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Racecar engineering™

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EXPLOITING THE REGULATIONS
How one manufacturer took the rule book to the limit

21ST CENTURY INDYCAR
We talk to those in the know about the changes on the way

BMW FORMULA 1 POWERHOUSE
Looking back at the German marque's legendary turbo engine

GLOBAL RACE ENGINE

EXCLUSIVE FIRST SIGHT

IS THIS THE 4-CYLINDER FUTURE OF WORLD MOTORSPORT?

Le Mans report
Our technical spotters delve into the latest developments

KERS with a difference
Flywheel-electric combination for new Flybrid-Marelli system

Mid-season update
The FIA's Tony Purnell on Global Race Engines, KERS and cost-caps

Just in case you hadn't noticed, this month's issue of *Racecar Engineering* is all about engines. By way of explanation, what originally prompted this was our curiosity regarding the so-called Global Race Engine. We had heard of Audi Sport's Ulrich Baretzky proposing the concept at a motorsport conference in Oxford last year. We also knew the FIA had been sufficiently interested to commission an initial feasibility report on the subject from highly respected automotive engineering firm, Ricardo. The more we dug into the subject, the more interesting it became and the more we became convinced that the concept of a multi-discipline motorsport engine made sense.

We spoke with a number of senior people in the motorsport world to solicit their views on the Global Race Engine, but it was one man in particular who crystallised our thoughts on the subject. Dave Mountain, founder of Mountune Racing, has a wealth of experience designing and building engines for motorsport. He also enjoys close relationships with a number of major motor manufacturers.

The point he makes is that the ongoing push to improve fuel consumption as well as the overall efficiency of roadgoing engines means they will increasingly be optimised to achieve those goals. At the same time, they will become ever less appropriate for the rigours of motorsport. It would therefore seem to make good sense to develop a cost-effective engine capable – with adaptation – of being used in a number of different racing and rallying categories. In any event, read on – we think you may become convinced as well.

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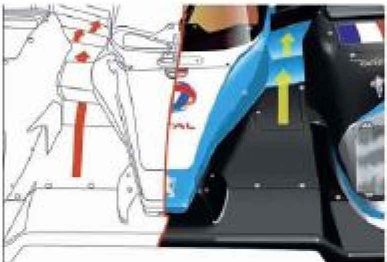

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The International Journal of Motorsport Technology
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FORMULA 1

Max Mosley declares 'we now have peace'

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Thirteen teams for 2010 Grand Prix season and FIA president agrees not to stand for re-election

Already colourful, the Formula 1 grid in 2010 will feature an additional six cars

LAT

ON 24 JUNE, after a day of high drama in Paris, the controversy raging in Formula 1 finally appeared to have been resolved. An 11th-hour deal was struck between motorsport's governing body, the FIA, and the Formula One Teams' Association (FOTA), which heads off a threatened breakaway series. As part of the deal, which was brokered in crisis talks held before the WMSC meeting between FOTA chairman, Luca di Montezemolo, F1 commercial rights holder, Bernie Ecclestone and FIA president, Max Mosley, the latter agreed not to run for re-election in October, while FOTA teams agreed to sign up to a new Concorde Agreement that will last until 2012.

As a result, the entry list for the 2010 Formula 1 World Championship has been confirmed as comprising the 10 current teams plus the three new squads, listed earlier in June – Manor Grand Prix, Team US F1 and Campos Meta (*see sidebar*), all of which will use Cosworth power. Formula 1 fans can therefore look forward to the prospect of 26-car grids in 2010, and beyond.

Speaking following the WMSC meeting, Mosley

> teams agreed to sign up to a new Concorde

said, 'I will not be up for re-election. We now have peace. There will be no split. We have a reduction in costs. There will be one F1 championship in 2010, but the objective is still to get back to the spending levels of the early nineties within two years.'

The rules for 2010 onwards will be the 2009 regulations as well as further regulations agreed prior to 29 April 2009. In addition, the manufacturer teams have agreed to assist the new entries for 2010, by providing technical assistance, and further agreed to the permanent and continuing role of the FIA as the sport's governing body. They also committed to the commercial arrangements in place for the FIA Formula One World Championship until 2012, and have agreed to renegotiate and extend this contract before the end of that period.

Rather overshadowed by the apparent resolution of the Formula 1 situation, the WMSC also agreed a number of changes to other branches of motorsport, most notably to the format of World Rally Championship events, which will be freed up from their current rigid structure in a bid to re-establish their individual characters.

FORMULA 1's NEW TEAMS

Campos Grand Prix


Adrian Campos

This multi-championship winning Spanish team was set up in 1998 by former F1 driver Adrian Campos. The team's headquarters will be in Madrid with a technical centre in Valencia. As well as the engine deal with Cosworth, Campos has a technical partnership with Dallara to produce its chassis.

Manor Grand Prix


John Booth

The inclusion of this team surprised many, but there's plenty of pedigree in the form of Manor boss John Booth – a no-nonsense, single-seater man who's been winning races for years – and technical director, Nick Wirth, once boss of the Simtek F1 team and now head of Wirth Research Ltd (WRL), an engineering company founded by him in 2003, and which has had success in both the IRL and ALMS. Wirth is to be Manor GP's technical director, a role he filled at Benetton between 1996 and 1999.


Nick Wirth

US F1


Ken Anderson

The least surprising of the new entries, this American-based operation made its intentions to compete in F1 clear well in advance of the recent budget capping controversy, and is thought to have already attracted plenty of investors. US F1 is to be based in Charlotte, North Carolina and run by Ken Anderson and Peter Windsor. Anderson has previously been a technical director in F1 and is the man behind the Windshear facility, while journalist Windsor was once team manager at Williams.


Peter Windsor

Photos: LAT

TOURING CARS

BTCC unveils NGTC regulations

THE BRITISH TOURING Car Championship has revealed a new set of regulations aimed at reducing cost and increasing the spectacle of the UK's premier tin-top series. Stand out features of the 'Next Generation Touring Car (NGTC)' regulations include the adoption of turbocharged 2.0-litre engines, but also the banning of rear-wheel drive and diesels. It is hoped the regulations, due to come into force in 2011, will slash budgets by around 50 per cent.


Next generation Touring Cars will all be based on saloon bodies, rather than the hatchback style of the S2000 cars

The budget cut will be achieved through

> running costs will be some 50 per cent below the present level

the standardisation of major components, such as subframes, gearboxes, suspension and brakes, coupled with the durability of the new 300bhp turbo engine and further standardisation of parts within this engine.

PERFORMANCE PARITY

The NGTC engines will be fitted with a controlled-specification turbo (probably a low pressure unit), wastegate, intercooler and ECU to reduce both development costs and opportunities for technical infringements. Teams not wishing to undertake their own engine development programme will have the option of using a TOCA-developed NGTC engine that will be equal in performance to the non-TOCA provided engines. The BTCC believes engines should last an entire season without a rebuild.

NGTC cars will also be based on larger models, with an increased minimum length of 4.4m and a standardised width of 1875mm. There will be a new front aero package, while all cars will be wind tunnel tested in an effort to ensure aero equality.

RACECAR SAYS...

WHILE THE NEW regulations look sensible – particularly the engine rules – we can't help feeling that the mix of FWD and RWD cars currently racing brings a technical interest to the package without spoiling the show, so it's a great shame to lose that. It's also a great shame to lose the BMWs..

From 2011 onwards, the current S2000 cars will still be able to compete on an equal basis with the NGTC cars, with both types having their performances equalised until 2013, when those running to NGTC specification will be given more engine power.

BTCC director Alan Gow said: 'Our teams now have clear direction on what the future BTCC car will be, whilst (very importantly) protecting their investment in the S2000 cars they currently run right up until 2013. Of huge significance is the fact that we have now achieved a massive cost reduction, with car / engine build and running costs that will be some 50 per cent below the present level.'

Most BTCC team bosses have welcomed the new regulations, but Motorbase principal David Bartrum is unhappy that the new rules mean an end for RWD cars. It's believed the reasoning for the change is down to safety considerations, principally driver positioning in the car.

■ *See interview with Dave Bartrum on page 91*

BRIEFLY...BRIEFLY...BR

ASTON'S ALMS

Prodrive boss David Richards has said that he is hoping to compete in the American Le Mans Series with the Aston Martin Racing LMP1s later this year. The programme is expected to take in two ALMS rounds: the prestigious Petit Le Mans race at Road Atlanta and the season-ending Laguna Seca event.

BMW BACKS NEW ENGINES

BMW has said it would welcome a move to a single spec engine in the WTCC for 2011, although it has still to commit to the series. Meanwhile, SEAT has also welcomed the new 1.6-litre turbocharged engines – expected to be rubber stamped by the World Motor sport Council soon – and has made a commitment to staying in the WTCC, even though it will now have to drop its successful diesels.

LOLA WITHDRAWS

Following its omission from the FIA's entry list for the 2010 Formula One World Championship, the Lola F1 Team politely thanked motorsport's governing body for giving 'serious consideration' to its entry and announced it was withdrawing its application. The company is believed to have been well advanced with the design of its new F1 car.

BOGIEMAN

Former *Racecar Engineering* editor Charles Armstrong-Wilson took best time of the day in the MIRA-built Lindley Special at the inaugural Border Bogie gravity race at Denholm in the Scottish borders. According to the onboard Race Technology data logger, the powerless 'bogie' exceeded 42mph on the fastest part of the course – coincidentally, about the same speed Charles managed uphill at the Gurston Down hillclimb some years ago (only joking, Charles!).

WATCH THIS

Renault F1's 2.4-litre V8 running at 20,000rpm
Go to http://www.racecar-engineering.com/vids

• MORE NEWS ONLINE AT WWW. RACECAR-ENGINEERING.COM

LE MANS

Peugeot wins but protests

French manufacturer takes its concerns to the FIA

+ NEWS EXTRA www.racecar-engineering.com


IAT

2009 was Peugeot's year at Le Mans, yet still it saw fit to lodge a complaint with the ACO

AUDI WAS THE subject of a protest from arch rival Peugeot in the run up to this year's Le Mans 24 Hours. The French manufacturer called for the ACO to clarify the regulations, claiming that the flaps and appendages on the R15's front wings were in place to generate downforce and therefore not within the regulations. But the ACO, the Le Mans organising body, dismissed the protest. Peugeot now intends to take its appeal to the FIA.

Audi arrived at Le Mans with a special, low-downforce version of its R15, featuring a reduction in the nose vent, moves to clean up the airflow around the wheelarches, a re-profiled tail section and smaller rear wing end plates.

The German manufacturer eventually finished third, all three R15s suffering problems at various stages, while Peugeot claimed first and second, its 908 coupés bringing the French company its first victory at Le Mans in 16 years.

Full Le Mans technical report on p31

CAUGHT!

JTR's **Nick Tandy** was excluded from the results of race one of the British Formula 3 Championship's Hockenheim event after irregularities were found with the airbox of his Mygale-Mercedes'. The team later explained that the problem was caused by a lump of rubber from the track that had flicked up and cracked the airbox.

PENALTY: EXCLUSION FROM RACE

Kirk Almquist, crew chief for the no 7 NASCAR Sprint Cup car driven by Robby Gordon, has been fined heavily and placed on probation until the end of the year for rules violations at the Lowes Motor Speedway event, where the rear axle housing of Gordon's Toyota was found to exceed the allowable toe of plus or minus one degree. The axle, when inspected, was canted too far to the right, which can help with corner entry and mid-corner stability.

FINE: US$50,000 (£30,000)

PENALTY: LOSS OF 50 DRIVER AND OWNER POINTS

Andrew Crnkovic, a crew member for the SS-Green Light Racing no 07 team in the Camping World Truck Series, has been suspended indefinitely from NASCAR for violating its strict substance abuse policy.

PENALTY: SUSPENDED INDEFINITELY

SPORTSCARS

Racer for the road to hit the track

THE STRIKING CAPARO T1 supercar, described as a Formula 1 car for the road, is to have a high-profile race series of its very own from 2010.

The Pro1000 series, which is the brainchild of Nigel Rees – managing director of promoter Global Sports Ltd and a former racer – will make use of a modified version of the supercar.

A similar plan to run a series in 2009 with chassis from Delta fell through, but earlier this year GPL was able to hook up with Caparo, which was also looking at starting its own series, and now plans are well advanced to have two series – one for professionals and one for amateurs – in operation by 2010.

2010 will see the inaugural race series for Caparo's striking T1 road car

Stuart Scarbrough, sales director at Caparo, says: 'We have built the successful and iconic Caparo T1 supercar and were keen to introduce a T1 race series for talented amateur drivers. We met with GSD, we liked what they were doing and concluded that we could use the same fleet of cars to operate a 10-race 'pro' series and a six-race amateur series. We have designed the T1000 as a variant of the T1, with modifications to suit the needs of the series, particularly costs and ease of operation.'

The racecar features a two-seater, carbon composite monocoque with a detuned MCT V8 delivering 470bhp with a 10,000km rebuild life. The transmission is a six-speed Hewland sequential unit.

For aero, the T1 will not use its full downforce package, but shallower diffusers and aerofoils to help promote overtaking.

The series is to be run centrally – similar to F2 and FPA – with full spares and technical support at each meeting. As yet no organisation has been chosen to run Pro1000, although Sportscar team Damax is currently involved in developing the car and running the ongoing test programme.

SURPLUS PARTS

ROUSH YATES RACE PARTS

HAVE YOU EVER wondered where all the surplus Ford engine and chassis parts go from the various NASCAR racing series? In high-end Sprint Cup, Nationwide, Camping World Truck and ARCA divisions, all racing parts have a set lifespan, but Roush Yates Engineering is now making inspected and reconditioned race parts available through its website. Parts available range from complete engines to wrist pins and even transmission parts.
See www.roushyatesparts.com for more information.

E-NEWSLETTER

UPDATE

www.racecar-engineering.com

EVERY WEEK THE *Racecar Engineering* team sends out its own e-newsletter, featuring the latest motorsport industry news, product spotlights and more than a little opinion.
To sign up for the free newsletter, visit www.racecar-engineering.com and enter your details in the newsletter box.

NEW FROM AP

AP RACING BRAKE PADS

LEADING BRAKE AND clutch manufacturer AP Racing has introduced its own range of brake pads, featuring five different compounds to suit applications from fast road to full competition use. The compounds available are as follows:

APF401 - a competition pad suitable for both circuit and rally use

APF402 - strictly a competition pad, but for circuit and rally use only. Not suitable for road applications

APF403 - a general competition pad, not suitable for road use

APF404 - an excellent high-performance road and track pad

APF405 - suitable for high-performance road, track and lightweight circuit car applications

For more information see www.apracing.com

ON THE WEB

NEW WEBSITES FOR MOTORSPORT SUPPLIERS

CRP TECHNOLOGY HAS released a new website full of general information about the company, including news, events and details of the firm's capabilities. However, as far as we are concerned, the best things on the site are the detailed case studies on everything from Sportscar racing to MotoGP.
Visit www.crptechnology.com

MEANWHILE, FERREA RACING Components has launched its own online TV channel, broadcasting a range of videos, from a complete tour of the Ferrea Racing facility to videos of Ferrea's customers' achievements at the track, as well as the top engine builders installing its components. Ferreatv.com will soon feature new streaming videos spotlighting new components, tips on how to install parts and answers to questions posted by customers.
Visit the new online TV channel at www.FerreaTV.com

To find out about the latest new websites in the industry visit www.racecar-engineering.com

Universal soldier

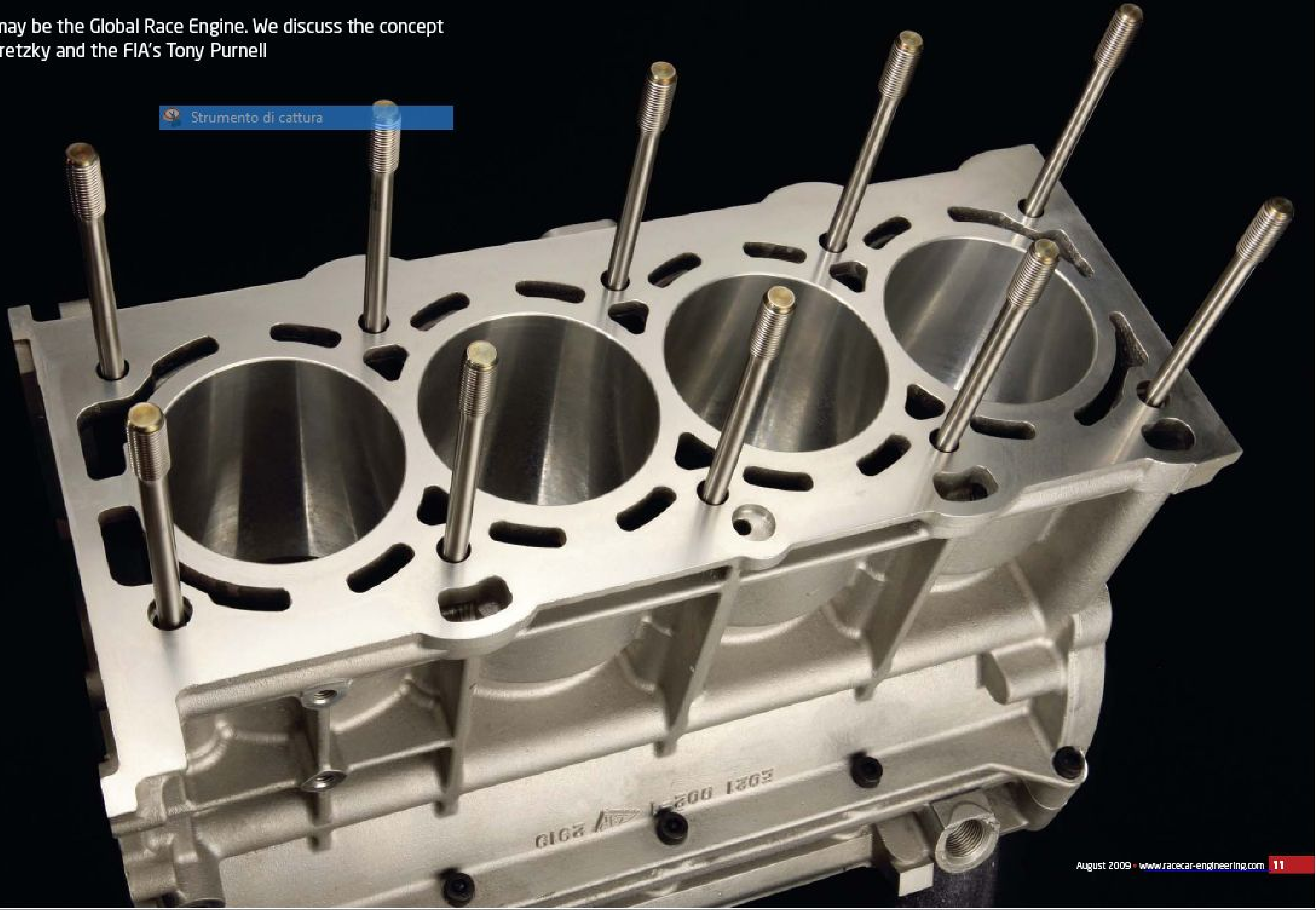
The future of motorsport may be the Global Race Engine. We discuss the concept with Audi Sport's Ulrich Baretzky and the FIA's Tony Purnell

BY GRAHAM JONES

A one-size-fits-all engine providing the motive power for a large number of global motorsport disciplines? Even a few years ago, such a suggestion would have been quickly submerged under the weight of vested interests and corporate egos. But times, and economic circumstances, have changed, and it seems the suggestion of such a concept has now sparked interest in a number of quarters, some of them unexpected.

It was Ulrich Baretzky of Audi Sport who first proposed the concept of the so-called Global Race Engine (GRE) at a motorsport conference in Oxford last year. 'One of the biggest expenses of going racing is the cost of engine development and also the fact that for all different categories of motorsport, you have to develop a different type of engine, which is very expensive. I therefore came to the conclusion that to make it efficient you need to have one type of engine – not one make, but one type – in answer to the issues of environmentally-sustainable motorsport and customer demand.

'This pointed to an in-line, four-cylinder, turbocharged engine with direct injection being an appropriate basis for all championships, starting at about 600bhp for Formula 1 and going down to something like 200-250bhp for Formula 3. They would all be based on the same dimensions, however, so for areas like rally and F3,



GRE could incorporate canted block, to assist aero and weight distribution, plus integral dry sump/main bearing housing, as with Mountune MT1 engine

Considerable thought has been given to minimising external pipework on MT1 with fluid routing mainly within the engne casting and an integral oil cooler

the engine would be [over-engineered], but this could also mean you might be able to run one engine for the whole season in these categories. This was the basic idea behind it, and we then sat down with colleagues at Volkswagen and came up with a proposal that we sent to the FIA in March.

A SET OF DIMENSIONS

'I have to emphasise that this is not a one-make engine, but a set of dimensions within which you can work to make your own engine. Then it is homologated and you cannot make any other changes. You must also make all of the major parts – block, head and so on – available part-machined so smaller tuners can still work with their own branded and homologated engine.

'There is freedom with certain aspects of the engine, but there would be minimum weights for specific components, such as connecting rods, for example, to avoid extreme expense. Once the engine is homologated, development is frozen, except within the areas specified for development. If such an area was the injection system, for instance, then this could be developed without restriction and, after three years, we could sit down and decide on the next area to be developed – say, internal friction.'

Aware of Baretzky's concept and interested by it, the FIA decided to delve a little deeper.

> "you must also make all of the major parts available part-machined"

'We quite liked the idea and felt it was interesting thinking,' explains FIA consultant, Tony Purnell. 'We looked at Baretzky's ideas and, at about the same time, Alex Hitzinger, who had previously been involved with the WRC and Formula 1 engine programmes at Cosworth, came on board. Suddenly, we had within the FIA some real engine design knowledge, so we thought we would take the opportunity to explore the idea further. We joined forces with Ricardo and, at the FIA's instigation, they produced a fairly detailed report on the subject in February-March this year.

'About that time, we got a hint – no more than a hint – that even NASCAR might consider changing its powertrain as some of the teams were concerned about the shift of public opinion in America with the new Obama administration, so we actually included consideration of NASCAR in our study, just to see how global the concept could be.

As I remember, the main thinking of that first report was that the requirements of the most powerful formula should probably have the greatest effect on the engine architecture.'

SPREAD OF OPINION

The report was duly published as something of a 'straw man', as Purnell puts it – 'you hold it up in order for it to be blown apart' – whereupon it was read by a number of people and, predictably enough, generated a spread of opinion. 'Some manufacturers thought it was very important for their marketing to use a production-based engine for categories like World Touring Cars and that to have a special power unit that would be part of some Global Race Engine initiative was rather off-target for their marketing aims, so that was a bit negative,' observes Purnell. 'Then others felt that to have 'one size fits all' was too ambitious and that having, say, a 500kW NASCAR engine and scaling it down to a 300kW Formula 3 engine was a bridge too far.

'It seems to have evolved now into an idea where a lot of people think that a downsized engine, probably four cylinder and probably turbocharged, with direct injection, quite possibly with a hybrid element, is in all our futures. As a result, there really hasn't been much argument about the configuration, as I understand it, but I think they're looking now at a 1.6-litre version for the smaller formulae and a 2.0-litre version for the bigger ones, but still based on the same block, head and bore centres.

'It is fair to say that Baretzky's idea has triggered a lot of interest and comment. A number of the manufacturers met in Paris recently to discuss the idea and the IRL is interested, the rally people are interested, World Touring Car is interested and Formula 3 is interested so, as an idea, it's clear this has caught on a bit more rapidly than had been anticipated.'

While Purnell wouldn't be drawn on any specific timetable for the introduction of the Global Race Engine, he did provide a hint as to where the FIA thinks it might first appear. 'I think there are some formulae that really want to get on with their next powerplant,' he says, 'so while Formula 1 is currently looking at 2013, I think IRL is looking at doing something sooner. But it's Formula 3 and World Touring Cars that want to get on, so I think the 1.6-litre might be the earliest version of this.'

