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LE MANS 2013

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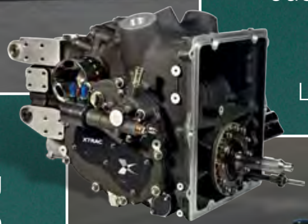

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CONTENTS

4 NEWS

8 WHO IS READY FOR 2014?

10 LE MANS CAR BY CAR

16 TEST DAY REPORT

21 HOW TO BLOW AN LMP1 DIFFUSER

28 AUDI'S DEVELOPMENT OF A V6 ENGINE

38 AUDI'S R18 IN PROFILE

44 TOYOTA TS030 - NEW FOR 2013

48 LOTUS T128 BUILT FOR THE FUTURE

52 FERRARI 458

55 ASTON MARTIN V8 VANTAGE

57 BEHIND THE SCENES WITH GREAVES

61 RADIO LE MANS - YEAR-ROUND SERVICE

62 RICARD DIVILA'S STRAIGHT TALK

The indecision surrounding the future of the GTE regulations has cost the category potential entrants, and with new regulations to be implemented in 2016, the arguments are still rampant, and a decision appears to be a long way off yet.

The GTE category already boasts Ferrari, Porsche, Aston Martin, Corvette and Chrysler's Viper. In the print edition of the magazine, you will find pictures of Toyota's still-borne GTE car, the Lexus LFA, that raced at the Nurburgring under the Gazoo racing banner. Toyota planned to run the car at Le Mans in 2012, but stepped up its LMP1 project from a test programme to a race programme after Peugeot withdrew in January 2012, leaving the GTE as a step too far.

Is change being demanded when evidence suggests that it is not actually needed?

McLaren had a GTE car that was built and ready to race, but they considered that they would get a single year of use out of it before the regulations changed, and so pulled the plug on the programme.

Honda has an NSX built in America, another potential welcome addition to the fold, but not one that is about to make it to Le Mans in a hurry, especially while the discussions are on-going.

Some want to have GT3 engines in a GTE chassis, others say that the GT3 cars should be morphed into GTE, creating an equalisation formula that will allow very different concepts to race together. As one engineer said in 2012, 'if we could agree on a starting point for the discussion, we would be doing well.'

All of this assumes, in the very first instance, that anything needs to change at all. What would happen if the GTE cars were allowed to continue as they are, as would GT3, while if there was an appetite for hybrid GTE cars, a separate category could be formed?

New cars are coming all the time. Ferrari switched to the 458, Porsche the 991, while Corvette is developing the C7R. With McLaren, Honda and Toyota, this would make six new cars.

Is there a need to tap into the GT3 manufacturer base at all? Sure, there are so many cars to choose from that the variety on the grid would be impressive if they all committed. But who would want to, and who is needed? How many more manufacturers do you need to make a successful category? More than eight appears to be greedy to me.

The running costs of the GTE category are more per kilometre, roughly double those of a GT3 car. The engine rebuilds occur roughly twice as often per season as the GT3. And yes, as the WEC was launched, the GTE category was so under supported that Corvette paid the entry fee to the FIA, despite having only a GTE-Am programme through Larbre Competition. Now, under stable regulations, the category is flourishing.

Is GTE sustainable? The governing bodies say 'no', that the costs are too high and need to be brought under control. Yet the evidence is there that manufacturers are interested, and are prepared to spend money on a GTE programme. That, and there is a market for year-old cars, in a burgeoning GTE-Am class.

If there is a need to change, and let's face it, nothing stays the same forever, then the convergence committee has to start making decisions. I wonder, though, if change is being demanded when evidence suggests that it is not actually needed.

Porsche unveils LMP1

Porsche released the first images of its LMP1 contender just after the Le Mans test weekend, becoming the first of the manufacturers that will contest next year's World Endurance Championship to break cover.

Audi and Toyota have tests planned in the coming months, but Porsche has had to take a big risk with regard to the regulations in terms of being ready first, before the regulations have been defined. The LMP1 car completed its first laps several weeks earlier than planned. 'We are well on schedule,' said Fritz Entzinger, Head of the LMP1 programme. 'Our newly-formed team has worked with utmost concentration on getting this highly complex vehicle on the track as soon as possible. This allows us a few additional weeks for more testing and further development. From 2014, the regulations are primarily based on efficiency. This makes the competition amongst engineers more interesting and presents us with completely new challenges.'

Porsche returns this year with a factory team for the first time since 1998, when Laurent Aiello, Allan McNish and Stephane Ortelli won overall. Read all about the manufacturer's 2013 GTE contender in this month's edition of Racecar Engineering.

Caterham targets customer teams

British team Caterham says that it wants to build cars for customers following its toe-in-the-water attempt at Le Mans with Greaves Motorsport this weekend. The team has embedded engineers with Greaves, which runs a Nissan-powered Zytek.

Caterham's personnel is led by Caterham Group CTO, Mike Gascoyne, who said that participation in Le Mans 2013 was the perfect opportunity for the Group to see first-hand how they could apply its existing expertise and facilities to a Sports Prototype programme.

'Within the Caterham Group we have a great deal of experienced personnel with a wide range of technical expertise – from powertrain development to carbon composite design,' he said. 'We have the tools, the talent and the heritage to do the job in a marketplace that is currently light on existing players so it makes sense for us to go and see first-hand how we might take advantage of business opportunity that fits with our capabilities.'

Between Caterham Technology and Caterham Composites, Caterham Group's experienced personnel are specialists in a variety of areas that would lend themselves to developing a Sports Prototype programme.

The Group's core personnel include members of staff who have delivered previous LMP programmes and are also working on a current Sports Prototype project for an external customer. With the ACO's cost control model for the LMP vehicle market, a Sports Prototype programme would also fit within Caterham's modus operandi of affordable, quick-to-market solutions.

Audi 'no' to North America 2014

Audi has announced that it will delay its North American involvement for 2014 due to the sheer volume of work currently underway at Audi Sport. The team ran at the Sebring 12 hours in March this year with its 2012 and 2013 cars, and Audi's head of motorsport, Dr Wolfgang Ullrich, stated that he wanted to find a way to return in 2014. However, with the United Sports Car Racing series having LMP2 as its top category next year, Ullrich was also quoted as saying that he wanted to develop a Daytona Prototype.

'It's difficult to say when we will know what we do in North America next year,' said Ullrich. 'The hold up is that we are too busy, we have too much other work to do. If it is going to be an additional programme there is only a small chance that we can do it next year anyway. So it's more likely to be delayed a bit, that's not a problem. But for sure we will push and perhaps improve the activities with the customer racing programme, the R8s, and we are discussing how we can do that now.'

It could be that Audi is waiting to see how the proposed DTM America championship develops. If it takes off in 2015 then it is likely that the German marque would not feel the need to run in USCR beyond its customer programme.

Rebellion commits to LMP1

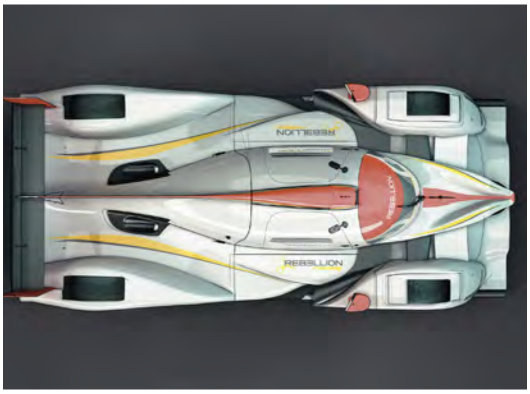
Private team links with ORECA to build an LMP1 to new regulations and believes that it has the opportunity to take on the factory programmes in 2014

BY ANDREW COTTON

British team Rebellion Racing was the first to announce that it will contest the LMP1 category at Le Mans in 2014, with a new coupe built by French company ORECA and powered by a development of the Toyota RV8KLM engine currently featured in the team's Lola. The agreement is for three cars, two to race and one as a spare, although Rebellion says that it will consider selling customer cars should there be demand for them.

Without a hybrid system, the car will weigh 830kg and will generate a limited 148MJ per lap of energy through its internal combustion engine. Maximum petrol flow will be 93.5kg/h, but its fuel tank will be 64.4 litres, enabling it to do around 40 minutes on a tank of fuel.

This, says the team, will enable it to run just behind the factory teams, and allow them to pick up positions should their hybrid systems, or racing, cause problems. 'They will compete with a new car, a new hybrid system, while we will compete with a simple car,' said team manager Bart Hayden. 'We have to be efficient with the aero package but with our experience we will do a reliable car, and a quick car. The hybrid systems are very complicated.'



The design of the R-One will be led by ORECA's head of design, Christophe Guibar, who was responsible for designing the ORECA-01. The R-One is not expected to hit the track until March of 2014, meaning that it will be around ten months behind the development of the Porsche LMP1 that was testing in the week before the test session at Le Mans.

ORECA began designing the car in 2011, but it wasn't until an agreement was reached with Rebellion in March that the process took a meaningful step forward.

'There will be teething problems, but it is our job to find them,' said Hayden at the launch of the programme, at the Le Mans test day in June. 'By starting early, has Porsche got it right? The regulations have not been fixed yet. We can be super fast and super reliable, but the development of a hybrid may not be the right way. If you say that you are never going to win, then you are going to fail.

'The new regulations for 2014 provide a great opportunity for privateer LMP1 teams to challenge for overall race wins. We are motivated by the prospect of those victories and having truly established ourselves in the LMP1 category over the past seasons, we want to build upon our successes. We are delighted to be able to commit our future to the LMP1 category at such an early stage. We have chosen ORECA to develop and build the Rebellion R-One because they have a strong record of success, they have produced many successful prototype cars and they share our passion for endurance racing.'

There is no decision on the suppliers for the programme, although following the demise of Lola as a supplier to customer teams, Rebellion has forged a close relationship with the Canadian Multimatic company, which designed the new aerodynamics for the car this year, and produced new dampers to improve the handling. ORECA also has a list of preferred suppliers, and these details have yet to be finalised.


REBELLION
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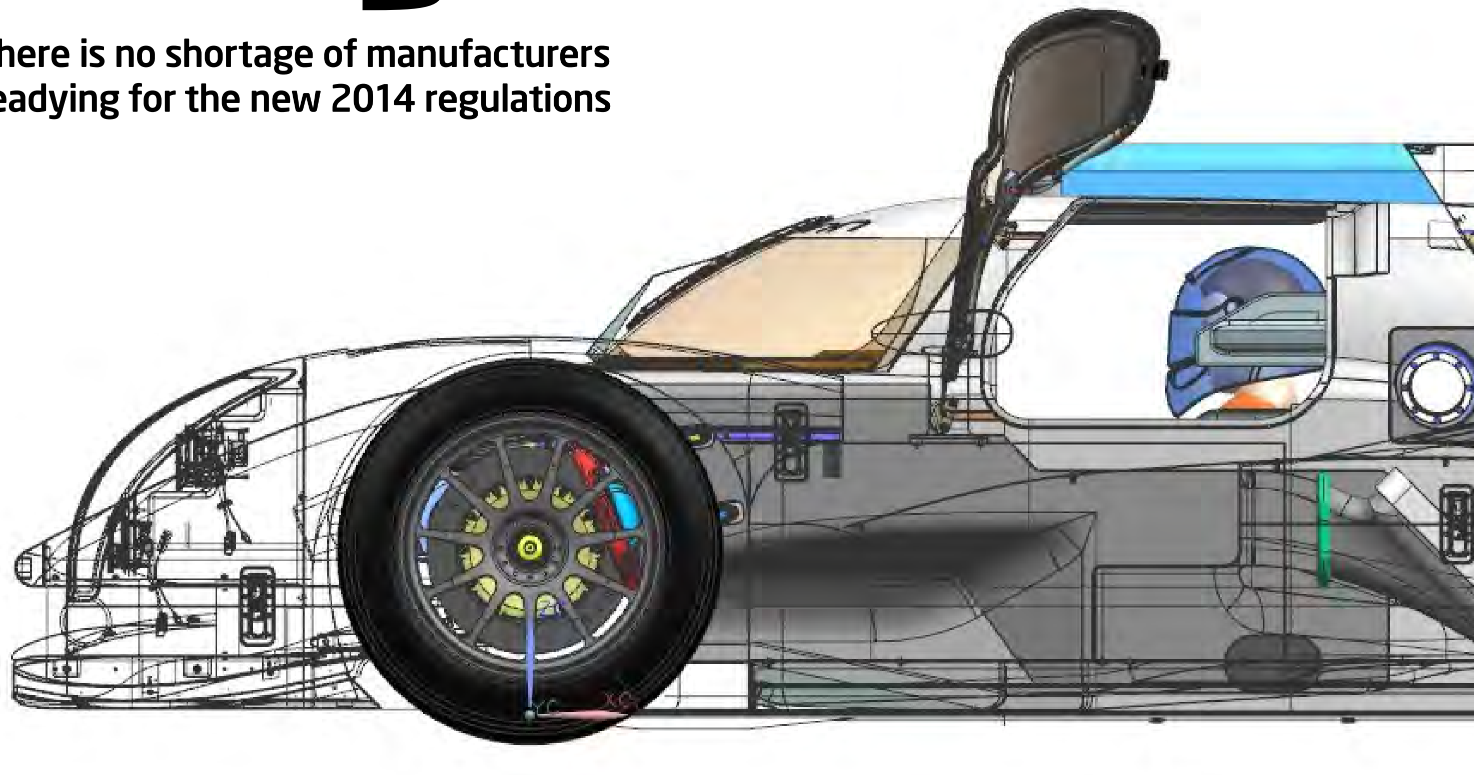
Talking 'bout the new generation

There is no shortage of manufacturers readying for the new 2014 regulations



Private team Rebellion racing's announcement at the Le Mans test day that it will partner ORECA to build and supply LMP1 cars in 2014 sparked a wealth of interest from private teams and constructors eager to contest next year's Le Mans 24 hours against Toyota, Audi and Porsche.

British-based designer Nicolas Perrin, who designed an open top prototype around a tub of the Aston Martin AMR-One in 2012, has a closed coupe design ready to build. The car will cost £1million and can run with a Williams flywheel system should a customer elect to run in one of the hybrid categories.

Dome also has a car that is in the wind tunnel, and ready to be built if a customer can be found. Like Perrin's design, the company could run as a factory, but would prefer a manufacturer link up. Adess, the German company that built the Lotus chassis, is clearly ready, while there are also rumours that CN car manufacturer Wolf also has a car in design, although this could be for Grand Am.

