is more to i-MoGen than just the vehicle deliverable. Taking a wider view, the whole purpose of doing it was to grow our business in these areas by showing the world that we have got the necessary tools, skills and real world experience. The i-MoGen programme has honed a lot of those skills. The development of the supervisory control system, for instance: supervisory control is not new, but the way we've optimised the energy within that control system *is* new. The supervisory control system will be useful for future work, and we have also developed a simulation tool in which you build such control strategies. It's called VSIM and was substantially developed within the programme. It has also been validated: it predicted 4.0 litres per 100km fuel consumption – and we achieved between 3.98 and 4.3, which I don't think is too bad considering the complexity of the system. In addition, the modelling of the Diesel Particulate Filter was extremely useful and impressive.

How did you approach the actual putting together of the complete vehicle?
Hybrid vehicles are clearly very complex, and the risks of getting it wrong are quite high – and if you do get it wrong, you tend to have sparks. So the approach of using our simulation toolset was to build a control system in software, which then ported into the vehicle quickly and safely, and all pre-tested in the PC and on the bench. We took this approach and it worked virtually straight out of the box. It was then a matter of developing that control system in the vehicle and fine-tuning all the little interactions that make it a real and robust vehicle. Driveability is a good example: how you let in torque assist and then ramp it out when you back off; how regenerative braking comes in dependant on vehicle speed, and what energy management approaches do to the driving feel. These sorts of things are very hard to simulate, but very easy to feel in the car whether they are right or wrong. However, it is important to get the basics right first time.

What is the next step? Will there be a second-generation i-MoGen?
Probably not yet. The i-MoGen programme's promotional opportunities have now begun. We've already been doing roadshows [at OEMs] in Europe; soon we'll be taking i-MoGen to the US and then to Japan. We'll be showing people firstly that we've learned a lot about hybrid cars, the development approaches and the real world issues; next, we'll show that these are the kind of results that can be achieved in terms of low fuel consumption but still with a very driveable vehicle. We will also sell the fact that we've got the technology to offer a range of solutions to other people, and also stress that other concepts are possible. More importantly, this is our own work in collaboration with Valeo and so it is not confidential. We can talk about it in detail. Our current client work in these areas is confidential and so we can never discuss this openly.

What other classes of vehicle can the i-MoGen concept be extended to?
One of the most detailed concepts we have done with similar technology is looking at a gasoline SUV vehicle. These vehicles are quite large and one of the problems they have is fuel consumption – they're doing approximately 20 mpg (14 litres/100 km) in some cases. What we are seeing at the moment is the dieselisation of some of these, and in most cases they result in vehicles that are good to drive and good on fuel. But taking these big diesels to SULEV or Euro 4 emissions levels and beyond has major cost and fuel consumption implications. We can show that downsizing the gasoline V8 to a V6 and mild hybridising it may be a better and more cost-effective solution than the diesel in some markets where ultra low emissions are required. ■



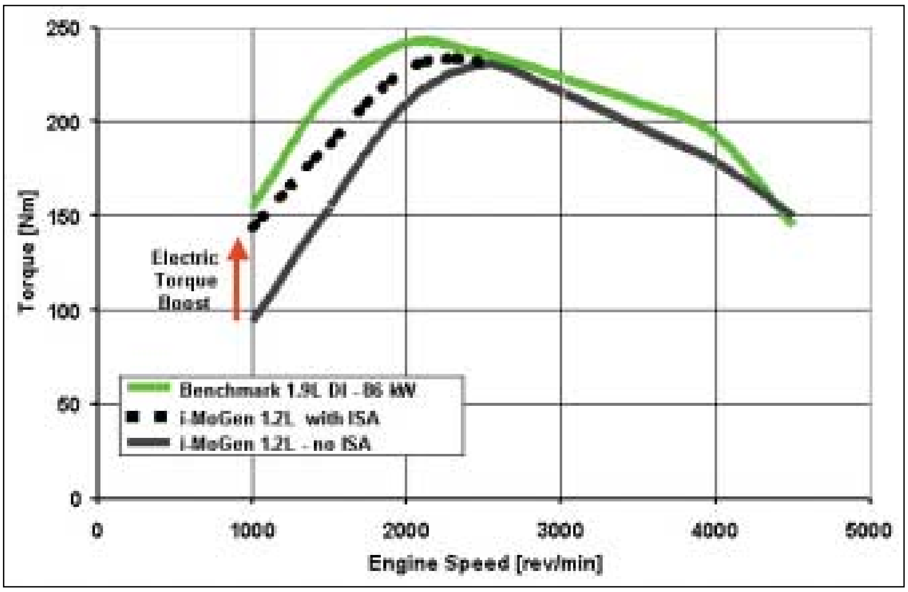
ENGINE DOWNSIZING

Interview with Ian Penny, Director of Diesel Engineering, Ricardo

What is the thinking behind using such a small engine in a medium-sized car?
Downsizing is a key concept, because at low loads when you are driving the car in an urban environment you have inherently lower friction in a small engine – so therefore your underlying fuel consumption is lower, too. You set the same performance envelope as the bigger engine in terms of peak power and rated torque by pushing the little engine, by improving the combustion system, the turbocharger and the fuel injection equipment. All those tie in to give you that advance, but where you won't get that advance is at low speed because your turbo is sized to give you that [peak] power and has little effect at, say, 1000 rpm. That's where the i-MoGen hybrid concept comes in, with electric torque assist at low speed.

What are the crucial developments that are now enabling engines to be downsized?
The limits on downsizing are launch feel (low end torque) and NO_x emissions. The i-MoGen torque-assist maintains launch and low end performance, while the latest high-pressure fuel injection equipment, coupled with our expertise in developing combustion systems for small cylinders, manages NO_x emissions. These are the key components but integration and optimisation of the overall system is essential.

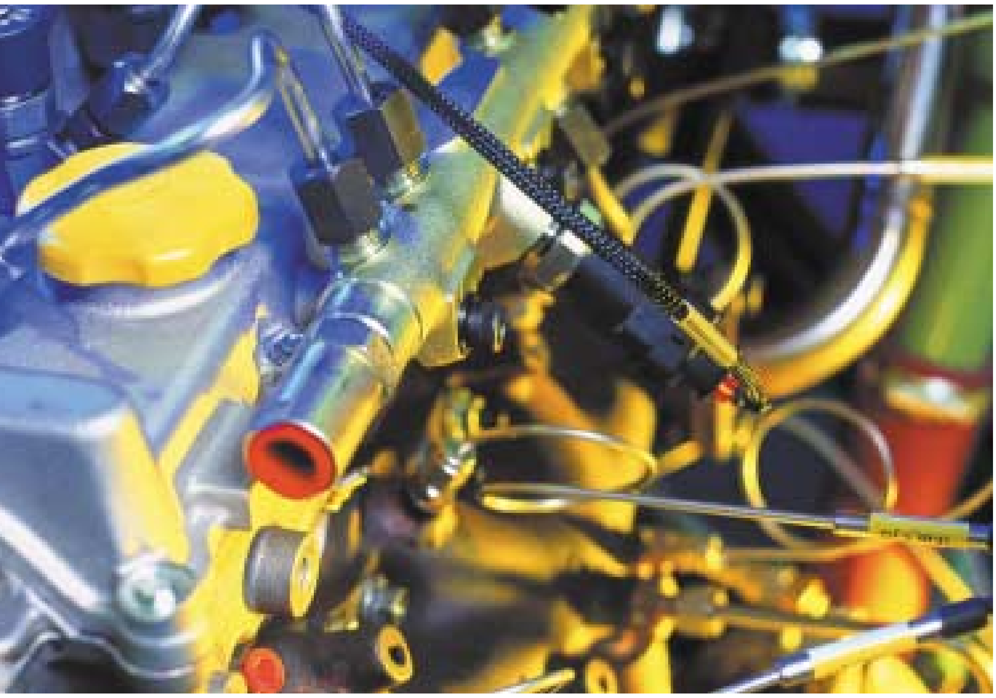
How much lighter is the downsized engine?
A direct comparison is complicated because i-MoGen does without certain familiar components. For example the starter motor, alternator and water pump are either deleted or not integrated in the engine. The base engine weight would reduce by 30-50 per cent on a like for like basis: a fully optimised conventional 1.2-litre engine would be around 90kg.