Baretzky himself is of the view that the concept should be introduced sooner rather than later. 'We are in an economic situation where everybody is struggling,' he says. 'Motorsport is an essential part of marketing and a useful tool for [technical] development if you do it in the right way, so the sooner [the GRE concept] is applied the better. If you imagine that I go to my board of directors and ask for $8 million to develop a rally engine and they say, "Well, what else can it be used for?", and I say, "nothing, that's it," they would say, "You are mad!" But if I can go and say to them I need $8 million to develop an engine that can be used in rallying, Formula 3 and Touring Cars, then it is much easier to get agreement on that.'

PRODUCTION COSTS

On the cost aspect, the two men appear to be very much in agreement. 'I have to say that unless something cheap comes out of this, then there's no point in doing it,' says Purnell. 'One thing that is apparent is the cost of converting a production engine to a racing engine is pretty significant, so if there was a common kit of parts where a manufacturer could say with ease and without facing a massive price tag, "oh, let's go World Touring Car," or "let's go World Rally Car," then that's got to be attractive. If we lose sight of the fact the real incentive is to allow significantly lower costs for any manufacturer wishing to enter two or three motorsport categories, then we've lost sight of the whole idea.'

> "the manufacturers feel they need to sprinkle their own pixie dust"

To be clear then, there currently seems to be no question of the FIA leaning towards a sealed concept for the GRE, whereby engines are provided by a single supplier and no blueprinting or 'optimisation' is permitted. 'I don't think that's what the manufacturers want,' responds Purnell. 'We played around with the idea of a standard engine in terms of Formula 1, but the manufacturers feel they need to sprinkle their own pixie dust, otherwise it's not theirs, and you can understand that. I think it will be a bit more like, "There's a kit of bits, perhaps some bits you have to use and some others you machine your own way." I'm sure there will be a significant list of restrictions.

'You can't have hollow, 'unobtainium' valves and such like. While the camshaft, for example, might be on a fixed axis, I can imagine that people would be allowed to play around with valve angles, combustion chamber shapes and piston design – that sort of thing. Again, you could envisage a standard piston provided as a casting, which could then be machined as manufacturers wished. I think that's the right sort of balance, especially today, when complex machining isn't so expensive compared with a few years ago.'

Taking things a step further, might Baretzky and his colleagues have actually started developing an engine along GRE lines, we wondered?

'No, because until the rules are agreed, there is no point in us beginning work, but we have done some simple designs and sketches,' he admits. 'While we want it to be a good engine, we also want it to be a simple engine, because simple engines tend to be good engines, but it would not be a production engine, because if you look at categories like Touring Cars and rallying, manufacturers can be handicapped by not having a suitable engine in their range, and those that do always have an advantage. That is why there is apparently unanimous understanding from all manufacturers that, "no, we do not want a production-based road engine because we are fed up with all of this balancing performance nonsense."

'A good example of this is of a manufacturer that wants to be

COMMENT

What the motorsport world thinks of the Global Race Engine initiative

DAVE RICHARDS (CHAIRMAN AND CEO), PRODRIVE

"I think for us as Prodrive especially, it is a very interesting possibility. If we could produce a 1.6-litre base engine and use it for a rally programme, a Touring Car programme, Sportscars and F1, we would be laughing. Regarding the issue of whether a four-cylinder engine would be compatible with the Aston Martin brand image, I think you have to be pragmatic about motorsport, and what is required in motorsport is not always what you can run in your road cars. We have been very lucky to have a production engine that we can run [at Le Mans] but, in the future, we might have a 2.0-litre turbo engine in our car or a different type of engine, and you also have to look at hybrids. Nothing is written in stone at the moment, and we have to look to the future with both our racecars and our road cars.

HENRI PESCAROLO (OWNER), PESCAROLO SPORT

I don't know that it is really clever [for endurance racing], because it is a very different requirement for an engine to race for 24 hours instead of one hour. They cannot be technically similar. I think the best thing is for there to be equivalence in each category. If you look at Formula 1, between the first and the last car you have about the same power, the rest of the battle is about aerodynamics. It is not necessary for each engine to be the same, but simply [to have] the potential to be equal in performance. But you can't have an engine that needs to be rebuilt every 3000km – that would be stupid. I don't think you could have the same type of engine in 24-hour racing.

As for the adoption of a 2.0-litre turbo engine, I don't think it would change anything, because everybody is saying we must do something for ecology, but I think the 250,000 people who are coming to watch the race are not coming to see electric cars [run] in perfect silence, they come to have a really good spectating experience. I think the actual engines are now very good, and it is not like a little bit less fuel consumption will change anything. The most important thing is to have a reliable engine, a powerful engine and something attractive for the spectators.

BRUNO FAMIN (TECHNICAL DIRECTOR), PEUGEOT SPORT

Up until now we have not been very involved in this issue, we have been so concentrated on our Le Mans effort. The most important thing is to wait for the FIA WMSC [meeting] at the end of June. Everything can change before then and we see no point in wasting time on the discussion until they have made a definite decision.

JASON HILL (CHIEF ENGINEER), ASTON MARTIN RACING

I think the situation is changing as the days go by. The idea that an engine could do everything from Formula 1 to rallying is a bit flawed. If you take a 2.0-litre turbo producing 500kW and bolt it into a World Touring Car without a turbo on it, producing about 230kW, it's not going to be the best engine

LAT

in Touring Car racing having to produce 2500 cars to homologate a design because its standard [engine] is not able to rev above 6500rpm. As a result, they have to design a new cylinder head, valve system and so on, all just to be able to run in a championship.'

This begs the question as to whether a purpose-designed race engine forming the basis for the GRE would actually end up being more costly than homologating a production-based engine with the necessary components. Baretzky is clearly of the view that the former approach is the way to go. 'While the initial cost for the first year may be a bit higher, the cost in years two and three would be much lower because the design would be such that components like cranks, blocks and heads can be used for a second or even third year. Whereas the dream of Formula 3, say, might be to get the cost of its engine package down to 50,000 euros ($69,000) a year, under [the GRE] idea the cost could be as low as 30,000-50,000 euros ($41,000-$69,000) a year by using the same parts.

> "simple engines tend to be good engines"

'That is why the homologation process is so important. It means that over the [specified] period, the engine is not devalued because development cannot overtake it. Even if a manufacturer joined the process with an engine in the middle of a homologation period, they would not gain an unfair advantage. The rules would be such that all the engines would be the same, with areas like bore centres possibly fixed, with maybe margins of +/-1mm so engineers can play a bit, and no definitions on things like valve angles etc. But once homologated, then it is fixed and you cannot change anything beyond the allowed areas of development. It is therefore not like Formula 1, where everything is defined. It is important to have a development path, but one where the cost is controlled by the areas that can be developed and where spending crazy money is not beneficial.'

There appears to be consensus then that, in the interests of exhaust emissions, fuel efficiency and relevance to future road car engine design, the GRE would incorporate direct injection, but surely such technology is a costly option?

'Some people say that direct injection is far too expensive,' responds Baretzky, 'but it would be up to the FIA to nominate a supplier for the injectors, the whole high-pressure system and electronics so there is no room for excessive pricing – the components would then be supplied at one price for everybody. The same would apply for turbochargers, but obviously there could be different suppliers, such as IHI or Garrett, for different categories. After the three or four-year period, you can open the market back up and benefit from other companies that might have arrived in the meantime and can make a specific component more efficiently and / or cheaper. It would also allow smaller companies to maintain their presence in a particular area of the market where at the moment development costs are starting to become prohibitive.'

COMPRESSION IGNITION

And what of diesels? Baretzky's own company, Audi, has been at the forefront of introducing diesel engines in top-level motorsport, and it has been joined by others, such as Peugeot and SEAT. But does compression ignition have a place in the GRE concept?

'We are talking at the moment about a petrol engine, but I would like very much in the future to talk about a diesel engine as well, because I would not rule out diesel in motorsport,' replies Baretzky. In Europe, 50 per cent of the cars now sold are powered by diesel engines and we have a lot of customers running very sporty diesels by conviction. The diesel engine itself is not as developed as the petrol engine, so my feeling is we should use the potential of motorsport to really push this development more quickly in terms of efficiency and power outputs.'

Interestingly, Cosworth's

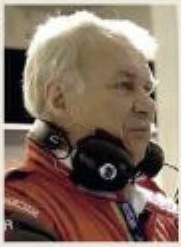
COMMENT

in the world, with a pretty miserable mid-range. I think you need some adaptation of that. You can have a basic formula, however, and I think the latest ideas for a 1.6-litre turbocharged engine for WRC and Touring Cars has a good chance. As a concept, I see no problem technically, but whether it will be of interest to the manufacturers remains to be seen.

DAVE MOUNTAIN (CEO), MOUNTUNE RACING

I think we have to accept that production engines of the future will not be motorsport suitable. The more sophisticated we get with finite analysis, weight reduction and cost reduction, the more production engines are going to be really honed just to do the job they're designed to do – there won't be any leeway at all. The idea of having a motorsport-based engine therefore makes a lot of sense and, in the long run, it may be more cost effective just to make a cylinder block and head that's designed to do the job. There is clearly a lot of detail still to be worked out but, as long as essentially any interested party is able to get the parts, and they're at a sensible cost, then I think the concept is a good one.

ULRICH BARETZKY, (HEAD OF ENGINE TECHNOLOGY) AUDI



The most important thing to look at will be fuel efficiency. That is why I have suggested allowing the injection and induction to be very free, to create a lot of development work there, but without doing silly things like making tiny journal sizes that will affect the reliable life of the engine. But we also do not want to have exotic materials, surface treatments or coatings that are not really relevant to production. We should encourage and allow [technologies] that may look exotic today but could be relevant in the future. This should not be a set of rules for just a couple of years, but for a decade or more, and then, at a certain point, if we need to downsize the engines more, to three-cylinder 1.5-litre, or even 1.2-litre, then you could transfer over a lot of the parts without having to start from scratch and spend all of that money again.

BRUCE WOOD (TECHNICAL DIRECTOR), COSWORTH RACING

The IRL engine rules were very good, in that they fixed a number of the parameters designers often agonise over that really make no difference to the show, but on which a vast amount of time and money can be spent. I would definitely suggest fixing some of those parameters. In addition, as the desire will be to use the engine in a whole range of different applications, you need to think hard up front about the series for which it is likely to be required, otherwise you could end up changing a lot down the line. It would also be nice if people were able to develop a new variant of the engine in, say, six months rather than the usual 10 or 11 months it takes to get a new race engine out.

LAT

technical director Bruce Wood echoes Baretzky's view on diesels. 'For my money, there's no doubt diesel is going to play a significant role with road cars in the future,' he says. 'As such, petrol and diesel are also going to be the main fuels for motorsport, so that would need to be taken into account, in my view.'

NOISE SUPPRESSION

While the primary focus with the GRE concept is on cost and efficiency, both in terms of fuel consumption and exhaust emissions, Baretzky raises another significant point for consideration.

'Another thing motorsport has to consider is noise regulations,' he says. 'If you look at something like a Formula 3 car now, we have seen problems with the 140dB threshold with an engine that does not really seem to be aggressively loud, and at a lot of tracks in England now, you have a sound level of 108dB. You cannot do that without a turbocharged engine, in my opinion. As far as I am aware, there is also a new European law that says the maximum noise level allowable in the grandstands will be 110dB, and I have heard that at a Formula 1 race in 2008, a level of 134dB was measured. If this is not addressed, there will be no racing at all.'

> "it is important to have a development path, but one where the cost is controlled"

Finally, we wondered about the oft-quoted objection to a concept such as the GRE, that companies like Ferrari or Aston Martin would not be interested in competing with four-cylinder engines, as they do not fit in with the performance image of either marque's roadgoing products.

'I think people always imagine this happening next week,' responds Purnell, 'and what we're thinking about really is the next decade. It cannot have escaped people's notice that President Obama has recently passed into law new legislation on emissions and fuel consumption targets for cars sold in the US, and you can see where it's all going. Will Ferraris be legal to sell in the company's best market – California – in a few years? Even more radical is the thought that perhaps one day, the whole idea of performance cars on the road will evaporate. It's well known that we could get rid of all the speed signs in Europe and just have cars that you can't drive faster than the set limit. That technology is out there and I think it's in our future.

'I'm thinking next decade [for GRE], and that's when you say to yourself, "Ferrari making a four-cylinder turbo? Out of the question!" Well, maybe not. I have a strong feeling that everybody is going to have to produce engines that are just fabulous on fuel mileage compared with today's – and today's are pretty good.'

Baretzky is even stronger in his views on the subject. 'You have to look at what the world requires, not what Aston Martin or Ferrari requires,' he says. 'Who are they? In terms of [producing] 40 million cars per year, they are nothing. You have to look to the mass production market, so people can relate [motorsport] to what they are driving. We are a bit in danger of losing our way. In the good – or bad, depending on how you regard it – old days, motorsport was ahead of technology development. Now my feeling is that it is lagging somewhat behind.

'We need to educate people that downsizing is not necessarily boring and guide them to reasoning. Ultimately, we want to keep our mobility at a reasonable cost and minimise environmental impact, and we in motorsport cannot just close our eyes and pretend we are on an island so nothing around can touch us. If we do this, we are lost. The worst thing that can happen is if someone from outside imposes on motorsport the rules and we then have to react to them. That is not the way to do it.'

FIRST PRINCIPLES

Simon McBeath is an aerodynamic consultant and manufacturer of wings under his own brand of The Wing Shop – www.wingshop.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

Produced in association with MIRA Ltd

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Maximum gain

Working the details on a formula car's aero in search of -CL max

Photos: S McBeath

The 1999-spec Mansell Motor Sport EuroBOSS Benetton B199, as tested in the MIRA wind tunnel

The wheels on a single-seater racecar have a profound influence on its aerodynamics. They are large contributors to drag (responsible for as much as a third of the total drag on an F1 car of this period) and they are also generators of positive lift, effectively reversing a few per cent of the car's hard-won downforce. However, the effect of the wheels on the horizontal and vertical forces cannot be isolated in a full-scale wind tunnel like MIRA's because total forces are measured at the wheel contacts, and so include the aerodynamic contributions of the wheels. Furthermore, in this case the wheels cannot be rotated at 'road speed', which is influential on the measured forces, though we can do something about this latter point.

Following the initial baseline runs at different speeds on the Mansell Motor Sport EuroBOSS series Benetton B199 that were reported in last month's Aerobytes, the car was then fitted with 'trip strips', first on the front wheels, then on all four wheels. As illustrated above, a trip strip is a length of right-angle stuck onto the tyres whose aim is to trigger flow separation on the wheel at about the same place it would occur if the wheel were rotating. The reason being the flow stays attached around much more of the circumference of a non-rotating wheel, and this tends to exaggerate wheel lift and drag readings (see Aerobytes V18N5). Note that the separation point on a rotating wheel varies with various factors, including speed and a wheel's width-to-diameter ratio, so trip strip positioning is somewhat empirical.

TRIP STRIPS

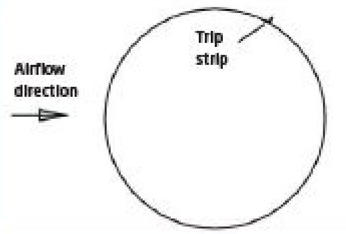


Figure 1

Approximate location (20-25 degrees from TDC) and proportion of the devices used

Nevertheless, their effect on the Benetton was quite pronounced, as shown in table 1 overleaf.

The trends are quite clear, with the trip strips producing small reductions in drag but significant increases in downforce, via reductions in overall wheel lift and lift at each axle. The aerodynamic balance remained similar to the baseline setting after both front and rear trips strips had been fitted, the proportionate effect front and rear being fairly similar.

So, assuming that fitting trip

> "the separation point on a rotating wheel varies with varying factors"

TABLE 1

Changes to aerodynamic coefficients by fitting 'trip strips' to the tyres

	CD	-CL	-CLf	-CLr	% front	-L/D
Without	1.014	1.978	0.788	1.190	39.85	1.952
With front trip strips	1.004	2.072	0.873	1.202	42.01	2.064
With front and rear	1.000	2.205	0.873	1.332	39.58	2.206
Total change	0.014	0.227	0.085	0.142	-0.27	0.254

TABLE 2

The effects on the coefficients of dropping the front wing height

	CD	-CL	-CLf	-CLr	% front	-L/D
Before	1.000	2.205	0.873	1.332	39.58	2.206
After	1.002	2.203	0.889	1.314	40.35	2.200
Difference	0.002	-0.002	0.016	-0.018	0.77	-0.006

TABLE 3

Changes to coefficients following fitting a rear Gurney

	CD	-CL	-CLf	-CLr	% front	-L/D
Before	1.002	2.203	0.889	1.314	40.35	2.200
After	1.041	2.248	0.884	1.364	39.31	2.159
Difference	0.039	0.045	-0.005	0.050	-1.04	-0.041

TABLE 4

Changes to coefficients after shortening the rear Gurney

	CD	-CL	-CLf	-CLr	% front	-L/D
Before	1.041	2.248	0.884	1.364	39.31	2.159
After	1.033	2.244	0.886	1.359	39.48	2.172
Difference	0.008	-0.004	0.002	-0.005	0.19	0.013

FRONT WING
Dropping the front wing height with spacers made a negligible difference

REAR WING
Adding a truncated Gurney (40mm less each end) slightly improved overall efficiency

strips meant the wheel forces were more realistic, we now had a -CL of approximately 2.2. Last month we surmised that the initial baseline -CL value of about 2.0 was probably underestimating by around 25 per cent, given that a 'moving ground' -CL value of about 2.65 was typical of a medium-high downforce F1 configuration in 1999. With the fitting of the trip strips, the underestimate now looks to be about 17-18 per cent. The remainder of the underestimate will be arising from the wind tunnel's fixed floor boundary layer interacting with the car's front wing and underbody.

MORE DOWNFORCE!

As delivered to the wind tunnel the Benetton wings were set to their maximum angles front and rear. Although the half-day session was barely enough to map some of the basic parameters, the temptation to look for more downforce was irresistible. Following the team's experience with the B199's predecessor, a B197, one of the first things tried was to drop the front wing height. This was found to 'sharpen up the front end' on the older car and was obviously on the team's list of ideas to try on the B199. So a pair of 17mm machined spacers were inserted between the wing and its support pillars to reduce the wing's height by that amount. The results are shown in table 2.

> "The Gurney added a useful increment of rear downforce"

This change on its own could be a useful fine adjuster of balance, but the small gain in front downforce was almost exactly matched by the small loss at the rear, so the change to overall downforce was negligible. Other spacer dimensions would probably be worth trying as alternative balancing options.

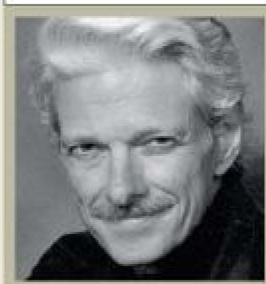
Attention was then switched to the rear wing. Available adjustment on this consisted of just two options – steep and not so steep! With the steep (26 degree) option already selected, the obvious thing to try was to add a Gurney. So a full span 12mm aluminium angle strip was taped to the trailing edge of the upper flap, and the change in coefficients is shown in table 3.

The Gurney added a useful additional increment of rear downforce, and raised the -CL to the maximum value attained in this session, roughly 2.25. However, in this instance the Gurney, which was a tad on the large side, did not produce a very efficient benefit, drag increasing by almost the same amount as total downforce, hence the -L/D value dropped. The small loss of front-end downforce was down to additional mechanical leverage from the rear wing, but still balance shifted to the rear.

Finally, the rear Gurney was shortened by 40mm at each end to try to recover some efficiency by reducing the wing's potency near its tips and the associated vortex drag. This time the results are shown in table 4. This small modification had a bigger effect on the drag than on the total downforce, resulting in a gain in efficiency of 13 'counts' (0.013 gain in -L/D) for just four counts reduction in total downforce.

More insights into the Benetton B199's aerodynamics next month.

Many thanks to Kevin Mansell at Mansell Motor Sport.



FIRST PRINCIPLES
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The main reason Red Bull has used pull-rod suspension this year is due to changes in the 2009 F1 aero regulations

THIS MONTH:

Q1 What are the advantages of pull-rod suspension?
Packaging, mainly

Q2 What do the numbers stamped on a torsion bar mean?
Rate, or in other words, the effective diameter for the active part of the bar

Push or pull?

Q1 I am hearing all sorts of outrageous claims about the pull-rod suspension used on the rear of the highly successful Red Bull F1 car, but does pull-rod suspension actually offer any clear advantage over pushrod?

A In terms of suspension dynamics, no. Both layouts can be made to have the same wheel rate, the same motion ratio / displacement curve and so on. Both also affect dynamic load transfer in the same manner.

The differences come down to packaging, with small effects on overall c of g height, aerodynamics and component accessibility. Pull-rod suspension generally places the shocks, springs and rockers low in the car. Depending on whether something else has to be moved to make room, this generally lowers the overall c of g of the car, which is good. Since these components are a fairly small part of the total mass, however, the benefit is correspondingly small, but it is there.

Mygale uses pull rod rear suspension on its Formula 3 design

PERFORMANCE ADVANTAGE

On the downside, accessibility of the shocks, springs and rockers generally suffers. It is easier to get at these parts when they are on top of the transaxle or foot box than when they are down under other components, but when millions of dollars are on the line, it can make sense to put up with some extra hassle to gain a small performance advantage.

The shocks, springs and rockers take up space and create a wider package near the ground. If they get in the

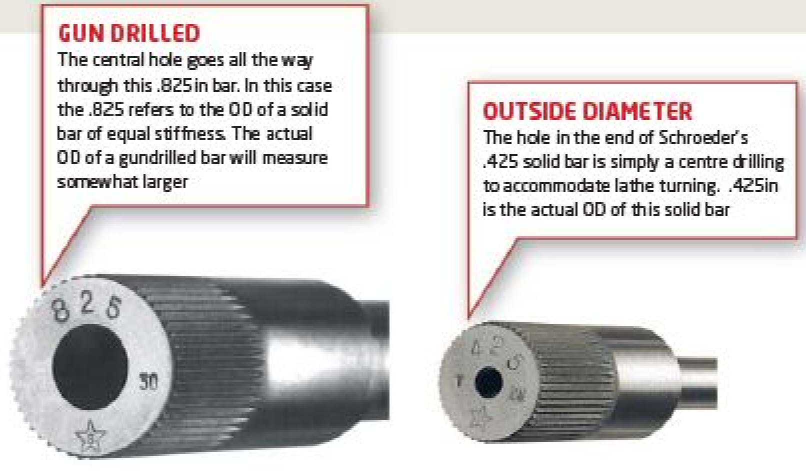
> **"Any net weight reduction depends on the particulars of the individual design"**

way of under-car airflow, it is often a better choice to use pushrods. This last consideration was crucial in making pull rods a rational choice for the rear of the car under the new 2009 rules. As part of the effort to reduce and narrow the upwash behind the car, diffusers were required to start further back than before, and the flat portion of the underside had to extend further aft to suit. That creates an opportunity to put components low down alongside the transaxle, without aerodynamic penalty. The Red Bull team just saw this opportunity and used it.

WEIGHT SAVING?

Some have suggested that there is a reduction in overall weight with pull rods, but I am sceptical. It is true that a pull rod can be made more slender than a pushrod, and perhaps lighter too, because it does not have to withstand large compression loads so does not need to incorporate as much buckling resistance. However, compressive loadings on the upper control arms increase, and the weight can easily come back there. Any net weight reduction therefore depends on the particulars of the individual design.

The important thing to bear in mind, though, is that the Red Bull car's overall success should not be attributed to this one feature. Rather, it stems from a larger willingness to consider new possibilities, combined with the engineering understanding to properly evaluate, select and apply such possibilities, and then to integrate them and optimise the total package.



Thanks to: Schroeder Torsion Bars www.schroedertorsionbars.com
Email: schroedersteering@yahoo.com Tel: 001 818 565 1133

Number crunching

Q2 What do the numbers stamped on the ends of torsion bars mean? I understand one is the length and the other is the rate but, while the one for the length makes some sense (it appears to just be the overall length in inches), I can't see what the one for rate relates to. Can you explain?

A The number people sometimes call 'rate' is actually the effective diameter for the active part of the bar, in thousandths of an inch. The active portion is the turned-down portion in the middle, where most of the twisting occurs. If the bar is solid, the effective diameter is the actual diameter, whereas if it's hollow, it is the diameter of an equivalent rate solid bar.