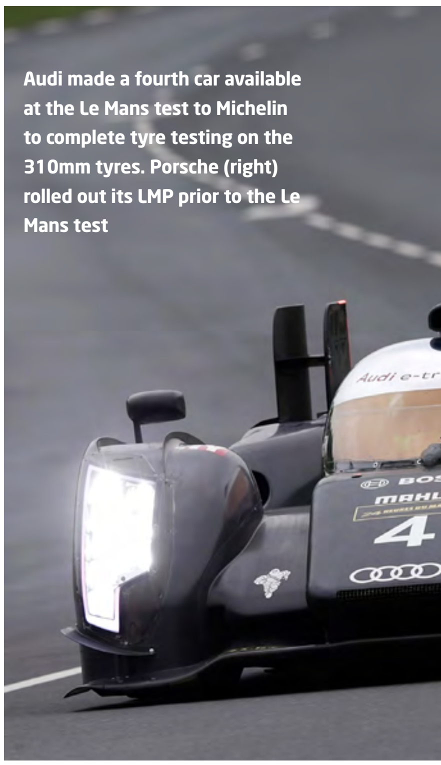
ORECA's chassis, due to run on track for the first time in March, 2014, with an evolution Toyota powertrain to that currently run in the Rebellion Lola, could also be made available for sale, while Nick Wirth has a coupe designed, and is understood to be working with HPD in the US.

Oak Racing has its design on the drawing board and says that it is the only manufacturer to be in a position to get a car ready before the end of the year.

'I think it will be the only car ready for the start of the season,' says Oak Racing's Olivier Quesnel. 'I don't think Dome will be ready for 2014, and I don't believe in the Lotus project.'

Both Dome and Lotus fully expect to be ready for 2014 and dispute this sentiment. 'The new car is under development at Raug Aerospace in Switzerland we ran a shakedown before the end of the year before proper testing starts in the new year,' continued Quesnel. 'So it will be ready for the start of the season. It will accept all engines and of course it is a closed car as it is for LMP1 and LMP2. The target is really LMP1. The first monocoque will be finished by HP Composites by mid July.'

Understandably, Oak says that it can compete against the factory teams. 'We hope we can win races against the works teams but you know I was in charge of Peugeot, so I know how much goes into the official team cars. I think the car will be



Audi made a fourth car available at the Le Mans test to Michelin to complete tyre testing on the 310mm tyres. Porsche (right) rolled out its LMP prior to the Le Mans test

competitive but what we need is a good engine. If we find one with a good hybrid system then we should be strong. HPD, AER and maybe some other will have suitable power trains.'

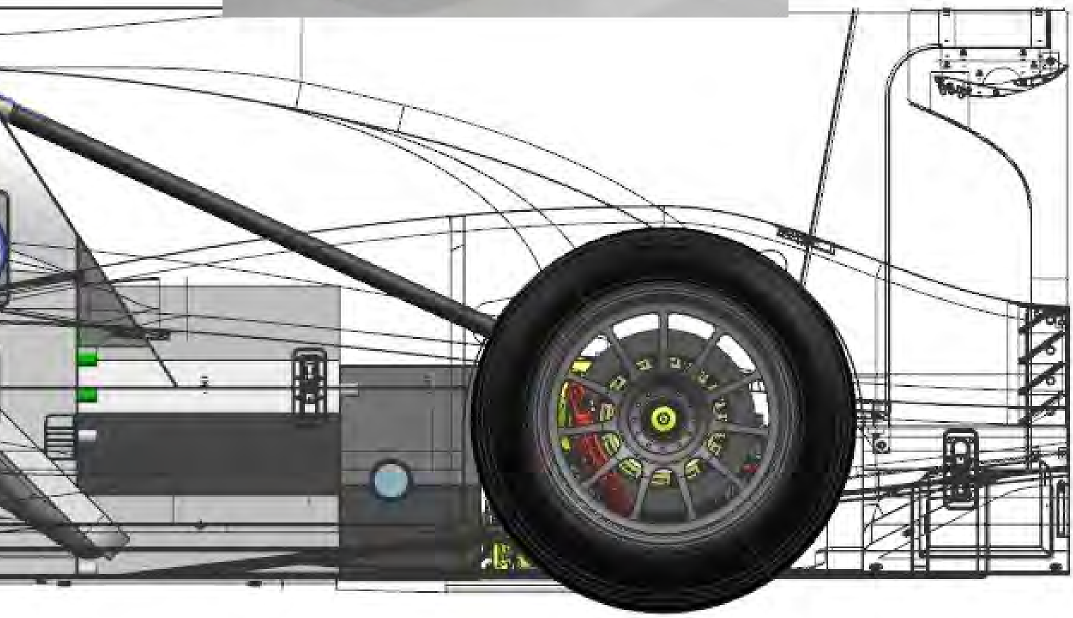
SUPPLIERS

John Judd is designing a 4.4 litre V8 engine that the company believes can compete in the non-hybrid category of the regulations. 'The engine will be based on our current V8 platform, and will be Direct Injection,' said company founder John Judd. 'We had it on the dyno today, and we have optimised it for lean burn and efficiency. I think that the factories will do their analysis and if they do their homework, they will be quicker, but there is an opportunity for the private teams to get results next year. It's a big learning curve for the hybrids, which are complex cars, and the manufacturers can expect trouble.'

AER is another to have an engine development programme for 2014, and is believed to be talking to Oak Racing, while Zytek are actively working on a hybrid and engine for 2014.

Michelin is already working on the 2014 Le Mans tyre, and ran it at the Le Mans test day in the number 4 Audi, working with Marco Bonanomi who set fifth fastest time overall with a 3m27.894s. Bonanomi was clocked at 325.8mph, fourth fastest car of the day at the test session, the narrow 14-inch tyres creating less resistance, making the cars faster in a straight line.

Audi created a car that was available with measuring capability exclusively for tyre testing. The engineers are already in the process of simulating the aerodynamic effects and the axle loads to be expected on LMP1 cars in 2014.



Nicolas Perrin says that his car will be ready four months after the button is pressed. Dome (top) is already well advanced with its wind tunnel programme

Runners and riders at Le Mans 2013

The origin and development of this year's contenders

Audi R18 E-Tron quattro

Since the first race of the year at Sebring, it has been apparent that the R18 has undergone an incredible transformation. The car this year runs with a diffuser that uses the exhaust gasses to reduce drag and increase top speed, at the expense of fuel economy. At the opening round of the World Endurance Championship, the car used 21 per cent more fuel than the previous year, to go 1.5 per cent further. The exhaust is a hot side inside layout with the exhaust running through the v-angle of the engine, through a single turbo. Downstream, it has switched to a twin exhaust layout to blow hot air over the diffuser. At the Le Mans test session on June 9, Marco Bonanomi drove a fourth Audi R18, running on Michelin development tyres for the 2014 season.

HPD ARX-03

The changes to the HPD are largely Michelin-based, as the French manufacturer looked to phase out its smaller tyre, and put everyone onto the larger version. That meant a change to the front aero, and from the front axle, everything is new, including the bodywork, splitter and suspension geometry. The team got the new front tyres working at Spa in May, opening up the louvres over the front wheels, which delivered better downforce. The HPD does not have the flared rear wheel arches featured on the other LMP1 cars, preferring to run an updated version of the Le Mans package run last year.

Toyota TS030

The 2013 Toyota may share its model designation with the 2012 version of the car, but there have been some significant changes. A new tub sees a more central seating position for the driver, and the provision for a front-mounted hybrid system has been removed, leading to improved aerodynamics at the front. The splitter has changed, making the car less sensitive to operating temperatures, although after the opening two races a change to the suspension made the car more comfortable under braking. New Michelin tyres, common to both Toyota and Audi, mean that lap times in cold temperatures - particularly at night - should be significantly lower than last year. Toyota has reduced its reliance on Formula 1 philosophies, and improved the serviceability of the car. With one eye on the future, the Toyota is running 2014 parts in its hybrid system. A broken connector caused the Hybrid system to fail at Spa, leading to an increase in reliance on the brakes, which subsequently overheated and caused the car to retire.

Lola B08/60

Rebellion Racing continues to run the B08/60 at Le Mans, but has introduced a significant upgrade kit to the car thanks to its partnership with Multimatic. An upgrade in tyre technology at Spa was a significant boost to performance, but at Silverstone the team introduced the revised wheel arch extensions that increased aerodynamic efficiency, and at Spa introduced new Multimatic dampers. The result of the aero package was that the car could use its front tyres more effectively, and had better handling. The team hopes that, with the increased weight and slower refuelling for the Audi and the Toyota factory cars, coupled with the three litre increase in fuel capacity for the petrol cars, the overall lap time deficit will reduce from five seconds to three at Le Mans in 2013.

Lotus T128 (above)

The result of a design study started by SCE Solutions, based in Munich, the Lotus tub is built to the new 2014 regulations, while the gearbox is bespoke and almost certainly does not allow the car to meet the strict €440,000 cost cap placed on the LMP2 field. SCE founder Stephane Chosse designed the car to demonstrate the capabilities of the company, but couldn't sell it. As he was also working as chief of aerodynamics at the HRT Formula 1 team, alongside Colin Kolles, the pair decided to build the car themselves. The two formed the company Adess GmbH (Advanced Design and Engineering Systems Solutions), and the Kodewa team entered the car. The car uses torsion bar front suspension, while the rear features a third element, Formula 1-style. The bespoke Hewland gearbox is magnesium cased, with an aluminium bellhousing.

Pescarolo 01 - Nissan

Serge Saulnier sold his team to Jacques Nicolet in 2007, and Saulnier Racing linked with Pescarolo Automobiles in 2008. Nicolet and Pescarolo split in 2009 and the cars ran as Oak-Pescarolos before an agreement was reached with the Morgan Motor Company to badge the cars as Morgans for the 2012 season. The first proper Oak chassis is under development and will run for the first time in late 2013.

Zytek 07S

The Caterham name is new to Le Mans, badging up a Zytek Nissan entered by Greaves Motorsport with a view to investigating a future customer programme. The move reflects the expanded Caterham Group's growing status and ambition on the international stage, as well as the continuing commercialisation of its engineering and design consultancy arms – Caterham Technology & Innovation (CTI) and Caterham Composites.

Last November, Caterham Cars announced a 50:50 Joint Venture partnership with Renault, which will see the British company develop and build its first mass-market sportscar. Engineering teams from CTI and Renault are currently developing the design of the vehicles for both Caterham Cars and Alpine.

A cross-functional team of Caterham engineers, technicians and data analysts will be embedded within the successful Greaves Motorsport team to run the number 41 Zytek in the LM P2 category.

ORECA 03 / Courage LC70

There are no fewer than nine of the ORECA-built chassis racing at Le Mans this year, eight of them powered by Nissan engines that are prepared at ORECA's engine facility based at Magny Cours. During the test, four ORECA chassis finished the day in the top five places. Two of the chassis run as Alpines, the chassis badged as A450s. All use the original Courage LC70 chassis.

Ferrari 458 Italia (above)

Ferrari has had its wings clipped since Le Mans last year, with a reduction of five litres in fuel capacity compared to 2012, but Michelotto has been hard at work to claw back an advantage. The aerodynamics of the car have been changed. A new splitter has been introduced which features a small channel that has been opened up in the middle part of the splitter which reduces pitch sensitivity. The suspension is modified to double wishbone, in line with the other GTE cars. The front bumper has also been changed, and is now closed immediately over the splitter. The openings in the bonnet have been reduced, the wheel arches more rounded, the rear wing reprofiled and the rear bumper has also been changed to facilitate the extraction of air and to make the diffuser more efficient. It's a lot of work in a car that should be the main challenger to the Chevrolet Corvettes.

Viper GTS-R

The car has undergone something of a tidy up since last year. The team trimmed weight from the wiring loom, developed a new rear wing to 2013 regulations and installed the double wishbone front suspension. Turning vanes at the front have been installed, and the team has changed to JRI dampers. There is a bigger front brake package, but the balance of performance measures have been set since Road Atlanta in October last year.

Porsche 911 GT3 RSR Type 997

Powering the 911 GT3 RSR is a particularly efficient six-cylinder boxer engine with a four-litre capacity. With a mandatory air-restrictor, it generates 460 hp (338 kW) and drives the 310 millimetre wide rear wheels. The diameter of the front wheels has increased by 30 mm to measure 680 millimetres. The Porsche sequential six-speed gearbox is operated via paddle shifts on the steering wheel.

The nose and rear panels are adapted to the flared front and rear wheel arches, as are the door sill and the wheel arch coverings. The aerodynamic concept is complemented by a new ducting of the intake air. Openings in the rear side sections, as known from the turbo variants of the Porsche 911, replace the air scoop on the engine hood, which is very similar to the 911 GT2 RS street sports car.

Porsche 911 RSR Type 991

Porsche's new Le Mans contender ticks most of the boxes required to upgrade from the 997, but not all, and there is a significant handling problem with the car that the company does not expect to be fixed by Le Mans. The car has a longer wheelbase (by 100mm), is significantly lighter (enabling the Manthey team to move around ballast as required), has a double wishbone front suspension (as do the majority of GTE teams), and the engine is better placed within the chassis due to the wheelbase. However, the engine is not the direct injection unit that will be placed in the 991 GT3 road car, which is not available until the autumn. This car therefore uses the same four litre flat six engine of the 997 model. The car's weak point is tyre wear, though with PFC, introduced new front brake material at the Le Mans test day to help to solve the issue.

Chevrolet Corvette C6R

Development work on the C6R has been stymied this year as the Pratt and Miller team concentrates on the development of the C7R, announced at the Petit Le Mans in 2012, and which will make its race debut at the Daytona 24 hours in 2014. There are a few aero tweaks to the car, including a new rear wing and the cooling system has changed slightly with a new radiator. The car spent two days at the Windsheer wind tunnel, as part of its regular Le Mans build up.

Aston Martin Vantage V8

Aston Martin has produced a car that is, by its own estimation, 30 per cent new and has been cited as the car that the competition most fear. It is the only car to have competed against the Corvette in the American Le Mans Series (at Sebring), and the majority of the competition in Europe and so has unrivalled knowledge of its competition. The car has an upgraded double wishbone suspension, new aerodynamics that see a larger sill housing the exhaust down the side of the car to help with the heat transfer issue of the 2012 cars, and a new fly-by-wire throttle that helps the drivers on downshifting into corners. At Spa, the car stunned the opposition as it double stinted its tyres on both professional cars. The drawbacks for the car are that it still suffers from drag, and so runs lighter, has a larger air restrictor, runs without a Gurney at Le Mans only, and carries 10 litres more fuel than the opposition.

Let battle commence

The Le Mans test day was mostly wet, but Toyota and Audi revealed some secrets

The test times at Le Mans made for impressive reading for Audi, with Loic Duval blitzing last year's qualifying time with a 3m22.583s and its cars filling the top positions. It could have been a tenth faster had he matched team-mate Lucas di Grassi's fastest time through sector 1, but this was on a track that was not completely dry, and the 3m20s barrier must be under threat if qualifying stays dry on Wednesday and Thursday evenings.

There were few mistakes from the Audi team – a practice driver extraction caused the fire extinguisher button to go off on Saturday, and Duval crashed on Sunday morning, caught out by a piece of his windscreen wiper coming off, causing him to veer off line and onto a wet section of track.