If you had a truly clean sheet of paper, would you go for three cylinders or four?
In this application I would still favour a four cylinder engine – mainly due to NVH considerations. There would be significant NVH problems with a three cylinder's reduced firing frequency and torque recoil at low speeds. The four cylinder engine offers a better performance-emissions-economy-NVH balance but it costs more. I expect three cylinder engines are more likely to emerge in the smallest vehicle segments.

What about friction?
A three cylinder engine can have lower friction, though this benefit is largely offset if a balance shaft is used. The three cylinder also requires a larger flywheel, clutch and intake system, again related to the reduced firing frequency. These can lead to higher inertia which then causes higher fuel consumption and/or worse transient response.

Are there any other benefits of downsizing?
Apart from improved fuel consumption, the downsized engine will naturally be quieter and more refined than a larger engine. For one, it has smaller, lighter reciprocating components which reduce vibration forces on the vehicle. Another aspect which hasn't been fully exploited yet is that with a downsized powertrain the crash protection is improved. The lighter and smaller powertrain is easier to package and you can provide more crush space around it.



The team leader
Brian G Cooper, Ricardo

The challenge
To develop a lightweight downsized high-speed diesel engine from a donor unit; to optimise engine performance for hybrid operation; to match driving characteristics of a conventional 2-litre turbodiesel; to achieve anticipated Euro 5 emissions

The design
Four cylinder 1.2-litre DI diesel using latest-generation Bosch CR fuel injection, Valeo ISA, Garrett VNT turbocharger

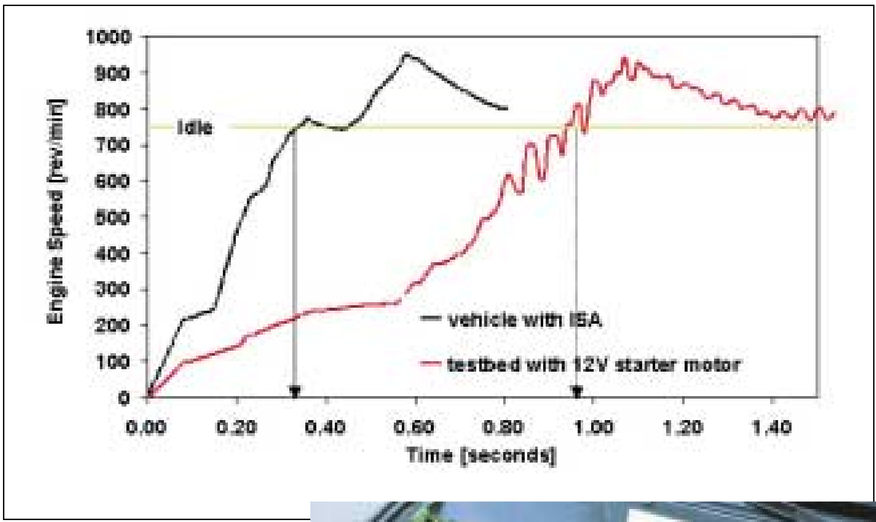
The result
100PS/74kW (83PS/l/62kW/l)
230Nm (192Nm/l)

You are running quite a low compression ratio of 17.5:1. Are diesel compression ratios coming down? Is this indicative of a trend?
Yes, compression ratio reduction is a strong trend and we expect ratios of 16:1 in the next few years -- and as low as 14:1 in the longer term. The lower compression ratio limits peak pressures at the same power and allows you to reduce weight, cost and friction. Alternatively, the lower compression ratio allows a substantial performance increase without major structural change to the engine.

What gives you your lower limit? Why did you stop at 17.5:1?
Historically, combustion noise and cold start considerations forced compression ratios in the 19-21:1 range, but as technology progresses these areas have been controlled through more sophisticated injection strategies. Today, the key limitations are cold and altitude driveability issues, in particular white smoke and misfire. These issues are not fundamental and will be resolved in the next generation of diesel engines with more sophisticated air fuel and control systems. A compression ratio of 17.5:1 is typical of current engines and shows that we have not taken any extreme measures to achieve the high performance. We would use a lower compression ratio in a future evolution of this powertrain, coupled with the appropriate air, fuel and control system developments.

How have you arrived at your aftertreatment strategy?
The i-MoGen combustion system will meet Euro 5 NO_x with the application of a passive De NO_x catalyst only. However, to comply with particulate emission levels we also need to use a diesel particulate filter (DPF). We decided to use an electrical DPF rather than one which required post-injection and other complications for thermal regeneration. We used the VSIM software developed on the i-MoGen programme to look at all of this. With VSIM we were able to model an electrical DPF and look at the fuel consumption penalty of just heating it electrically or post-injecting some fuel into an oxidation catalyst up front, generating an exotherm to heat the DPF. All options are open, and because of the 42 volt hybrid electrical system and the application of the common rail FIE system we were able to choose the best one.

How do you decide on the amount of electric assistance to provide?
It could be anything from zero to 100 per cent electrical – after all, you could have a pure-electric Astra with nothing but a massive and expensive battery. Or you could have a 50/50 hybrid, for instance. But once you begin putting in big power electronics and batteries it all gets very expensive – and that's why we see the mild hybrid as giving the best value for money. You won't get better fuel consumption if you go more down the electric route, because the most efficient way of changing from one energy to another is a small diesel engine. Hence, i-MoGen's electrical power is approximately 8 per cent of the rated diesel power – a mild hybrid.



42 volt electric system allows rapid start and rise to idle speed (above)

Mild hybrid hardware fits standard underhood space (right)

Chassis dynamometer testing of i-MoGen hardware confirmed simulation predictions of 4 litres/100 km in the NEDC cycle (below)

We have already discussed weight optimisation: what further gains are on the horizon?
An automated manual transmission (AMT) would be one. The human driver is generally not good at getting the best fuel consumption, but with an AMT you can optimise the gear-shifting to give the best fuel consumption for any condition. Ideally, the next phase of this programme would be to do this commercially for an OEM and develop, say, a six or seven-speed AMT.

What kind of further gains would you be looking at with an AMT?
As the engine has already been down-sized we might expect to achieve a further three to five per cent, but the most significant improvement would be in driveability. ■

INTEGRATED STARTER-ALTERNATOR

Interview with Laurent Thery, Valeo

How long has Valeo been working on Integrated Starter Alternator systems?
Valeo has been working on starter-alternators since 1997. We started with the belt-driven machines – which should enter mass production earlier [than the flywheel mounted devices] – and have been studying the ISA concept since 1999.

What was the main priority in the design of this system?
The main priority of the design was to achieve the best power to volume ratio (space allowed for the machine was very limited on the car) at the lowest possible cost.

How much torque can the ISA feed into the vehicle? How much electrical energy can it generate?
On the i-MoGen vehicle, maximum torque available from the ISA varies from 45Nm at 1000 rev/min to 30Nm at 2000 rev/min (between 5 and 6 kW of mechanical power).The maximum electrical energy generated is 6kW.

What guided your choice of battery and battery location?
We needed a battery able to provide power for boost, to accept sufficient power during regenerative braking phases and capable of withstanding charge/discharge cycles. At the time the programme started, several technologies answered these needs (Li-ion, super capacitors and NiMH) but NiMH appeared to be the solution closest to production. Battery size has been limited (for weight and cost reasons) and since this type of battery is not well suited for an underbonnet environment, we were able to take advantage of the spare wheel cavity. This was the least intrusive yet most readily accessible place for the battery on such a demonstrator, but location under the floor of the passenger compartment could be considered for a production vehicle.

What were the most difficult challenges in the programme?
One challenge has been to design and realise an ISA able to fulfil the torque/power requirements and which fitted into the limited available space. However, full system integration has been the biggest challenge – getting the best from all the systems and ensure that they all communicate correctly together.

Who (Valeo or Ricardo) led the integration of the system into the vehicle?
Ricardo, as project leader, led the integration of the system into the vehicle.

Was there a language barrier?
Language has not been a problem on this project.

Was it difficult to establish the control parameters for the system in the vehicle?
Definition of the control parameters of the system started very early: this helped to define clearly the way the ISA system should be controlled by the supervisory controller. Moreover, simulations of the system by Ricardo and complete mapping of the machine performances helped to provide a good idea of the system behaviour in advance. Difficulty came more from all the parameter adjustments needed on all individual components than from the complete system control.