From these numbers, you can calculate a rate at the end of a known length lever arm that equates to the rate of a coil spring acting at a similar point.

In most cases, however, you don't need to do that because torsion bar manufacturers offer charts in their catalogues and on their websites for exactly this purpose.

But for those who are interested, here's the equation all the same:

$$S = (\pi G d^4) / (32 R^2 L) = (.098 G d^4) / (R^2 L) \quad (1)$$

where:

- S = rate at lever arm end, in lb/in
- G = shear modulus of material (11,500,000lb/in² for most steels, 11,800,000lb/in² for spring steel)
- d = diameter of the active portion of the bar, in inches
- R = effective length (moment arm length) of lever arm, in inches
- L = length of active portion of the bar, in inches

For d, you use the 'rate' number stamped on the bar, with a decimal point three places from the right. For L, you use either your own measured length for the active portion or, as a rule of thumb, the stamped or catalogued length minus four inches. R is the distance from bar axis to lever arm end – not along the arm if it's curved or angled – but perpendicular to the bar axis.

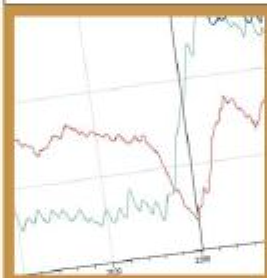
If you have a bar with no stamped numbers, or with the numbers worn off, and it's hollow, you can calculate the rate using measured inside and outside diameters of the bar, with the following formula:

$$S = (\pi G (do^4 - di^4)) / (32 R^2 L) = (.098 G (do^4 - di^4)) / (R^2 L) \quad (2)$$

where:

do = outside diameter, in inches
di = inside diameter, in inches

All other variables are the same as in equation (1).



FIRST PRINCIPLES

Databytes gives insights to help you improve your data analysis skills each month as Pi Research's engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month.

To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

Thermal management

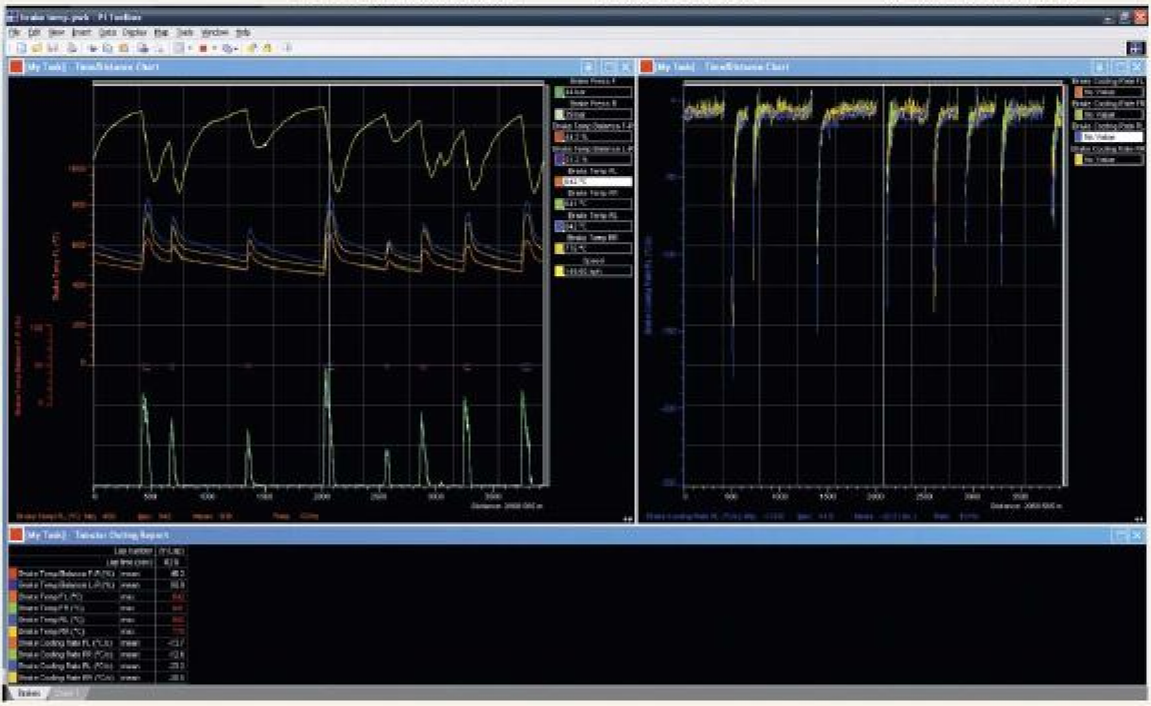
Non-contact brake disc and tyre temperature management integrated with data acquisition systems

Heat management of certain components of a race car is a crucial area of performance and reliability engineering. Two of the most important parts, brakes and tyres, are among the most difficult to measure due to the fact they are fast moving and, in the case of brakes, reach extreme temperatures out of the measurement range of many devices. Non-contact infrared temperature sensors are available, which can help with this problem. All materials emit heat as infrared radiation. An infrared temperature sensor detects the quantity of this radiation from a material and, with knowledge of the material's emissivity properties, converts this into a calibrated value for surface temperature. Different materials have different emissivity, which determines how much radiation is emitted so for example rubber tyres, steel brake discs and carbon brake discs all need different calibrations. Depending on the working temperature range, the sensor would be more or less sensitive to different wavelengths of infrared radiation as the wavelength of peak radiation varies with temperature in accordance with Planck's law.

> "Different materials have different emissivity"

BRAKE TEMPERATURE

Brakes have an optimum operating temperature where they give maximum retardation for a given pedal force. Outside of this range, the driver may suffer a "long pedal" where the brakes must be pressed harder to attain maximum retardation. At



Screen grab of a lap by a car equipped with four brake temperature sensors. It can be seen that although the left-right balance is good at around 51 per cent, the front-rear balance shows that the rear brakes are too hot.

extremes of temperature, the brake discs and pads may suffer increased wear, meaning over a race distance performance will be affected. In endurance racing this will result in more pit time to change the components. Brake disc temperature sensors can be used to monitor the effectiveness of the brake cooling. Sensors with a maximum measurement temperature of 1000°C are suitable for measuring both steel and carbon brake discs. For the best data, it is necessary to sample disc temperature at up to 10Hz. Mounting the sensors can be quite tricky, as it is necessary to have them within around 70mm of the disc, but the electronics inside the sensor itself have a maximum operating temperature typically less than 100°C. The best place for them is to mount them on a low surface with low thermal conductivity. A bracket inside the brake duct is good; clamping it to the upright is not so good. It is possible to use sprung thermocouples in contact with the disc to measure their temperature but these sensors are damaged easily.

A nice way of looking at brake temperatures and ensuring the duct blanking is correct is to create maths channels which calculate brake temperature balance. This is a similar channel to brake balance itself i.e. Brake Temp Balance = Brake Temp F/(Brake Temp F + Brake Temp R). If you are using four temperature sensors, left-right as well as front-rear balance can also be calculated. Once the most loaded wheel is correct, you can work on making the balance as close to 50 per cent front-rear and left-right as possible. It is best to gate this channel so it is calculated only during braking itself; when there is some brake line pressure, for example. This will mean that, although you have uneven amounts of blanking, the brakes will be used more evenly and give more similar amounts of retardation to one another.

Different blanking can be tried to try and keep the brakes in their optimum range while keeping drag at a minimum. An engineer can get away with just two

Monitoring your brake temperatures is crucial, as is sensor mounting

sensors on the car; front and rear on the most heavily worked side (left on a clockwise circuit and right on an anti-clockwise circuit). Find what blanking works for this side and simply match it on the other. The use of four sensors, one per wheel, allows fine grained control of brake blanking meaning it can be tailored left-right as well as front-rear.

Something else which can be calculated is brake cooling rate. Take the derivative of brake temperature and gating this channel when the driver is not braking to calculate the cooling rate in °C/s. Zooming in on a chart over a straight and taking a mean of this channel gives an indication of how the cooling is working on each wheel.

Screen grab of a lap by a car equipped with four brake temp sensors. It can be seen that although the left-right balance is good at around 51 per cent, the front-rear balance shows that the rear brakes are too hot.

"Tyre temperatures change slowly so only need to be logged at 5Hz"

TYRE TEMPERATURE

Every engineer is familiar with the process of taking tyre temperatures with a probe on the inside, middle and outside of each tyre after a run. By noting the temperature after a run it is possible to tell how the tyre was worked in that run. An advantage of taking the temperatures this way is that it also tells you what the core, as opposed to surface, temperatures are. This approach is unable to tell you how the tyre works during a run and how quickly it gets up to temperature. Infrared sensors can be used, one per wheel, to determine how the tyre surface temperature changes during running. Sensors with a sensing maximum of 150°C are suitable for tyre usage. Tyre temperatures change relatively slowly so only need to be logged at around 5Hz. It is possible to use just one sensor per wheel. Even better is to mount three per wheel pointing at the inside, middle and outside of each tyre. This requires twelve sensors per car and a data logging system which has enough inputs. Mounting the sensors is quite simple on the rear of the car, as the wheels do not yaw. There is plenty of bodywork close to the tyre on an open or closed wheel car. The front is slightly more complicated, as it is difficult to keep the sensors pointing at the correct section of the tyre while the wheel is moving. This issue can be ignored and the sensors pointed at the tyre statically. The temperature data will be skewed when the car is steered and should be ignored. An alternative is to mount a stiff L bracket from the top upright bolts extending across the rear of the tyre upon which the three sensors can be mounted. In this way they will move with the steered wheel and aim at the correct strip of tyre.

The speed at which the tyres get up to their optimum temperature at the start of a run is interesting and also whether they are going above their recommended maximum operating temperature at any point. By correlating the readings from the tyre probe with the sensor readings some knowledge about how core temperature affects surface temperature can be learned. A further important aspect is whether the temperature is even across the tyre. If they are always more or less the same, especially after cornering, it can be seen that the tyre's surface is being used evenly. If one edge is warmer than the other across a tyre it may be an indication of uneven use, which can be corrected by adjusting the camber or other settings. If the cross-tyre temperatures start even enough but diverge during a long run this shows that the tyre is wearing unevenly, again something that can be corrected with car set up.

It might be possible to export the tyre temperatures to Excel and plot them against their distance across the tyre in an X-Y plot. The gradient of the linear regression (trendline) will show how even the tyre temperature is across the tyre; the flatter the line, the more even the temperatures. Sufficient data of good quality was not available to test this theory.

CONCLUSION

Brake and tyre temperature management are an important part of engineering a race car. Infrared sensors can provide never-seen-before data and augment existing information to allow better decisions to be made on car setup.

Produced in association with Pi Research

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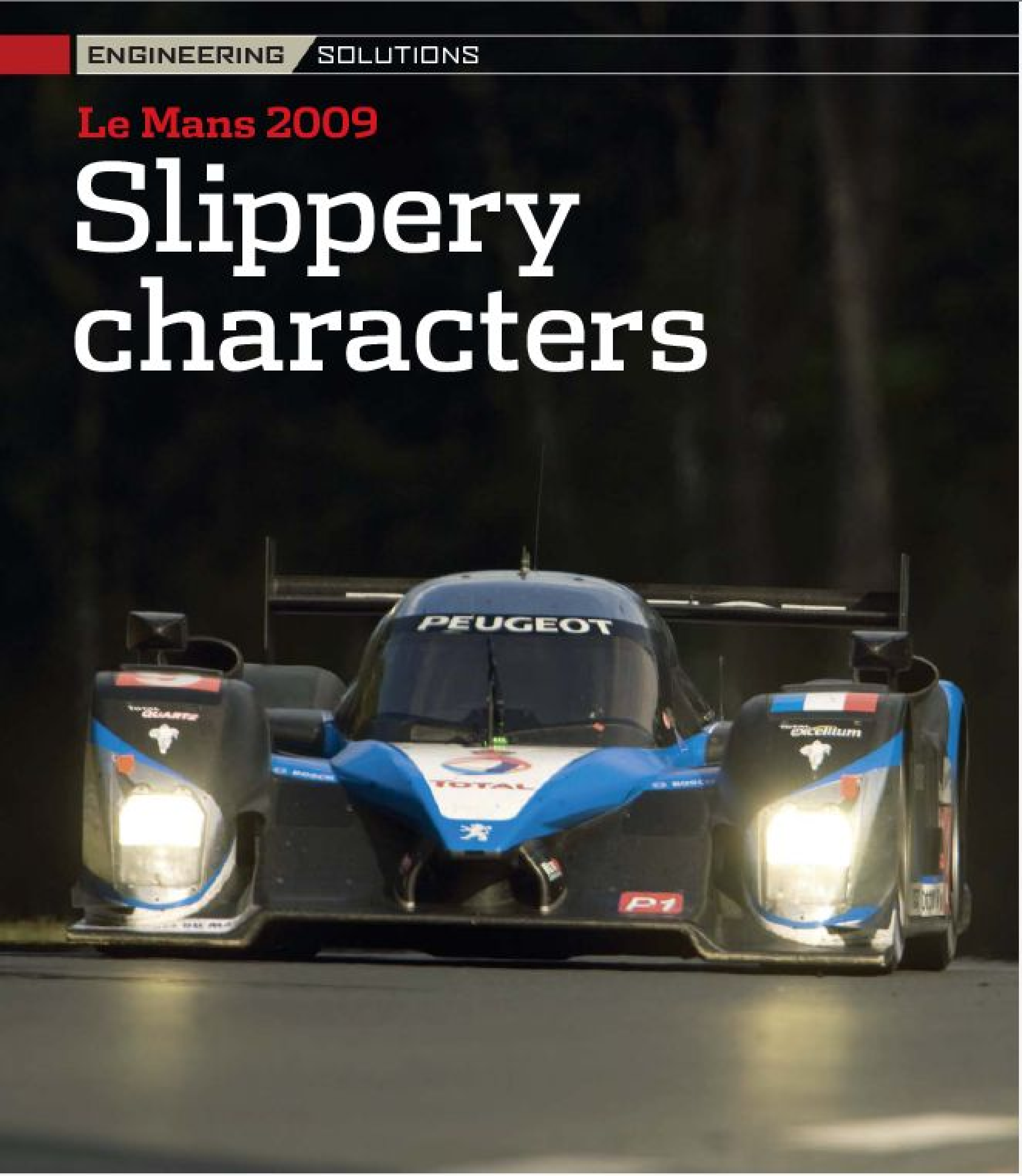


Le Mans 2009

Slippery characters

New aero and engine regulations meant it was all change at the 2009 24Hrs of Le Mans

BY SAM COLLINS

The winning Peugeot 908 HDI FAP averaged 134.63mph (216.66 kph) over the 24 Hours of Le Mans. This is a race run on a unique circuit made up of both public road and purpose-built race circuit. It is defined by high speed sections like the iconic Mulsanne straight, which means competitors do all they can to get the best straight line speed possible, without giving away too much of a car's cornering ability. This year, all the prototypes had to be fitted with revised floors and rear wings, while all closed cars had to be fitted with air conditioning to prevent the cockpit temperature from exceeding 32deg C. The diesel runners also had to contend with a late rule change, which saw the oil burners fitted with smaller restrictors, down from 39.9mm to 38.3mm, and a 30kg weight penalty. A reduction in boost pressure of 6.5 per cent was also enforced for the diesels at the start of the year

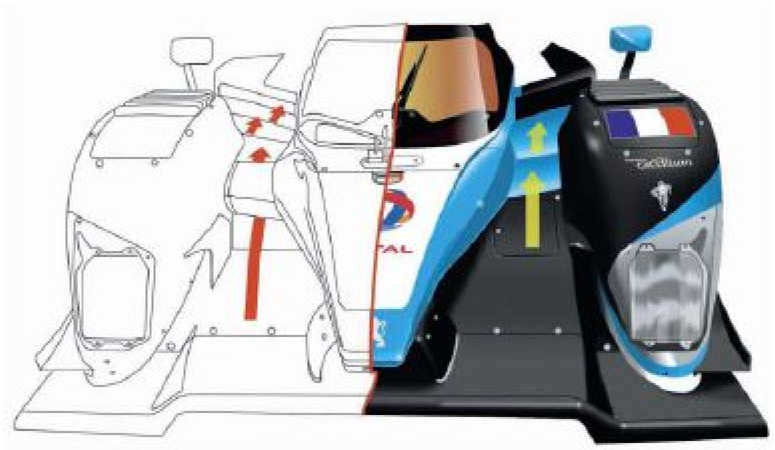
"Because the technical rules have changed we have less downforce and less power" explains Peugeot Sport's Technical Director Bruno Famin. "So we have had to deal with less downforce and less drag meaning we have had to adjust almost everything on the car, even if you can't clearly see it. The new front end design is to allow us to balance the car aerodynamically whilst at the same time reducing drag. The drag reduction is necessary due to the equivalency changes and the consequent loss of power. Also the requirement for closed cars to have air conditioning to prevent the cockpit temperature from exceeding 32deg C has called for the incorporation of a power take-off at the end of the gearbox to drive the compressor."

A number of teams struggled with the setup for the track as the usual test day a fortnight before the race was cancelled, something one senior team member said was 'dangerous and irresponsible.'

Bruno Famin was less extreme, adding "the main difficulty with Le Mans is that you cannot come to test here. But the only way to understand the track is to come and race. It is even harder this year because we have no test day. I think that this year it is different because the wear on the tyres is not much, so the key point this year will be whoever can get the longer use of the tyres will definitely get an advantage." This was especially relevant with the introduction of another new ACO regulation limiting the number of tyre changers allowed in the pitlane.

Only two mechanics and one wheel gun are allowed to cross the line (the European equivalent of going over the wall) compared with four crew and two guns in previous years. The time necessary to change all four wheels thus increased from around 15 to 35 seconds and a full pit stop, with tire and driver changes plus refuelling, now lasts nearly a minute. As a result of the new regulation, teams needed to complete several stints on the same set of tires.

"We estimate an additional time loss over the entire race of eight minutes, the equivalent of more than two laps," explained Matthieu Bonardel, Michelin Four Wheel Competitions Manager before the race. "Our goal is to do quadruple stints in the LMP1 category, triple stints in LMP2 and double stints in GT-safely and without significantly undermining tyre performance." Four stints at Le Mans represents around 700km at an average



Peugeot fitted the works 908 HDI FAPs with a new front section to reduce drag, (Sebring spec left, Le Mans right). Hatches on the front of the bodywork allowed mechanics to access the bodywork fastners.

SPEED TRAPS

Low drag means high top speeds and at Le Mans the highest speeds are achieved on the approach to the first chicane. *Racecar Engineering* and *Speed TV* went to that location during qualifying to see just what those top speeds were. We found that, as was the case last year, the ACO's official timing was around 30kph lower than it should be.

TABLE 1

Le Mans top speeds 2009

Chassis	Engine	Class	Speed
Peugeot 908 HDI FAP	Peugeot 5.5L twin turbo V12	LMP1	211.8mph / 340.86kph
Aston Martin Lola B08/60*	Aston Martin 5,993cc V12	LMP1	209.0mph / 336.35kph
Aston Martin Lola B08/60	Aston Martin 5,993cc V12	LMP1	205.3mph / 330.4kph
Audi R15	Audi V10 TDI 5499cc Twin Turbo	LMP1	205.0mph / 329.92kph
Courage LC70	Judd 5496cc V10 NA	LMP1	202.5mph / 325.89kph
Oreca 01	Aim V10 5496cc N/A	LMP1	202.0mph / 325.09kph
Pescarolo 01	Judd V10 5496cc N/A	LMP1	202.0mph / 325.09kph
Audi R10	V12 TDI 5499cc twin turbo	LMP1	196.7mph / 316.56kph
Ginetta-Zytek GZ09	Zytek 4496cc V8 NA	LMP1	196.6mph / 316.4kph
Porsche RS Spyder	Porsche 3400cc V8 N/A	LMP2	191.9mph / 308.83kph
Lola B08/80	Judd 3394cc V8 NA	LMP2	188.0mph / 302.56kph
Pescarolo 01	AER 1995cc I4 Turbo	LMP2	180.7mph / 290.81kph
Corvette C6.R	GM 6993cc V8 NA	GT1	180.7mph / 290.81kph
Zytek 07S	Zytek 3396cc V8 NA	LMP2	179.7mph / 289.2kph
Porsche 911 GT3 RSR	Porsche 3795cc flat 6 N/A	GT2	178.0mph / 286.46kph
Ferrari F430 GT	Ferrari V8 3998.6cc NA	GT2	175.9mph / 283.08kph
LolaB09/86	Mazda/AER 1995cc I4 Turbo	LMP2	174.6mph / 280.99kph
Radical SR9	AER 1995cc I4 Turbo	LMP2	171.7mph / 275.36kph

*Prodrive variant

PROTESTS

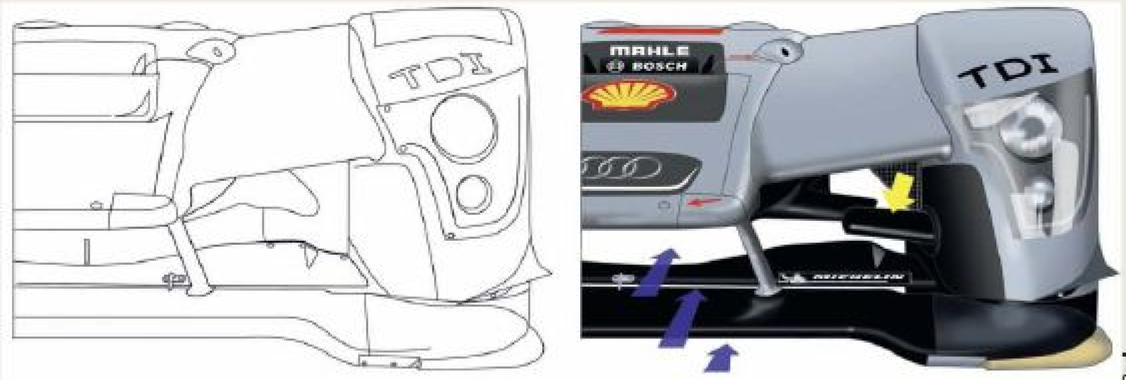
Not every aerodynamic modification that appeared at Le Mans was considered legal by all. When Peugeot saw the new Audi R15 TDI aerodynamic setup they were stunned, the revisions to the car's nose were considered by the French team to be well outside the regulations, and subsequently a protest was lodged. The French team felt that the R15 breached article 3.6.2 of the current technical regulations which states:

> 3.6.2 No aerodynamic element can be added on the bodywork apart from
>
> - Two aerodynamic elements maximum at the front and within the frontal plan of the front fenders/
>
> The following are considered aerodynamic elements:
>
> - Any bodywork element the function of which is only to generate down force and is not permitted by the regulation (at ACO discretion)

Peugeot contested the flap which links the two front wings and the appendages on the inner surface of the front wing. It argues that these appendages and this flap effectively form part of the bodywork and their sole purpose is to generate downforce. "These bodywork parts are considered to be aerodynamic elements" explained a Peugeot Sport press release. "Since they do not appear on the list of aerodynamic elements authorised by Article 3.6.2, they are consequently not permitted. Certain aspects of the car's non-compliance were pointed out to the ACO last March at the 12 Hours of Sebring, a round of the ALMS. Our protest dossier was already ready at the time, but the Automobile Club de l'Ouest made assurances that it would take the necessary steps ahead of the Le Mans 24 Hours."

The ACO rejected Peugeot's protest but the French firm has decided to appeal the decision at the FIA court in Paris. A resolution had not been reached as Racecar closed for press.

Another dispute was less acrimonious; Porsche raised a question about the legality of the Ferrari F430 GT rear aerodynamics. As a result, the Italian cars were forced to fit hastily made shadow plates behind the rear wheels.



The revisions to the front end of the Audi R15 TDI caused much controversy at Le Mans. In its Sebring specification (above left) the nose ducts were filled with a mesh; for Le Mans (above right two 'horns' had been added (yellow arrow), and the front wing stay had been reworked. Peugeot contested the leagity of these parts

Teams using the Ferrari F430GT at Le Mans were forced to make a last minute bodywork change after Porsche queried the cars' legality. Small extensions were added behind the rear wheels (seen here in unpainted carbon) to ensure compliance. The Italian cars were dominant in the race, filling the podium.