Yet with four cars, three of them taking part in the race and one completing tyre testing for Michelin's 2014 rubber, Audi was able to work through its development programme faster than Toyota, which had just two cars and a very limited amount of dry-weather running. Toyota finished the day 4.998s off Audi's pace, although the gap should be closer come qualifying, and in race conditions, the Japanese-owned team feel that they can find and exploit some of Audi's weaknesses.

The situation wasn't so bad for Toyota – theoretical bests put the number 2 Audi at 3m22.583, the number 3 at 3m24.716 and the number 1 at 3m24.894, while the Toyota's theoretical best, more relevant at Le Mans than anywhere else due to the traffic, was a 3m26.780.

The two Toyotas completed nearly 2,300km of running on the Sunday, with the number 7 car working on aerodynamic set up, while the number 8 worked on tyre and set up evaluation. Audi worked on aerodynamic set up and tyre pressures throughout the damp morning session, and when Duval found a clear lap in the afternoon, was able to set fastest time.

Alexander Wurz did runs of 1, 5, 4, 3, 5 and six laps in the

The TS030 features cooling holes on the inner face of the rear wheel arch, one of the few locations where openings are allowed under the car

TOP SPEEDS AT THE LE MANS TEST DAY

1	1 Audi Sport Team Joest Audi R18 e-tron quattro	LMP1	Benoit TRELUYER	328.8
2	2 Audi Sport Team Joest Audi R18 e-tron quattro	LMP1	Loic DUVAL	327.8
3	3 Audi Sport Team Joest Audi R18 e-tron quattro	LMP1	Lucas DI GRASSI	325.8
4	4 Audi Sport Team Joest Audi R18 e-tron quattro	LMP1	Marco BONANOMI	325.8
5	7 Toyota Racing Toyota TS030 - Hybrid	LMP1	Kazuki NAKAJIMA	322.9
6	8 Toyota Racing Toyota TS030 - Hybrid	LMP1	Sébastien BUEMI	322.9
7	21 Strakka Racing HPD ARX 03c- Honda	LMP1	Jonny KANE	316.3
8	12 Rebellion Racing Lola B12/60 Coupe - Toyota	LMP1	Neel JANI	315.4
9	13 Rebellion Racing Lola B12/60 Coupe - Toyota	LMP1	Cong CHENG	313.6
10	24 OAK Racing Morgan - Nissan	LMP2	Alex BRUNDLE	307.3

number 7 Toyota in the morning, while Kazushi Nakajima managed four and eight laps, Nicolas Lapierre three. At the end of Nakajima's 8-lap stint, Toyota fuelled up 67 litres, from a new maximum of 76, an increase of 4.1 per cent per tank since 2012.

'In 2012, both Toyotas were able to manage 11 laps in a stint, which means that they were using about six litres per lap,' says Racecar's strategist Paul Truswell. 'Audi sometimes did 12 laps on its 58 litres of diesel, although some stints were 11.

'Three litres is not even enough for a lap, but it might make the difference between 11 and 12 laps for Toyota. And you get the feeling that somehow, that it must make the difference. Such rule changes are not made in isolation, they are made in consultation with the entrants concerned, and we know that Toyota has been lobbying for a performance break.

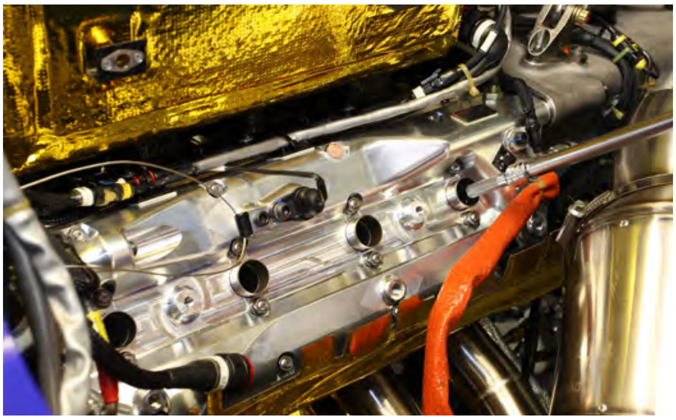
'So it is reasonable to expect the Toyota TS030 Hybrids to be able to manage 12 laps in a stint this year. It will mean that at the start of each stint, the cars will be 2¼kg heavier, and the pit-stops will take around a second longer. The ACO chose to increase the tank size of the petrol engined cars and not decrease the size for the diesel-engined Audis. It seems pretty obvious that Toyota needed the increase to get an extra lap and it wouldn't have the same negative impact on Audi - or at least that's what Toyota must think.

The Audi R18s all featured new front splitters including the all-black number 4 car which was conducting tyre tests. Toyota's revised tail section made its debut at Spa and is the result of extensive development in the TMG wind tunnel in Cologne. It features a number of very small detail changes

FASTEST SECTOR TIMES AT THE LE MANS TEST DAY

	SECTOR 1		SECTOR 2		SECTOR 3		FASTEST LAP	THEORETICAL	ACTUAL
1	3 L.DI GRASSI	31.761	2 L.DUVAL	1:18.985	2 L.DUVAL	1:31.669	2 Audi Sport Team Joest LMP1	3'22.583	3:22.583
2	2 L.DUVAL	31.929	3 L.DI GRASSI	1:19.069	1 A.LOTTERER	1:33.388	3 Audi Sport Team Joest LMP1	3'24.716	3:25.358
3	1 B.TRELUYER	31.947	1 A.LOTTERER	1:19.559	3 L.DI GRASSI	1:33.886	1 Audi Sport Team Joest LMP1	3'24.894	3'25.647
4	8 S.BUEMI	32.392	4 M.BONANOMI	1:20.102	8 S.SARRAZIN	1:33.996	8 Toyota Racing LMP1	3'26.780	3'27.581
5	4 M.BONANOMI	32.694	8 S.BUEMI	1:20.392	7 K.NAKAJIMA	1:34.542	4 Audi Sport Team Joest LMP1	3'27.369	3'27.894
6	7 K.NAKAJIMA	32.813	7 A.WURZ	1:20.740	4 M.BONANOMI	1:34.573	7 Toyota Racing LMP1	3'28.095	3'29.593
7	12 N.JANI	33.033	12 N.JANI	1:22.085	12 N.JANI	1:36.849	12 Rebellion Racing LMP1	3'31.967	3'31.967
8	21 D.WATTS	33.160	21 J.KANE	1:22.338	13 M.BECHE	1:37.323	21 Strakka Racing LMP1	3'33.771	3'35.631
9	13 A.BELICCHI	33.546	13 A.BELICCHI	1:23.145	21 D.WATTS	1:38.273	13 Rebellion Racing LMP1	3'34.014	3'34.724
10	24 O.PLA	33.964	24 O.PLA	1:24.671	24 O.PLA	1:38.589	24 OAK Racing LMP2	3'37.224	3'38.801

The Audi's Le Mans specification rear end features a lower rear wing. The double rear wing end plates are directly inspired by the TS030



Toyota's V8 engine does not feature direct injection, but it is thought that the 2014 specification unit will

'From what we have seen so far this year, Audi has a much thirstier car than last year - indeed, by my reckoning, they might only be able to get 10 laps out of a tank.' At Silverstone, Audi used 21 per cent more fuel to go 1.5 per cent further than the Toyota.

Looking at the sector times, Duval's fastest second sector, from Tertre Rouge to Mulsanne, was 78.985s. di Grassi was marginally slower, and Lotterer slower by half a second again, while the fastest of the Toyotas, driven by Sebastien Buemi, was 80.392s, more than 1.4 seconds slower on that section alone. Was the Audi running less downforce? Clearly not, as Duval was also fastest through the third sector, from Mulsanne to the start finish straight, which he managed in 91.669s, compared to Stephane Sarrazin's 93.996s, more than two seconds slower. This does not look good for Toyota, although there may, just may, be some respite in the fuel economy. If Toyota is able to complete 12 laps on a tank of fuel compared to Audi's 10, they will have more options when it comes to strategy particularly if, as the test day suggests, they are using around 5 and a half litres per lap, enough for 10 laps only. If Toyota can do two laps more on a tank of fuel, it may have more options.

However that, too, comes down to tyre choice. Audi has quadruple stinted its Michelins before, and there is no reason to doubt that they could do so again. Michelin has also produced a tyre better suited to the cold night temperatures, meaning that the pace will be faster at night.

Audi fears Toyota's fuel economy, particularly with the three litres extra per stint that the Toyota has been given for this weekend's race. Toyota fears Audi's speed. Certainly, there will be a big change to previous years when Audi had the advantage of economy, while the opposition proved to have superior speed.

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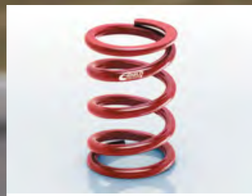
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A load of hot air?

Formula 1's blown diffuser theory was topical in 2011. While designers are still trying to master it in 2012, one student applied the theory to a Pilbeam Sportscar

BY SAM COLLINS

In 2010 and 2011 there was one major area of discussion surrounding Formula 1 aerodynamics. With the banning of the multi-level diffusers pioneered by Brawn, Toyota and Williams, Red Bull had found a new way to boost the performance of its car's underbody – it had placed its exhaust exits lower than was then conventional, so the gas from the pipes blew into an area around the rear wheels.

Using exhaust gases for aerodynamic gain was not new. Various Formula 1 cars over the years have featured 'exhaust-driven diffusers', many of them designed by Adrian Newey, notable as the designer of the current breed of Red Bulls. Key to this is using the gases expelled by the exhausts to energise the flow around critical components such as wing elements or, more importantly, the diffuser.

The concept is not only limited to open wheelers and has also made an appearance in Sportscar racing, with the Allard J2X of 1992. While that car is largely forgotten, it housed its exhaust tailpipes in a through-car tunnel, in theory increasing downforce. The concept had dropped out of fashion of late, possibly because the tools required to fully understand what is going on with the airflow were not well developed. Even then, it was the preserve of high-end cars such as the highly advanced Allard.

"Using exhaust gases for aerodynamic gain was not new"

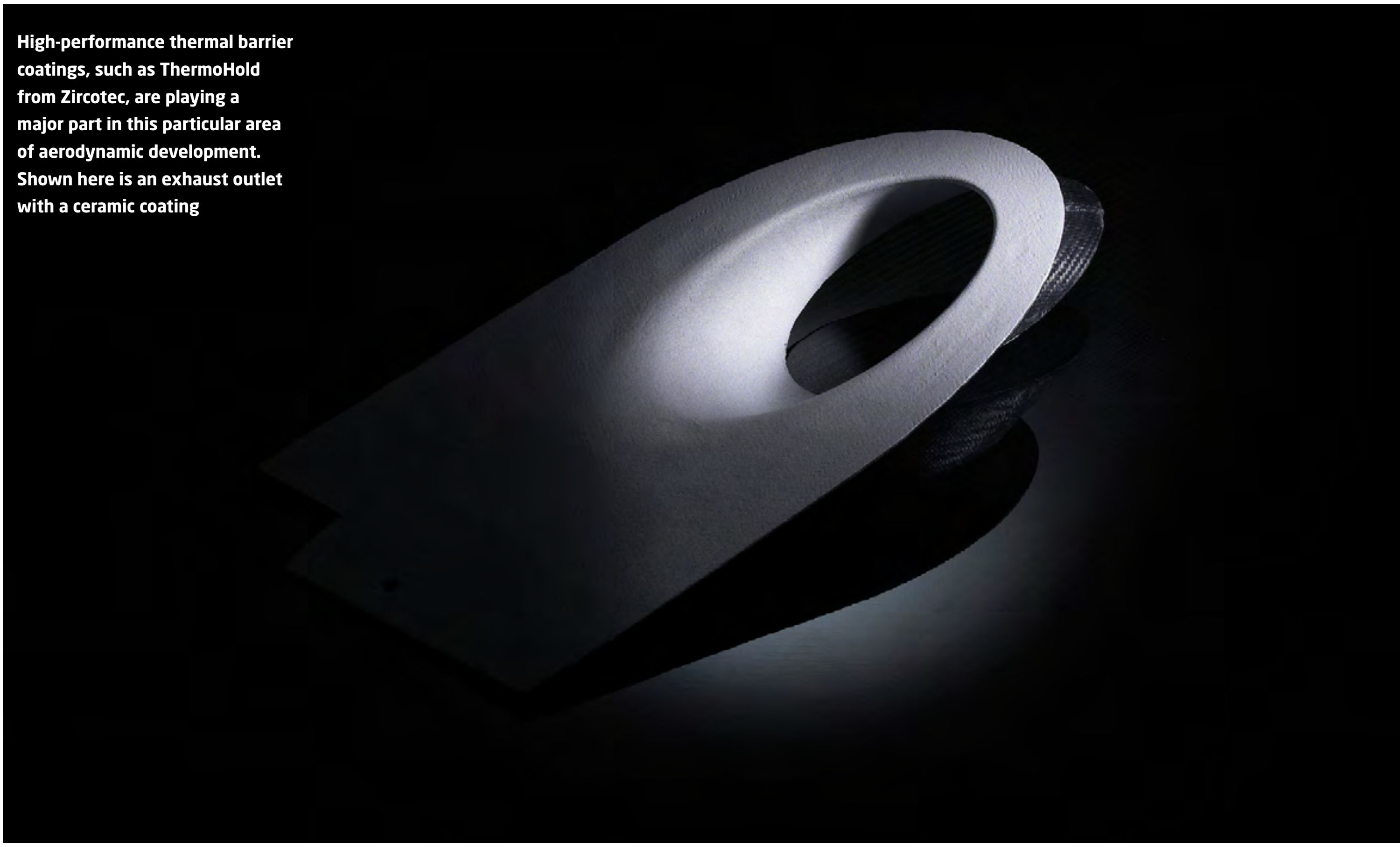
HOLLAND CALLING

It was a subject that fascinated Dutch graduate, Thijs van Rees, who was working on a Phd at Cranfield University. He decided to make the concept the subject of his thesis, but not on the traditional top-end open wheeler. Instead, he picked out a mid-range, full-bodied car as the model for his study.

'I used the Pilbeam MP98 CN regulations Sportscar [shown in lead pic, above]. It was developed purely in CFD and later tested on track, which is fairly unique in that category,' explains the Dutchman, who now works in Formula 1 with Williams. 'The regulations for that class of car stipulate that exhausts must be mounted in a specific area and must point either rearward or sideways, which gave me an interesting challenge. But they do not prevent you locating them in an area that can bring aerodynamic gains.'

To study the implementation of such a layout on a mid-range car (turnkey CN machines retail for around £80,000-£100,000 ($125,575-$157,000) makes this an unusual piece of work, and the results of the research are substantial. Van Rees was heavily influenced by Red Bull's recent designs, which appear to be all about the flow structure around the rear wheel.

'Their concept was to manage the wheel wake at the rear of the car, and that was to improve the flow through the diffuser,' he explains. 'Tyres are


High-performance thermal barrier coatings, such as ThermoHold from Zircotec, are playing a major part in this particular area of aerodynamic development. Shown here is an exhaust outlet with a ceramic coating

very strange things. The radius and the contact patch changes continuously, and this is a very important aspect in terms of aerodynamics, especially in open-wheel cars. At the base of the tyre there is a vortex created and, if this gets into the diffuser, it reduces its effectiveness. Using the mass flow from the exhaust to drive this vortex away from the diffuser and other critical areas effectively makes the diffuser larger and more efficient.'