How much energy is saved by the 42 volt air conditioning system?
30 per cent is saved by the 42 volt air conditioning system compared to the mechanical system. The 42 volt air conditioning system has advantages other than energy saving: it allows the air conditioning to operate during engine stop, pre-conditioning of the passenger compartment is now possible, and the belt-less solution provides packaging advantages.

Is this ISA a feasible system for volume production?
Market/OEM acceptance of the system is based on power demand. It drives the choice between an integrated or belt-driven starter-alternator. The ISA should be targeted for high power applications and bigger cars: the belt-driven starter-alternators are aimed at the other applications. Nevertheless, an ISA like this is feasible for volume production.

What would you change on a second-generation system?
For same power output as the existing system, a second-generation system would be based on a belt-driven machine. If the driveability of the vehicle needs to be improved, more power in boost/alternator mode will be needed. In that case, the choice of battery technology may be different, and the type of machine (belt-driven or integrated) will be defined depending on the final power output. ■

The team leader
Laurent Thery, Valeo

The challenge
To provide a robust electrical machine capable of providing mild hybrid operation for the i-MoGen vehicle

The design
A 6kW water-cooled flywheel mounted Integrated Starter-Alternator (ISA)

The result
Effective in providing torque boost, regenerative braking, and stop-start operation. An enabler for the DPF aftertreatment technology

THERMAL SYSTEMS

Interview with Pascal Revereault, Ricardo

Has working on the i-MoGen programme been an interesting challenge for you?
Yes it has. Before i-MoGen I had been working on conventional engines in conventional installations. So coming to i-MoGen was like having a clean sheet of paper to start from. Normally, a cooling system is about little more than protecting the engine; with i-MoGen it's more a case of having a lot of tools in your hand and making the most of them to create a thermal system in phase with vehicle targets.

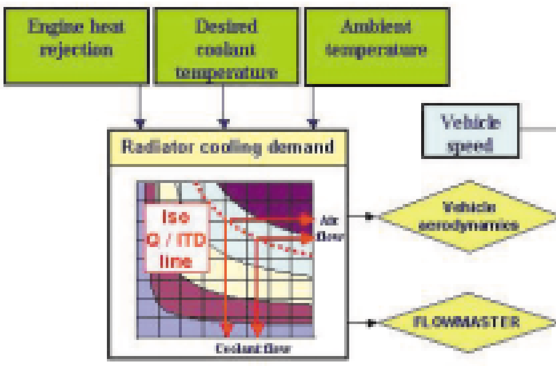
What does this mean in practice?
Sometimes you need to cool, sometimes you want to keep heat in the system – which is more difficult with conventional vehicles. It was really a case of analysing which thermal parameters are important to the vehicle and how we can best manage them, instead of being constrained by a standard design.

Which parameters are the most important?
We knew that emissions and fuel consumption would be the main drivers; we also knew from engine testbed work which thermal parameters would have an impact on these. The only difference is that in the past we didn't have the ability to play with these. As an example, with i-MoGen we've got electrical pumps and ancillaries allowing us to adapt the cooling to the actual engine needs as opposed to an engine-driven pump dictating the coolant flow.

What is the energy used by a conventional engine-driven water pump?
We normally quote a top figure of one kilowatt, and in our case the electric pump we use has a maximum consumption of 600 watts. Our single pump does the job of two in conventional cars – the normal water pump and heat soak pump.

What takes place in the crucial warm-up phase?
Rather than taking the heat away we try to keep it inside the engine to benefit consumption and emissions; at the same time you want heat to distribute into the oil system so as to reduce friction. Another priority is to get some flow through the EGR cooler, even after a cold start.

How quickly do the pump and valves cycle?
In terms of energy management it's more efficient to get into a quasi steady-state condition, so you want to keep these stable rather than stopping and starting them.



How do you heat the cabin when the engine rejects so little heat?
Valeo has developed PTC heaters which electrically heat the air flowing into the cabin. Their power demand is obviously supported by the Integrated Starter Alternator (ISA) and they provide direct and efficient conversion of the electrical power.

What are the thermal requirements of the Integrated Starter Alternator?
It's water cooled, as part of the main system. It's tricky, as it has electrical components which we need to keep at a fairly low temperature. We located it downstream of the radiator, the coolest point in the system. The cooling strategy recognises the cooling needs of the ISA and increases its coolant flow accordingly.

If you had a completely clean sheet of paper, what would you include? Would you cool the ISA separately, for instance?
What's viable is one pump and several well-located valves. I don't believe we need more than that at present – maybe in the future when electrical loads become greater we might think about a secondary cooling system.

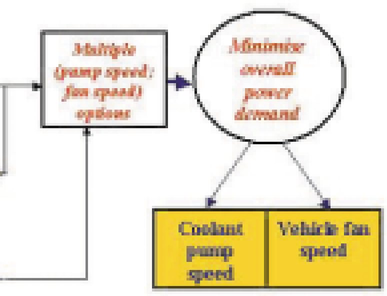
Could these lessons be applied to a gasoline engine, or maybe a big V8 diesel?
Gasoline would require a rather different approach, with more initial heat to manage. With the big diesel you could use basically the same philosophy. ■

The team leader
Pascal Revereault, Ricardo

The challenge
To optimise thermal energy management within the cooling system to minimise consumption and emissions; to minimise parasitic energy losses by dispensing with mechanical pumps and front-end drives

The design
Low-capacity, high heat rejection system with intelligent operation of valves and electric pump. Additional PTC cabin heaters

The result
An intelligent thermal management system supporting powertrain and vehicle targets



EXHAUST AFTERTREATMENT

Interview with Craig Goodfellow, Ricardo

What was your broad strategy in addressing the issue of exhaust aftertreatment?
First of all, we identified the target for vehicle tailpipe emissions: we set this as half of the future mandated light duty diesel Euro 4 limits for 2005 – in effect 0.0125 g/km particulate matter, and 0.125g/km NO_x. Once we'd identified these targets, we had to look at the strategy required to achieve them. And because of the traditional trade-off between NO_x and particulates, we had to decide whether to target low NO_x or low soot engine-out.

Why did you decide to go the low engine-out NO_x route? Are there lower energy levels involved?
It's partly robustness of the aftertreatment system. The opposite strategy of reducing NO_x significantly with the aftertreatment would have meant either SCR (selective catalytic reduction) using urea as a reductant, or a lean NO_x trap technique. SCR is well proven on heavy duty engines but the temperature window is poorly suited to lighter vehicles; with lean NO_x traps, there are questions about their durability, the ability to run the diesel engine rich, and fuel sulphur levels. We felt it the best overall strategy to control NO_x in the engine and then tackle higher levels of particulates with a particulate filter.

Did the fact that i-MoGen is a hybrid affect your decision?
Clearly, the engine's stop-start operation did not work in our favour, but the fact that it's a small engine helps as it pushes up the average load and increases your exhaust temperatures. But because it is a hybrid system we suddenly have available 42 volt electrics and high levels of power. This enables a whole new technology for the aftertreatment system where we can employ an electrically heated particulate filter.

Is the electrically heated particulate filter more energy-efficient?
We predict that the electrically heated diesel particulate filter (DPF) will give us a fuel consumption penalty of less than 0.5 per cent. That compares with technologies like the lean NO_x trap where the penalty can be up to four per cent. The DPF clearly uses a lot of electrical power during regeneration, but it isn't a continuous power requirement as it only regenerates once every several hundred kilometres. The supervisory controller operates the whole powertrain so as to maximise the electrical power to the DPF during regeneration.

Could you talk us through the process?
The strategy of the system is to initiate a regeneration cycle with a short burst of electrical power: once the soot starts to burn, its reaction with oxygen is itself highly exothermic. This makes the regeneration largely self-sustaining.

How does the combination of DPF heating and diesel inlet throttling work?
We throttle the engine in order to reduce the airflow going over the heater element: this raises the exhaust gas temperatures to over 550ºC to initiate filter regeneration, but it also affects the combustion itself. We therefore manage the other combustion parameters to maintain torque so the regeneration isn't noticed by the driver: the EGR and the fuelling rate will also change because we are influencing the air fuel ratio.