TECH SPEC

ORECA 01 - NEW CHASSIS COMPLYING WITH THE ACO/FIA 2009 REGULATIONS

Chassis: Carbon/aluminium honeycomb monocoque, Araldite adhesives/resins; symmetrical double roll bar

Engine: AIM 90-degree angle

Power output: 650bhp at 7500rpm (max)

Bodywork: LMP1 aerodynamic regulations; carbon/Kevlar honeycomb with aerodynamic components and Araldite adhesives/resins

Transmission: Xtrac 6-speed sequential gearbox; semi-automatic steering-wheel mounted gear change

Suspension: Double steel wishbones with push rod rocker arm activated spring/damper unit

Welded front and rear hub carriers; PKM/ORECA shock absorbers

Wheels: OZ Racing 18-inch rims

Brakes: Carbon brakes. 6-piston Brembo callipers

Tyres: Michelin

Steering: Rack & pinion; Kayaba electric power assistance

Dry weight: 900kg

Electrical system: Military specification wiring harness

Fuel system: 90-litre fuel tank; Bosch fuel pumps

ORECA's 01 is the ultimate evolution of the Courage LC70 LMP chassis.

speed of over 130mph (210kph), more than twice as long as a Formula 1 Grand Prix race at about the same average speed. But the tyres lasted well, and lap times were relatively similar. A full technical data review can be found at www.racecar-engineering.com studying the implications of the rule changes in far more detail.

One manufacturer with something new to test was ORECA. The rapidly growing French concern purchased Courage last year and has steadily been developing the LC70 LMP1 chassis, but for this year's race it introduced its ultimate evolution, the ORECA 01, which retains the tub of the LC70 but is otherwise all new. "The design office's major objective was to compensate for the downforce loss due to the smaller flap while increasing performance" explains David Floury. "In order to achieve this, we carried out our biggest wind tunnel programme to date. With the new rules and regulations, solutions that were applicable in 2008 are no longer valid this year", explained the Technical Manager. "We are not subject to any style-related constraints, so we reviewed numerous configurations, including some that were undoubtedly unique. We could have had a more aggressive car with a more spectacular look, but in the end our need for performance influenced our decisions. Globally, the car is more streamlined with a lower nose" David Floury continues. "We have worked on airflow quality, with more flowing forms, including even the side pods. Aerodynamics might have an impact on performance, but it also enhances reliability and improves cooling. Finally, we carried out specific research about operating the car with the new wing. This research has led us to take different decisions to our competitors but many of the novelties are not necessarily visible to the naked eye."

> **"With the new rules and regulations, solutions that were applicable in 2008 are no longer valid this year"**

The new design is fitted with the Japanese AIM V10, which produces around 650bhp. A number of other mechanical changes have been incorporated too, as Floury explains: "We have developed quite a lot since the beginning of the year; we've made no compromises and we've redesigned everything. A big breakthough was made with dampers specific to the LC70E, which is the direct result of our cooperation with PKM. We've also changed the spindles, hub carriers and rims with firm objectives in mind: reliability, performance, particularly in the tight corners, weight reduction and the reduction of time during pit stops."

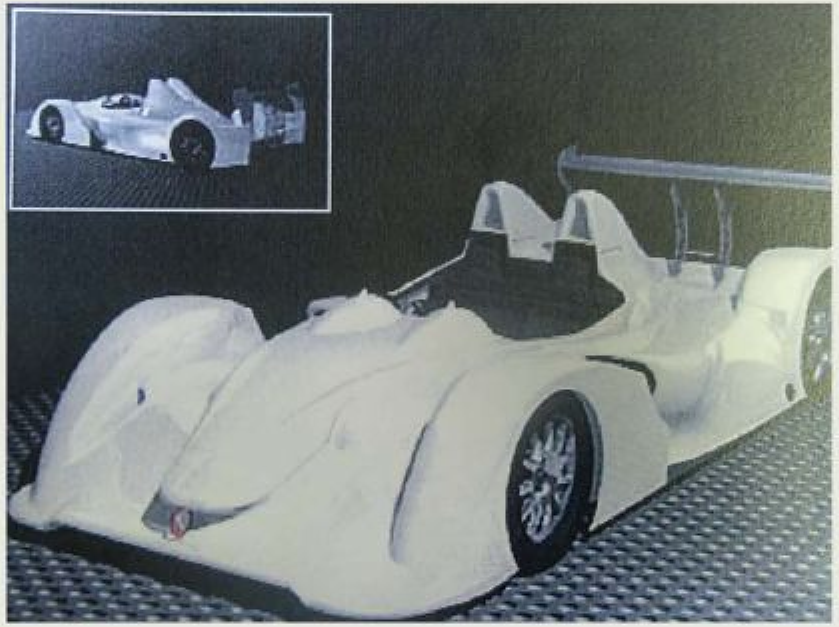
Floury's team spent time revising the brakes and electronic systems in a quest to save weight. The package seems to work, as at Le Mans the ORECA chassis set a fastest lap of 3m33.514s with a top speed of 202.0mph (325.08kph) compared with the older Courage LC70E run by the Signature team with a fastest lap of 3m39.326s and a top speed of 202.5mph (325.88kph). These rule changes have left many teams disgruntled and the future direction of the race has been called into question. As a result, the ACO called a meeting of the manufacturers to discuss future technical regulations; the result will be revealed in October, *Racecar* will of course report.

Prodrive modified the front of its Lola B08/60s in an attempt to reduce drag, the concave panel where it usally has dive planes mounted (above left) being replaced with a smooth, convex part

Pescarolo fitted these controversial semi rim blanked wheels to its works LMP1. Porsche had previously not been allowed similar items

PESCAROLO ACO SCHOOL CAR

Pescarolo has been working with partner Sora Composites to develop a new, low budget, lightweight racing school car for the ACO. Announced as part of the new ACO Endurance racing school, it can accommodate two people up to 195cm in height and meets FIA chassis standards. Different engine choices give performance levels to suit drivers of varying abilities. The first track tests will take place in November this year



TECH SPEC

PROTOTYPE LE MANS ENDURANCE, DOUBLE SEATER RACING SCHOOL CAR

Engine (2 options):

GM:

Type: V8 LS3

Cubic capacity: 6200cc

Power limited to 360bhp in the school version

Maximum torque: 540Nm for this power output

Nissan:

Type: V6 VQ37VHR, longitudinally mounted Cubic capacity: 3696cc

Power output: 358bhp at 7000rpm

Bore and stroke: 95.5 x 86mm

Maximum torque: 420Nm at 5200rpm

Transmission: rear-wheel drive, 6-speed sequential gearbox, limited slip differential; tri-disc steel clutch, diameter 140mm

Chassis: Carbon monocoque

Bodywork: composite (fibreglass)

Front suspension: double wishbones. pushrod/rocker arms, anti-roll system and dampers

Rear suspension: double wishbone. pushrod/rocker arms, anti-roll system and dampers mounted on the top of the gearbox housing

Dampers: fixed monotube

Brakes: 4-piston callipers (diameter 38mm and 44mm), grooved steel ventilated discs diameter 323mm, thickness 28mm

Front tyres: 24/65-18 (on 18-inch rims)

Rear tyres: 27/68-18 (on 18-inch rims)

Dimensions and weights:

Dry weight: 820 kgs (constructor's figure)

Weight distribution: (F/R) 45 per cent/55 per cent

Length: 4360mm

Width: 1900mm

Height: 1090mm

Wheelbase: 2710mm

Front track: 1652mm

Rear track: 1603mm

Fuel tank capacity: 100l

Ground clearance: 70mm

Born slippy

Mark Boghe, Product Market Manager Automotive/Racing at Bekaert explains the developments of DLC coatings for endurance racing over recent years

It has been 15 years since the first engine components within the racing industry were treated with Diamond-Like Carbon (DLC) coatings.

These Diamond-Like Carbon coatings are characterised by two highly different properties that make them extremely interesting for applications where individual components are subjected to extreme wear and friction. The two main characteristics of the DLC coatings are in fact their resistance to high wear and their very low coefficient of friction.

DLC coatings are manufactured in vacuum furnaces. The components that need to be coated are mounted in the furnace and during the coating process a carbon layer is deposited on the surface through a plasma-assisted chemical process.

In order to improve adhesion, application specific adhesion and transition layers are used. Since these layers do not change or improve surface roughness, it is very important to specify the correct initial roughness prior to coating. A roughness Rz of < 0,8 µm is vital in order to achieve successful results.

In the past 15 years, DLC coatings have been successfully integrated into engines of F1-Teams. and also earned a solid reputation in other championships. Here is an overview of engine components that can be DLC coated:

- Finger Followers
- Tappets
- Camshafts
- Intake Valves
- Pistons
- Gudgeon pins
- Piston rings

An important goal of the engine builder is not only to increase engine performance but to make components lighter and more reliable. In endurance racing conditions, these characteristics lead to the following results:

- Performance = faster lap times
- Less weight = the possibility to improve the weight distribution + faster lap times + less fuel consumption at equal performance
- Reliability = continuous high performance throughout the whole 24-Hour Race
- Reduced consumption = less pit stops

In today's endurance races, most of the components in the valve train are coated. The DLC coating will protect these engine components against any wear. The application of DLC coatings guarantees that the performance remains equal during the entire race and at the same time friction losses are reduced.

Research indicates that by coating the finger followers and the camshafts, the friction losses can be lowered by up to 45 per cent compared with an uncoated system (Figure 1).

The valve train has always been the main area for applying DLC coatings. The application allowed an increase in rpm without generating additional wear. More recently, new potential applications have been explored. The piston assembly is a clear example of another area in which DLC coatings are successfully applied. For instance, gudgeon pins are often coated with DLC, since the DLC layer protects the part against wear. As a result, the upper bushing can be removed from the conrod, allowing a smaller, and thus lighter, design.

A new development is the DLC coating of the piston itself. Coated pistons can increase the power output of an engine by up to 2 per cent (diagramme 2) and simultaneously increase the lifetime, thanks to decreased friction losses. These results were confirmed by several extensive tests, always showing reduced wear of the piston skirt. (Figure 2)

DLC coatings have showed their benefits in multiple racing championships, especially in endurance races, where reliable performance and wear resistance play a vital role. Thanks to the high wear resistance added by the DLC coating, teams can rely on a high performance engine throughout an entire race.

COATED COMPONENT PERFORMANCE INCREASES

Figure 1

Comparison of frictional power losses between coated and uncoated finger followers

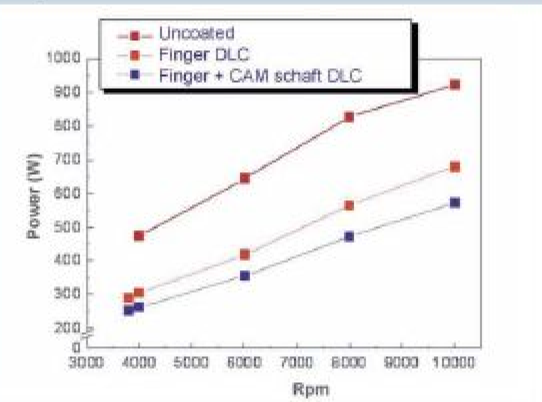
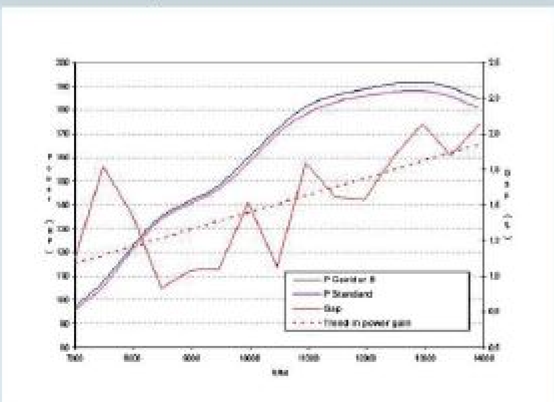
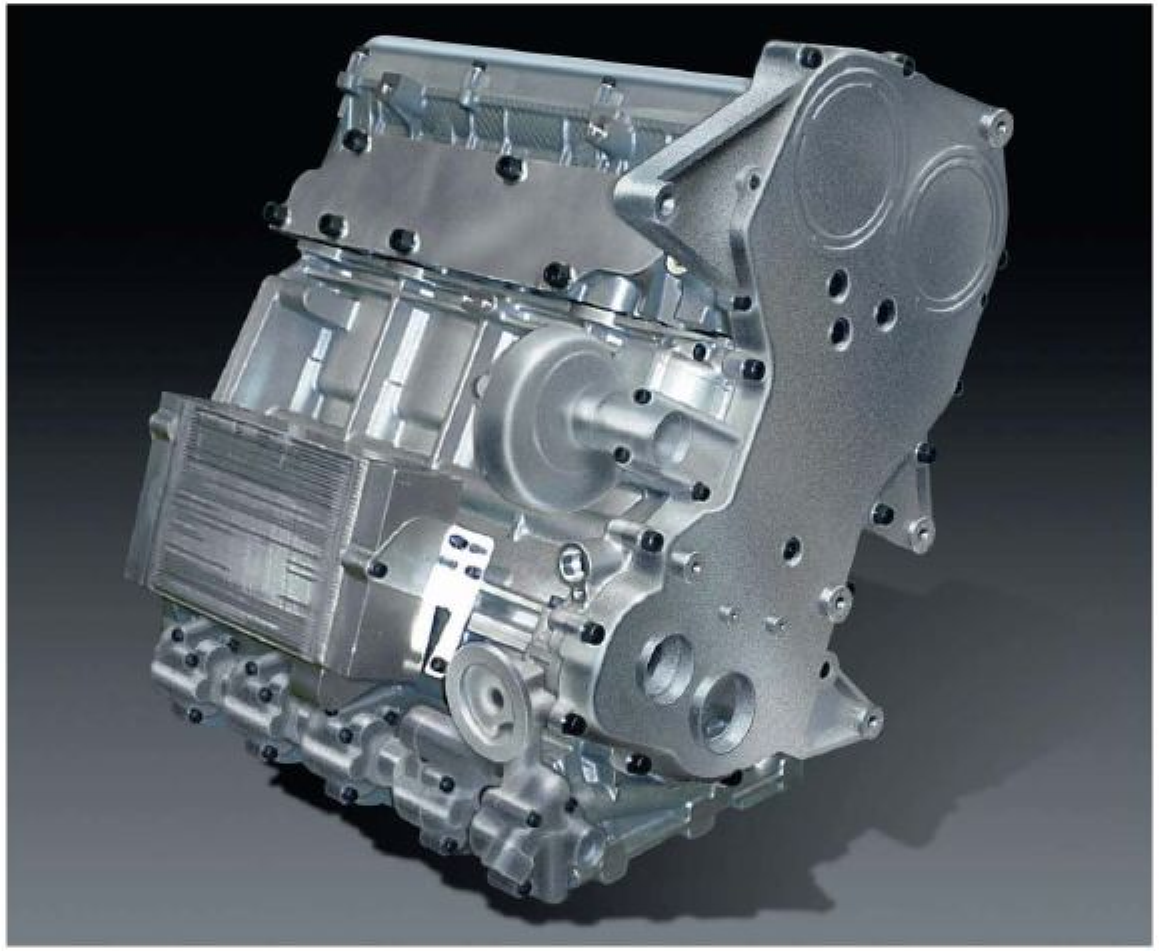


Figure 2

Graph showing power increase for Bekaert Cavidur B coated pistons over standard components





Both World Rally Cars and Sports prototypes could utilise a Global Race Engine. The Mountune MT1 was originally developed for LMP

LAT

LAT

Blueprint for the future

The story behind the Mountune MT1, a power unit that could easily be a prototype for the Global Race Engine

BY GRAHAM JONES

We couldn't let this issue of Racecar Engineering pass without providing some background on the subject of this month's cover photo. As should be clear by now, it is not a shot of the first-ever Global Race Engine cylinder block – primarily because one doesn't exist yet – but significantly, it very easily could be.

The power unit in question is the MT1, developed in-house by Essex-based Mountune Racing for use in the Reynard LMP 675 Sportscar project that was under way in 2001. It is a 2.0-litre, 16-valve, in-line four of alloy construction, which is designed to be turbocharged. The dry weight, including manifolds, flywheel, turbo, oil cooler and alternator, is under 100kg, with the bare block weighing in at just under 25kg. Power output in turbocharged form is in excess of 500bhp, peaking at 6750rpm, matched by a flat torque curve with approximately 550Nm from 3800rpm to 6500rpm. In the Reynard application, it was planned to use a Pectel engine management system. Significantly, the engine block is inclined at 30 degrees, producing a low engine height, and incorporates an integral dry sump / main bearing housing for strength and durability. Fluid routing is primarily within the engine castings, to minimise external pipework, and there is an integral water-cooled oil radiator to ensure stable temperatures. The block will accept a Ford Duratec cylinder head, although Mountune plans ultimately called for a purpose-designed head. The engine was intended to be installed as a semi-stressed member via two chassis A-frames.

Rebuild objectives were 5500km for the engine in endurance specification and 2500km in sprint specification, with running costs said to be competitive, and possibly less than currently available engines. In short, the MT1 specification sounds almost like a checklist for the Global Race Engine as it is currently being mooted, yet frustratingly, the project was shelved before ever having a chance to prove its worth.

'We were very keen on getting involved with an LMP2 engine,' explains Mountune boss, Dave Mountain. 'We saw what Lola had done with MG and we thought it was a great project – a small, light car with a four-cylinder turbo – and it was relevant to us because of our rally experience. We started to talk to Reynard about it and clearly they had similar thoughts. We had found an oil company prepared to come in and sponsor the engine, and the idea was we would actually supply engines free to Reynard. At the same time, they had found a team that wanted to run their new car and it was all looking great. They were well under way with the chassis, we were well under way with the engine – I guess we had about 90 per cent of it done – and then, unfortunately, our oil sponsor pulled out. A few weeks later, Reynard closed its doors and that was the end of that.'

> “power output in turbocharged form is in excess of 500bhp”

It didn't all stop at that point, the Reynard 02S-P675 project eventually evolved into the Zytek and Creation LMP1 chassis, but sadly the engine itself never went much further.

'It was a good car,' observes Mountain, 'but that was our opportunity gone really. We conceived our engine in the Reynard chassis battling it out with the (AER) MG-powered Lola. The Lola had an upright engine position, while we were going to use a heavily angled power unit so we could run a lower engine cover. A lot of thought went into the aerodynamics and we thought we had a better car coming along as a package, but it never saw the light of day – at least, not as originally conceived.

'We tried a couple of times to get the project up and running again, but we just couldn't find the investment to do it. Ninety per cent of the engine exists, but you can't underestimate the cost of building an engine, finishing it and developing it. That costs money, and without a customer or even interest from someone,

The MT1 block was cast by Zeus, now part of Caparo. Note the inclined layout

> the MT1 specification sounds like a checklist for the Global Race Engine

it wasn't possible. We just had to take a reality tablet and say, "what a shame."

'In total, there are about half a dozen MT1 engine sets in existence – certainly half a dozen blocks were cast and fully machined and there were a few cranks made, as the plan was to run three prototype engines early on but that never happened.'

GRE RELEVANCE

In 2001, when the Mountune project was conceived, the Global Race Engine concept hadn't even been thought of, but could Dave Mountain now see the MT1 as the basis for such a power unit?

'Yes, I could,' he replies. 'It would work perfectly as a current LMP2 engine, as that's what it was designed for, and it would be absolutely great as a World Rally Championship engine because it would be very solid. As for Formula 3, it would be over-engineered but more than capable of doing the job. It would possibly be heavier than the lightest current F3 engines, but I think it would be a very good basis for a GRE. It was built to be fully stressed, it's a neat package in the way we made the intercooler and oil coolers part of the engine with no external pipes – all those sorts of things – so yes, it would be a good basis for a multi-purpose engine. Obviously, a few years have gone by since the MT1 was originally designed, and we could possibly get a bit of weight off it now, but again, if everyone has to use the same thing, then why take chances? I think you want something that's solid and durable, and if it's 2kg too heavy, it's not really an issue.'

BORES AND STROKES

One of the thorniest of issues when developing a new race engine is deciding on the bore and stroke. As Mountune originally developed the MT1 engine with the aim of running it in turbocharged form, how would the 89mm bore eventually chosen sit with the requirements of other possible motorsport series we wondered?

'In that respect, it's also absolutely ideal for LMP2, World Rally Car and Touring Car,' responds Mountain. 'It would be too big for an F3 engine, but then you'd probably put some liners in it and reduce the bore. If you go with a bore size much larger than the 89mm we chose, then you end up with detonation problems unless you're going to run some very tricky fuel, and I think those days have gone, so 88mm to 89mm is absolutely ideal. You get quite a combustion chamber, a good flame path and good thermal efficiency.

'This is why I was a bit concerned when I heard the original concept for the Global Race Engine (GRE) might include Formula 1. Some of the bore sizes that have been spoken about there are pretty huge, and that would start to compromise the whole idea of a multi-purpose motorsport engine, because if you have to reduce the bore size quite dramatically [for other applications], then you have a very long engine for everything else and start to lose all your thermal efficiency. As it appears, the GRE concept now seems to be moving away from the idea of including Formula 1 and I think that's sensible.

> you want something that's solid and durable, and if it's 2kg too heavy, it's not really an issue

On a final point, Mountain also believes the GRE should be rev limited in the interests of cost and reliability. 'You'd have an air restrictor on the turbo,' he says, 'and I think you ought to have a boost limit, which we don't have currently, and a rev limit. If you control all those factors, then it keeps good parity across the formula and removes some of the pressure spikes, which is what breaks engines. If everyone has the same performance and it's within target, then we want the engine to be stressed to the minimum level possible so it will run and run. You want an engine that lasts all season in my opinion, and that's quite possible. 'Formula Palmer Audi, for example, has demonstrated that it is possible to go 10,000 miles between rebuilds, which is great, and what people want. This business of 1000-mile engines is just too expensive.'

So there we have it – an engine conceived the best part of a decade ago, yet looks more relevant than ever to the circumstances in which motorsport, and the world, currently finds itself.

As Mountain says, 'The FIA, or indeed anyone who is interested, is welcome to come and have a look at the MT1. It's just sitting here and, speaking personally, I think it would be a very good starting point for a GRE.'

State of the nation


LAT

EXCLUSIVE

Significant change is on the way at all levels of motorsport. FIA consultant Tony Purnell provides an update on some of the key issues

BY GRAHAM JONES

Cost containment, Kinetic Energy Recovery Systems (KERS) and the Global Race Engine (GRE) – these are the hot topics in motorsport at the moment. While conducting our research on the latter subject for this month's issue, we spoke once again to FIA technical consultant, Tony Purnell (see V18N11) and, in doing so, gained further insight into current federation thinking, not only on future motorsport power units, but also on KERS and the trials and tribulations of cost capping.

> "maybe we need to consider freer rules"

GLOBAL RACE ENGINE

As far as the GRE is concerned, it is clear from Purnell's comments that the idea remains very much a 'work in progress', with the possibilities spanning a technical spectrum. At one end, there is an engine defined by a clearly specified cost cap and fuel flow rate, and little else. At the other, there resides a concept more akin to that of the original Formula Ford Kent engine – closely specified, with a number of standard components, but able to be handed over to manufacturer engine departments and specialist tuners for assembly and refinement within a set of defined guidelines.

'You look at that spectrum,' explains Purnell, 'and then you ask, "What do we want from motorsport?" Do we want to go back to an era when people came up with wonderfully different, inventive approaches, or do we want to go the NASCAR route of pure entertainment and forget the engineering? That is one of the great debates of the moment.

'I believe it has evolved now into an idea where there appears to be a lot of common thinking. A number of people think that a downsized engine, probably four cylinder and possibly turbocharged, with direct injection, quite possibly with a hybrid element, is in all our futures. As a result, there really hasn't been much argument about the configuration as far as I understand, but I think they are looking now at a 1.6-litre version for the smaller formulae and a 2.0-litre for the bigger ones, still based on the same block and head.'