COMPUTER SAYS 'NO'

But to fully understand these flows is a complex challenge, only really made possible by recent technological advances. Indeed, when van Rees attempted to run his first simulations he discovered it required more computing power than the clusters at Cranfield could supply, so he was forced to simplify his model.

'One of the important things to remember is that the exhaust is a very high temperature gas flow, and you have to manage that in the simulation,' explains van Rees. 'To do it fully, you have to understand the changes of the properties of the gases. The velocity, density and the thermal conductivity are all influenced so, for me, CFD was really the only way to survey all these factors.'

Van Rees' simulation was basic by current F1 standards, but nonetheless highly revealing, and he found substantial gains to the aerodynamic performance of the Pilbeam. 'Just using a very rudimentary design, the MP98's downforce increased by 11 per cent, and more detailed studies could almost certainly bring greater gains. The drag level also increased but, even so, there was an overall gain.'

With the widely reported change in Formula 1's exhaust regulations often called a ban on blown diffusers, many of the innovative layouts, such as those used by Red Bull, were outlawed. However, blown diffusers are not banned *per se*, and the teams are still actively trying to optimise their exhaust plumes. 'It is still important, but when you have changes in performance of the order of magnitude that we are seeing with the tyres and getting the tyres to work, it's not our higher priority,' explains Ross Brawn of Mercedes. 'Last year it was one of the predominant performance factors, but this year it is nothing like as significant as it was. I think the cars that came first and second at the Spanish Grand Prix had very conventional exhausts so, unlike last year, the cars with innovative positions are not pulling away from those who are conservative. The range of performance between the solutions is much smaller now. But we still do a lot of work on it, both in CFD and tunnel testing. You can't do everything in a wind tunnel and, obviously, you cannot generate hot gas. It's a combination of both that gives the best results.'

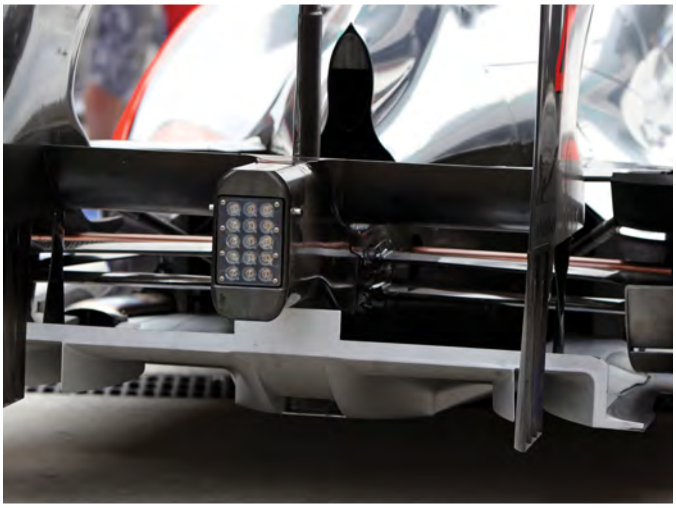
Indeed, most modern F1 teams are now working on simulating exhaust flows in the wind tunnel, but it is notoriously difficult to do, as Giorgio Ascanelli, technical director at Toro Rosso, admitted in pre-season testing: 'Our simulation capacity is limited in this respect. It depends on the pulse, the speed of exhaust flow compared to the speed of the airflow, the expansion rate, the temperature, ride height, cornering speed and we cannot simulate all of these things with sufficient certainty.'

THE TMG CONNECTION

However, some wind tunnels are more advanced in this respect, and Toyota Motorsport GmbH (TMG) in Cologne is a popular destination for Formula 1 teams chasing aerodynamic gains, partly because both of its wind tunnels are capable of simulating exhaust gases, as engineer, Chris Herbert, explains. 'We have two systems at TMG. In wind tunnel one, we use an air amplifier inside the model connected to a compressed air line. In wind tunnel two, as part of the wind tunnel assembly,

"exhaust is a very high temperature gas flow, and you have to manage that in the simulation"

This close-up of the Red Bull exhaust outlet shows how the floor is being blown directly ahead of the rear wheel with the exhaust pointing to the inside edge of the rear tyre to stop the vortex interfering with the flow through the diffuser. Note the cut out just ahead of the wheel where the flow will go down



Shown in white at the bottom of the picture, the McLaren diffuser covered with a ceramic thermal barrier coating

A further iteration of the exhaust blown floor, as seen on the Mercedes, showing the attachments to channel airflow through the diffuser

we have a large accumulator for the storage of compressed air and this is fed directly into the strut, then into the model.

In both wind tunnels, the compressed air lines are fed down the main strut and into the model via the cockpit. In wind tunnel one, the air lines terminate at the air amplifiers, which are located in the engine region. The air amplifiers use the compressed air to entrain additional flow, which is drawn from the roll hoop and then fed into the tailpipes. In wind tunnel two, the supply is simpler, with the compressed air lines being directly connected to the tailpipes.'

However, it is not really possible to replicate the gas temperatures in the wind tunnel. 'Doing the temperatures is very difficult,' admits Lola's Julian Sole. 'We have a cooler in our tunnel but, once you start pumping hot gases in, you are working it overtime. I'm not sure anyone in F1 is doing that.'

Herbert elaborates: 'It is not possible to heat the model scale tailpipe flow. We cannot simultaneously replicate a scale equivalent of both the speed and mass flow of the full-size car in the wind tunnels. Therefore, based on our experience, as well as a lot of testing and configuring, we know the appropriate level to set the wind tunnel tailpipe velocity to replicate actual exhaust gas behaviour.'

"We cannot replicate a scale equivalent of both the speed and mass flow of the full-size car in the wind tunnels"

It would seem, then, that van Rees was right in that the only real way to get a full simulation of the heated gases is to either run the car on a track and see what happens – which is not simulation at all – or to use CFD.

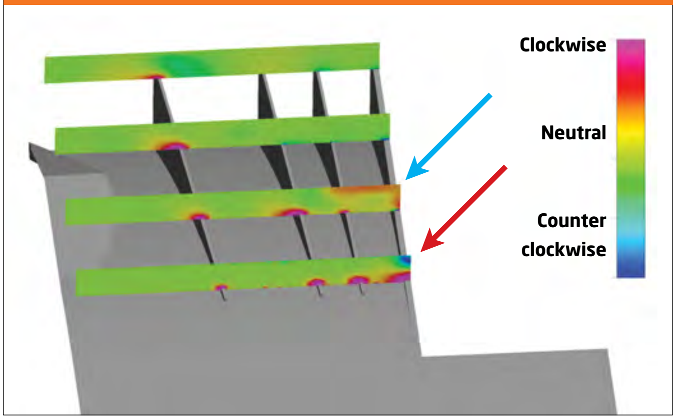
'We use CFD to visualise the flows,' continues Herbert, 'and we use our PIV (Particle Image Velocimetry) technology to ensure a good correlation between tunnel results and CFD modelling, in the same way we use PIV to enhance the accuracy of our CFD for other aerodynamic work. CFD can also be used to assess whether the plume impinges on the tyre surface and, if necessary, to simulate the thermal effects on the air around the tyre.'

THERMAL MANAGEMENT

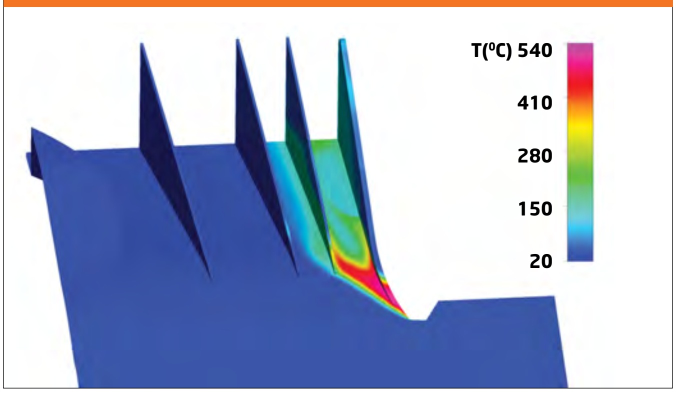
As Herbert hints, the temperature of the gas has more than an influence on the dynamic properties of the exhaust plume. It also has significant implications for the materials and structures of the car itself. Exhaust temperatures of 650-1000degC are commonplace and any team contemplating a blown diffuser has to take this into account.

There are several different solutions available to help cope with this, including gold foil wrapping or thickening of carbon fibre structures, but ceramic coatings such as those offered by the Oxfordshire-based firm, Zircotec, are now an essential

DIFFUSER VORTICITY



DIFFUSER TEMPERATURE



Top: the vortex from the rear wheel of the Pilbeam with an unblown floor can be seen to reduce the overall efficiency of the diffuser
Bottom: the blown version of the floor, showing the temperature of the exhaust gases into the diffuser (both images from Thijs van Rees' thesis)

ingredient. Its zirconia-based product, ThermoHold, has a thermal conductivity of less than 1.7W/mK, compared with 4W/mK for alumina. Its origins are in the nuclear industry and Zircotec was previously part of the UK's Atomic Energy Authority. The firm uses gas plasma spraying to load molten ceramic powder onto composite parts, building up layers until a thickness of somewhere between 250-400microns is achieved.

'Our coating reduces surface temperatures by 125degC and enables hot exhaust gases to pass over delicate carbon parts like diffuser strakes, protecting them from delamination. Not having to do complete re-designs helped teams reduce the introduction time for the blown floors,' says Peter Whyman, Zircotec's sales director. The influence of CFD-generated simulations of the heat distribution are clearly crucial.

'We are now seeing engineers incorporating the coating into the design, rather than merely solving heat issues after they find them. Our first coating applications provided a safe solution. With reliability proven, teams are now seeking performance gains by maintaining high gas speeds. Our ability to finely adjust the surface finish means we can offer a smooth finish with no impact on thermal protection.'

"teams are now seeking performance gains by maintaining high gas speeds"

So, with the simulation of the gases on the MP98 modelled and understood by van Rees, why has the Lincolnshire-based constructor not yet implemented the concept on its car? Well, as always seems to be the case in engineering, the reality is more complex than the theory. 'There is a slight problem in that the regulations in that category state we must use in-line, four-cylinder engines, and so we would need to have split the exhaust system somehow without losing performance, or only have it blowing on one side, giving an imbalance,' explains Pilbeam.

THROTTLE DEPENDENT

John Iley, now Caterham F1 performance director, was instrumental in the design of the Allard J2X, but says he was not a fan of the system: 'As a rule, I am not a supporter of such a system as it makes the car's performance too throttle dependent, which does not provide the basis for a stable platform,' he told Mike Fuller of mulsannescorner.com. 'However, the location on the J2X Allard was far enough rearward that its effect was greatly reduced. The main drive to route the exhausts this way on J2X was to achieve an incredibly low and tidy rear deck for the lower rear wing, not to utilise a blown diffuser principle.'

Van Rees elaborates on the instability Iley mentions: 'Obviously, these designs rely on exhaust mass flow, and that relies, of course, on the driver's foot being on the throttle. It means a driver can get on the throttle earlier because the mass flow massively increases downforce, and therefore traction.'

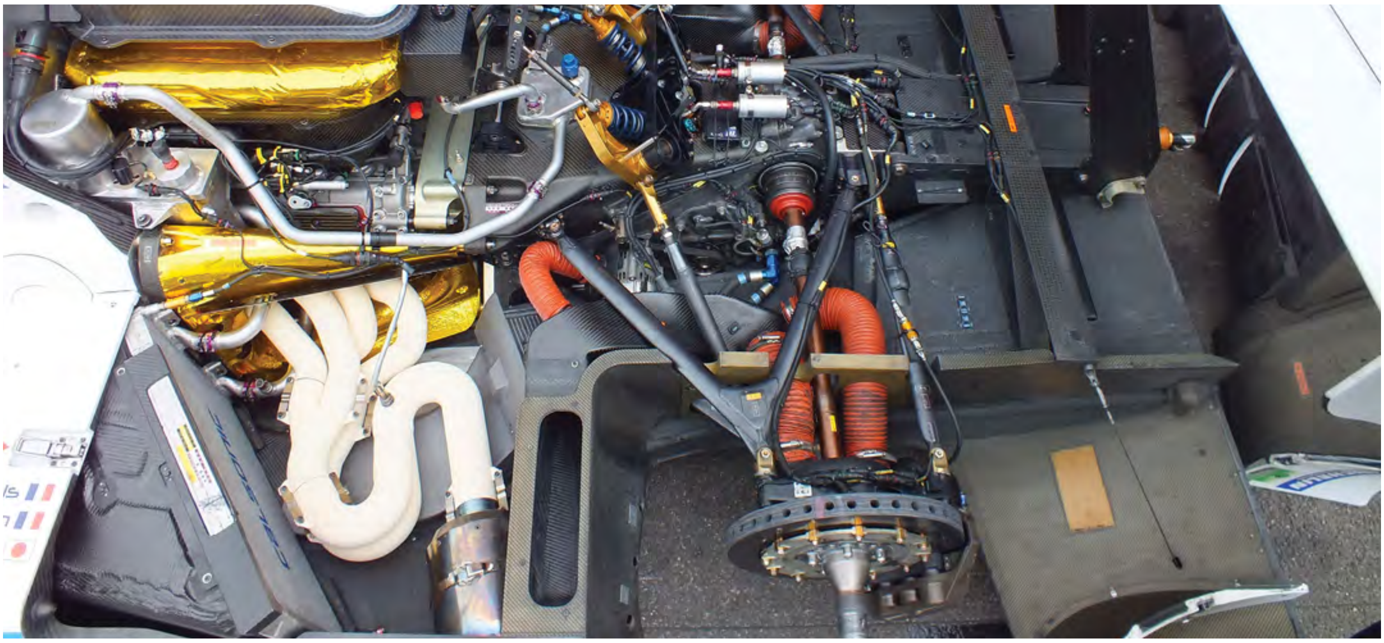
But in a section of corners where the driver is balancing the throttle, the mass flow from the exhaust is constantly changing, as is the downforce level. This makes cars with a so-called 'cold-blown' diffuser (where the exhaust mass flow is purely dependent on the driver's right foot) somewhat unpredictable, as Iley mentions, though van Rees suggests there are ways of making it a bit easier: 'You could do things like keeping the brake pedal on the car as you go through the corner and drive through on the throttle, all the time keeping the mass flow rate going through the system,' he suggests.

In 2010 and, particularly, in 2011, Formula 1 teams used a more advanced solution to this problem. A 'hot-blown' diffuser is used to maintain a constant stream of gas through the diffuser to keep downforce levels consistent. When a driver goes off throttle with a hot-blown diffuser, the engine throttles are kept open, fuel keeps being injected (and is ignited through careful mapping), maintaining the necessary gas flow. Naturally, this approach has a detrimental impact on fuel consumption but, put simply, the more fuel burned, the more exhaust gas is produced, and potentially the more downforce created.