How long does the purge cycle take?
For an oxygen-based regeneration it is fairly quick – it's usually over in a couple of minutes or so. This compares with the NO_2-based regenerations you have with other passive trap systems: these typically take up to 20 minutes. The driver should not notice the process: the control system calculates the loading on the particulate filter and will ensure the process is smooth and safe. That's the thing about i-MoGen: a lot of the technologies on the car have been known for a while, but we now have the control system capability to make these things work in an integrated manner. The control challenge on this has been phenomenal.

Is it too early to get any idea of the costs?
It is still early days, but there's no big cost issue at the moment. What you should bear in mind is that all the components in this system are already available off the shelf: the DPF is from Emitec, and the rest of the units are from Johnson Matthey. There's nothing fancy here: the magic is in the way it is all controlled.

You claim the DPF's efficiency is 99 per cent for carbonaceous soot. Does this open the door to diesels in places like the US, where there has been heightened concern about particulate matter?
It may well do. The advantage of our system is that we are avoiding two of the technologies the US has traditionally not favoured: firstly those requiring any kind of metallic-based fuel additive for filter regeneration, and secondly circumventing high levels of NO_x aftertreatment which would require urea injection and the establishment of a urea infrastructure. ■

The team leader
Craig Goodfellow, Ricardo

The challenge
To provide a robust aftertreatment system for the i-MoGen vehicle providing less than half the emissions levels allowable under Euro 4 light duty diesel legislation for 2005

The design
Low NO_x combustion system together with a close coupled diesel oxidation catalyst with an element of passive $deNO_x$ activity, an underfloor silicon carbide electrically regenerated particulate filter

The result
A system meeting the programme emissions targets with the capability of particulate filter regeneration under low speed and load

SYSTEMS INTEGRATION

Interview with Don Newton, Director of Control & Electronics, Ricardo

The team leader
Peter Fussey, Ricardo

The challenge
To provide a control architecture, hardware and software capable of optimising the performance of the i-MoGen vehicle in terms of its fuel consumption, driveability, emissions performance and internal climate control

The design
The use of complete vehicle simulations and rapid prototyping tools allowed a successful implementation of the control strategies in Ricardo's VEMPS unit (Vehicle and Engine Management Prototyping System)

The result
An integrated control system that provides the driver with a complex vehicle that drives like a conventional one

Is it true to say that systems integration is the key to the whole i-MoGen project?
Yes, in many ways it is. Our job is to co-ordinate all the sub-systems so that the end product is effectively more than the sum of its parts.

You have a vast number of systems here. Where do you begin?
With this project, and with many others, you generally start with some simulation work. You can explore ideas freely in simulation without having to build expensive prototype systems and vehicles. So we were able to look at a lot of 'what-if?' scenarios – for instance, what happens if we do a lot of boosting with the electric machine, will the batteries drop too low? You can also look at the effects of these decisions on parameters like fuel consumption and emissions.

Do you model the whole vehicle?
Yes – when you do simulations it is important that you capture the whole loop. A good example is the DPF (diesel particulate filter), which needs to regenerate periodically. To regenerate, the DPF is heated up by an electric heater, which is a significant electric load. When you switch the heater on, you have to generate the electricity, which means the electric machine starts generating – which in turn means the engine has to work harder, making the exhaust gases hotter. This in its turn actually improves the DPF regeneration process. You have to consider the system as a whole.

How much did your thinking change as a result of the original simulations?
We spent quite a lot of time thinking about the new components, for example, how to control the electric machine. Effectively, you have an infinite number of ways of supplying torque to the wheels – you can boost electrically and use less engine, or generate and use more engine, for instance. The controller has to make a decision on the split between the engine and ISA .

What does this strategy consist of, and how does it operate?
It looks at how you optimise the use of electrical energy in the electrical systems. The i-MoGen vehicle has many electrical loads – water pump, electric fans, air conditioning and so on. The question for the optimisation really boils down to this: you've got a certain amount of energy to generate, when is the best time to generate it?

How do you define 'best' when it comes to deciding the time to generate?
In our case 'best' meant going for low fuel consumption and low NO_x emissions, because we couldn't expect too much NO_x reduction from the passive De NO_x catalyst.

But isn't there often a trade off between NO_x and consumption?
Yes there is. So what we do is introduce something called an objective function, which is effectively a weighted sum of the fuel consumption and NO_x emissions – and what we then want to do is minimise the objective function as you go along. The objective function analysis talks about costs and benefit, so if you generate, it's a cost, and if you motor, it's a benefit. At the beginning of the programme we asked ourselves the first question whether we should motor with the ISA, boosting electrically on the move in order to reduce emissions. It's not an easy question, as all that electricity you use to boost has to come from somewhere, and because we've got a lot of electrical loads on i-MoGen we have already used up a lot of our regen' energy. So there's no 'free' electricity – anything we use for boost we have to generate.

With the strategy running we soon confirmed that with our optimisation criteria, there are very few occasions when you would motor to reduce the objective function.

Could this be applied to any combination of power sources?
Yes, and not just different power sources. You could extend your parameters to include, say, NVH as one of your cost functions.

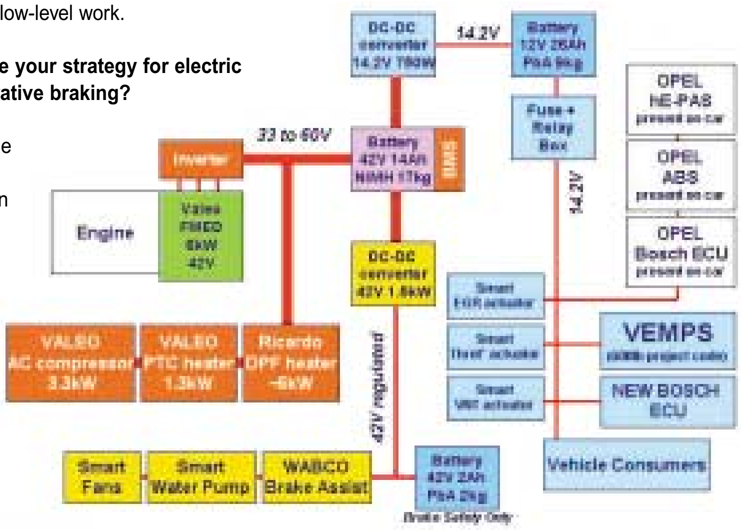
Are there other real world constraints you have to take into account?
When you go to the real world, you get other constraints coming in. One of these is that for the battery to maintain a normal life the zone of state of charge we are allowed to play with constrains these types of strategies. Other functions get ramped out as the state of charge nears its limit.

How does the strategy work in terms of the components interacting?
The idea is to have a supervisory controller, where one module looks after everything else. On the vehicle there are five control units: Bosch for the fuel injection, the Ricardo VEMPS rapid prototype controller running the supervisory control strategies as well as new engine-related functions such as thermal management and exhaust aftertreatment, and three Valeo controllers looking after the battery, the ISA and the HVAC system. The supervisory architecture allows the other controllers to do all the low-level work with the I/O; they talk in reasonably high-level language to the supervisory control. This allows us to develop hybrid strategies independent of the low-level work.

How did you define your strategy for electric boost and regenerative braking?
There are two ways we need to boost the vehicle. Turbo lag compensation, when the ISA bridges the gap between the torque the driver calls for and what the engine can supply: this helps driveability. You've also got full load acceleration, when the system gives it everything. For regen' braking we decided on the simplest approach – to ramp it in as soon as the fuelling goes to zero. You can hardly feel this in operation as it is effectively compensating for the reduced engine braking from our small engine, and it also has a big advantage [over brake pedal triggered systems] in that you regenerate more frequently because you don't need to move your foot.

How do you set about calibrating a hybrid vehicle?
You have to deal with the interactions between engines and ISAs and things like energy management. Because we have used the same tool as Bosch used for their engine control unit, it simplified calibration of things like the EGR and the VGT, which are in the VEMPS unit. An important area was the phasing out of the electric assist: the ISA only works below 2200 rev/min, so you have to phase it out and phase in the engine without the driver feeling any steps in torque.