Interestingly though, as Purnell explains, there seems to have been a conceptual shift concerning Formula 1 and the GRE. 'When we first started, we thought that Formula 1 might take the lead and be the driver for all this, but I think that might have changed. Formula 1 has hitherto been on a different planet from anything else – the casting technology teams use, the way they approach weight – none of it fits well with the idea of a cost effective set of parts. Then there's increasingly a feeling that for 2013 (when new Formula 1 engine regulations are due for introduction), it would be nice to introduce this concept that, if we got the technical challenge right, then at least we could increase the probability of [the new engine] being useful to R&D departments for their production cars. That makes us feel that maybe we need to consider freer rules rather than almost designing the engine through regulation.

> "the initial rush of interest [in the GRE] surprised us a bit"

'It's just a debate that's going on at the moment. There are no decisions or sure ways to go. In some ways, I think the initial rush of interest [in the GRE] surprised us a bit. I don't think we're ready at the moment to state the framework for this in any way because we are still exploring it. It is certainly fair to say that [the concept] has triggered a lot of comment and interest though.'

RACING WITH KERS

Turning to other matters, we asked Purnell for his thoughts on KERS in Formula 1 this season. Did he subscribe to the view of some of the sport's pundits, we wondered, who appear to have written off the technology because some teams have been struggling with their systems.

'It goes back to this question of technical competition,' he responds. 'There is a view that because all cars don't have [KERS] – that is, some teams have failed to bring their systems to the race track – it's a bad thing. The comment would be something like, "Oh, it's confusing. Some cars have KERS and some don't." The opposing view is that if you set a technical challenge, then it's not a challenge if everybody makes it to the grid simultaneously with wonderfully sophisticated equipment, all within a gnat's hair of each other.

'It has become apparent that racing, if you have KERS, is different from racing without it. Drivers of non-KERS cars, for example, find it very difficult to get by a KERS car and the KERS cars rocket off the grid, so I think it's an extra element. I suspect by the end of the year, there may be more KERS cars on the grid and they'll be better sorted. Going into next year, I can see some of the issues that have prevented teams fielding KERS competitively, especially regarding weight distribution, being addressed, with the rules tweaked to avoid that pitfall.

'For 2010, I think it's likely that, in order to be competitive, you will have to have KERS – I think that's the way it will end up. Whether it will be quite the strategic element that people imagined it to be, I'm not sure. I think if everybody has one, then Formula 1 being Formula 1, it will evolve the best algorithms for any given situation. They will all use the same one, so the idea of it being strategic I suspect will fall by the wayside. Personally, though, I think it's all worked out rather well.'

Motorhomes may be exempt, but running an F1 team to the £40 million cost cap will still be hugely challenging

COST CAPPING

Finally, discussion turned to arguably the thorniest issue of the moment – cost capping in Formula 1. Purnell: 'Well, it's been a big journey this one,' he says with a smile. 'Intellectually, I think a lot of people like the idea of budget capping, as it actually creates a level playing field. The initial drive was really about the engine – we wanted to allow a technical competition, but realised that without some financial constraints, we'd never get a new powertrain because the sophistication level is such that it would cost fractions of a billion dollars and, with the current economics, no one is going to ask a board of directors for a quarter of a billion dollars to do a new powertrain. As a result, we felt we essentially had our hands tied – if we thought it was the right direction for Formula 1 to do an electro-petrol powertrain, we were unable to invoke it because no one could afford to do it.

> "we don't seem to be delivering… extreme comfort for the participants"

'That was really the catalyst for budget capping. Now, however, we've got to the stage where it has multiple attractions, and one of them is that if people know what they're getting into with spend, then they can make investment decisions. That said, to manage a team under the [£40 million ($65 million)] budget is a huge challenge. You will have to have a really tight, really efficient operation, and for many managers in Formula 1, that takes them into a different world.'

In terms of whether the £40 million cap figure for Formula 1 will stand for 2010, allowing for the fact that certain major budgetary considerations are excluded (for example, marketing, motorhomes, engines and driver salaries), Purnell is clearly of the view that it will.

'Yes, I think so,' he says. 'As far as attracting new teams goes, it is very clear to us that it is going to be a successful initiative. As far as preserving technical competition, I think it is apparent that we can make a much more challenging technical competition with the cap and, in changing liabilities into assets on the balance sheets of these big companies, we can deliver there. What we don't seem to be delivering is extreme comfort for the participants, and I think that's the bottom line. The situation is split down the middle at the moment.

'Pragmatically, though, you have to say that history suggests it will resolve itself. In F1 you can never say never because things are always possible.'

NASCAR offers the pure entertainment end of the motorsport spectrum

Indy Car: the years ahead

Ironically, the global economic downturn is offering the IRL a chance to re-shape the future of IndyCar for the better

BY IAN WAGSTAFF

Once a hot bed of innovation, but now vilified in some quarters as a pseudo-spec series, Indy Car is at an arguably make or break point. There's no doubt its custodians understand the problems but, as the 21st century enters its second decade, they also realise that costs and spectacle do not necessarily equate to engineering challenge. However, that does not mean they will just settle for entertainment with their next car, as NASCAR has done; attempts are still being made to square the circle.

As an engineer, the Indy Racing League's senior technical director, Les Mactaggart, would like to see the formula offer a technical challenge as much as any one: 'People say we need to get away from spec cars and let teams do their own thing. If the sport could afford this, we would do it.' However, he has to be realistic, in more ways than one, and the economic downturn has brought a new aspect to deliberations. When the Indy Car 2011 project was

LAT

For some time the IRL has effectively been a spec series for the current Dallara chassis, and although a few attempts have been made to qualify for the Indy 500 using a Riley chassis, these have not been a success. The series organisers still feel that the single chassis formula is the best option financially

INDY CAR DEVELOPMENT

1994
Tony George announces formation of the IRL

1997
First IRL Indy 500 using G-Force and Dallara chassis

1998
Improved headrest and seat. Car weight reduced. Riley & Scott joins chassis suppliers

1999
Introduction of SWAMS wheel retention system. RPM reduced to 10,300

2000
Reduction of engine size from 4.0-litres to 3.5-litres. Weight further reduced

2003
Honda and Toyota join Chevrolet as engine suppliers

2004
Further reduction of engine size to 3.0-litres

2006
10 per cent ethanol used. Honda now sole engine supplier

2007
Engine size back to 3.5-litres, but now fuelled by ethanol

2008
All qualifiers now use Dallara chassis. New side intrusion panels introduced

2011
Date originally scheduled for introduction of new formula, now postponed to 2012...

first announced, there was no indication of what was about to happen to the global economy. But now, the existing engine supplier, Honda, has suggested that the rule changes be delayed to 2012, and even that may be extended. Volkswagen, meanwhile, which seems to be the most interested potential new party, has said it would like them to remain at 2011, but that it will not be a deal breaker were it to be a year later.

TREMENDOUS OPPORTUNITY

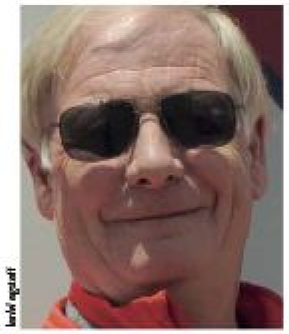
But in these trying times there are those who believe the IRL is faced with a tremendous opportunity. Former Lola chief designer, now with Target Chip Ganassi Racing, Ben Bowlby, points out the rules have been about 'forcing inefficiency on cars' since the early 1980s. 'The cars would go too fast if we didn't have numerous air brakes bolted on, such as oversized rain lights and wickers on the rear wing end plates. We are burning a load of fuel we don't need to. Nobody is looking at us and saying, "here is a forward thinking series."'

Indianapolis Motor Speedway was initially built in 1909 as a proving ground and Bowlby reckons it should still reflect this today. The IRL has already intimated that it may change from ethanol to a more road-relevant fuel, but Bowlby says perhaps it should go further and not mandate any one fuel in particular. 'The amount of fuel should be given to the teams by its calorific value, then we should get on with it. We should certainly see some interesting stuff then.' He also points out that there are 'some wider concepts that should be taken into account' and that Indianapolis should be poised to capitalise on these. 'Formula 1 has too much inertia, but the IRL could do something newsworthy that would make engineers like me stick around.'

As Bowlby's colleague at Ganassi, Julian Robertson, says, 'Ben and I are just itching to do a 'kick-ass' Indy car. We both have a pretty good idea of what you need to do to make cars race well. I keep telling Les we ought to design the car for him! What I would like to see is a lightweight engine and a lightweight car – you could do something awesome that is unlike any racecar ever seen before.

'I would like to see everything swing back to a point where there were a lot more areas on the car that you could change to gain an advantage. Everything is currently clamped down, partly for reasons of cost, partly to keep the smaller teams competitive. Indy Car needs to be back driven by technology. It needs multiple engine suppliers. As an engineer I would want any chassis, but that isn't going to happen. It is a pity motor racing has gone like it has.'

> **"Indy Car needs to be back driven by technology"**



Les Mactaggart, IRL's senior technical director

THE ENGINE CHALLENGE

The engine seems to be uppermost in the IRL's mind as a means of introducing both competition and, ultimately, challenges for the engineers. At the time of writing, negotiations were still under way with Audi / Porsche / Volkswagen, the Fiat Group and existing supplier, Honda. The Volkswagen brand is a strong candidate as it is opening a new plant in Tennessee during 2011, so it will be strategically important for it to have a high profile in the US. The Fiat Group's interest suggests a possible return to Indianapolis of the Alfa Romeo name, which the Italian company wishes to re-launch in North America.

A number of detailed technical negotiations have already taken place between the IRL and the above. 'We are committed to having a smaller engine,' says Mactaggart, 'a more efficient one that generates its maximum horsepower at high boost – obviously on road courses. Adjustable horsepower will be very important to us in the future, but by reducing the amount of horsepower we run on ovals we can open up our wing regulations and give the teams more to do in terms of car set up. This is better than my using the aerodynamics of the car as a speed control. The strategy is to have a truly adjustable engine in terms of power.'

LAT

Toyota (above), Honda (above right) and Chevrolet (below) have all supplied engines to the IRL in the past, but since 2006 the Japanese marque has been the sole supplier. Now, however, Volkswagen is keen to supply four-cylinder engines to the IRL and its Formula 3 engine block (below) could be the basis

GLOBAL RACE ENGINE

Mactaggart is interested in the fact that Audi's Ulrich Baretzky is predicting that racing engines of the future will be small and highly efficient. Audi's philosophy is that there should be a global racing engine, effectively the same configuration but in different states of tune and power to suit a formula or series. As such, it could be a low-power version running in Formula 3 or a higher power, forced-induction variant to run in higher formulae. This has to be cost effective for the engine manufacturers. They could come and go in various series, the opportunity for entry being all the easier as the architecture of the engine is more or less defined.

'It makes a lot of sense commercially,' Mactaggart observes, 'and it makes a lot of sense for us from a competition point of view, too. We want to become more road-car relevant in terms of technology, giving us a greater fan base. There will be a greater level of identification in the series, not necessarily in the shape of the car but in the type of technology – low drag, fuel efficient, the type of fuel used.' The latter may be still under discussion but Mactaggart insists it will be relevant to what the consumer buys: 'We hope to become the technical development area for improving fuel efficiency vs power.'

> **"The strategy is to have a truly adjustable engine in terms of power"**

Many of the teams would also like to see the use of turbocharging. Dreyer and Reinbold team owner, Dennis Reinbold, feel that this can be brought in to control the different speeds on the ovals and on the road courses. 'On an oval you can get up to speed within a couple of laps with almost any engine, but on a road course you have to have competitiveness,' he says. 'It would be a nice challenge for manufacturers to come up with an engine for both.' However, he underlines that 'it is going to be critical to contain what the manufacturers coming into the sport do. To me, competitiveness and cost efficiency are the two main things.' Reinbold has been on the wrong end of engine choice before and that, he says, pointing to the number that have gone by the wayside, 'can kill teams'. Panther Racing engineer, David Cripps, echoes these thoughts about how many teams have gone out of existence since the start of the IRL.

CONSUMER RELEVANCE

HVM owner, Keith Wiggins, agrees with Mactaggart that anything chosen should be more relevant to the everyday consumer. 'As an engineer, you want to be faster and come up with as different a concept as possible, but we all realise that cost control is the only way we can go forward. One chassis makes sense, but I do think we should have competition between engine manufacturers. It has been proved in Grand-Am that you can have competition at the same time as regulating the performance, but details have to be left so the engineers can flourish. We do not want to become an A1GP where we bring the cars out just for the weekend.'

So what type of engine does Wiggins envisage? 'A diesel would be a great challenge but to most Americans who pour gas (petrol) into their cars, it does not have a great caché. What the future of motor racing really needs is an electric engine, but we do need to position ourselves in the best possible light.

'The key will be to find the engine configuration that works. At the moment, we have varying mentalities – the European vs the American outlook – four cylinders vs eight or six is quite a fundamental challenge.' It is felt that Honda favours a move to a V6, while Volkswagen would prefer an in-line four. As Wiggins says, 'Finding common ground will be difficult. A compromise is probably a six cylinder because of a number of areas, not the least of which is structural, as the engine is bolted into the car as a stressed member. We would also like to get 2000 miles out of an engine, another aspect that would be a challenge to a small engine.' Wiggins is another to point out that a turbo could be used to help control speeds on the oval tracks.

Meanwhile, Robertson points out that 'part of the problem is that the cars have outstripped the ovals, although it is hard to outstrip a road course. Going back to the 900bhp Champ Cars, laps of over 230mph were being achieved. Then, with the Hanford wings, speeds of 240-250mph were being seen. A sensible speed at Indianapolis is up around the high 220s, anything in to the 230s is starting to get dangerous. Everything is now being done to try and get us into the safe ball park.' Echoing many of those involved, he also feels 'we need an engine where the power can be changed according to the kind of track being used.' For him, a turbocharger should be used with a four cylinder powerplant. This will allow more freedom for engineers.

Another of Robertson's colleagues at Ganassi, Andy Brown, warns 'CART got itself into trouble as its horsepower levels were way too high for the ovals. If you had a suitable horsepower figure to create a sensible aero package for the ovals, you would be terribly underpowered for the road courses. The advantage of the turbo – as long as the manufacturers play ball – is you can have one for road courses and one for ovals, effectively giving you two different horsepower levels. That would be a way out of the quandary.

'However, I'm not looking forward to dealing with the complexity and the problems of heat that come with a turbo installation. Neither have I missed all the arguments about, "Hey! His pop-off valve is better than mine.." that used to go on in the CART turbo days.

LAT

With the Handford wing fitted CART racers of the past were seeing speeds of 240-250mph on the ovals. According to Robertson, this was too high. He believes a sensible speed for Indy Cars is something in the high 220mph range

LAT

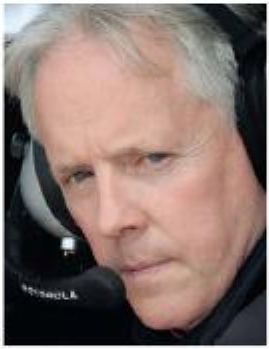
Keith Wiggins (HVM Racing)

'I hope the next formula has a better balance of horsepower, drag and downforce. The current cars haven't changed much since the mid-1990s. When they get too fast, the IRL just throws a bunch of drag at them to slow them down again. They have a superb opportunity now, so we no longer have to have all these artificial crutches – these wickers left, right and centre. That would be good for racing. Wickers are not good for the car behind because of the turbulence they create. The bigger aero wake created by all the current appendages obviously creates a bigger tow for the car following on behind, but that's no good if this same turbulent wake is robbing the car behind of downforce to the point where the driver can longer keep racing at full throttle.'

> **"Any modern powerplant can certainly provide good racing"**

Andretti Green Racing race engineer Eddie Jones agrees with Brown about future powerplants. 'The automobile industry has to move towards smaller, more efficient engines. With global warming there is a long-term inevitability about this that cannot be avoided. I think Honda, which supplies us with wonderful V8s, is very mindful of how it approaches the future. I expect the vision of the other engine manufacturers is the same. It would not surprise me if we went from a V8 to less cylinders, perhaps turbocharged. Any modern powerplant can certainly provide good racing.'

Mactaggart sees this initiative as ultimately not just involving the car manufacturers. Specialist engine suppliers were present at the initial IRL and manufacturers' round table last year but the talks have continued with only the car makers. However, says Mactaggart, 'once we actually define the formula, we may open it up to manufacturers other than the major suppliers – Cosworth, Ilmor, Zytek or AER (which currently has a four cylinder for endurance racing). This gives Indy Car an element of protection if the economic downturn continues and the major manufacturers no longer see motor sport as viable. It gives us an alternative platform to continue.' Robertson likes this idea. 'We could swing back, not perhaps to the little local engine shops, but at least to the quality engine guys, such as Cosworth.'



LAT

Eddie Jones (AGR)

BARETZKY ON THE IRL

Ulrich Baretzky, head of engine development Audi Sport, has confirmed to *Racecar Engineering* that his company still hopes to become a power unit supplier to the Indy Racing League.

'I last spoke to them at the end of last year, in Hamburg, but they have been very busy recently with the Indy 500,' he explains. It is Baretzky's belief that another engine suppliers' round table is to be held shortly: '[The IRL] knows that time is running out. Making rules is one thing, making an engine is another. The timing is theirs, not ours.'

'I think it has been decided that the IRL will use a turbocharged, 2.0-litre, direct injection petrol engine. They have thought about including both V6 and four cylinders, but this is no way for us. Honda believes that downsizing to a V6 is enough, but the majority of road engines are four cylinders. I don't believe we should make a compromise. We should only use the mainstream, and that is an in-line four.'

Baretzky says he found broad agreement in his talks with Honda in Japan: 'They agree with the four. The problem is with Acura in the States. I hope that [President] Obama will help convince these guys that even a six cylinder, whatever the size, is too big.'

PLATFORM OF ADJUSTABILITY

Mactaggart is adamant that Indy Car should not have an equivalency formula. 'That would be very difficult to control. We need to provide a platform of adjustability between manufacturers and cars so that teams can limit any deficiencies in their chosen engine to a minimum. The one thing that team owners really do not want is to find themselves penalised for choosing the wrong engine, as happened in the pre-Honda exclusivity days.'

The IRL's other question concerns the chassis. 'A one-make chassis series is still seen as being the commercially efficient model for the teams,' says Mactaggart. 'However, alternatives are still being examined. It could be that the governing body takes a greater control over the design and control of certain key aerodynamic areas. It might be that other manufacturers could come in. But the playing field would still remain even.'

Taken to the ultimate, this could mean that the IRL would draw the car, but that would probably mean the traditional chassis manufacturers, such as Lola and Dallara, would not be interested. 'I think it would be important to still have slight visual differences. If you are not going to allow that, you might as well have one single chassis manufacturer, but we haven't thought of a clever way of doing this yet.'

SAFETY CONSIDERATIONS

Whatever happens, safety will be a major aspect in the specification of the next car. 'We are looking at bringing the bodywork out so it is flush with the wheels,' explains Mactaggart, 'but the problem with this is that it reduces drag dramatically, as 60 per cent of it is created by the wheels. However, if we narrow the track and narrow the bodywork, the aesthetics of the car will remain the same. If not, there's a risk the car could look like a beached turtle.

'The clever part – and we are working on some ideas – will be how to prevent front-to-rear wheel contact. It may be nothing more complex than a flexible blade that comes off the rear energy structure, something about six inches wide that sits behind the rear wheel. As another car's front tyres push into the blade, so this is pushed against the rear wheel, preventing physical contact between the two and the resultant doubling in acceleration. We need to look at ways of preventing the two wheels from touching.'

On this subject, AGR owner, Kim Green, who has praised the work that Tony George and his team have carried out to make the racing safer, says, 'We must continue with this. There are ways to make the cars even safer and hopefully they will work hard on this for the next car.'

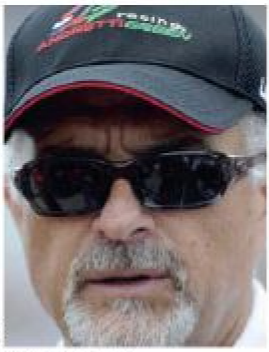
Dennis Reinbold is another who thinks the chassis should be spec. 'This kind of racing runs well in our formula. This way we can run closer on the mile-and-a-half tracks... we have guys racing at 220mph, side-by-side, two or three abreast. When that happens everybody in the place stands up and takes a deep breath.' He goes further by stating 'I would like to see the car manufactured at Indianapolis, perhaps in the area being developed around the Speedway.' That does not mean that he rules out Dallara or any other of the other European manufacturers, suggesting, 'perhaps they could design it in Italy and build it here. The main reason for saying this is that I think it is very important to work on cost containment for our series. Relying on a chassis manufacturer from another country has always been an issue. For the health of the series the chassis and engine costs need to be lower than they currently are. When we make the change over to new chassis and engines it would be nice to address both of these areas.'

> 'The clever part will be how to prevent front-to-rear wheel contact'

Although it is not a done deal – other European manufacturers have recently approached Mactaggart – Dallara still seems most likely to continue as the sole chassis supplier. Reinbold points out that, whoever supplies the car, 'The chassis has to be something that comes complete as a package in its maximum downforce trim, then for the ovals we can remove or organise specific parts. It should be street course led.'

Green is another with a radical suggestion for the future. Because of his team's experience in the multi-class American Le Mans Series, he sees an opportunity not really open to the current breed of cars: 'I wonder if on the road courses we could not run the Indy Cars and Indy Lights cars at the same time. Obviously, the Lights cars cannot run as long because of the size of their fuel tanks, but perhaps somewhere in the future this is an opportunity. We used to get 30-odd cars at St. Petersburg in the ALMS in four different classes, but they did have fenders (wings).

However, perhaps the next Indy car will, although open wheel, have some way of preventing wheel-to-wheel contact, which is obviously pretty dangerous.'



Kim Green (AGR)

LAT

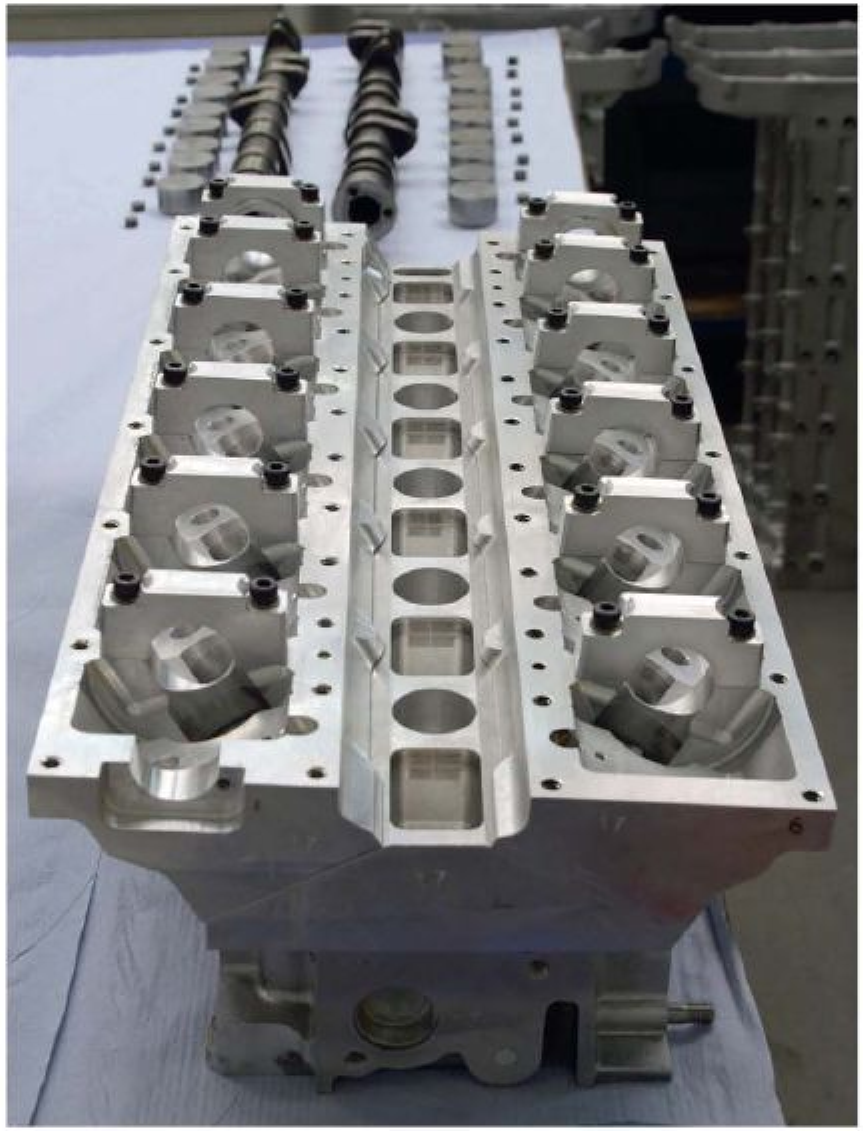
Whatever happens, the IRL certainly has the opportunity to change for the better, even perhaps lead the way in open-wheel racing. Mactaggart concludes: 'we used to see a five to 10 per cent improvement in the cars year on year. Now it is difficult to find a half to one per cent. We now need a major change to re-set everything.'