The Renault RS27 Formula 1 engines fitted to the two cars that took the greatest advantage of hot-blown diffusers – the Renault R31 and Red Bull RB7 – burned 10 per cent more fuel than normal during the Australian Grand Prix that year, simply because the throttle stayed open when the driver was off the accelerator pedal.

'In general, our goal is to optimise the overall performance of the car [for that read: race results]. For many purposes, this can be simplified to optimising the lap time,' explains Rob White, deputy managing director (technical) at Renault Sport F1. 'One of the performance trade-offs within this optimisation is the extent to which exhaust gas energy is deployed to gain aerodynamic performance vs engine performance degradation (eg power loss, fuel consumption penalty, driveability penalty, durability or reliability risk).

'With off-throttle blowing, this is typically achieved by some combination of exhaust design to increase gas velocity, such as smaller tailpipe diameter, or nozzle, exhaust design to deliver exhaust gas to where it can influence aero (longer tailpipe), and throttle position – more open equals more air. Also things like cylinder cutting with no fuel or spark reduces torque to compensate for open throttles. Ignition retardation by later



The aerodynamically efficient Dome S102. Current ACO regulations state the floor must be continuous but it does leave scope for exhausts to be exited into the wheelarch, which could increase downforce, even in a cold-blown situation

spark timing increases exhaust temperature, and reducing torque compensates for open throttles. Finally, you also need to look at post-combustion – fuel burning in the exhaust after the combustion chamber.'

> **"increased fuel consumption is not the only downside of running a hot-blown diffuser"**

But, as White is keen to stress, increased fuel consumption is not the only downside of running a hot-blown diffuser: 'There are things to consider, like engine power being compromised by increased back pressure and acoustic compromise. Driveability, too. Cylinder cutting is a blunt tool, so managing torque transitions is challenging, and can cost lap time, and there may be second-order effects from vibrations associated with cylinder cuts, though this is typically marginal. Increased temperatures are also more difficult for engine and car components – notably, exhaust valves and exhaust components.'

So, despite the effective ban on hot-blown floors in Formula 1, they are not banned in many other categories and F1 teams are instead finding ways of using cold-blown diffusers inside the current regulations, engineering the cars' bodywork to have a similar influence.

WIDER APPLICATION

Why are blown floors not being used more widely elsewhere? According to Audi Sport, a turbocharged engine does not produce enough mass flow to be able to take advantage of the concept, ruling out the current generation of diesel-engined Sports Prototypes, Indy cars and the forthcoming new generation of Formula 1 cars from 2014 onwards. But what about normally aspirated racecars, such as the Dome S102.5 or Toyota TS030?

It is clear to White that the concept has applications across many areas of motorsport, at least where regulations allow, and hints that those who say that blowing a floor with a turbocharged engine does not really work may be incorrect: 'All of the above is generic and equally true of any high-end race engine with electronic engine control, fly-by-wire throttle and unrestricted control of individual cylinder ignition and fuel injection. Note that a turbocharged engine would have additional scope, relative to a normally aspirated engine.'

Sole, of Lola, feels the reason the concept has not yet been taken further is not so much technical as commercial: 'We had blown floors in F3000, so we have some experience of that. Doing it on a Le Mans Prototype is difficult, but not impossible as the regulations say you must have continuous surfaces. Also you can hit budget limitations, not least through burnt bodywork as you develop. Moving the exhaust position around is expensive, with the cost of new pipes and bodywork, as well as the R and D.' However, his conclusion is enigmatic: 'There are other ways to take advantage of the aerodynamic impact of the exhaust, other than working the diffuser...'

Hot blown floors are outlawed in F1 but attempts to utilise cold blowing continue, as seen here on the Red Bull RB8

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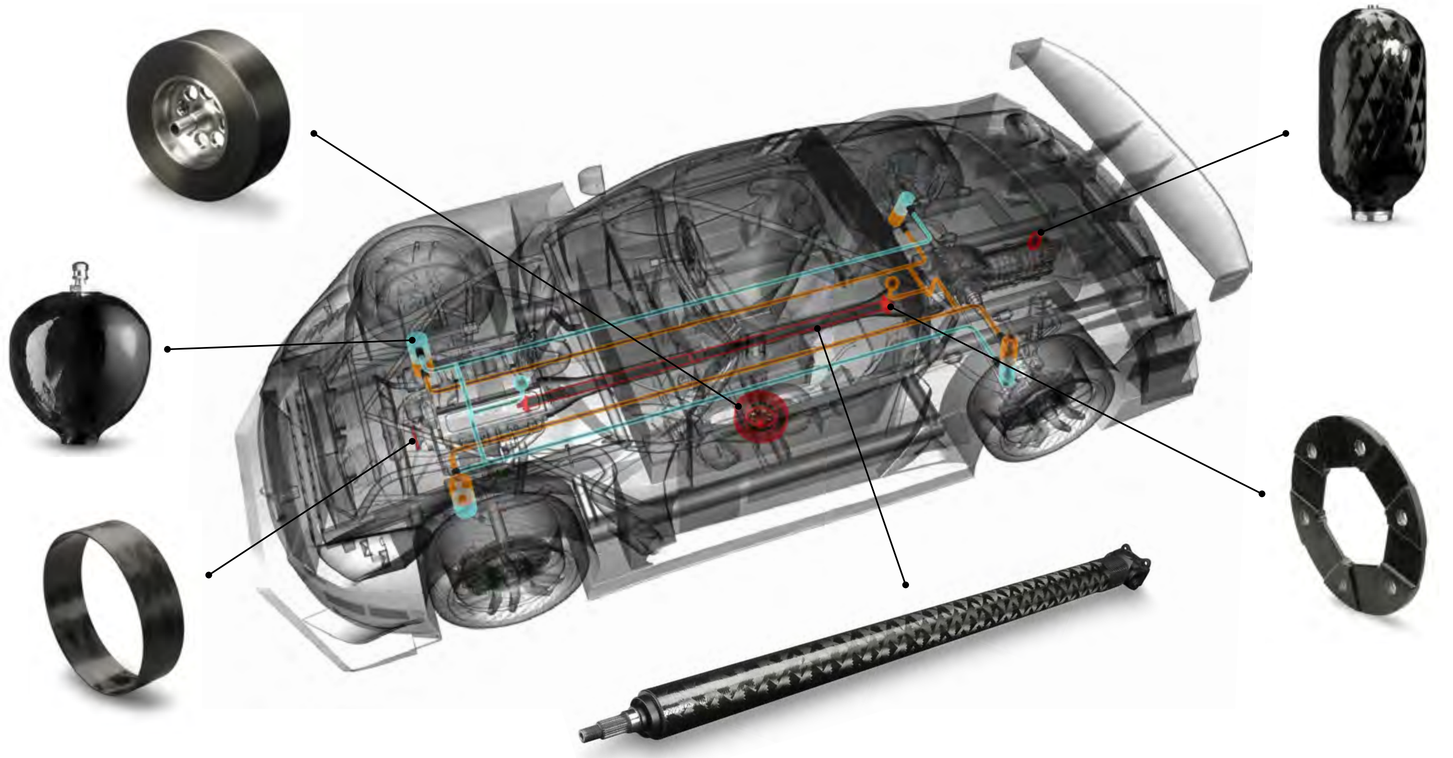

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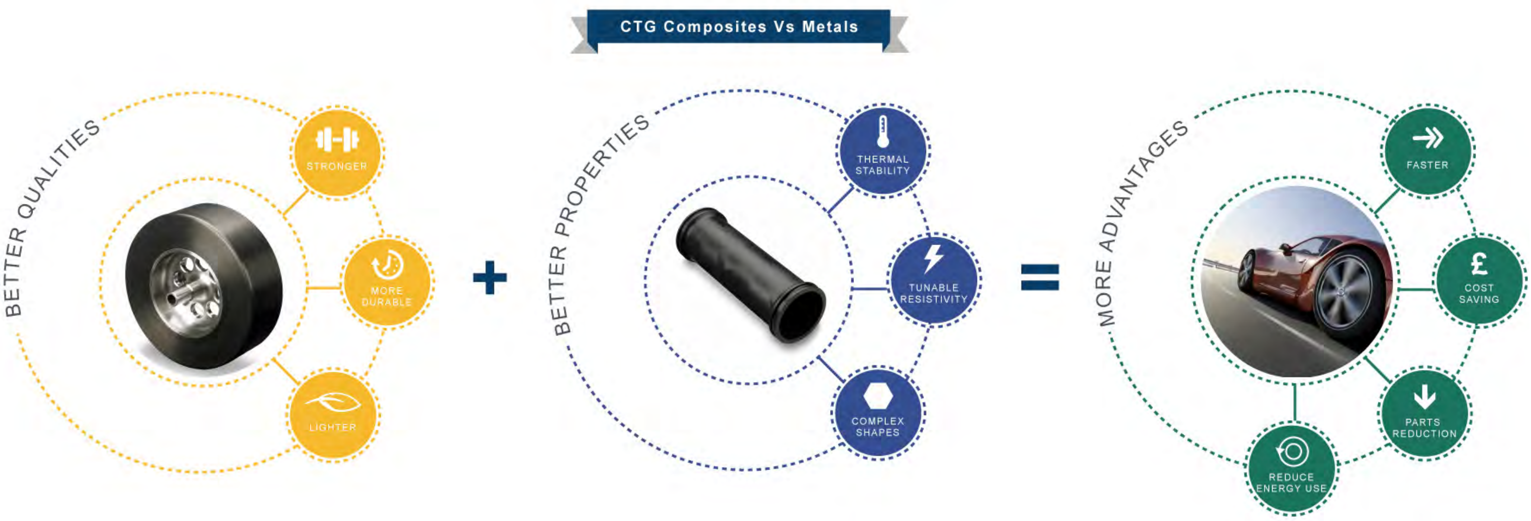

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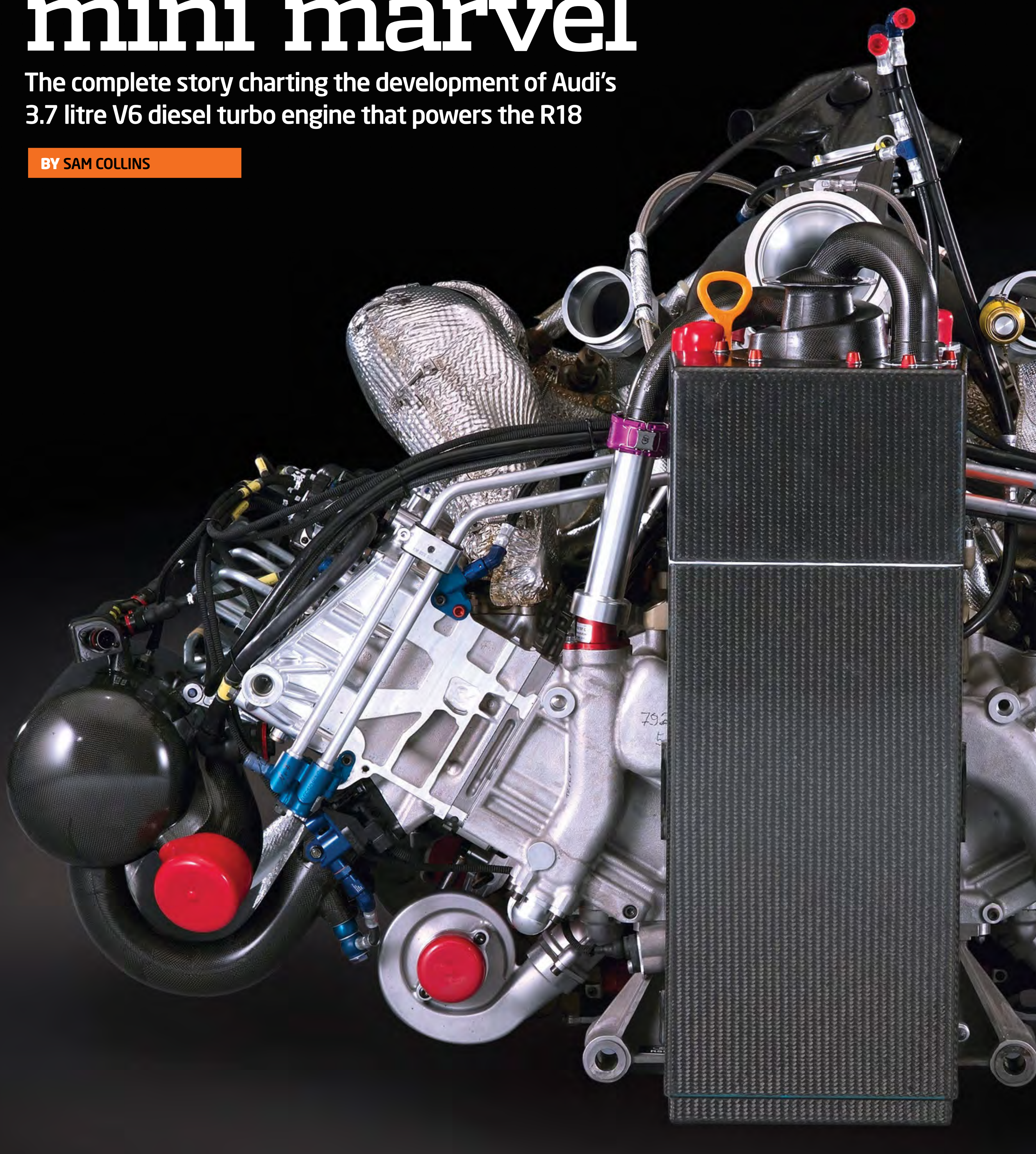
Audi's mini marvel

The complete story charting the development of Audi's 3.7 litre V6 diesel turbo engine that powers the R18