In terms of validating the original simulations, has the vehicle's performance shown these predictions to be accurate?
Yes, for example, we were predicting about four [litres per 100km] and we got about four. ■



Seeing – and being seen

Now fifteen months into his chairmanship of Valeo, Thierry Morin has established a clear vision for the future of the multi-faceted Paris-based Tier 1 giant. But, as our interview reveals, many difficult decisions had to be taken along the way

Mr Morin, for a year now your name has been associated with the global restructuring of Valeo. What has been achieved so far?
When I took over as Chairman of Valeo in March last year, Valeo had just recorded its worst losses ever. Against this background, one of my main objectives was to restore the company's profitability. I am glad to say that we are well under way to achieving this. Our operating results for 2001 show a continued recovery which can be attributed to the efforts we have undertaken in several areas.

My first challenge was to refocus the Group on its core businesses on the one hand, and to boost its innovation and technology on the other. This implies not only restructuring action plans, such as reduced supply base or non-core business divestitures, but also enhanced R&D within our strategic Domains. Valeo is building its future through innovation and high technology and we will continue these efforts in 2002.

Valeo has recently announced the closures of some sites in North America. Is the Valeo business in the US more difficult than in other regions of the world?
Valeo has nearly 25 per cent of its business in North America. It is a fact that the North American automotive market is currently experiencing a downturn. Valeo is closely linked to the vehicle manufacturers' production schedules. However, we have been proactive in anticipating this downturn thanks to the efforts that are now instrumental in turning the company around.

Let's take a closer look at Europe. What are your economic expectations for the European automotive industry this year and what are your plans for Valeo?
In the expectation of a further slowdown in the European market, Valeo will reap the

benefits of the actions begun in 2001 and will continue its recovery. Our worldwide restructuring process will further strengthen the competitiveness of our industrial base. We are also increasing joint customer development programmes of leading high-technology cost-competitive systems. To do this, we are capitalising on our technological expertise in our key Domains presented at the Frankfurt Motor Show last year: "Electrical Energy Management", "Seeing and Being Seen", "Vehicle Thermal Systems", "Vehicle Access and Security" and "Driveline Systems".

What is happening with your Rochester site? Which exact profitability prospects do they have to fulfil and what is further planned with this factory?
We are implementing a four-point plan to create a profitable future for our Rochester facility: customer partnership, supplier consolidation, operational efficiencies and labour cost optimisation. Our goal is to ensure that the VESI (Valeo Electrical Systems Inc) business at Rochester becomes viable.

You'll try to better integrate the supplier base. What does that mean exactly?
Our objective is to reduce the costs of the global supply chain by reducing the number of suppliers, select the best and offer them more volume in return for better productivity and technology. This should further enhance what we call the Valeo extended enterprise, which includes both Valeo and its suppliers.

To this end, we have several key programmes. We have a preferred supplier programme, which today comprises 50 selected top suppliers. We also launched a global e-procurement programme with on-line catalogues and on-line bidding designed to optimise purchasing, procurement and supplier integration. This saves time, facilitates communication, and strengthens ties with our best suppliers. Additionally we are implementing specific logistics programmes to reduce transportation costs.

To reduce your production costs, you will increase standardisation. Is that possible for a supplier who has to meet many different wishes of its customers?
Our goal is to standardise components and processes to ensure quality and reduce costs within all Valeo and supplier plants. Using this standardisation approach, Valeo is able to concentrate on its integration know-how in order to respond to individual customer demands for complete and innovative customised systems.

At the Frankfurt Motor Show you defined Valeo's key Domains – Electrical Energy Management, Seeing and Being Seen, Vehicle Thermal Systems, Vehicle Access and Security, and Driveline Systems. Could you give us a short overview and what new developments are in the pipeline?
"Domains" are a visionary approach to customer-led innovation to better meet customer expectations. They are our fields of expertise. The Domains approach is the foundation of our marketing and technology strategy. Through Domains, we further identify and exploit the company's synergies.

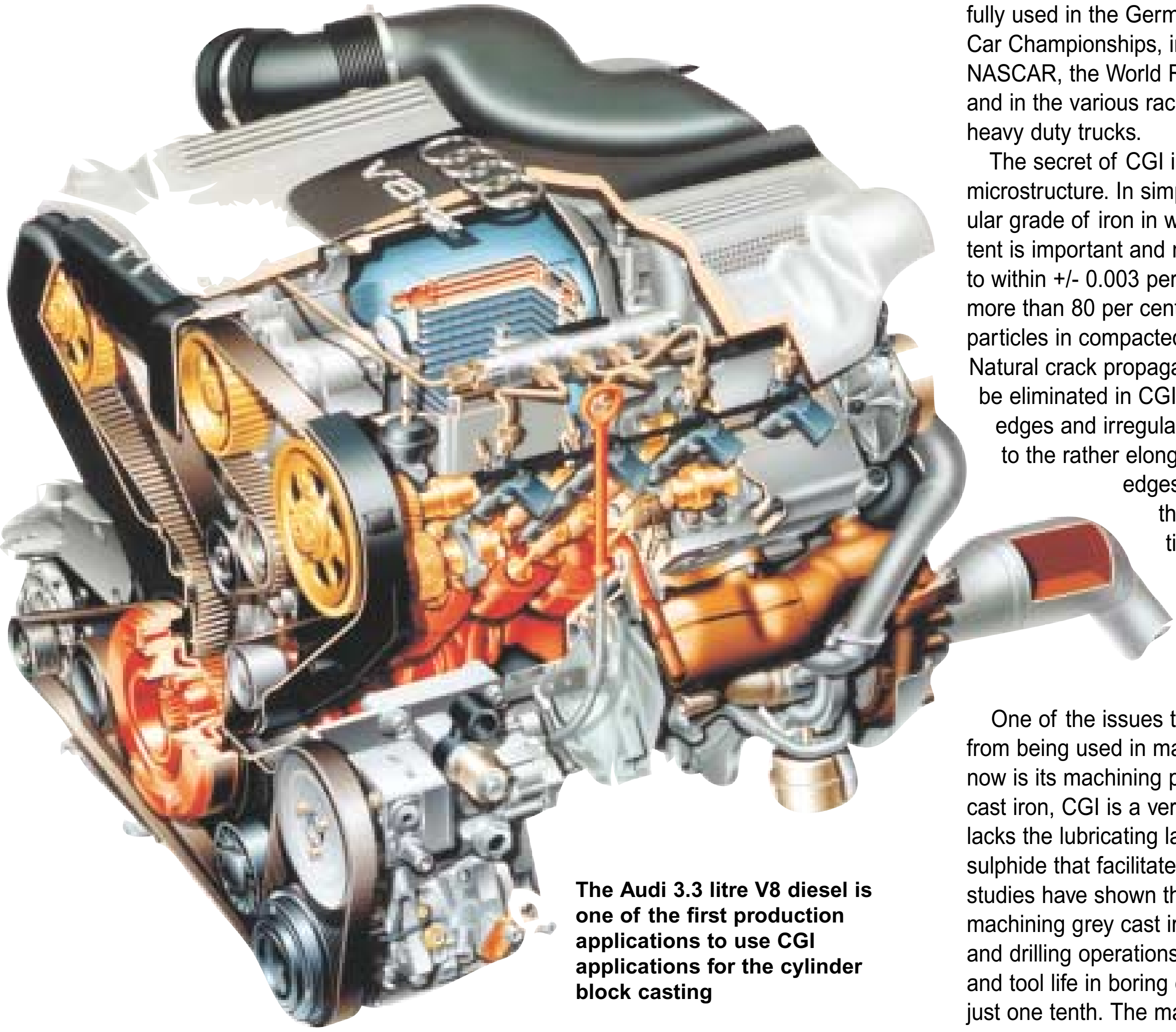
We sign technology partnerships where appropriate and have just entered an alliance with International Rectifier to strengthen the technologies in the Electrical Energy Management Domain. We are demonstrating to our customers how Domains work in practice by equipping several vehicles with numerous integrated innovative systems. Our "Seeing and Being Seen" vehicle now interlinks lane departure warning, rain-light-tunnel sensor, flat blades, parking slot measurement, hybrid parking aid with radar, wash/wipe sensor and rear camera with sensor fusion. Already, many of our customers have expressed enthusiasm for these advanced systems combinations that demonstrate the importance of the Valeo technology for the automotive industry. ■

AutoTechnology

This article is taken from an interview originally published in AutoTechnology 2/2002 page 42-43. The international magazine for automotive engineering, production and management. For further information contact AutoTechnology@bertelsmann.de or visit the magazine's website www.auto-technology.com

Material Gains

New materials promise to give the cylinder blocks of the future far greater performance. William Kimberley talks to the Ricardo design team about their ideas



The Audi 3.3 litre V8 diesel is one of the first production applications to use CGI applications for the cylinder block casting

During the last 18 months there has been a great deal of debate about material usage in future diesel engines. With talk of peak pressures increasing from the current 160 to 180 bar to around 190 to 210 bar for light duty diesel engines, existing materials are reaching their limits. This is allowing new materials and solutions to make an appearance.