EXCLUSIVE

Mind games

We investigate the challenge of framing motorsport regulations with a look at the Volvo Touring Car cylinder head of the 1990s

BY GRAHAM JONES



The Volvo Touring Car programme was a classic example of ingenious engineers thinking their way around what initially appeared to be tightly framed regulations, and cylinder head development was at the heart of its success

It was an unlikely basis for a racecar. Despite that, the Volvo 850 estates fielded by Tom Walkinshaw Racing on behalf of the Swedish manufacturer during the 1990s remain among the most memorable vehicles to have graced modern Touring Car grids. They may not have been regular winners on track, but the racing estate cars were outright victors in the publicity stakes, as well as firm favourites with race crowds up and down the UK.

Beating out a distinctively uneven five-cylinder thrum from beneath its bonnet was a TWR-developed engine that, later in the decade (1998) and fitted to the smaller S40 saloon, would bring Volvo the Touring Car glory it had been seeking. That engine was in many ways like the original 850 estate car it powered – not an obvious choice for the track, but one which, with careful reading of the regulations and some clever thinking, was turned into a winner.

Now all this may have taken place over a decade ago, but there are some salutary lessons to be derived for cost-conscious motorsport rule makers everywhere, including those who will eventually frame the regulations for the Global Race Engine, should the current deliberations start moving from discussion stage to reality. It is also an example of how the law of unintended consequences can be unleashed from the wording of an apparently clearly written technical document.

One of the more ingenious aspects of the Volvo Super Touring engine was the cylinder head, and to understand how it came about, we spoke with Charlie Bamber, currently managing director of UK-based Menard Competition Technologies (MCT). Bamber is a veteran of TWR's Jaguar Sportscar programme and Nissan's Infiniti programme in North America. He was also chief engineer of the company's race engine department throughout the Volvo programme and responsible for the conception and development of the Touring Car engine.

Bamber's point in discussing the details of this project with *Racecar Engineering* – the first time this information has ever appeared in the public domain – is, as he says, 'to show how making regulations to drive down cost can actually drive it the other way. What we've got [with the Volvo cylinder head] probably compares very well with the diffuser situation that Formula 1 found itself in this year.'

Understandably enough, a roadgoing engine is just that, so its design parameters and specification are unlikely to be optimised for motorsport.

VALVE ANGLES

In the case of the Volvo cylinder head, one of the most significant compromises involved the included angle of the valves.

'It's set at 58 degrees,' explains Bamber. 'This is not for a good reason in terms of engineering. Rather it involves the equipment used on the Volvo engine production line. A single cutting machine could incorporate two machining heads if the valves were angled further apart, thereby allowing you to cut two sets of valve openings at the same time. If Volvo engineers had gone for a race-style alignment – say, where you had maybe 12 degrees on an inlet and 13 degrees on an exhaust, for a total angle of 25 degrees – then the machine tools would clash. As a result, you couldn't manufacture such a layout as efficiently and [the head] ended up with a very steep spread in the valve angle. It's not for good combustion, it's driven by a desire to manufacture the head more cost effectively.

'This gives you some problems straight away because what it does is put a huge volume in [the combustion chamber] and if, for example, you're competing in a series where the compression ratio is free, then the only way of raising the compression ratio is by pushing the piston into that void. And when you do that, you compromise the gas exchange. Between Ricardo and Volvo, they built a prototype and came up with a 260bhp engine. I think at that time in the BTCC most teams were probably on about 285bhp, or thereabouts.'

In short, it was clear some radical thinking would be required to turn this very competent road engine into a competitive race engine, and that was exactly what TWR brought to the table when it was awarded the contract in late 1993 to build and run the racing Volvos.

> "some salutary lessons for cost-conscious motorsport rule makers"

'One of the first things we chose to do was look very carefully at the regulations,' recounts Bamber. 'They said you must run a standard cylinder head, you must retain the standard included valve angle and you must keep the inlet port in the position it is as standard. You can fettle the port to make it bigger, you can add material (but you're not allowed to weld) and you can fit big valves, but you have to use the standard head. The intention of that quite tightly framed regulation was to drive costs down.'

The fact a certain well-travelled road is paved with good intentions was clearly demonstrated as Bamber and his team started to 'drill into the regulations', as he puts it.

Valve angles and inlet port positions had to remain as standard measured from specific reference points, opening the door wide to interpretation

LAT

After the 850 estate Touring Cars, Volvo switched to the 850 saloons. All cars were run by Tom Walkinshaw Racing

CAMS AND CARRIERS

The first area they looked at was camshafts, and it immediately became obvious that for the sort of profile required to achieve the desired performance, the limiting factor would be the inability of the standard cylinder head to accommodate cams with the necessary base circle diameter. At the same time, the more radical cam profile required tappets larger than the standard engine's 32mm offerings; 36mm was the preferred diameter, as it would allow the team to run cams with sufficient lift for the largest valves that could be fitted to the combustion chambers. A standard production camshaft, for example, would have approximately 300thou of lift, while the ultimate cam TWR was looking to run in the Volvo engine had 825thou of lift. The challenge was to make the chosen cams and tappets fit and still comply with the rulebook.

The Super Touring rules said nothing about the angle the head had to sit on the block – a loophole TWR exploited to great effect. The standard Volvo head is on the right in this photo, the fully compliant TWR version on the left

Going back to the regulation that said you could remove as much material as you like from the standard head casting, the decision was taken to cut off the sections where the cams are fitted and fabricate new, purpose-designed carriers that bolt to the central core of the Volvo head, thereby allowing the optimum specification of cam and tappet to be fitted.

PORTS AND VALVES

Having overcome that obstacle, the focus then shifted to optimising the design of the inlet port. As Bamber puts it, 'Why have an 825thou lift cam when the maximum flow of the standard port probably peaks at the 400thou mark? The standard head has a decent-sized opening, but it's limited. If we want a port that flows at a very high lift, then it's actually going to have to be a lot steeper [than standard].'

The homologation papers specify that the distance between the cylinder head face and a centre line through the ports may not be altered from standard. To deal with that requirement, Bamber and his team decided to cut back the vertical head face containing the ports, thereby producing a steep run directly onto the back of the valve. In order to retain the critical measurement between head face and port centre line, material was added to the port openings, which was permissible under the regulations.

With that achieved, they turned to the combustion chamber shape and valve choice. 'Valve size was free,' says Bamber, 'so you work out your smallest possible stem diameter and then rig test it to make sure it survives. In this case, we used a 3.5 to 4.0mm stem. Turning to the combustion chamber, you need to maximise the flow of the new valve. That was achieved by chopping the chamber out, to make sure you have the best possible gas exchange, and putting as much volume back in the chamber as you can. Effectively, what you've done is dropped everything further in and back in the casting.'

THE WEDGE EFFECT

The *pièce de résistance*, however, relates to the fact the Touring Car regulations of the time did not stipulate how the cylinder head was to sit on the engine block. Significantly, the measurement of the included angle for the inlet and exhaust valves related to the production head, which had a uniform height across its width. By machining the head face to a 'wedge' and cutting back the face of the port where the inlet manifold mounts, Bamber and his team were able to achieve a significantly steeper inlet port angle, a more optimum inlet valve angle and a shallower exhaust valve angle, all of which still complied with the homologated dimensions. The final steps involved machining the piston crowns to produce the desired compression ratio (13.5:1) and some additional skimming of metal from what remained of the original head casting.

'You're now left with that section of the original head that says "Volvo" on it,' smiles Bamber, 'so it's a standard head with a standard water jacket, standard valve angle and with the inlet ports at the height specified by the regulations. But you've gone from an engine that was stuck at 260bhp to one that ended up with 325bhp, and the fastest car at the end of the straight on many occasions with a body that had a frontal area greater than the other cars. The regulations were designed to reduce costs, but because of the way engineers read those regulations, you ended up with something very different from what the organisers intended.

> “a £15,000 version of a £200 head”

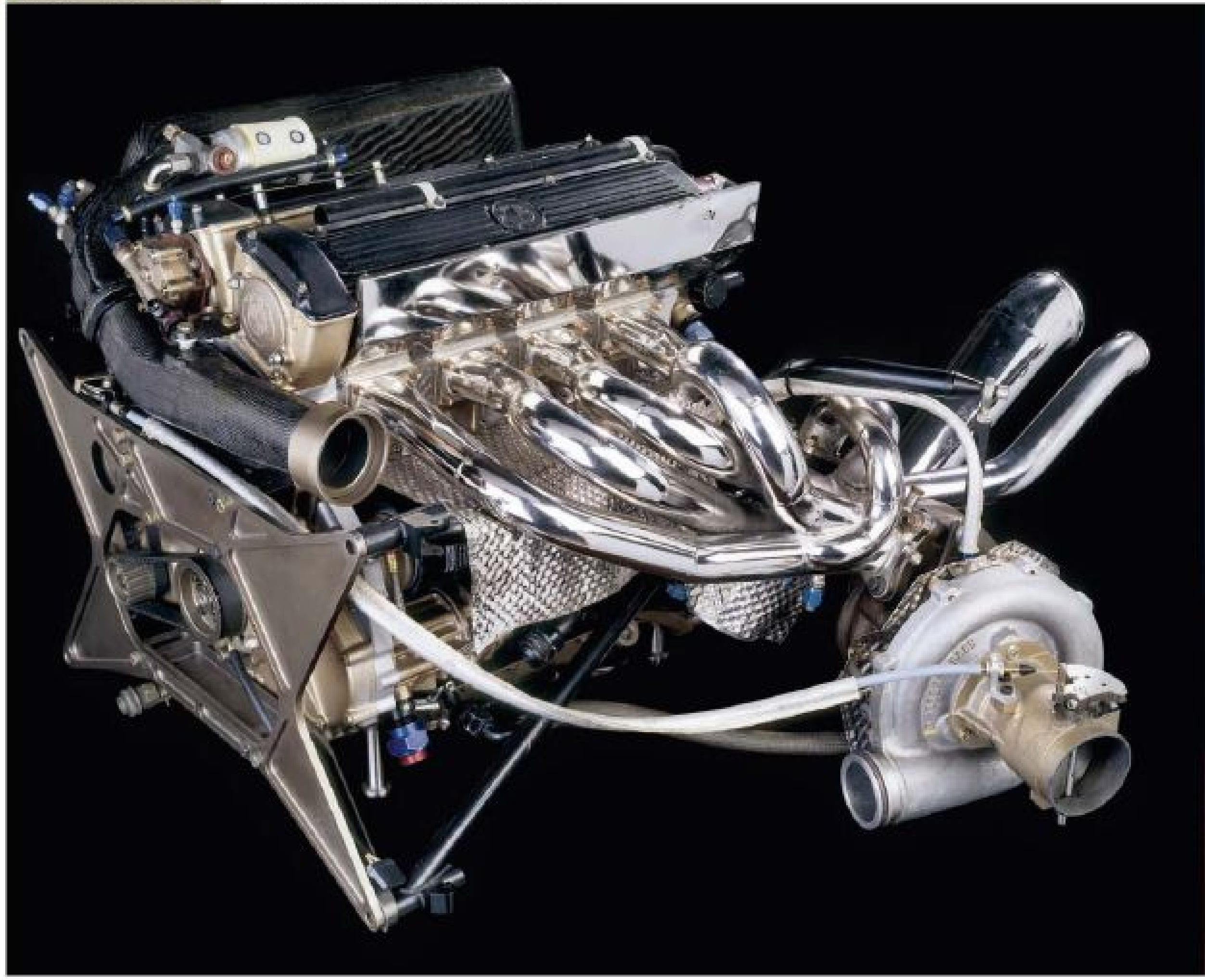
COST CONTROL?

'That head, in the 1990s, in the small volumes produced cost in the region of £13,000 to £15,000 per head to make. In short, you've produced a £15,000 version of a £200 head. The argument then has to be, "Why not just let somebody have the head they want?" If the regulations had permitted it, we could have spent £15,000 on tooling and £200 per casting, machined up some heads, topped and tailed them, and we would have had the five-cylinder head we wanted. After the initial investment in tooling, we could probably have been making heads at £450 each. Instead, we had heads coming out at between £13,000 and £15,000 apiece as a result of regulations formulated to keep costs down.'

Given the 'free-thinking' approach taken by TWR, it's seems a fair assumption the Volvo head would have been questioned, and Bamber confirms this: 'It was queried at every race, and time and again, proved to be within the regulations. It is a production head – there is no way it was anything else.'

LAT

In 1998, fitted into the smaller S40 saloon, the TWR-developed engine brought Volvo the Touring Car glory it so richly deserved



Based on the humble production M10, the BMW motorsport engine was developed into a successful naturally aspirated F2 engine (above) and ultimately into the phenomenally powerful turbocharged F1 engine (above left)

Heart of iron

BMW confounded the sceptics by turning a production, four-cylinder, iron-blocked engine into a title winner during the 1980s

BY CHARLES ARMSTRONG-WILSON

To enter Formula 1 with a stock block-based engine, even almost 30 years ago, was an extraordinary move. A production-based unit had not seen success in F1 since Ferrari in the 1950s. For that matter, nor had one based on an iron block, yet the BMW M12/13 had both and went on to deliver a world championship. But, without the benefit of hindsight, how did a technology-driven company like BMW end up entering the sport in such an apparently disadvantaged position? The view from inside the company was more optimistic.

Jochen Neerspach had been competitions manager at BMW since 1972 and founded the famous M Team that spawned the company's sporting brand. One of the engines in its armoury was the legendary M10 four-cylinder engine. This had been introduced in 1961, in the company's range of 1500cc Neue Classe saloons. However, for its time, the canted, overhead-cam unit was very advanced and was quickly adopted as the engine to have in motorsport. With a central camshaft operating valves either side of the head it offered good combustion chamber shape and excellent breathing. The unit powered the 1800 TISA [Tourismo International Sonderausführung] version of the saloon in 1964, possibly the first homologation special, and won the German Touring Car title for BMW that year.

ENGINE DEVELOPMENTS

The M10 quickly found homes in Sportscars and single seaters as competitors exploited its advantages over the pushrod fare commonly available at the time. BMW responded with developments to make the engine more powerful, notably the Ludwig Apfelbeck-designed radial valve head. This four-valves-per-cylinder engine had each pair of valves, inlets and exhausts, set diametrically opposite each other. Plus the stems were at angles to the longitudinal and transverse planes to create a truly hemispherical four-valve combustion chamber. It did, however, require a port for each valve, necessitating eight inlet trumpets and a pair of four-into-one exhaust manifolds. But, despite its complexity, it delivered 310bhp from a normally aspirated 2.0-litre when run on methanol and nitro.

A greater success was BMW's more conventional twin-cam head, which delivered close to 300bhp and, from the late 1970s, re-asserted BMW's success in European F2, producing three champions in five seasons. It was this engine, the M12/7, that Neerspach's department supplied to a number of Touring Car outfits both sides of the Atlantic, and a parallel programme, with McLaren North America, produced even more impressive results. Once turbocharged, this unit delivered 600bhp for qualifying and taught the company an enormous amount about the implications of putting the engine under a lot of stress.

> **“for its time, the canted, overhead-cam unit was very advanced”**

Schnitzer, too, ditched its normally aspirated 2.0-litre saloons in favour of turbocharged 1.4-litre versions to meet the national saloon series' equivalency formula. With 1.2Bar boost from a KKK turbo, they were enjoying more than 400bhp and won the 1978 title against the might of Porsche and Ford. Through all this the company was banking a wealth of knowledge and developing a workable package that could be easily scaled to F1 proportions. Renault had already made the break from

TECH SPEC

BMW M12/3 ENGINE

- Head: aluminium
- Block: iron
- Cylinders: four
- Capacity: 1499cc
- Bore: 89.2mm
- Stroke: 60mm
- Compression ratio: 7.5:1
- Pistons: Mahle
- Piston weight: 365g
- Included valve angle: 40 degrees
- Inlet valve diameter: 35.8mm
- Exhaust valve diameter: 30.2mm
- Turbo: KKK, then Garrett
- Maximum revs: 11,500rpm
- Weight, including turbo and intercooler: 170kg
- Engine management: Bosch
- Fuel: synthetic by Wintershall
- Intercooler: Behr

the normally aspired, 3.0-litre norm with its V6 turbo that year and it didn't take a huge leap of imagination to spot the BMW engine's potential.

However, on being presented with the proposal, the board banned any work for F1 under threat of dismissal of the entire motorsport department. It's chief engineer, Paul Rosche, was undeterred and continued development of a 1.5-litre unit in secret with F1 aspirations. For Neerspach, the F1 ban was too much and he left to join Talbot and opened talks with BMW to take the F1 engine project there to be raced as a Peugeot Talbot project. However, Dieter Stappert, Neerspach's assistant at BMW and now his successor, appealed to the board. They were not against F1 per se; they just didn't like the way Neerspach had steered them into a corner on the matter, or so it seemed to them. With him gone, Stappert was able to convince the board of the value that an F1 engine racing under the BMW brand would bring to the company.

THE F1 ENGINE

A deal was struck with the Brabham F1 team and the engine was unveiled in the back of a BT50. The team also fielded a normally aspirated, Cosworth DFV-powered BT49D to cover their options. Having struggled for several seasons with the Alfa Romeo V12, it was fully acquainted with the pitfalls of stepping away from the well-honed Cosworth package. BMW was not overly impressed with this approach, though, and felt the team was not fully committing to the project – a situation that would be reversed a few years later.

LAT

The M12/13 engine in the Brabham BT53 of 1984 produced 880bhp in race trim but much more in qualifying

To create the M12/13, BMW started with the production iron block and machined it to remove all unnecessary weight. By dispensing with stiffening ribs and some water channels on the inlet side, 5kg could be lost. A steel crankshaft, combined with titanium con rods, brought the stroke down from the road car's 71mm to 60mm, and with Mahle pistons of the standard unit's 89.2mm bore gave a bore-to-stroke ratio of almost 3:2 and a capacity of 1499cc.

Initially, the cylinders ran a 6.7:1 compression ratio, based on experience with the Touring Car engines, and were fed by German-made KKK [Kulne, Kopp and Kausch] turbos via intercoolers. Fuel was supplied from a Bosch, high-pressure, electric pump during start up before a Lucas unit driven directly off the inlet cam on the right took over. In this configuration the M12/13 delivered 557bhp at 9500rpm. What pleased then Brabham designer, Gordon Murray, most was its weight. Having spent years with the large, heavy Alfa 12, the BMW, complete with turbo, intercooler and radiators, was only 30kg heavier than a bare DFV.

> “the qualifying power figures became the stuff of legend”

The car made its public debut in a practice session for the 1981 British Grand Prix at Silverstone and recorded a straight-line speed of more than 190mph. It was not without problems, though – pick-up out of corners was poor and its fuel consumption was voracious. For a typical race distance the BT50 would have to carry 47 gallons of fuel, while the Cosworth-engined BT49 needed nine gallons less. Every time it was weighed up against the BT49, it made sense to run the normally aspirated car.

The BMW engine remained unraced all year and finally made its debut at the first race of the 1982 season, the South African GP. Unfortunately, both cars retired and didn't see combat again until the fifth race of the season, at Zolder in Belgium, where Nelson Piquet scraped a fifth place. But tensions were growing between the teams in Munich and Chessington. Piquet's failure to qualify the car at Detroit two races later was a low point. His racecar expired after just six laps and the spare had such poor pick-up out of corners, even the future World Champion couldn't get it onto the grid.

Brabham sent over another Cosworth-powered BT49 for the Canadian GP with the result that Stappert feared the relationship was coming to an end and BMW would have to pull out. But Murray held faith with BMW, although hearts then sank when Piquet's main car developed a misfire. The spare ran faultlessly, however, scoring the first Formula 1 win for the BMW engine. The crucial development, it turned out, was a simple but vital change to the fuel metering that transformed the car from a lag-ridden nightmare into something as drivable as a DFV.

POWER CLIMB

From this moment on, progress was continuous with power climbing to 740bhp in 1983, and 880bhp in 1984, helped by a switch to Garrett turbos and a 7.5:1 compression ratio. But it was the qualifying power figures that became the stuff of legend, with figures from 1000 to 1400bhp often quoted. The truth is, nobody knows what they were for certain, as BMW's dynos were

TABLE 1

Power development

Year		Boost	Power
1983	Race:	3.0Bar	740bhp
	Qualifying	3.2Bar	800bhp
1984	Race:	3.8Bar	880bhp
	Qualifying	4.5Bar	1050bhp
1985	Race:	3.6Bar	850bhp
	Qualifying	5.4Bar	1200bhp
1986	Race:	3.6Bar	850bhp
	Qualifying [M12/13]	5.5Bar	1200bhp
1987	Race:	3.8Bar	900bhp
	Qualifying	4.0Bar	n/a

AN OLD ENGINE MYTH

© Loosey/dreamstime.com

One of the enduring stories regarding the M12/13 is that they were built around high mileage road car engines. The tale goes that the engineers discovered that blocks that had spent a long life racking up miles in road cars were wonderfully stress relieved. This gave a longer racing life under the extreme pressures of turbocharging. Reports claimed BMW's M Sport engineers were to be found frequenting Munich scrapyards to source well-used blocks from BMW saloons.

Ulrich Baretzky of Audi Motorsport worked on BMW's Formula 1 engines in the early 1980s and rolls his eyes at the suggestion: 'We kept being asked this,' he recalls, 'and it wasn't true. But Paul Rosche became curious, so we tried it.' They built up an engine around an old road car block and tested it on the dyno to see what would happen. 'It didn't even get warm before it blew up,' recalls Baretzky.

Where the story came from, then, is obscured in the mists of time, but it was probably the work of an overzealous PR representative or a journalist letting his imagination run away with a snippet of information picked up during an interview. It was definitely not from spying on BMW engineers cruising Munich scrapyards.

unable to measure such outputs. But it did become a powerful and reliable unit despite its humble origins. Brabham got round the engine's thirst by re-introducing race re-fuelling for the first time in many seasons, helping to give Piquet the drivers' title in 1983. The following year, engines were also supplied to Arrows and ATS and, in 1986, Benetton.

PACKAGING ISSUES

Despite its success, nobody could deny that the engine's configuration did create some packaging issues. While it was tall and slim compared with a V8 and easily shrouded by the monocoque, the plenum was large and stuck out the side, requiring bodywork that blocked flow to the rear wing. Around this time, an old acquaintance of Murray's, US transmission designer, Pete Weismann, got in touch. Years earlier, they had worked together on a concept for a mid-engined, Offenhauser-powered Indy car. It suffered the same packaging problems and they considered laying down the engine to put the plenum behind the driver. This put the drive in the wrong place, but Weismann proposed getting round this with a transverse gearbox that had the input at one side and the output in the middle.

On hearing of Brabham's experience with BMW, Weismann flew to the UK and turned up at Chessington with a Tamiya model of the Brabham doctored to show how it could work. Murray was sold, and within half an hour, so was team owner, Bernie Ecclestone. BMW, however, was less enthusiastic – an attitude that Murray feels compromised the project. 'There was just no effort from BMW to make it work,' he recalls, echoing suspicions of a lack of commitment by Brabham years earlier. Munich did go ahead, however, and produced an installation with the unit canted over at 72 degrees to the vertical, the M12/13/1, and it was installed in what became the Brabham BT55.