BY SAM COLLINS

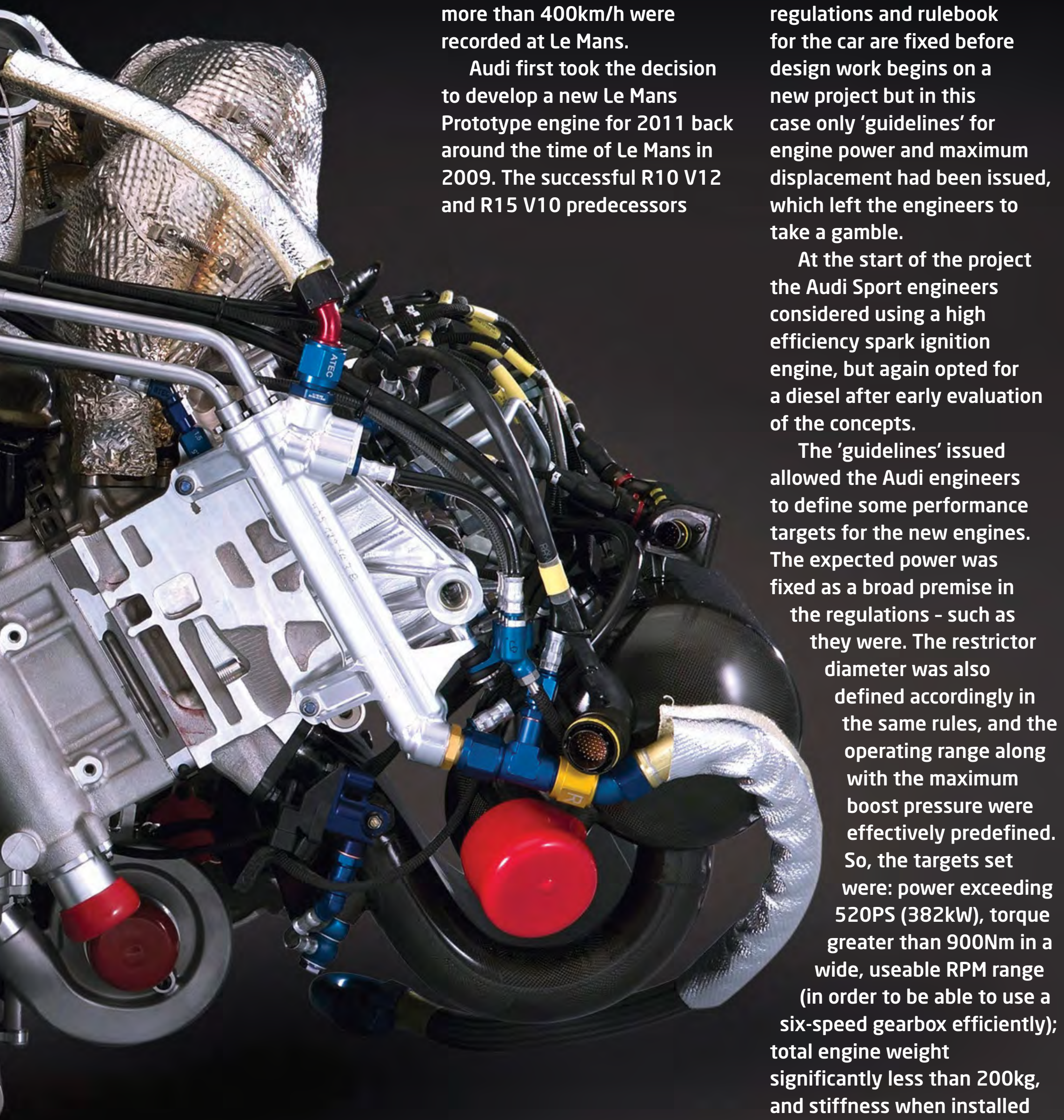


When design work began, with no rulebook fixed, engineers were left to take a gamble

Downsizing was the buzzword when Audi Sport was developing its new engine for the 2011 Le Mans 24 Hours. The ACO had outlawed the big 5.5-litre engines used previously and forced the manufacturers to think small. For diesel engines, the upper displacement limit was set at 3.7 litres and the maximum number of cylinders set to eight, while petrol engines were restricted to normally aspirated 3.4 litres and 2-litre turbo.

The reasons for this reduction on the maximum capacity for diesel engines were primarily those of safety and equivalency. Concerns were being raised about the speed of the works LMP1 cars as Peugeot and Audi were locked in a development war. This led to a dramatic reduction of the lap times in qualifying, but also increasingly during the race to within striking distance of the 'eternal' record of 3m 14.8s from 1985 where maximum speeds of more than 400km/h were recorded at Le Mans.

Audi first took the decision to develop a new Le Mans Prototype engine for 2011 back around the time of Le Mans in 2009. The successful R10 V12 and R15 V10 predecessors supplied a starting point which allowed the German engineers to develop the new unit in just 20 months. For the new design, it was imperative to assess whether the chosen concept, which explored previously unknown technical territory in many aspects, could also be successfully developed in the short development time.



Usually the engine regulations and rulebook for the car are fixed before design work begins on a new project but in this case only 'guidelines' for engine power and maximum displacement had been issued, which left the engineers to take a gamble.

At the start of the project the Audi Sport engineers considered using a high efficiency spark ignition engine, but again opted for a diesel after early evaluation of the concepts.

The 'guidelines' issued allowed the Audi engineers to define some performance targets for the new engines. The expected power was fixed as a broad premise in the regulations - such as they were. The restrictor diameter was also defined accordingly in the same rules, and the operating range along with the maximum boost pressure were effectively predefined. So, the targets set were: power exceeding 520PS (382kW), torque greater than 900Nm in a wide, useable RPM range (in order to be able to use a six-speed gearbox efficiently); total engine weight significantly less than 200kg, and stiffness when installed in-car as a fully stressed design, with supporting elements. The restrictor diameters and boost pressures were reduced still further for 2011. This resulted in a power and torque reduction and a slight shift of the power point in the rev range.

The next question was; what size and shape would this engine be? The definition of the number of cylinders was also on the agenda at the beginning of the concept stage. An eight-cylinder engine would have had the advantage of being able to transfer the enormous amount of experience gained from the area of the 12-cylinder R10 engine. However, Audi was convinced that a six-cylinder block had greater potential with regard to frictional losses, weight and compact dimensions. The targets for the new engine resulted from the demands to reduce engine dimensions and to be able to change the car's weight distribution. The overall dimensions of a 3.7-litre V6TDI engine showed the advantage of its shorter length, but a V8 engine could be fitted lower in the car achieving lower height and width dimensions.

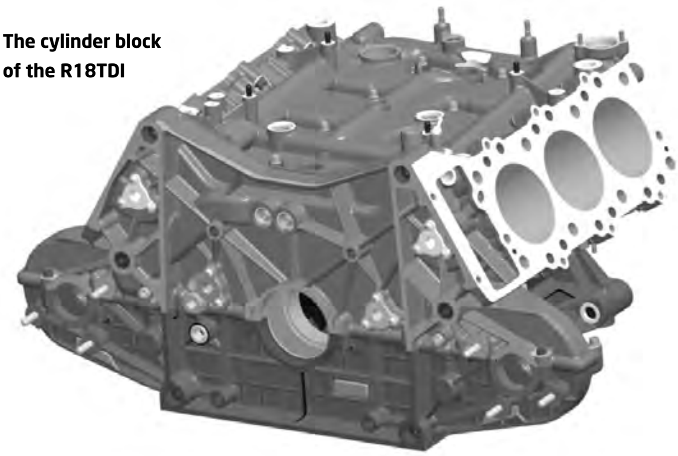
The regulations also permit engines with a capacity of less than 3.7 litres. With the weight and size of the engine crucial to overall car performance, a smaller capacity was also considered but - as was the case with the R15 engine - the choice of a 3.7-litre displacement was made with the underlying intention of keeping the specific load as low as possible. With increasing displacement, the engine's effective mean pressure sinks for the same attainable power (air mass).

The next step was to design a block. It would have to be as compact as possible and lightweight. Its design is also heavily influenced by many other factors. In order to reach the weight target, the majority of the engine had to be manufactured from light metal alloys and - at the same time - be able to withstand combustion pressures permanently above 200 bar.

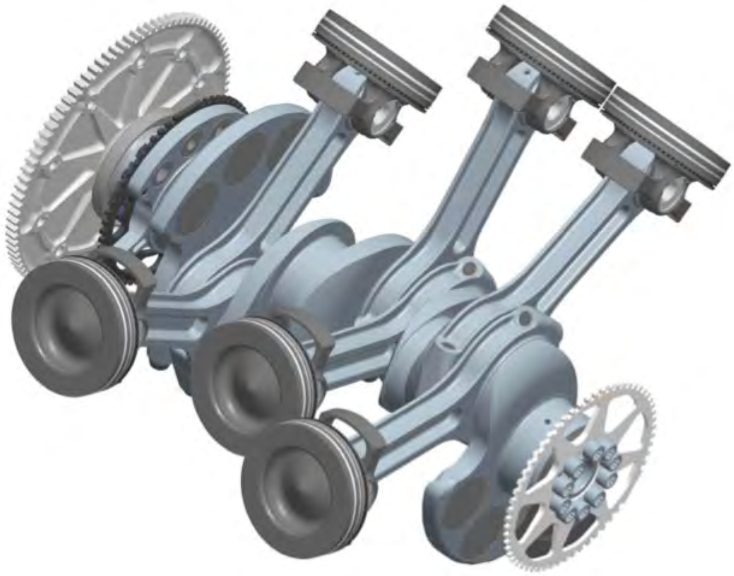
The R18 V6 cylinder block is manufactured from hypoeutectic alloy using the low-pressure sand

SWEPT VOLUMES FROM V12 TO THE V6TDI					
Displacement	5500	5500	5500	3700	3700
Cylinders	12	10	8	8	6
Swept volume	458.3	550	687.5	462.5	616.6
Increase		20%	50%	0.92%	34.56%

SIZE COMPARISON BETWEEN THE V6TDI AND A V8 TDI	
When V6 TDI 3.7 = 100	**V8 3.7-litre in comparison**
Engine length	18%
Engine width	-2%
Engine height	-7%



The cylinder block of the R18TDI



The obliquely divided steel connecting rod is manufactured with an optimised profile and further refined with regard to stiffness, optimum dynamic bearing stability and minimum weight by FEM calculation

casting method. The cylinders themselves are Nikasil coated. Completely new engine block architecture was required due to the large cylinder bank angle. The cast water channels, with a fork to the heat exchanger, have only a joint to the water cooler in an otherwise closed system. The relevant oil galleries are integrated in the block for piston cooling. The crankcase below the main bearing centre line – the so-called bedplate – is manufactured as complex, heavy-duty cast component. The precision casting blank has equally high strength (RM 35 MPa) and ductility owing to the directional solidification. The minimum wall thickness is less than 2mm.

The final block design featured a slightly long stroke as a result of piston loads, engine size/installed height and combustion chamber thermodynamics. The installation height of the engine is influenced substantially by the stroke. The stroke increased by five per cent when compared to the V10 and is accounted for by the increase in the crankshaft centre-line from the bottom plate. The 120-degree cylinder bank angle led to the Audi engine achieving a very low mounting position and therefore a low centre of gravity.

It was also designed specifically to suit the steel piston's lower compression height. Due to the larger bore of the V6TDI, the piston area loading is increased by approximately five per cent for the same ignition pressure. Meanwhile, the 120-degree cylinder bank angle is a result of the following points: lowering of the centre of gravity, layout and drive of ancillary components, firing interval and the mono-turbo exhaust layout. With this cylinder bank angle, the bedplate can still be connected extremely well to the crankcase. The cylinder spacing was adjusted to suit the increased bore so that the land width could be retained. As a result, the closed-deck engine block achieves the required stability.

KEY ENGINE ELEMENTS

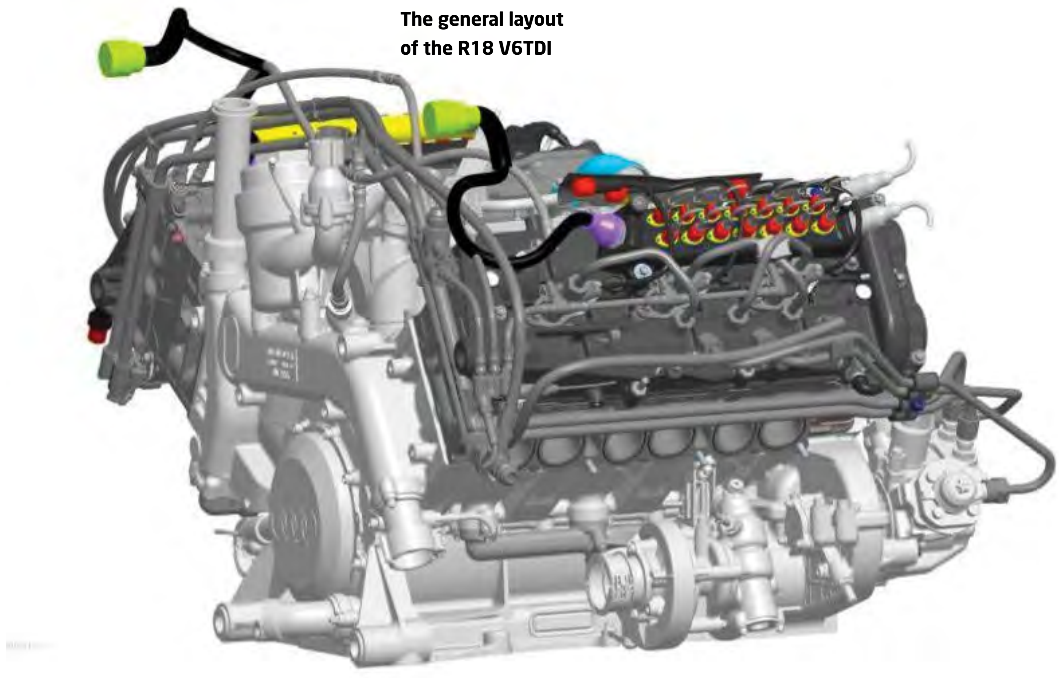
At the heart of the engine is the cranktrain, topped with some innovative steel pistons, which are one of the key elements of this engine. Due to the high piston loads generated in a race engine, the maximum load limit for the aluminium piston with a fibre-reinforced bowl rim was achieved during development of the V12TDI. Steel pistons were fitted to the R15 V10TDI from the very beginning. The larger bore and increased loads on the R18 V6TDI piston necessitated extensive analysis of the thermal management of the piston and piston rings.

The piston is manufactured from heat-treatable steel. This material combines the properties of high temperature resistance and good thermal conductivity with excellent machining properties. In addition to the higher temperature resistance, the steel piston has the advantage that the top-land is smaller than that of an aluminium piston. Owing to the greater transferable force in the pin bore, the gudgeon pin fitted to the steel piston can be considerably shorter, which in turn allows a weight reduction. As a result, a weight saving is even achievable when compared to the aluminium piston. The steel piston, made by Mahle, has a combustion bowl developed specifically for this application. The high thermal loads made the use of two piston spray nozzles necessary – one for the piston base and the other for the cooling channel.

The reduction in displacement and number of cylinders led to a direct increase in the litre and/or cylinder power and therefore, inevitably, to higher piston loads. In conjunction with the extremely short development time of the engine, the reliability of the piston had to be proved by calculation at an early stage of the design.

The design of the piston bowl, the lowest possible compression height as well as minimum weight are actually contrary to achieving the stiffest possible and operationally reliable design of the piston, which is subdivided into different disciplines. In addition to the actual stress analysis for the piston and liner, a perfectly functioning ring package is also required.

The crankshaft was



The general layout of the R18 V6TDI

designed around several key areas: the bearing load through the RPM range and load spectrum (ignition pressure and inertial forces); torsional and bending stiffness; free moments of the first and second order; vibration sensitivity and lightweightness.