One of the talks of the town is compacted graphite iron (CGI), the material that is being heralded in some circles as the panacea to any problem. Robust and able to withstand higher pressures than either aluminium or grey cast iron, it is being championed by both Ford and Audi. Both have openly stated that they will be launching V6 diesel engines with CGI cylinder blocks in 2003. Once fully ramped up, it could mean as many as 400,000 units a year being produced between the two companies.

According to some more bullish reports, though, this is nothing but a drop in the ocean: there is talk of a potential 10 million engines a year made using CGI blocks. Whether this number will ever be remotely reached is open to question, but what is not beyond doubt is that Ford is investing more than $1 billion over 10 years in its new Lion V6 engine that will power future Jaguars, Land Rovers and Fords. A V8 derivative is also in the pipeline, so Ford for one is taking the CGI solution very seriously.

CGI is not a 'new' material as such – Ford engineers have been working on it for the last two decades and Audi has used CGI for the blocks of its high-performance 3.3-litre diesel. However, annual production volumes for this Audi engine are typically around only 3500 to 4000 units. In North America, Caterpillar is using some CGI parts, while Chrysler uses a type of CGI for the bed-plates of its 4.7-litre and 3.7-litre V6 gasoline engines for use in Jeep and Dodge trucks. A number of car and truck manufacturers have also been evaluating CGI in their motorsport activities, and as such it has been successfully used in the German and British Touring Car Championships, in Formula 3000, NASCAR, the World Rally Championship and in the various racing championships for heavy duty trucks.

The secret of CGI is found in its microstructure. In simple terms, it is a particular grade of iron in which magnesium content is important and needs to be controlled to within +/- 0.003 per cent. It must also have more than 80 per cent of its graphite particles in compacted or vermicular form. Natural crack propagation avenues tend to be eliminated in CGI, thanks to its rounded edges and irregular surfaces – in contrast to the rather elongated flakes with sharp edges and smooth surfaces that characterise conventional grey cast iron. Where normal grey cast iron has a tensile strength of 25 kg/mm^2, that of CGI is 40 kg/mm^2.

One of the issues that has inhibited CGI from being used in mass production until now is its machining properties. Unlike grey cast iron, CGI is a very low sulphur iron so lacks the lubricating layer of manganese sulphide that facilitates machining. Various studies have shown that compared with machining grey cast iron, tool life for milling and drilling operations in CGI can be half and tool life in boring operations restricted to just one tenth. The machine tool power requirements are up to 30 per cent higher, while other specific recommendations include larger spindle motors and spindles, stiffer tool holding and increased damping.

Until very recently, it has been impossible to machine CGI cylinder blocks with the speed and economic efficiency required for high-volume series production – but things have now changed. Working in partnership with a number of organisations including Ford, the PTW Institute at Darmastadt University, Aston University, ABB for foundry automation, Grainger & Worrall for rapid prototyping and Lamb Technicon for high-volume machining, the Swedish company SinterCast – which developed the material – has come up with a number of solutions.

What has so excited some in the automotive industry are the superior properties of CGI, which allow smaller and lighter engines with improved performance and fuel economy. This has led to predictions that 80 per cent of all light duty diesel engines will be made out of this material in the future. Nevertheless, popular though CGI may become, there will still be a place for grey cast iron and aluminium in future diesel engines, says Paul McNamara, director of design at Ricardo.

"When you look at the range of materials available for the design of a modern cylinder block it becomes immediately apparent that they each have their respective advantages and disadvantages, depending on the engine configuration and duty," says McNamara.

"It's not just a case of which material has the highest specific strength or the lowest unit cost – otherwise the industry would simply decide upon the optimal material and fix upon it for all future products."

McNamara goes on to describe how the particular challenge of designing a modern V-configuration engine lends itself to some of the advantages of CGI. "On these engines you have complex casting geometry between the bulkheads of the cylinder block where you need to maintain thin wall sections under fairly high structural loads. There is a critical Z-shaped section at this location which is a fundamental aspect of the V-configuration, and the additional strength of CGI can enable a more compact – and lower-weight – design solution."

Despite the talk of increasing engine ratings, particularly for diesel passenger car applications, McNamara's view is that this need not in itself translate into a requirement for higher strength materials. "We are currently doing research and development work focused on starting diesel engines with lower compression ratios which have very high ratings but maintain current cylinder pressures. This means that even for future increasingly high output diesel engines we may well continue to use grey iron or aluminium for applications demanding lower engine weight."

But while the Ricardo view of the future for automotive diesel blocks is that CGI will find application in V-configurations while more conventional materials will continue to dominate for in-line engines, this rule may not extend to the heavy truck sector. Ian Johnstone, chief designer for advanced technology engines, takes up the story:

"It's a personal view, but I believe that CGI is likely to play a significant role in heavy-duty truck engines as well as in the automotive sector. Maximum cylinder pressures are likely to continue increasing on truck engines, and with 220 bar being the figure we are currently aiming for, CGI has attractive properties for both in-line and V-configurations." However Johnstone does not view CGI as a panacea, even for this sector. "We know that many manufacturers are working on CGI blocks and liners and we can understand the rationale for this, but we need to keep an open mind as there may well be many instances where more conventional materials offer a more appropriate design solution."

Ricardo design director Paul McNamara: the additional strength of CGI can be valuable in the design of V-configuration engines

While Ricardo is nevertheless undertaking its own investigations into the material and has a research engine with peak pressures up to 300 bar, it is also considering other materials and solutions for future (2010-2015) engines. One such is the plastic coolant sleeve for automotive engines where the coolant jacket is not included in the block casting, but rather is a separate sleeve fitted over the cylinders. One advantage, says Andy Skipton-Carter, chief designer, light duty diesel engines, at Ricardo, is a weight saving of 1.5 kg, while the coolant jacket is not compromised by casting requirements and can be optimised. The material and construction of the sleeve can be chosen to minimise thermal and acoustic radiation. It does mean, though, that a robust sealing system is required to prevent leaks, and there will be some reduction of powertrain bending stiffness.

Skipton-Carter and his team are also looking at separate crankcase covers where they are fitted to each side close to the crankcase. Again, an additional weight reduction of around 900g is a major factor, while the material and construction of the covers can be chosen to minimise thermal and acoustic radiation. Other advantages, says Skipton-Carter, are that the bulkhead holes will provide good internal engine breathing, and an integral oil drain, breather, dipstick tube and loom trunking can be provided within the covers.

Another area being investigated by the light duty diesel team is that of the advanced monoblock concept, which to many will hark back to the pre-war days of Bugatti amongst others. Again, there are weight advantages, bore distortion is reduced due to the removal of the head bolt load and there are not any head gasket durability problems. Additional benefits, says Skipton-Carter, are improved cooling around the top of the cylinders, and fatigue resistance is increased as the structure can be pre-loaded. However, the whole design is far more complicated and would make rigorous demands on the cylinder head casting and the machining of the cylinder bore and gas face features.

Ricardo is also looking at advanced skeletal structures being made out of stress bearing materials of either iron or aluminium, but with the external parts that carry less load being made of plastic.