This car's innovation extended far beyond the engine layout and embraced a whole low-line, long-wheelbase philosophy that yielded a 30 per cent reduction in frontal area and would eventually set the pattern for the entire grid. But in this embryonic incarnation it brought a succession of problems, including traction, mainly due to weight distribution.

> "the engine's configuration did present some packaging issues"

In fact, the new engine proved to be a major source of issues, initially manifested by its much higher operating temperatures compared with the upright version and an inability to pull out of some corners. Brabham revised the cooling system, increasing drag and compromising weight distribution in the process, but the car still struggled to get boost up out of the turns. There was a pressure pipe that had been incorporated into the engine cradle that may have been causing a restriction, but even with this bypassed, the engine struggled to achieve the same boost as the Benettons running the upright engine.

Eventually, Murray suspected it was an oil-scavenge problem with lubricant accumulating in the cylinder head on right-handers and believes he confirmed it in a controlled test at Mallory Park. Rosche disagreed, saying: 'We made many tests to see if there was a scavenging problem and never found one.'

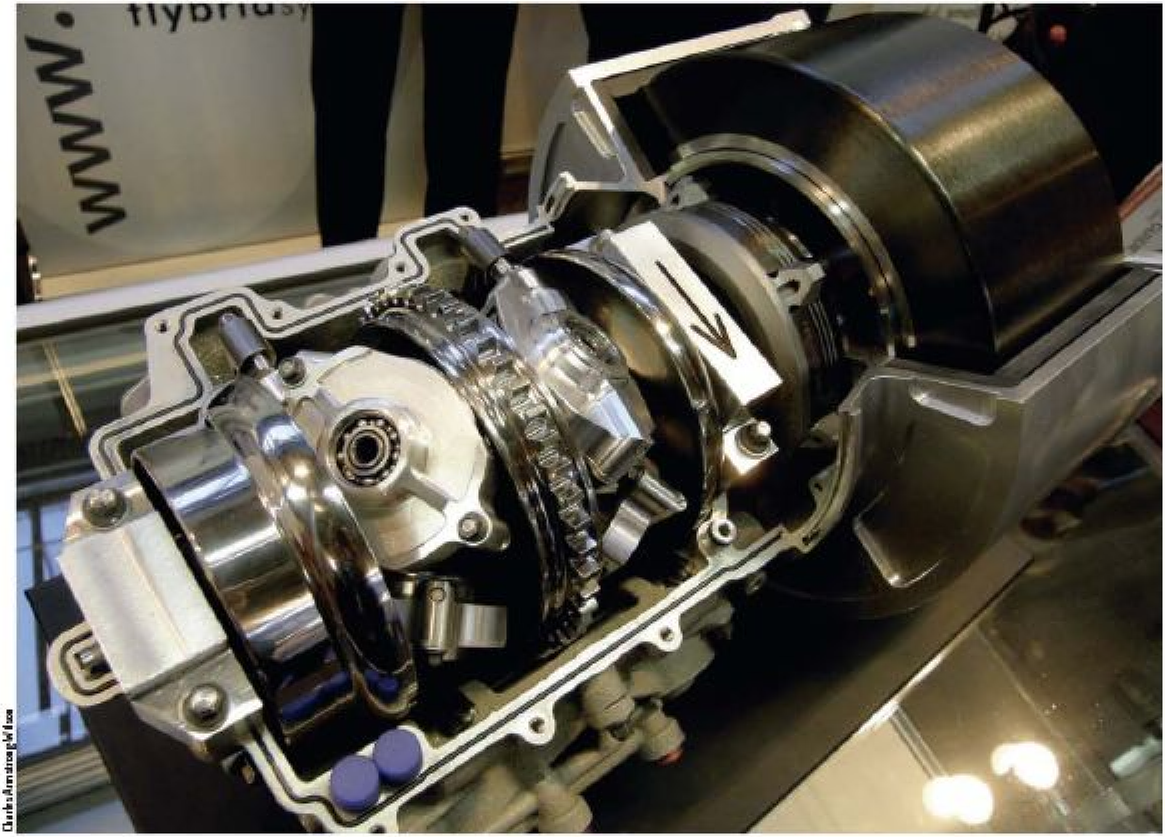
Eventually, the situation descended into a battle of politics over engineering. Murray became frustrated and left Brabham, while BMW attempted to pull out of F1 but Ecclestone held them to their contract for 1987. An attempt by Brabham to return to the old upright engines was thwarted when the entire stock was sold to Megatron, which then continued supplying customers until turbo engines were banned at the end of the 1988 season.

The BMW engine may never have won the constructors' title, but nor did Renault, with its much more sophisticated turbo V6. But the M12/13 did deliver the first turbo-powered drivers' champion and put BMW on the map for the first time as a serious F1 competitor. It also produced some of the most exciting numbers in F1 history.

LAT

In European F2 in the late '70s and early '80s, the BMW power unit was a proven winner, seen here in a March 792

On the money



A collaboration between Magneti Marelli and Flybrid Systems has produced a flywheel-based KERS solution that doesn't cost the earth

Above: Flybrid's mechanical KERS, showing the wound fibre flywheel and the Torotrak continuously variable transmission

BY SAM COLLINS

During a panel discussion on the subject of kinetic energy recovery systems (KERS) at the Professional Motorsport World Expo, Magneti Marelli's head of motorsport, Roberto Dalla, met Jon Hilton. The result was an innovative energy storage device aimed squarely at motorsport dubbed the flywheel capacitor. 'It became clear we had some interests in common during the discussion,' revealed Hilton. 'In particular, on their KERS they make the motor and all the electronic controls, but they do not make the battery. In other words, they are not in a position to supply a complete system. From our side, there has been a lot of talk about the packaging issues of trying to put all of the components in one place. Also, we have had one or two people expressing concern about CVT [continually variable transmission] development, although it has worked really well for us to date. We are also keen on better integrating flywheels into all-electric vehicles for road use, so this is directly relevant to that, too.'

Consequently, Hilton and Dalla agreed to collaborate on the development of the new storage medium. 'We decided to call it the flywheel capacitor because it behaves very like an electrical capacitor, where the terminal voltage drops as the flywheel speed goes down, just like a capacitor does. It also has a self-discharge rate that is not zero, but pretty low.'

> "a self-discharge rate that is not zero, but pretty low"

The new system retains most of the conventional Marelli F1 hardware in its usual locations, with the MGU mounted at the end of the crankshaft and the KCU mounted as teams see fit. However, instead of storing energy in its chemical form using batteries it stores its energy in

The flywheel capacitor system mates the existing Flybrid storage medium with the Magneti Marelli motor / generator unit (see detail shot below) and other Formula 1-spec componentry

> **“the flywheel capacitor does make it financially viable”**

kinetic form with a flywheel. 'We take the electricity and, where we would normally take it and put it into a battery or electrical capacitor, we instead put it onto the terminals of the motor and use it to spin up the flywheel,' Hilton elaborates. 'When you switch the power off, the flywheel keeps spinning so, when you want the energy back, you turn the motor into a generator and the power comes back.'

The flywheel assembly itself is near identical to the current Flybrid design (the full article on which can be found at www.racecar-engineering.com) but, where its driveshaft would mate with the CVT on the new system, it drives an electric motor that runs at full flywheel speed. This is one of the key areas of the system's current development, as Hilton explains: 'As we normally run at 60,000rpm and the Marelli motor does not currently run as fast, we are looking at that. Also the controller needs the frequency to be able to cope with that speed, though from the point of view of monitoring the state of charge it is easy. All you need to do is fit a single sensor.'

LAT

The Magneti Marelli motor / generator unit

WITHIN BUDGET

The 2010 Formula 1 technical regulations released in early May allow for an increase in KERS performance for teams operating within the £40 million cost cap. Yet in 2009, some teams spent upwards of £20 million alone on energy recovery systems and integrating their complex cooling demands into the tight environs of a grand prix car. It would seem then that within a cost-regulated formula KERS is really a step too far, but it could be that the flywheel capacitor does make it financially viable.

Not requiring batteries also keeps the cost of the system lower than many others, and reduces cooling demand, too. Whilst even the latest lithium ion battery cells and capacitors have significant cooling requirements a flywheel does not, which also aids packaging. 'We both see a lot of other series interested in KERS who would like to do it but, after looking at the F1 experience, they realise it's prohibitively expensive,' adds Hilton. 'With battery electric KERS the users are throwing the batteries away after perhaps just two race distances, but they cost tens of thousands of pounds per unit. It's not very environmentally friendly and it's just so expensive. In a sub-F1 class it's just not possible on cost to go that route. Our system is not a lot different on initial purchase cost, but the storage will last the whole season and that should make it very cost effective. There is currently a tender to supply the whole DTM series with KERS and the spec is that the system must last a full season, followed by a low-cost rebuild and then another full season. I think that's impossible with battery electric systems. It could also be a good F1 solution for a budget-capped or cost-regulated team, where you have to count every penny.'

> **“the storage will last the whole season”**

PERFORMING SEAL

The twin lip shaft seal capable of maintaining a vacuum on the Flybrid KERS unit

When we featured the Flybrid KERS system previously in *Racecar Engineering*, there were some key areas the company was unwilling to talk about until they were patent protected. A year later, with them safely covered by patents, John Hilton is willing to speak about the innovations that allowed them to tackle the biggest problems in the system.

The challenges stem from the 64,000rpm the flywheel needs to spin at to create sufficient power density in a small, light unit. At that speed, heat generation is the big issue, but one that Flybrid avoided by running its flywheel in a vacuum. But this then threw up the problem of how to lubricate bearings in a vacuum without the lubricant evaporating. Secondly, how do you get the power in and out while maintaining that vacuum?

The latter issue was dealt with by a particularly clever seal design that has twin lips running on the shaft with the gap between the lips filled with oil at atmospheric pressure. Because there is no pressure difference between the oil and the atmosphere, no air is drawn in. However, there is a huge pressure difference across the inner lip between the oil and the near total vacuum in the flywheel chamber, but because the oil molecules are much bigger than air molecules it makes it much harder for them to be drawn past the lip than would have been possible with air. The result is very low leakage – just 2.0cc in eight months of testing. Any oil that does pass through into the chamber is a special grade for use in vacuums that does not evaporate and can be cleaned out when the unit is serviced.

> "how do you get the power in and out while maintaining that vacuum?"

And the bearings themselves? They are simply mounted outside the seals of the vacuum chamber in atmospheric pressure and so present no problems with evaporating lubricants.

Stability index evaluation 2

Danny Nowlan explores methods of manipulation using simulation software to improve on-track performance

A number of issues ago (RE, V19N2), I presented a preliminary evaluation of the stability index from race data. While I commented then that I thought the technique had merit I was nonetheless concerned we hadn't quite broken down the components of the stability index. That's to say I hadn't quite sorted out inputs from outputs. This article will set out to address this.

The focus of this article will be to show you how a few basic techniques can be used to show conclusively if the car is stable or not. Along the way I'll be giving you a differential equations primer, and some very useful metrics will be shown. In particular, a way to evaluate steering effectiveness.

Before we start our analysis though, let's take a review of differential equations of several variables. For those of you with a strong maths background you can skip the next couple of paragraphs. For those of you who don't, read on. Let's say that we have a function of two variables. We'll express it as the following:

BY DANNY NOWLAN

$$z = fn(x, y) \tag{1}$$

The most obvious example of a function of two dimensions is a downforce map, which is a function of front and rear ride height. This is illustrated overleaf in figure 1.

As can be seen, as front and rear ride height changes, the function values change, and behave in the way we would expect. So when we say we have a function of two variables, before you head for the hills, just think of an aeromap.

Now let's consider a slice of this function along, say, the front ride height of, say, 4mm. Let's plot this against rear ride height. We're also going to consider a point at, say, a rear ride height of 16.4mm. This is shown in figure 2.

You will notice that at the 16.4mm mark I have illustrated the tangent to this slope. The tangent represents that point, which the function will do at that instantaneous point. As you can see, the slope is increasing so, if we increase the rear ride height, the CLA will go up and vice versa when rear ride height decreases. Think of it this way – you're turning a car and you let the steering wheel go. The tangent is the path you take. This tangent is also referred to as a derivative of z with respect to rear ride height or dy/dx. So, consequently, derivatives are tangents. It's that simple. This is the beating heart of calculus and, as you can now appreciate, is something your maths teacher didn't devise as a form of intellectual torture. This also has real-world applications.

The treatment we gave to the rear ride height slice is exactly the same as if we were to apply it to the front. This is the basis of the idea of partial derivatives. All it measures is the change in z over, say, x while keeping y constant, and vice versa. The notation we adopt for this is as follows:

$$\frac{\partial z}{\partial x}, \frac{\partial z}{\partial y} @ x = x_0, y = y_0 \tag{2}$$

The astute reader will recognise that for this to be valid it must be evaluated at the coordinates described in equation (2). Before leaving the discussion, I just want to close the subject by ramming home what the derivative physically means. When the derivative is positive, whenever x changes z accelerates away and vice versa. This is why derivatives are used to describe stability, because it tells you what happens when a variable changes. Remember a car is stable when we turn the steering wheel and the car understeers (the car or derivative is opposing the change) and it is unstable when we turn the steering wheel and the car swap ends (the derivative or car is propelling the change).

The last bit on our maths primer is the chain rule in several variables. If we have, say, z = fn(x,y) and x = fn(t) and y = fn(t) then we may write:

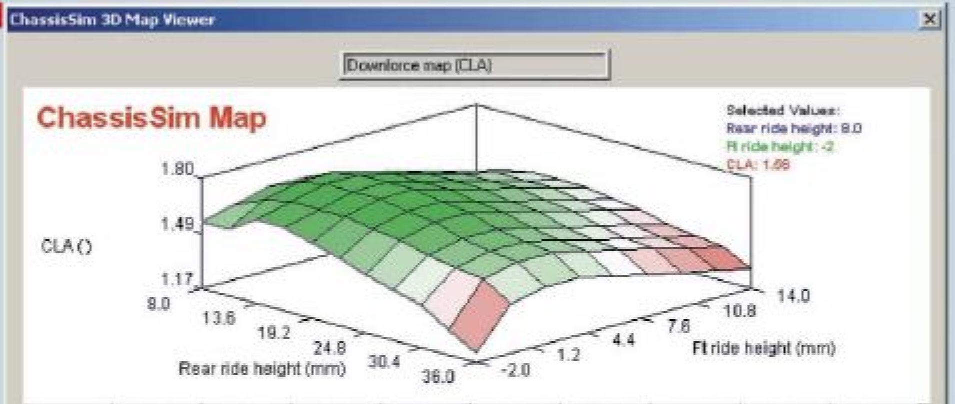
$$\frac{\partial z}{\partial t} = \frac{\partial z}{\partial x} \cdot \frac{\partial x}{\partial t} + \frac{\partial z}{\partial y} \cdot \frac{\partial y}{\partial t} \tag{3}$$

You are about to see how we can use this to devastating effect...

So let's turn our attention to the racecar itself. From my stability index evaluation article you will recall at a particular point that the racecar's yaw rate could

THE EVIDENCE

Figure 1
A graph of two variables



	-2.0	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0
8.0	1.566	1.60	1.65	1.65	1.60	1.56	1.51	1.46	1.41
10.8	1.56	1.67	1.72	1.72	1.67	1.62	1.57	1.52	1.47
13.6	1.65	1.70	1.75	1.75	1.70	1.65	1.60	1.55	1.50
16.4	1.65	1.70	1.75	1.75	1.70	1.65	1.60	1.55	1.50
19.2	1.60	1.70	1.75	1.75	1.70	1.65	1.60	1.55	1.50
22.0	1.56	1.67	1.72	1.72	1.67	1.62	1.57	1.52	1.47
24.8	1.51	1.65	1.70	1.70	1.65	1.60	1.55	1.61	1.46
27.6	1.46	1.60	1.65	1.65	1.60	1.56	1.51	1.46	1.41
30.4	1.41	1.57	1.62	1.62	1.57	1.53	1.48	1.43	1.39
33.2	1.32	1.55	1.60	1.60	1.55	1.51	1.46	1.42	1.37
36.0	1.23	1.46	1.50	1.50	1.46	1.41	1.37	1.33	1.29

Figure 2
1D slice of our two-dimensional function

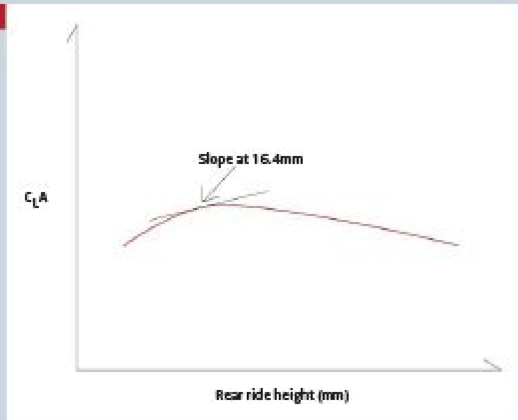


Figure 3
Plot of yaw rate vs steer angle

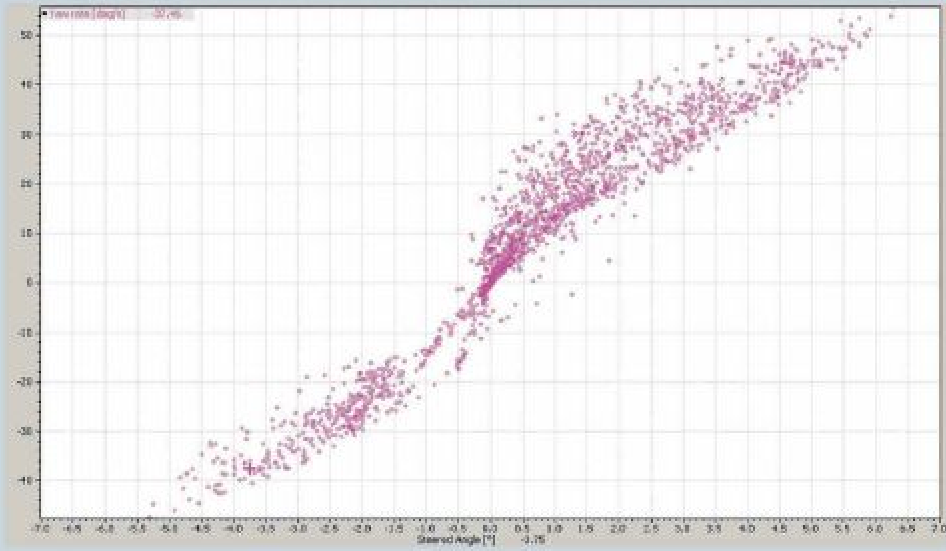
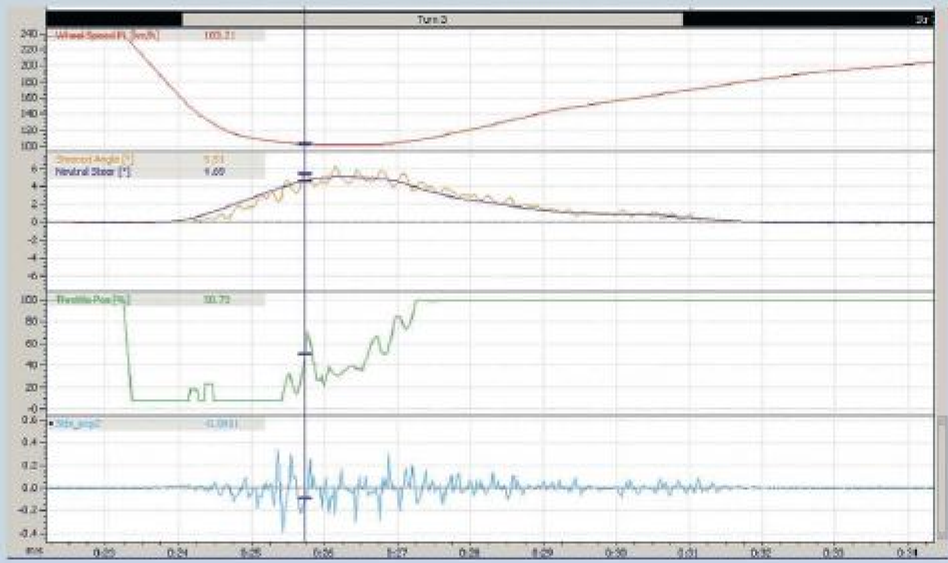


Figure 4
Plot of stability product vs time for a low-speed corner in an F3 car



be approximated by:

$$I_z r' = \left(a \cdot C_f + \frac{\partial N}{\partial \beta} \cdot \frac{C_f}{C_r}\right) \cdot \delta_s + \left(\frac{\partial N}{\partial r} + \frac{C_r' \cdot b - C_f \cdot a}{C_r \cdot V_x}\right) \cdot r + \frac{a \cdot C_f - b \cdot C_r'}{C_r} \cdot m_t \cdot a_y \quad (4)$$

Here I am going to take a leap of faith. I'm going to merge the yaw rate term into the lateral acceleration term. I realise that strictly speaking this isn't quite accurate, but bear with me because the results will sort themselves out. Also, before some of you stop reading this article, just remember a lot of discoveries in science were originated by leaps of faith.

Let's approximate yaw rate then as the following function:

$$r = fn\left(\delta_s ; a_y\right) \quad (5)$$

Using equation (3) it can be shown that,

$$\frac{\partial r}{\partial t} = \frac{\partial r}{\partial \delta_s} \cdot \frac{\partial \delta_s}{\partial t} + \frac{\partial r}{\partial a_y} \cdot \frac{\partial a_y}{\partial t} \quad (6)$$

And before we go any further recall that,

$$I_z \frac{\partial r}{\partial t} = \partial N \quad (7)$$

That is, the change in moment is the change in yaw rate multiplied by the yaw inertia. As you can see, there will be a strong correlation between this and equation (6). Manipulating equation (6) we can see,

$$\frac{\partial r}{\partial a_y} \cdot \frac{\partial a_y}{\partial t} = \frac{\partial r}{\partial t} - \frac{\partial r}{\partial \delta_s} \cdot \frac{\partial \delta_s}{\partial t} \quad (8)$$

Now recall the definition of the stability index as:

$$stbi = \frac{\partial N}{\partial a_y} \cdot \frac{1}{m_t g \cdot wb} \quad (9)$$

The astute reader will recognise straight away that equation (8) has the stability index wrapped up in it. Let me refer to equation (8) as the stability index product or stbi_prod. Obviously, strict SI units have to be observed here. That is, yaw rate and steer in radians and time in seconds.

The reader might ask the obvious question why I am using the stability product as opposed to the index? Yes, using equation (7) and (8) we can get to the stability index, but dividing by

$$\frac{\partial a_y}{\partial t}$$

turns this into a limit problem as the lateral acceleration goes to zero. Most data analysis packages will struggle with this, as numerically evaluating limits can be quite tricky, which in turn can lead to misleading results. This is not saying anything bad about these packages, but evaluating limits push this into Matlab – Maple territory. This is why we are sticking with the product, because of its ease of evaluation.

Before we go any further though, let's talk about the actual data I will be using to illustrate this concept. What I will be presenting is a ChassisSim simulation of an F3 car over a bumpy circuit. I'm illustrating this using ChassisSim for two reasons:

Firstly, ChassisSim will consistently drive the car at 100 per cent of its limits (unfortunately, we can't guarantee the same of a human driver). The reason for this will become apparent when we look at the data. Also, because it is a transient lap time simulation, it's the equivalent of looking at actually logged data.

Secondly, yaw rate is one of the variables logged by ChassisSim, so for the purposes of this illustration it makes our task quite simple.

The reason we are using an F3 car is because I want to see the effects of both high-speed and low-speed corners.

Let's now look at the stability product (stbi_prod) in further detail. Evaluating the derivative of yaw rate r, and steer angle is pretty straightforward. However, what about this below?

$$\frac{\partial r}{\partial \delta_s}$$

At first glance, you might be thinking where do we go from here? I know that's what I thought. However, remember what we talked about in our introduction when we were looking at slices of the aeromap. Well, let's do an xy plot of yaw rate vs steer. The results are presented in figure 3.