Its essential dimensions were determined using bearing load and hydrodynamic lubrication gap calculations in conjunction with FEM. In this way, the diameter and width of the main and connecting rod bearings were defined according to operational demands, and the crankshaft webs made for greater stiffness of the journal connection.

Because of the engine's design, the free moments of the first order acting outwards can only be minimised by balance masses on the crankshaft.

The weight target for the entire engine did not, however, allow complete balancing of the free moments, but the resulting vibrations caused by the imbalance are acceptable for a race engine. An additional weight on the front end of the crankshaft and an extra web ahead of the gear drive facilitate efficient compensation due to the large centre-to-centre distance.

The crankshaft's stiffness is so high that a vibration damper could be omitted.

On the drive-side, a light steel flywheel transmits the torque to the clutch. Teeth with straight-sided serrations replaced the flywheel flange previously used. In this way a conventional, high-strength crankshaft gear could be used.

An incremental toothed gear positioned alongside the crankshaft drive gear supplies the impulse for the Bosch Motronic rotational speed signal. Another incremental toothed gear at the front end of the crankshaft gives a redundancy of the rotational speed recognition.

At the top of the engine, the design owes a lot to its predecessors, especially the V10 engine. In the first development stage, the cast aluminium cylinder head design was tested in a single cylinder engine. The basic single cylinder unit used in the development of the V10 was modified rather than a new unit built. Some components were created quickly using the rapid prototyping process to increase the speed of development. The single cylinder engine was used for the main tasks in the combustion process development, and endurance tests.

But it is not the case that the V10 heads were carried over to the V6, not least as they had two cylinders too many. Many areas had to be re-dimensioned due to the increased loads caused by the larger bore. The included valve angle was optimised and the valve enlarged so that the bore diameter could be used to its maximum.

Further development of the ports and port positions were verified together with the definition of the included valve angle on the single-cylinder cylinder head using flow boxes and simulation. The basis for this was the previous engine on which the systematic for the swirl flow optimisation was carried out.

VALVE TALKING

Two inlet valves and two exhaust valves are aligned parallel to the cylinder axis. The valve seat rings are manufactured from sinter alloys that were specially designed for the high loads. The valve guides are produced from copper-beryllium alloy. The valve gear consists of natrium-filled steel valves, conical valve springs and finger followers. The injector duct positioned centrally at the cylinder head middle is well supported by ribs in the oil chamber and therefore ensures a stable combustion chamber plate.

The cylinder head cover with the engine mounting points is machined from solid billet for strength reasons. Thanks to the integration of the camshaft bearings in the cylinder head cover, the cylinder head has a particularly high stiffness level in the upper area. This allows the introduction of suspension forces via the monocoque and/or the gearbox.

Through optimisation measures, it was possible to omit a mounting point between the cylinder head and the monocoque. In the area of the gear wheel housing, a part of the cover and the housing was replaced by a carbon-fibre part to reduce weight.

The camshafts are steel and are hollow drilled for weight reasons. The cam lobe profile was modified when compared to the R15 V10TDI. Greater cam lift and modified valve timing were required to optimise the new combustion process.

Because of the engine's short length, it was not possible to position the high-pressure injection pumps alongside the engine on the timing gear housing. A radical change to the camshaft and pump drive was the result.

The gear drive was repositioned on the engine's power output face and the CP4 hydraulic pumps are located towards the rear.

The twin pump arrangement balanced the peak torque produced by the hydraulic pumps – but for increased weight when compared to the single pump design.The layout of the gear drive on the clutch side of the engine ensures that the gear drive runs relatively smoothly, and that only low alternating torque occurs.

In addition to the camshafts, gears also drive the oil and water pumps and the high-pressure fuel pumps. The needle roller bearing steel gears are supported in the housing using floating axles. One floating axle per cylinder bank simultaneously assumes the function of compensating for tolerances and height differences in the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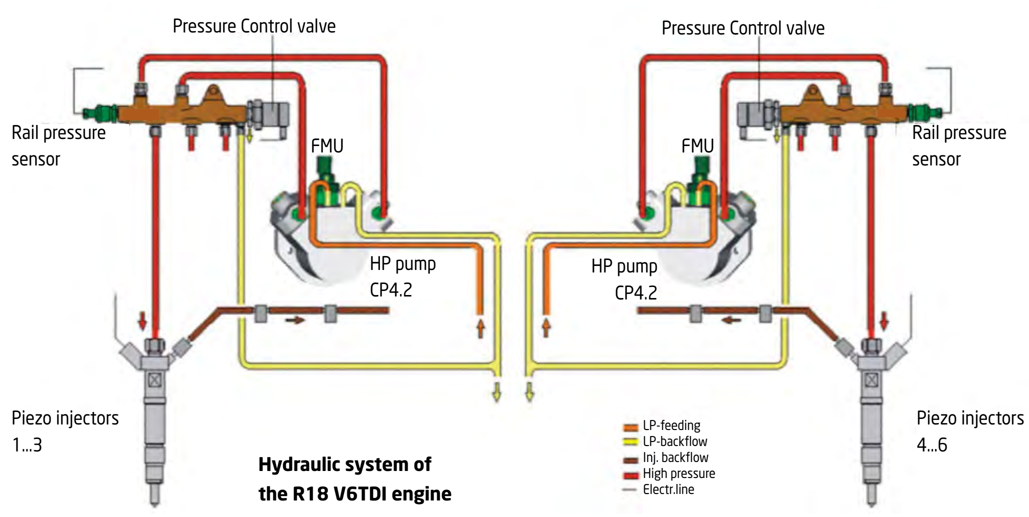

The hydraulic system of the R18 V6 TDI engine

cylinder head. The synchronously injecting hydraulic pumps are integrated into the gear drive with a ratio of 0.75. By reducing the drive speed, a high-load layout was possible for the highest injection pressures.

The piezo injectors are tailored to suit the engine. The nozzles were designed for the required output and tailored for the selected combustion process parameters through elevation angle, number of holes/type and nozzle protrusion. The low and high-pressure fuel systems are modified to suit the engine installation. Quick-release couplings in the feed and return circuits form the interface to the car. The fuel tank system with electric low-pressure supply pumps (lift pumps) was newly developed for the R18.

The inlet manifold length assumes a part of the charge exchange work, and is therefore a part of the engine calibration. In 2011, a relatively short inlet manifold equipped with a small plenum volume was used. The cross-sections are tuned to the inlet port area of the cylinder head. For 2012 the setup was reworked and a significantly larger induction manifold length used. The boost pressure monitoring system/sensors supplied by the organisers ACO/FIA are located on the inlet manifold.

The inlet manifolds and the plenum chambers are manufactured from carbon-fibre for weight reasons.

HOT SIDE INSIDE

With the ban of 'snorkel like' air intakes – ie air inlets protruding above bodywork parts – a central air intake was the only efficient solution for an LMP1 coupe. Two closed monocoque Le Mans Prototype racecars had previously been designed and built by companies within the VW group – the Audi R8C from 1999 and the Bentley prototypes between 2000 and 2003. The difficulties of achieving good airflow with low resistance for a twin turbo system installed on the side of the engine were known from the Bentley project. Therefore, in order to fully exploit the dynamic air pressure, great value was attached to achieving a very short, fully streamlined route for the intake air.

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The following considerations were obvious to the Audi engineers: a central turbo layout, exhaust channels mounted in the engine's V, a wide V angle to make space for the turbocharger and a large cylinder bank angle.

Several concepts were developed for the inner V area – especially the exhaust system within the narrow constraints of the aerodynamic outer bodywork. A fundamental question was whether a single turbocharger can generate the same or even better initial response than a twin turbo system.

The calculations made by Honeywell Turbo Technologies indicated that the mono turbo with VTG was the superior concept. On top of this came the significantly lower air mass due to the reduced restrictor size, when compared to preceding engines, which made a mono turbocharger possible.

A consequence of 'hot side inside' is an externally mounted intake system with very short charge-air piping, which is advantageous for improved response characteristics. The unfiltered-air side of the engine induction system is made along the car's roof. The ducting incorporates a low pressure loss air filter and airflow to the restrictor is optimised. Exploiting the dynamic pressure at high vehicle speeds generates a marginal increase in mass flow rate. The air is compressed to the permitted boost pressure in the compressor and enters the intercooler at temperatures of up to 200degC. After cooling, it reaches the induction system through a short carbon-fibre connecting pipe.

Another aim of the externally mounted intake system was to achieve the lowest possible blockage of the radiator exhaust air. A result of the centrally mounted turbocharger was that a very simple and light exhaust system layout was possible with the DPF at the back of the car. This was changed for the 2013 season to allow the development of a 'blown diffuser' (see *RCE V22N6*).

SINGLE TURBO

At the heart of the 'hot side inside' concept is the single turbocharger. A turbocharger with variable turbine geometry (VTG) was previously used on the R15 [7]. When compared to a conventional wastegate turbocharger, the advantages of this system, with an adjustable guide vane ring upstream of the turbine inlet, are mainly reflected in the significantly better boost pressure build-up in the lower rev range, in the dynamic, in response and also in more favourable fuel consumption due to the improved scavenging ratio.

The knowledge and experience gained with the VTG turbocharger were particularly important in the making of the decision to consider a mono turbocharger for the V6 for the R18, to start a completely new development and to race it.

As the entire air mass flow had to be generated by a single turbocharger, the result was a larger, heavier and inevitably more sluggish turbocharger. The larger dimensions, and the greater moment of inertia of the rotating components, led to a one of the most important

Audi's VTG turbo was developed with Honeywell Turbo Technologies, and was used in both the R15 and R18 prototypes

turbocharger development points – optimisation of the response characteristics.

A significant advantage was the change from a 5-speed gearbox to 6-speed, so the turbocharger could be designed for a narrower rev range. The targets set for the new turbo were lightweight design, boost pressure increase after pit stop, hairpin bends or after safety car phases, and temperature resistance above 1000degC.

Almost 3.7 kg could be saved through component optimisation and material changes in the first year. At the same time, the moments of inertia of turbine and compressor impeller could be reduced, which led to a considerable improvement of the response characteristics.

In addition to simple measures, such as simultaneous operation of the throttle and brakes to increase load and, as a result, to increase the exhaust gas energy by faster response of the ATL, a good opportunity presented itself to increase the exhaust gas temperature and thus ensure faster boost pressure build-up by retarding the main injection and/or post-injection. Indispensable for this was the previously described packaging of the exhaust pipes and turbine housing as well as the high-temperature resistance of the turbocharger for the lowest possible radiation losses of the exhaust gas energy.

The development of this unit was carried out in cooperation between the Audi Sport Engine Development department and Honeywell in Brno (Czech Republic) at the strart of the R18 concept. The design was tailored for the mass flow limited by the restrictor upstream of the compressor. Another design criterion exists in the boost pressure limitation stipulated by the regulations. Exhaust temperatures, mass flow and control dynamics determine design on the turbine-side. The exhaust temperature above 1000degC required for maximum engine power was a development target from the beginning and was implemented.

The turbocharger concept differs through its design as mono-turbo supplying two cylinder banks. The volute curl of the compressor and the turbine both have an influx flow field of approximately 180 degrees.

Particularly challenging was the development of the turbine for high exhaust temperatures, and precise boost pressure control immediately following the short gearshift times. The blades and levers of the turbine guide blades are high-temperature steel alloys.

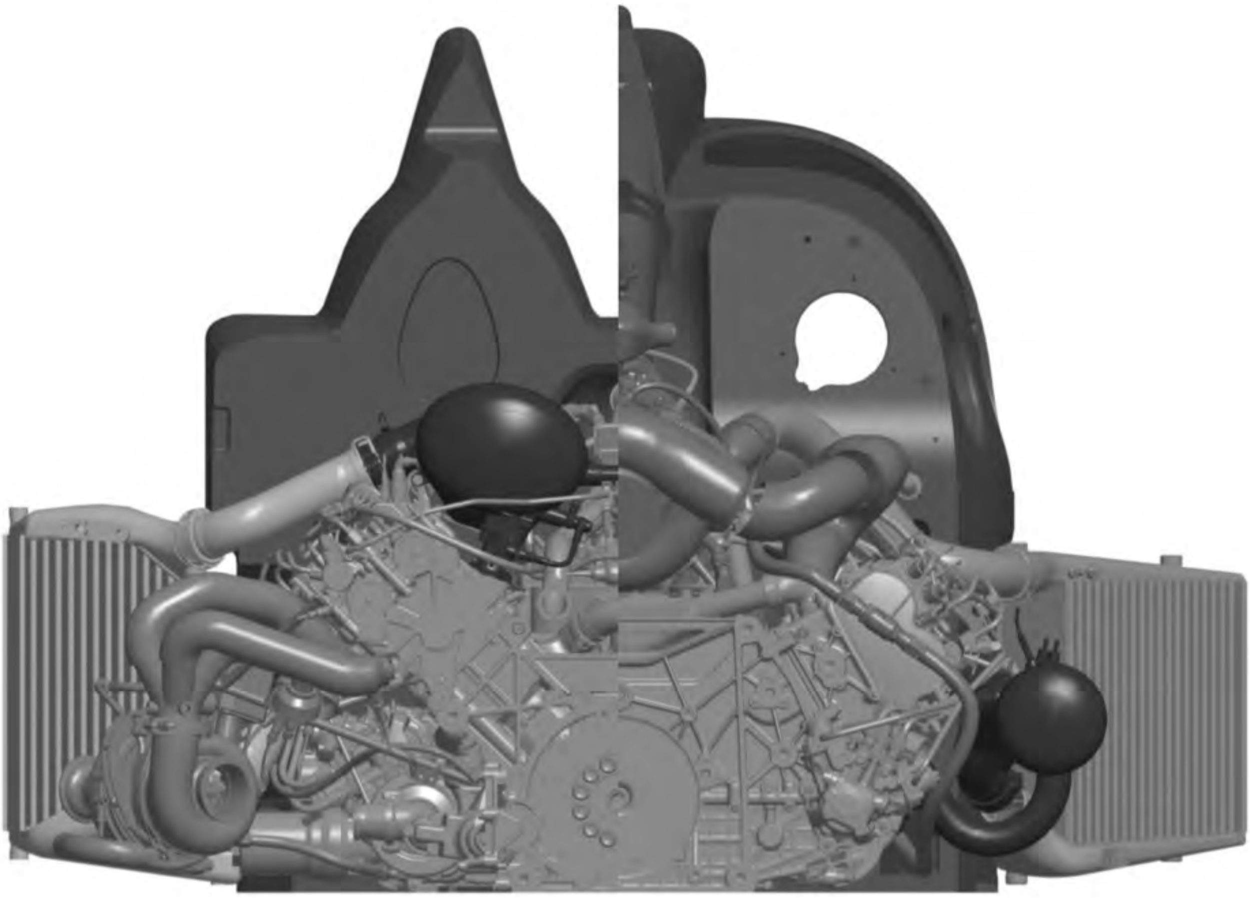
Blade control was made via a linear actuator with very high adjustment speeds, regulated by the engine control unit.