At the end of the day, though, both grey cast iron and aluminium will remain widely used for the mainstream light duty diesel engine, maintains McNamara, pointing to Volkswagen's forthcoming V10 in which aluminium is being used as far as possible for weight considerations. "There is no doubt that CGI will prove beneficial for V-configuration light duty diesel engines, but it is unlikely to be universal," he says, "as there will usually be other solutions available. Grey cast iron and aluminium will be with us as engine materials for a great deal longer yet." ■

Volkswagen V10 diesel: uses aluminium primarily for weight reasons

William Kimberley is editor of Automotive Engineer

Ricardo seminar series launches with Diesel Engines in Europe

Brendan Wilde (left) presented results of diesel market research, while Steve Whelan (above) highlighted future technologies

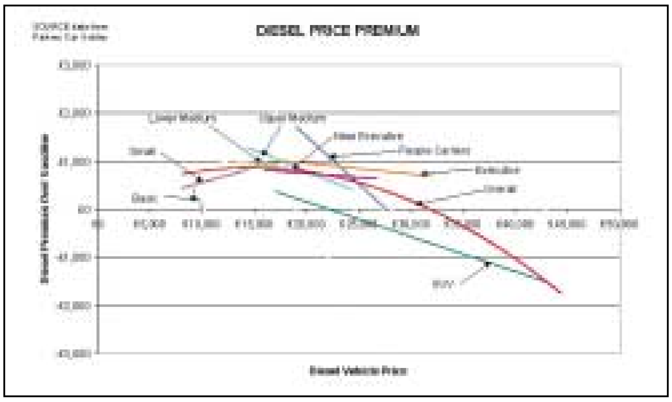
On May 23rd Ricardo hosted the first in what it intends to become a series of technical seminars on topics of interest and relevance for automotive industry executives. This first such seminar, entitled Passenger Car Diesel Engines in Europe, attracted a capacity audience of delegates, drawn from throughout Europe and representing a cross-section of the auto industry including vehicle manufacturers, Tier 1 components suppliers, and oil companies.

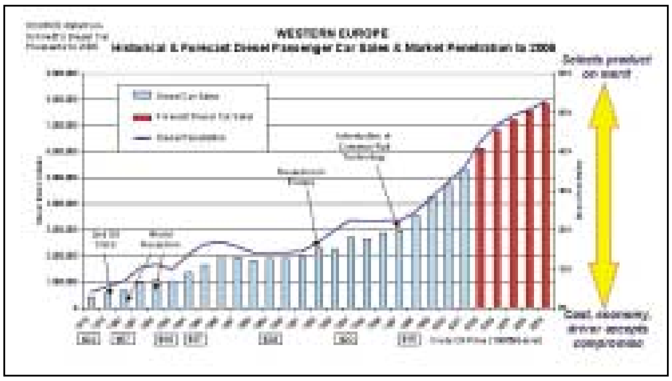
The seminar comprised two technical sessions. The morning session was led by Brendan Wilde and focused on why Europeans buy diesel passenger cars. Much of the material for this session was drawn from an in-depth research project investigating this subject conducted by Wilde and colleagues over the past year. A wide range of detailed results drawn from the study were shared with the seminar delegates. Recent trends in European diesel car purchasing were described, together with a detailed segmentation by country and by market sector.

Wilde then moved on to outline his findings as to why Europeans buy diesel cars, as well as the reasons for geographical and sectoral differences. For example, while Germany accounts for the largest number of diesel vehicles sold, the proportion of cars sold that are diesel is highest in France. The diesel penetration in minivans has overtaken that of SUVs, and diesel use in luxury cars has increased recently too. This topic sparked a considerable debate amongst the delegates. The discussions were made all the more informative and insightful thanks to the many metrics that Wilde presented. These included charts of predicted price elasticity for diesel cars in Europe for 2006 and predictions of the key growth segments between now and 2010.

The afternoon session was led by Steve Whelan, manager of diesel engine development at Ricardo Consulting Engineers. Whelan provided a broad overview of the technology trends of diesel passenger cars, including downsizing, boosting technologies, emission control systems, system integration and control, and mild hybrid systems. Given the breadth of this subject area, it was not possible to discuss each area in full detail.

From the questions and discussion that followed it became abundantly clear that there would be great interest in Ricardo organising a series of technical seminars focusing in more depth in a range of specialist areas of diesel engine technology. ■





Mild Hybrid Seminar set for September

The next Ricardo technical seminar is planned for September 26th and will focus on mild hybrid vehicle technology. The seminar will commence with a broad overview of alternative powertrain technologies, with reference to the Ricardo technology road map in this area. The overview will consider parallel, series and mild hybrids as well as fuel cells, and will demonstrate the attractiveness of mild hybrid technology in the short term. This will be followed by an in-depth description of the systems embodied in the i-MoGen project featured in this issue of RQ, as well as wider issues of mild hybridisation. As with all Ricardo seminars, ample opportunity will be given for informed discussion and debate, and delegates will receive a comprehensive set of presentation materials.

● For information about this and future Ricardo technical seminars, please contact Rob Thring at RHThring@ricardo.com or see the Ricardo website at www.ricardo.com

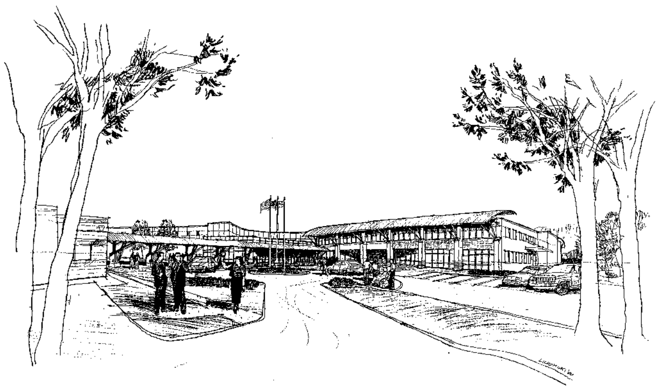
Detroit Technology Campus takes shape

Following the ground-breaking ceremony in December 2001, work is now progressing apace on the new Ricardo Inc technology campus in Van Buren Township, Michigan. As the ground is cleared and the structure of the new buildings takes shape, the scale of the expansion of the site into the new Detroit Technology Campus is immediately apparent. "The development of our Belleville site is a significant investment for Ricardo and is demonstrative of the confidence that Ricardo places in the future of its North American business," commented Ricardo Inc President, Jeremy Holt.

Ricardo views this development as a more fundamental strategic decision than one driven solely by the need to grow and consolidate its Detroit based facilities. Following a thorough review of all of its North American operations, the company decided to embark on this major expansion for a wide range of reasons, from hard financial concerns to the softer issues that are all important for a people-based business. "It's not just about optimising the cost structure of the business and providing headroom for expansion," continues Holt. "It's about achieving a critical mass for maximum operational efficiency in working on major customer programmes, sharing knowledge and technology between engineering teams – and providing a positive and rewarding working environment for our employees."

The new two-storey office and vehicle engineering complex will almost triple the size of the existing Ricardo facility and provides capacity for a further subsequent expansion of similar size to the current buildings. The new building comprises 49,000 sq ft (4550m^2) of office space which will be used for design, CAE, thermo-fluids, vehicle refinement, control and calibration engineering teams. Space will also be available for conference rooms, project offices, a technical library, administrative and support facilities. The garage area and vehicle workshop will occupy in excess of a further 20,000 sq ft, including confidential vehicle evaluation and assembly areas. The new campus will incorporate additional parking for 218 employee cars together with a confidential parking lot for project vehicles. Ricardo is taking the campus concept seriously, with a covered pedestrian access provided between the new building and the existing technical centre.

Ricardo CEO Rodney Westhead digs the first foundation – with the aid of some extra horsepower



Ricardo is not alone in recognising the potential of Van Buren Township as being an excellent business location, next to the Interstate network and only 10 minutes from Detroit Metropolitan Airport. In May 2002 Visteon Corporation announced that it will build its new global headquarters less than a mile from the Ricardo Detroit Technology Campus. Such a vote of confidence in the local area as an ideal location for the automotive supply chain is well appreciated by community leaders.