The results are quite striking. It is absolutely clear from fig 3 that a curve fit can easily be fitted to this data. What this means is that we can readily evaluate the gradient of:

$$\frac{\partial r}{\partial \delta_s}$$

The way we would implement this in the evaluation of the stability product is we would simply curve fit yaw rate vs steer angle, with all units being in rad/s and rad. We would then have a polynomial function that we can readily differentiate and this is what the

$$\frac{\partial r}{\partial \delta_s}$$

term is in the stability product. I leave the implementation of this to the reader. If you need to do it in a rush you can even do a rough eyeball linear curve fit.

Much more significant than this, however, the yaw rate vs steer curve is a very strong indicator of how effective the steering wheel is at turning the car. The gradient of this graph represents the control authority of the car. Control authority represents how sensitive yaw rate is to steering input. Consequently, you now have a very powerful tool to cross reference driver feedback. This is absolutely crucial in race engineering the car and I think is one of the best ideas I have come across in data engineering.

Let's now see the stability product in action. Consider our F3 car going through an extremely bumpy low-speed corner, as illustrated in figure 4.

To walk the reader through the traces, the top trace is speed, the second trace is steer and neutral steer, the third trace is throttle and the bottom trace is stability product.

Let's have a look at the comparison between the neutral steer and steering and the stability product. Some readers may recall my article on using the neutral steer line to evaluate racecar behaviour. Remember, when steering goes below this line we have oversteer, when it goes over the line we have understeer. Looking at the steering trace it is obvious the car is alternating between

> **“the power of the stability product is it is extremely straightforward to implement”**

understeer and oversteer. This is not surprising given ChassisSim is driving this car flat out.

However, of more significance is the relationship between the stability product and the steer line. When the steer line is above the neutral steer line the stability product is negative and when the steering trace is below the neutral steer line the stability product is greater than zero. This may seem like a trivial example but, because we know the car is being driven flat out, it gives us a great deal of confidence that the stability product is working as advertised. Again, this forms an excellent cross check against what the driver is telling you.

The power of the stability product is that it is extremely straightforward to implement. While it may not give us the elegance of the stability index, because the stability product is directly proportional to the stability index it gives us something that can be readily implemented in data analysis software. That is to say, it can be readily used at the track.

The stability product also reinforces the need to have a yaw rate sensor fitted to the car. I have stated before in a number of my previous articles that there is now too much money even in the junior formulae to simply rely on driver feedback alone. If you don't believe me, simply pick up the 'phone and ring up a Formula Ford team or above, and ask them for a quote for the season. And remember, when threatened, people always move into self-preservation mode. Consequently, a race team needs to have all the tools at its disposal to do a good job and, if necessary, *show* they are doing a good job. Put another way, what would you rather do, spend $1000 on a sensor to protect a budget of $140,000+ per year, or not have the sensor and be at the mercy of people with other agendas?

CONCLUSION

In closing then, it is apparent that the stability product and the yaw rate vs steer plots are invaluable tools for racecar stability analysis. The power of the yaw rate vs steer graph is it gives an instant picture of the control authority of the car. Also, because a curve can be fitted to the data, it makes the evaluation of the stability product that much easier. The power of the stability product is that it gives us a straightforward way of evaluating the stability index. While it may not have the elegance of the stability index, it is easily implemented in data analysis software, making it an ideal companion at the track and an invaluable tool to sort out what a racecar is really doing.

MT

Brawn GP goes lightweight

UK harness manufacturer continues to lead the field from the front

When Jenson Button crossed the finish line in this year's Turkish GP, he joined a select band of drivers – Alberto Ascari, Juan Manuel Fangio, Jim Clark, Ayrton Senna and Michael Schumacher – to have won six out of the first seven races in a Formula 1 season. He was belted in to his car with a Lightweight Silverstone Single Seater harness, one of a range of products that Willans will be exhibiting at the 2010 Autosport Engineering Show.

Willans, the world's leading brands of racing harnesses, has supplied 19 F1 champions and achieved over 250 grand prix wins. It also recently signed a technical partnership with the championship-leading Brawn GP team. Although many F1 drivers specify bespoke harnesses, the Lightweight Silverstone Single Seater is also available to buy off the shelf.

'Driver safety is paramount in F1, and the sport is continually taking steps to improve its safety record,' says Brawn GP team principal, Ross Brawn.


LAT

Jackie Stewart, F1 World Champion in 1969, used a Willans harness


LAT

Brawn GP's Jenson Button benefits from latest Willans harness in '09

At just 1.09kg the Lightweight Silverstone Single Seater is claimed to be the lightest of its specification in F1. It uses military-spec polyester rather than nylon webbing for superior stretch resistance and, while most Willans harnesses are assembled with computer-controlled sewing machines, the F1 items are still finessed on manual machines. The adjusters and release box casings are made from aircraft-grade aluminium, while the tongues and release box components are titanium.

Willans harnesses have been manufactured in the UK by Stockbridge Racing since 1967, and the company supported its first F1 World Champion in 1969 – Jackie Stewart, whose determined campaign for improved safety has saved many drivers from serious injury.

'We look forward to working closely with the Brawn GP team in our continual quest for lighter and safer driver equipment,' says Stockbridge Racing's managing director, Simon Perkins.

Talk to TT Are you thinking of exhibiting at the Autosport International Engineering show? Talk to *Racecar's* Tony Tobias. **Email:** expo@tonytobias.com, **or call direct on** 07768 244 880

SHOW TIME

AUTOSPORT INTERNATIONAL Engineering Show
14 - 15 January 2010 NEC Birmingham, UK
In association with Racecar engineering


TONY TOBIAS

Pole position starts here

Tony Tobias on why the UK is the place to stage a motorsport engineering show

The race is on. No entry, no chance to win anything. The UK is at the forefront of motorsport engineering and is therefore in pole position when it comes to kick starting the 2010 motorsport season.

The Autosport Engineering Show, which takes places at the NEC in January, is the premier showcase for leading-edge components, technologies and services – in fact, it's the perfect business forum.

The world's leading motorsport manufacturers and suppliers are located in the UK and, as a result, many overseas companies have established links and technical partnerships with the UK to help them find that 'competitive edge'.

The UK is recognised as possessing a unique blend of collective knowledge and specialist companies that help keep the world's leading racing teams at the front of the grid. Those teams visit the show to source suppliers of powertrain products, chassis, brake and suspension components, telemetry and datalogging equipment, as well as materials, services, facilities and technologies.

The UK motorsport industry has an annual turnover of £6 billion, of which £3.5 billion is exported. It is therefore the perfect location for a motorsport trade exhibition.

German steel supplier Tennant Metall, for example, found the show the perfect place to meet international customers from as far away as Australia, Thailand, South Africa and Japan. Barry Tennant now regards the show as his main platform to exhibit and feel the pulse of the industry.

> "the premier showcase for leading-edge components, technologies and services"

A total of 25,000 international buyers will visit the 2010 show to meet over 400 exhibitors from the world's leading suppliers. Simply put, if you're involved in the motorsport industry, you cannot afford not to be at the NEC Birmingham in January.

DAVID BARTRUM

THE INTERVIEW


LAT

Q How did you come to decide on BMWs for the BTCC last year?
Well, 2007 was a very tough year in Touring Cars for us because, to be honest, the SEAT Toledo we had was not a very good car and we had an awful lot of bad luck with damage. We got to the end of '07 and we thought that the SEATs hadn't really done us justice so I decided that I wanted to buy the best Touring Car machinery I could get hold of for '08. So I got in touch with Charly Lamm [manager of Schnitzer] at the WTCC round at Brands Hatch and started to get the ball rolling getting the BMWs from Schnitzer.

That was important. I wanted Schnitzer, I didn't want any other BMWs. I wanted Schnitzer's cars because I've had experience of Charly from before. If you buy Charly's cars you don't just get BMWs, you get Schnitzer on the other end of the 'phone, and that's become quite important for us.

Also, one of the joys of running the BMW is you get a massive infrastructure of teams around the world, and you've got the works teams testing parts constantly, so they go and hammer out thousands of kms testing, and then they say: 'This is a good part, it's for sale, do you want it?' So it saves us a lot of development time.

David Bartrum, team principal Motorbase BTCC team

- 1988–98: driver in various club and national saloon series
- 2001–2002: driver in some TVR Tuscan races
- 2003: brief period running privateer BMW in BTCC
- 2004: runs cars in Porsche Carrera Cup UK
- 2005: British GT/ SEAT Cupras/Carrera Cup
- 2006: Carrera Cup/ BTCC with Honda Integra/British GT
- 2007: Carrera Cup and BTCC in SEATs
- 2008: BTCC with BMWs
- 2009: BTCC with BMWs and Carrera Cup

Q What team changes have you made for your second year running the BMW?
For this year I wanted to add a few people to the team. We have got a very good team here, with good morale. In the workshop full time we have only got nine, but when we get to the race weekend, with the catering, the grid girls and everything else, we grow to a team of 28 across the two teams [BTCC and Carrera Cup].

I wanted to shore up the engineering side though, so I brought Richard Townsend in, who was one of the guys from Team Dynamics. He is a crucial part of the team. The other person I brought in this year is a guy called Toby Phillips, who is good with dampers.

Q How important are the dampers on a Touring Car?
Absolutely crucial. Most of the development work this year has been on the dampers. One of the things I did mid-season last year was to 'phone Charly Lamm and say, "Charly, we're struggling." And he said, "where do you think you're struggling most?" I replied, "Dampers. I need to understand the dampers." He then asked what I was doing the following weekend and when I replied nothing he told me, get the dampers, put them in a suitcase, and to come out to Schnitzer with one of our engineers. We then spent a whole day on their dyno just going up and down through the damper settings and we came away with a mass of valuable information.

Q Do you enjoy competing in the British Touring Car Championship?
I love the BTCC. The format's fantastic and it's run very well by Alan Gow. I love the cut and thrust of the competition, but sometimes I do despair of the physical side of it – because you do get a bit of unnecessary pushing and shoving.

RACE MOVES


Tony Eury Jr
LAT

Dale Earnhardt Jnr has split with crew chief **Tony Eury Jr**, who has now taken up a position in Hendrick Motorsport's research and development programme.

Meanwhile, **Lance McGrew** has replaced Eury as crew chief on the Earnhardt Hendrick-run NASCAR Sprint Cup Chevrolet.

It has been reported that Toro Rosso technical director **Giorgio Ascanelli** has turned down an approach from Ferrari. It is believed that the slightly more famous of Formula 1's 'Scuderias' wanted Ascanelli to fill a senior role at the team.


Giorgio Ascanelli
LAT

Former Honda F1 technician **Kevin Poole** is to run the Golf turbo diesel he built in 2002 in the UK's Volkswagen Racing Cup this year. The car in question made history when it became the first diesel -engined car to win a motor race in Britain seven years ago.

Vivian Candy, one of the legends of Irish motorsport, has died at the age of 60. The 'Candy Man', as he was known, was probably best known for using his connections with Marlboro to help fund Eddie Jordan's early career. He also raced himself, competing in British F1 and then twice at Le Mans.


Mark Deans
LAT

Mark Deans, Ford's director of motorsport, has retired. He has been replaced by Irishman **Gerard Quinn**, who has had previous experience working with Ford's rally team M-Sport.


Gerard Quinn
LAT

It seems likely that **David Lapworth will** head up the all-new Prodrive F1 team, should the team make the grid in 2010 *(see News, page 4)*. Lapworth formerly ran the company's Subaru WRC effort from 2000 to 2006.

Former Super Aguri technical director **Mark Preston** has been mentioned in

RACE MOVES


Mark Preston LAT

connection with a possible all-new Brabham-titled Formula 1 project involving Formtech – the German composite company that bought the remnants of the Super Aguri team last year and operates from its old Leafield HQ.

As tributes go, none can be more fitting than the win the late **Joe Tandy's** brother **Nick** took at Rockingham's British F3 meeting, just two and a bit weeks after JTR boss Joe died in a road accident. It was the first win in F3 for the JTR squad.


Tony George LAT

The Indianapolis Motor Speedway has denied reports that **Tony George** is no longer its CEO. That said, it has also confirmed that George is expected to spend less time working on track business and will concentrate more on the Indy Car Series in the future.

GP2 engineer **Stuart Robinson** has been showing well on the other side of the pit wall, finishing a fine second in a recent Scottish Formula Ford 1600 race at Knockhill.

Brawn GP is to keep **Will Stevens** on the driver development programme he started when the team was still known as Honda. Stevens is currently competing in Formula Renault UK.


Red Horse Racing LAT

In continued NASCAR cut backs, Richard Petty Motorsports released nine employees and cut wages during the second week of June and Red Horse Racing closed their number 1 NASCAR Truck Series team leaving defending series champion Johnny Benson looking for work.

Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect? Then send an email with all the relevant information to Mike Breslin at bresmedia@hotmail.com

DAVID BARTRUM
THE INTERVIEW

CONTINUED

Q How do you think the withdrawal of Vauxhall will affect the BTCC?
Any manufacturer going is disappointing. But when you really look at it, it's actually a good thing, because it levels the playing field. We're not on the same playing field they are, they've got a £3m budget, I believe. I think the cars will still be around though, and I'm hoping 888 [the team that runs the Vauxhalls] will too, because Vauxhall going is one thing, 888 going is quite another.

Q The BTCC has recently announced a new set of regulations (see News this month). What's your opinion on them?
What they're doing, and the reason they're doing it, is very good. They're looking at the future of Touring Cars and they're looking at the cost of Touring Cars. Unfortunately, I wasn't on the working group and I don't feel that rear-wheel drive was particularly well represented, because at the minute it looks like they're trying to get rid of it, and I'm not personally happy about that... Otherwise though, if you look at what they're proposing, then a lot of it is very good from both an engineering and a cost perspective.

Q What's your idea of the perfect racecar?
Well, it needs to be rear-wheel drive for a start! For me, personally, watching an RS500 [Ford Sierra Cosworth] in the late 1980s go through Paddock at Brands, with the noise it was making and with the flames coming out of the side – now that was a racecar...

AWARDS AND INTERNSHIPS

Wrenchman award

TOOL MANUFACTURER CRAFTSMAN is to sponsor a new end-of-season award to recognise an outstanding team member from each of NASCAR's three major championships. The NASCAR Craftsman Wrenchman Award, which is said to be worth up to $170,000 (£100,000) in cash and tools, is open to all team members and winners will be those deemed to have best showcased 'core Craftsman attributes of trust, quality, knowledge and innovation when performing their job with the race team.' Teams are being invited to nominate one team member and a selection committee will pick the finalists.

'The NASCAR Craftsman Wrenchman Award will celebrate and reward the everyday heroes of NASCAR who exemplify the attributes of the Craftsman brand, both in the garage and at home,' said Matt McDonnell, manager of brand development Craftsman, of the new award. 'It's also the perfect opportunity to establish a personal connection for the fans with important crew members who typically don't get to step into the spotlight.' Nominations will be invited this summer, with selections in August and the winners announced at Ford Championship Weekend at Homestead-Miami Speedway.

NASCAR Diversity Internship

THIRTEEN STUDENTS FROM across the United States have been selected to take part in the 2009 NASCAR Diversity Internship Programme – a scheme that gives college students from ethnic minorities the chance to complete a 10-week paid internship within the NASCAR industry.

Land of opportunity

Racecar's Lawrence Butcher speaks with some of the delegates who took the opportunity to get to the heart of the US racing industry on the MIA trade mission

June 2009 saw the 9th annual MIA business development trip to the USA, the aim of which, as ever, was to develop business relationships between UK-based companies and the US racing market. Starting off in Charlotte, North Carolina, delegates visited a number of top NASCAR Sprint Cup teams, including Michael Waltrip Racing, Penske and Richard Childress Racing. These visits were key in developing an understanding of both the engineering and business approaches in top-level Stock Car racing and, more importantly, how practices differ from team to team.

The US approach to racing was definitely an eye-opener for those more used to the European way of doing things, especially the scale of operations and the openness displayed by teams. The combination of these visits and an audience with Mike Fisher from NASCAR R&D brought home to people that while Stock Car racing is an area that needs real on-the-ground knowledge to successfully sell into, it is by no means a closed shop for international business.

INCREASE SALES

The message from NASCAR was clear: if your product can improve safety or reduce costs while not unfairly advantaging one team or another, we are open to discussion. Sandra Cunliffe from UK-based motorsport electronics specialist, DC Electronics, said, 'We decided to take part in the MIA trade mission to the USA as we are trying to increase our sales within North America. During this trip, the MIA provided us with the opportunity to hold face-to-face meetings with key people in the industry – people who otherwise would be very hard to contact directly. We certainly came away with a better understanding of the US market, as well as potential leads for future sales. Personally, I don't think that anybody should attempt to break into the US motorsport market without taking part in this type of trip.'

European visitors had their eyes opened to the sheer scale of operations at the heart of US motor racing. This is the Michael Waltrip Racing preparation area

VIP access passes gave delegates a chance to experience the thrill of the NASCAR spectacle from the pit lane at Lowes Motor Speedway

> "if you have a good product, then the US is definitely open for business"

UNPRECEDENTED RESPONSE

The teams' approach was equally encouraging, especially at MWR, where the attitude was, if we can gain performance from it and NASCAR will approve it, then there are grounds to do business. One company that gained unprecedented response to its product was next generation simulation company, Real Time Race. Its video-based simulation software generated interest from areas as varied as test rig companies and NASCAR's media operation. CEO Chris Leigh was more than happy with the results: 'The trade mission introduced our company to a plethora of the very best motorsport contacts in the North American market. It was hard work trying to keep up with the enquiries and contacts generated during the trip.'

Delegates were also able to get a real feel for why NASCAR is such a successful business at the All Stars Race at Lowes Motor Speedway, with VIP pit access giving a taste of the intense race atmosphere. Overall, the trip provided an invaluable insight into the trade opportunities available and underlined the fact that, if you have a good product, the US is definitely open for business.

Photos: Lawrence Butcher

Face-to-face meetings with US motorsport personnel were one of the key elements of the MIA trip

ROGER ESTRADA
THE INTERVIEW


LAT

Q What is your motorsport background??
I went straight to SEAT Sport from university and for three years was a designer on the WRC project. I wanted to go further, so said to myself "where is the best place in the world for motorsport" and decided on England. I left the sunshine and came here to work as a junior engineer for Mitsubishi Ralliart during the era of Tommi Makkinen. I worked up through being a rally engineer, test and development engineer and chief rally engineer, until I was the chief engineer.

Q What made you decide to start your own business?
When Mitsubishi hit problems, we tried to find someone else to carry on the programme but, in the end, decided to close. So I had to leave and decided to start my own company. At the same time I decided to do an MBA. I am an engineer but thought I was missing some business approaches to motor racing, so thought I would gain some new skills so signed up at the London Business School.

Q Did gaining an understanding of business change the way you operated as an engineer?
No question. The experience made me look at my engineering services in a totally different way. It made me have a wider vision in not just looking at the tiny detail but also looking at the broader picture. Looking at a product and thinking, "What is this going to give us value wise, the cost, does it add value to the product and for the customer?"

Q What areas of motorsport business do you specialise in?
I have the capabilities to do everything from design through to race support, and also to distribute products with an added value to the customer, such as dampers and paddle shift systems. On top of that, I do business development with products that come from outside motorsport. For example, we have recently introduced a new composite material from a military supplier. My key role is finding out what the market is for a product, how it needs to be promoted, what pricing structure to use and whether value can be added to the product. This is a vital service to offer, especially in the current climate, as it can it help customers reduce their costs.

Roger Estrada, director R53 Engineering Ltd
- 1997: graduated University of Barcelona, degree in Mechanical Engineering
- 1997–2000: design engineer for the SEAT Cordoba WRC
- 2000–2002: assistant to the chief engineer
- 2002–2004: development test engineer for the WRC Step 2 car
- 2004–2005: race engineer for Gilles Panizzi ('04) and Harri Rovanpera ('05)
- 2005–2007: chief engineer Mitsubishi Motorsports (WRC)
- 2007-present: director R53 Engineering Ltd

Q Do you think that engineering companies can miss out on optimising their profitability through not thoroughly understanding the marketplace?
I believe that a lot of companies have great engineering capabilities but can quite often miss the business side of a solution. They need to take a step back and look at who the product is actually for, and if it matches the clients' needs beyond simply the performance requirements. They need to focus more on the customer, and ask, "Who is the customer?" Then look at their products from a business perspective.

GOING OFFLINE


LAWRENCE BUTCHER

Conversion factors

Grasping NASCAR's appeal

I used to sneer at NASCAR when Deputy Editor Sam touted its merits, reeling out the usual ripostes like 'they only turn left' and 'I've seen more complex horse and carts'. But you will hear no more nay saying on my part - having been privileged to attend the All Stars race at Lowes and toured several race shops in the Charlotte area, I am converted!

It was the sheer spectacle of the show that blew me away. These guys really care about the fans, a somewhat alien concept to someone raised on European circuit racing, and does it make a difference. Whereas in Formula One it can seem like the sport's followers are an inconvenient necessity, they truly are seen as the life-blood of stockcar racing.

> **"it was the sheer spectacle that blew me away"**

Only once I had realised this did NASCAR's apparently medieval approach to regulation start to make sense. It always has, and will be, about the show, so while it may be nice to have the very cutting edge of technology on a car, if it doesn't improve the show in NASCAR, it is irrelevant.

Now don't think for one minute this means that Cup teams don't know how to use technology; they do.. But there is a catch - by ruling with an iron fist NASCAR can simply say a car is illegal if they feel it has too much of an advantage, regardless of whether it actually infringes any rules. Now while I am sure the FIA would love to be able to do this, they can't! Can you imagine the uproar if the Brawn BGP001 was declared illegal just because it was too quick?

So while stockcar racing is never likely to push the limits of technology in the way sports prototype or single seater racing does, it is definitely not bereft of innovation. More importantly, the TV ratings and crowds tell the real story. NASCAR's way works and European motorsport would do well to take notice.

Racecar engineering

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LATE APEX

Drilling for gold

Special thanks this month go to Charlie Bamber of Menard Competition Technologies, without whose assistance we could not have prepared such an in-depth story on the subject of 'regulation-busting'.

The five-cylinder BTCC Volvo engine of the 1990s is also a perfect example of how motorsport provides an ongoing battleground for teams' technical personnel to pit their wits against those whose job it is to frame the regulations. The aim, as Charlie explains it, is to 'drill deep into the regulations' in an effort to discover all possible avenues to maximise the performance potential of your car – while ensuring it remains legal, of course.

> " the bottom line is that regulators learned from Super Touring "

The full story on the development of the Volvo cylinder head begins on page 54 of this issue of *Racecar Engineering*, but in order to get a balanced view, we thought it would be interesting to hear the views of someone responsible for formulating motorsport regulations. Who better than a veteran of the scrutineering bays and technical boss of the BTCC, Peter Riches?

'In Super Touring, there was one extra word in the cylinder head regulations, which allowed the addition of material, whereas normally Group A, and now S2000 rules, only permit the removal of material,' he explains. 'This led to the Volvo and Ford [Mondeo] solutions, which were the most radical and expensive at the time, but it was an era when cost appeared not to matter. Some teams, for example, developed separate port castings that were inserted into a head after the original port area was machined out.

'In the same vein, Vauxhall developed its turned or "reverse" head, which was also allowed by the FIA at the beginning of the Super Touring era when the clause "if it doesn't say you can, you can't" was not around. Nor was the phrase that "freedom in one area of the regulations does not permit additional functions to be created".'

Interestingly, as Peter points out using extracts from the current S2000 technical regulations, many of the interpretations permitted by the Super Touring rules are now prohibited. In fact, the S2000 regulation drafters have tried to cover themselves against possible unperceived loopholes with the inclusion of a 'catch-all' sentence, which reads: 'Even if not explicitly prohibited, any modification that is not in keeping with the spirit of the regulations and/or that may increase the price of the car shall be banned without notice by the FIA.'

After many years on the front line of devising, enforcing and advising on motorsport regulations, Peter understandably has some well considered views on the subject. 'Regulations need to be clear and simple without room for different interpretations,' he observes. 'The simple word "addition" in the Super Touring rules led to massive changes [to the engines] and, to use a well-known phrase, "massive unintentional consequences".

'One of the issues surrounding regulations is also the firmness of the interpretation. If it is lax, then the regulations receive a far wider interpretation then was the original intention. You therefore need a strong scrutineer.

'The bottom line, though – regulators learned from Super Touring.'

So there you have it – from a man who knows.

EDITOR
Graham Jones