Commenting on these two important automotive industry developments, Cindy King, Supervisor of Van Buren Township, commented: "Ricardo's new Detroit Technology Campus and Visteon's new global headquarters are two examples of why Van Buren Township is a great place for businesses and residents. The Ricardo campus expansion will be an asset to Van Buren Township and help set a positive image in our community." ■

New Japanese distributor for Ricardo Software

Ricardo Software announced in June that it has appointed Sumisho Electronics Co. Ltd. as the distributor in Japan of the company's suite of engineering analysis software products. In addition to handling all sales enquiries in Japan, Sumisho will also provide support and training to new Ricardo Software customers in Japan. Commenting on the appointment, Ricardo Software president Dr Richard Johns said: "Sumisho Electronics Co. Ltd. has extensive experience in distributing and supporting engineering software and its appointment as our distribution and support agent will enhance the service that we are able to offer our Japanese customers, in particular by providing access to Japanese language and local time-zone communications." Sales enquiries in Japan may now be directed to: Science System Sales, Sumisho Electronics Co. Ltd., Tel:+81 (3) 5217-5390, Fax: +81 (3) 5217-5391 or e-mail rs@info.sse.co.jp

A State occasion

Ricardo has been a major partner to Bentley in a UK industry programme to develop a new State Limousine for the Queen

On May 29 at Windsor Castle near London, Bentley Motors chairman and chief executive Franz-Josef Paefgen formally presented the new Bentley State Limousine as a gift to Queen Elizabeth II from the British Automotive Industry on the occasion of her Golden Jubilee, the celebration of 50 years on the throne.

The result of a two-year collaboration by a consortium of British-based motor industry organisations, of which Ricardo was a leading player, the State Limousine soon entered royal service as a part of the official Jubilee celebrations. Its first official journey was on Tuesday, 4th June, when the car was used to take The Queen and The Duke of Edinburgh from the national Service of Thanksgiving at St Paul's Cathedral, London, and it will be used extensively throughout the Queen's Golden Jubilee Tour.

Ricardo was a major partner to Bentley on the programme, carrying responsibility for all powertrain integration aspects of the vehicle. "We were delighted to have been a key engineering partner to Bentley for this programme," commented Ricardo Vehicle Engineering managing director, Clive Hickman. "Ricardo has a wide range of design technologies appropriate to a challenge such as this, and we have a thorough understanding of the marque values necessary for a vehicle of this stature."

The project team created a digital buck to enable them to simulate and develop the under-bonnet package layout before moving into hardware. Not only did this provide a means of producing a high-quality engineering solution but it also saved both time and cost. The team were also responsible for the thermal management and refinement aspects of the powertrain installation, and were careful to ensure that the all-important marque value expectations of a Bentley product were maintained in the engineering work carried out.

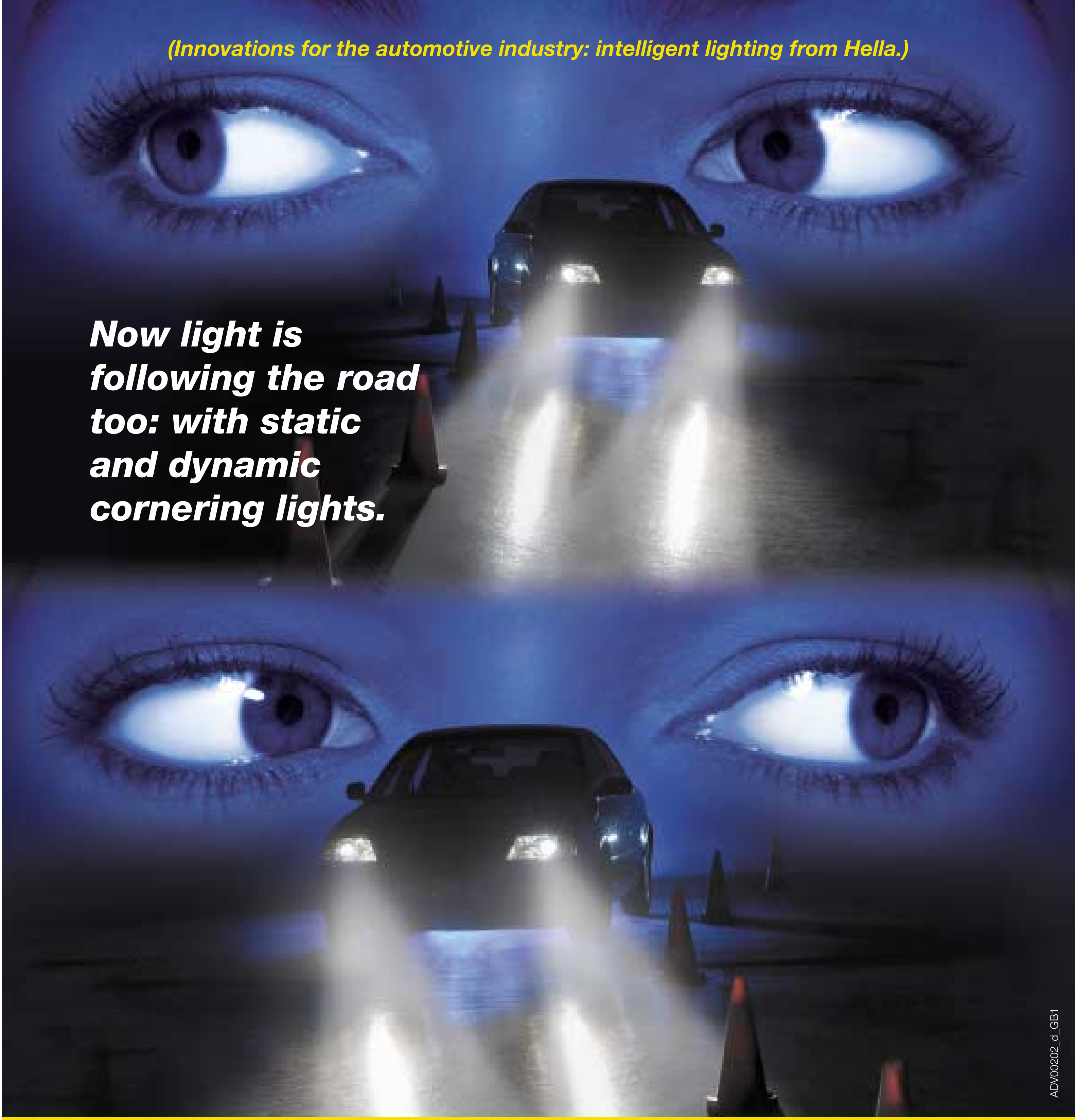
The basic statistics of the Bentley State Limousine give some indication of the engineering challenges it represented. At 6220 mm (249 in) in length and at a height of 1770 mm (70 in), it dwarfs the company's Arnage, from which the design is derived. Its wheelbase of 3844 mm (154 in), is around 1300 mm (52 in) longer than that of an average sized family sedan and it has a kerb weight of 3390 kg (7474 lb). Despite this, the vehicle can accelerate to 60 mph in 8 seconds and has a top speed of 120 mph (195 km/h).

The car is powered by a modified version of Bentley's new 400bhp, twin-turbo 6.75-litre V8 engine. Modifications have been made to the air boxes to allow them to package under the hood, while a larger alternator is fitted to cope with the added demands of the electrical system. The capability of running on liquid petroleum gas (LPG) will not only extend the range of the car but will also provide reduced emissions.

An association with such a high profile vehicle programme clearly has its own rewards for Hickman and his team. "Ricardo has supported Bentley with powertrain and chassis engineering services for many years, but it is particularly gratifying to have been involved in such a prestigious programme," said Hickman. Designed for a minimum lifespan of 25 years and 125,000 miles, the Bentley State Limousine is expected to be the Queen's principal transport at state and ceremonial occasions and will therefore be a familiar sight well beyond the end of the Golden Jubilee celebrations. ■

Her Majesty the Queen inspects the new Bentley State Limousine (top)

Ricardo digital buck for under bonnet layout (right)



VARILIS headlamps for static and dynamic cornering light.

Hella xenon headlamps put daylight into headlamps, now our VARILIS system is making the lamps intelligent: they supply the right kind of light for the respective traffic situation. The dynamic dipped beam or main beam light, for example, automatically illuminates corners and curves by being swivelled according to the radius of the curve being driven. And an auxiliary headlamp for static cornering illumination always switches itself on providing additional light when the vehicle has to drive round extremely tight corners – such as when turning off at junctions in town traffic, for example.

HELLA®

Ideas today for the cars of tomorrow

Hella KG Hueck & Co., Rixbecker Str. 75, 59552 Lippstadt, Tel.: +49 (0) 29 41/38-77 44, Internet: www.hella.com
Unlimited Job Opportunities for Engineers: www.hella.com