The turbocharger is mounted on ball bearings. The bearing housing is supplied with pressurised oil and drained

ELECTRONICS

For the R10 V12TDI in 2006, a new, dedicated, motorsport ECU – the MS14.x for diesel mode – was designed in co-operation with Bosch. Many details of the ECU were developed over the following years.

However, for use in the R18 e-tron quattro, a completely new ECU (MS24.x) had to be developed in order to be able to represent the hybrid and engine operation in a single control device. The software for the hybrid operation – as well as for the entire operating strategy – was developed, programmed and created independently by Audi. The software for this and for other in-house developed functions was written to a dedicated partition, separate from the basic engine functions, in the MS24.x ECU.



Side-by-side comparison of the engine bays of the R15 V10 TDI (left) and the R18 V6 TDI (right)

by one stage of the dry sump scavenge pump. All elements are equipped with quick-release couplings, allowing rapid replacement during races.

The turbine impeller sealing system to the centre housing, and the centre housing itself, were also new developments. The introduction of water-cooling to the rear wall of the turbine led to the sealing element components in the turbine area being subject to significantly lower loads. The cooling water flow was taken from the oil-water heat exchanger system via a parallel connection.

An additional water pump undertook the water-cooling for the 'hot' stop in the pits.

DYNAMOMETER

Audi set itself the goal in 2012 of becoming the first manufacturer to win the 24h of Le Mans with a hybrid car. To be able to achieve this goal a new car concept, the Audi e-tron quattro, was developed. The rear axle of the Audi e-tron quattro is powered by a combustion engine and the front axle by a Motor Generator Unit (MGU). An electromechanical flywheel accumulator acts as energy storage device for the Motor Generator Unit. A new drivetrain dynamometer was constructed at Audi in 2011 to enable this concept to be developed.

To accommodate the dynamometer in a test cell, the original dynamometer building had to extended from its original layout. The dynamometer is equipped with four wheel motors and/or two axles. The wheel motors, which are permanent-magnetic synchronous couplings, permit wheel speeds of up to 3,700 rpm as well as wheel torques of up to 4000Nm to be simulated. The installed wheel machine power is 1200 kW.

In addition, the dynamometer is also equipped with a battery simulator that can be used to simulate single hybrid components.

During development for 2012, the bearing housing was lightened by the substitution of material. The exhaust system's primary pipes are tuned in length and diameter to achieve good gas exchange and optimised flow to the turbine.

The integration of compensators between the 3-into-1 collector and the turbine inlet was necessary because of thermal expansion, and the connection of the banks in the turbocharger. The turbocharger in the inner 'V' is mounted on articulate couplings to the crankcase.

Through trim optimisation on the impeller, the map characteristics for higher mass flows could be moved and, as result, the nominal power point shifted into the area of optimum efficiency. Because of this, and due to improvements to the transition between impeller and housing, significant advantages in consumption were achieved with corresponding power gains.

Another measure to optimise the turbocharger in part-load operation was the new development of an electromechanical VTG actuator for the mono turbocharger to replace the production actuator previously used. The development was made in cooperation with the company MEGA-Line. Several targets for the new actuator were to achieve the optimum VTG position as quickly as possible under all dynamic driving and load conditions, to reduce the weight and create the possibility to expand the software functionality. The mechanical adjustment speed was increased by more than 50 per cent, the force level doubled and, at the same time, the weight reduced by almost 40 per cent. To expand the software functionality the previous communication interface was changed from PWM to CAN. The in-house generated programme code could thus be expanded and optimised with regard to robustness, reliability and diagnostic capability.

The exhaust manifold is equipped with a high-heat insulating cover to minimise heat dissipation into the engine bay. The turbine is largely thermally insulated. Gas flow to the DPF located directly behind

the turbine was optimised to guarantee uniform pressurisation of the particle filter. The DPF discharges via a short exhaust pipe that exits at the back of the car. The proven DPF substrate from the R15 was retained. The dimensions were optimised and tuned for low pressure loss for the required conversion rate.

INSTALLATION

To develop a diesel engine as a thoroughbred race engine is a great challenge from the very beginning. The task is further complicated by the need to integrate the engine perfectly in the very small overall package of a sports prototype.

As with the R15, the engine and car were designed as a harmonic unit without weak points. To obtain the ideal suspension setup, all the car's stressed components must have an equally high stiffness, which is why the engine is mounted rigidly as a fully stressed member between the monocoque rear bulkhead and gearbox. The stiffness could be further increased by the use of very light backstays between the monocoque and gearbox casing. The installation of a turbo engine is significantly more complex than that of a normally aspirated engine due to the air ducting. The intercoolers and water coolers are located on both sides of the monocoque in close proximity to the engine – the result is low-loss flow for low duct volumes. The car side cooling air ducts were optimised in the wind tunnel and ensure very efficient cooling of the charge air and water.

As with the R15, the engine and car were designed as a harmonic unit, without weak points

The R18 has been an imposing presence in sportscar racing. While both the Peugeot 908 and Toyota TS030 have beaten it in short distance races, the R18 has so far (at time of writing) proven to be unbeatable at Le Mans.

REVS AND LOADS

Because of the use of the mono turbocharger, it was necessary to increase the cylinder bank angle from the 90 degrees seen on the R10 and R15 to 120 degrees for the R18. This proved to be a very good compromise for the overall package concerning the centre of gravity position and sufficient stiffness for the fully-stressed engine as part of the whole car.

The number of main bearings reduced from six to four because of the number of cylinders. At the same time, the bore was increased by 3.5 per cent and, in addition, the maximum combustion pressure increased, which actually would have had to lead to higher bearing loads. However, by exploiting intelligent lightweight design for the entire crank mechanism, as well as clever mass distribution, it was possible to maintain the bearing loads level from the R15 in the R18.

With increasing revs, the maximum bearing loads reduce due to the ever-increasing inertia forces, while the mean bearing loads increase. The change of the cylinder bank angle, however, leads to an increase in bearing forces in the lateral direction. Particular effort was necessary from the design side to prevent sliding in the joint.

For lower revs, this effect is even more apparent due to the dominating gas forces, in the upper rev range the effect reduces because of the revolving inertia forces.

New strategy

The debut of Audi's latest R18 turned heads for the team's new thinking on fuel management as much as for the raft of tech and aero updates

BY ANDREW COTTON

The battle for the Le Mans 24 hours, 2013, started at Sebring, the opening round of the American Le Mans Series, where Audi ran one 2012 version of its R18, and one 2013 version. As it turned out, the race was a false dawn – the 2013 car was hardly quicker than the 2012 version and overall there was a lot of head-scratching as to how good it would be this year.

Then Audi arrived at the opening round of the World Endurance Championship at Silverstone with a completely different fuel strategy, found two seconds per lap – estimated to be worth five seconds per lap at Le Mans – and Toyota suspected trick new aero at the rear designed to reduce drag.

The cost of the extra speed was an increase in overall fuel used; the R18 used 21 per cent more fuel to go 1.5 per cent further than last year. Yet despite the extra speed, the R18 managed its tyres considerably better than last season. For all concerned it was an impressive step forward, and was certainly a strategy that few anticipated. That this year's car was faster is to be expected. That the strategy is so different was not.

AERO DEVELOPMENTS

Audi arrived at Sebring with what effectively amounts to a full width rear wing. The extensions on either side of the wing are fashionably labelled as rear wheel arch extensions, similar to those debuted by Toyota last year – the Rebellion team featured similar extensions as designed by Multimatic.

The aerodynamic effect of the extensions allow the engineers to balance the car better than last year, rather than to provide more downforce, although that option is clearly available. The ACO reduced the size of the rear wing in 2009, and stipulated that it had to have a single plane, forcing the teams to compensate by also reducing downforce

"This is an evolutionary car. We're not aiming for more downforce or less drag – we had a successful layout last year"

on the nose. By increasing the potential for downforce at the rear, balancing it out with more downforce at the nose is relatively simple.

'With regular aero development you try to gain efficiency, and that is the key factor,' says Christopher Reinke, overall project leader for the LMP programme. 'This is an evolutionary car. You are not going for more downforce or less drag, because we had quite a successful layout last year. The balance will be in a similar range, so through those parts of the bodywork you can gain the same downforce, but more efficiently. In theory you could reach a higher downforce level, but I can reach the same downforce levels putting the rear wing down.' The team carried over the monocoque, crash structure and headlights, but otherwise pretty much reworked the car from nose to tail.

'Where we feed the air in and where it escapes, it is similar. It is just ongoing development,' said Reinke. Will Audi be able to use the wheel arch extensions at Le Mans? 'I would expect that the efficient tool might be used at Le Mans by us as well.'

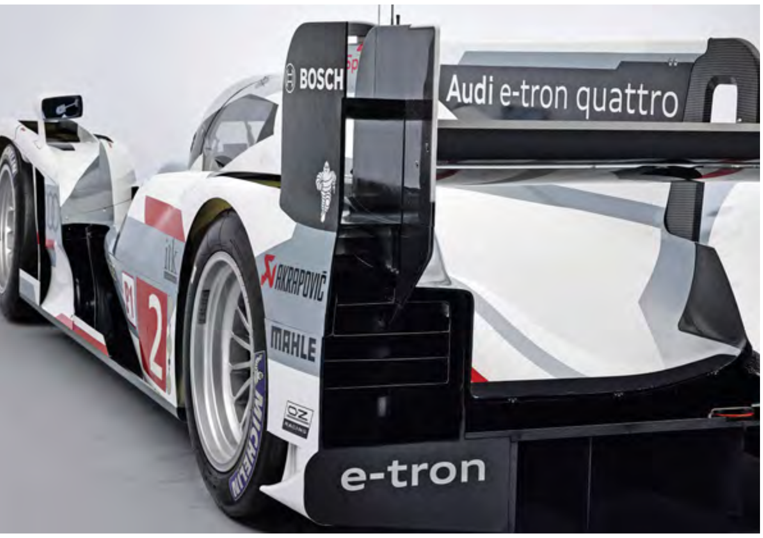
AERO EFFICIENCY

At Silverstone, however, the car underwent a significant change, and it is understood that the exhaust gases are channelled through the wheel arches, leading to rumours of a blown rear diffuser.

However, a blown diffuser in the traditional sense of the word is not possible with a turbocharged engine, as the gases emerging from the exhaust would be a little flaccid. What Audi is believed to be doing is playing with the air pressure behind the rear wheel in an effort to reduce drag.

Audi has confirmed that it has switched from a single to a twin exhaust layout, and Toyota says that there is enough mass to be able to change the pressure.

"Last year's hybrid system was purely laid out for Le Mans. With the solution we had, we would harvest only a third of what the rules allow"



Audi is believed to be playing with the air pressure behind the rear wheel to reduce drag (see separate feature).

Interestingly, Toyota also says that it has evaluated this concept and could introduce it to the 2013 version of the TS030. Toyota has experimented with blown diffusers before, notably in the TS010.

The suspension, chassis, dampers and gearbox are direct carry-overs from the 2012 car, but the traction control system is new, and was not optimised for cold tyre running. That partly explained why Allan McNish crashed on cold tyres at Sebring, the only place that the cars run without the aid of tyre warmers.

Audi launched a long-tail version of the R18 and raced it at Spa in May. 'Fielding the Le Mans aero variant on the third vehicle that hasn't been optimised for the lap times at Spa is an important element of preparation,' said Dr Wolfgang Ullrich, the Head of Audi Motorsport

At the opening WEC race of the season at Silverstone in March, Audi ran a new fuel strategy which could be worth five seconds per lap at Le Mans

HYBRID HALF-MEASURES

The principal gain in performance is expected to come from the mechanical flywheel hybrid system. Audi says that it has improved the efficiency of the flywheel system, and explained that it set up the Motor Generator Unit (MGU) for Le Mans in 2012. It has now built in the capability to adapt it to slower circuits, although this wasn't fully exploited at Sebring.

'Last year's hybrid system was purely laid out for Le Mans,' said Joest's technical director Ralf Jüttner. 'You go 330km/h four times a lap, and the MGU was laid out with the ratios and revs to charge the flywheel so that it fits to that speed. With these ratios, we went to the other circuits, where maybe we were at 290 or something, but we never fully charge the flywheel because we never reached the revs for it. There was never a solution prepared, but now we can change the ratios on the MGU and adapt to the drag similar to what you can do with the gearbox. We go to 285 at Sebring and we have a ratio that allows us to close-up to the optimum of charging the flywheel in the braking zones. With the solution that we had here last year, we would harvest maybe only a third of what the rules give us, so this year will be better.'

The issue of braking zones appeared to have the makings of a proper fight between the two manufacturers, but has since fizzled out. Audi claimed that the definition of a braking zone has been cut from 2g/second to 1g/second, which would help Toyota, which, through its super capacitors, can generate the full 500kJ of energy at each braking event. In practice, however, although the regulations stated 2g/1s minimum braking, in practice the 1g/s minimum was applied on the slower circuits as 2g force did not occur often enough on the slower tracks.

One of the improvements in performance comes from the decision as to who would run the

Audi has introduced screens to the cockpit linked to a roof-mounted camera to help with forward and rearward visibility

cars in 2013, and the approach to the setup of the cars is completely different according to whether or not it is Audi Sport or Team Joest race engineers who run the cars.

In 2012, Audi remained undecided which was the better option – the lightweight 'ultra' cars, or the hybrid 'quattro' models. At Spa, it seemed that the writing was on the wall as, in the wet, the quattros were significantly faster, but this was not entirely due to the four wheel drive with the hybrid activiated.

'This is a quattro only for a few seconds,' says Jüttner. 'There is a sort of a philosophy that we are a racing team, and the engineers say that we run too stiff. Talk to the drivers, and they say that we need to run stiff. Last year, one of the hybrid cars was engineered by the engineer from Audi Sport, and one from our engineer. The two hybrid cars were more under the Audi Sport control, and the two non-hybrid 'ultra' cars under our control. We had to split it up a bit. I cannot look after four cars.

'We set-up the cars according to how the drivers wanted and from data last year, and the cars were quick. Come the rain, the soft setup from the other cars worked. The quattro helped, but it doesn't make a difference of a few seconds. When it dried out, they were nowhere.'

ENGINE TWEAKS

Audi made few changes to the V6 engine for this year, although refinement is always the name of the game. The ACO reduced the air restrictor size for the 3.7-litre V6 engine in its balance of performance measures announced in January, meaning that the Audi will now run with a 45.1mm restrictor. 'We reduced the diameter of the air restrictor, by something like 10-12KW,' says head of engine technology Ulrich Baretzky. 'It was not necessary, but the ACO believed that it was. We had an increase on the injection pressure up to 2800bar, to improve efficiency and consumption and power. And the rest was working on next year's engine.'

COMING SOON...

The battle for 2014 is also high on the list of priorities of both Audi and Toyota. Both are eagerly awaiting the fuel flow sensor that is at the heart of the FIA regulations, but there is still no decision on who has been awarded the contract. The first incarnations of the Gill ultrasonic sensor were not a success, with a variation of more than 8 per cent and with no temperature control to accommodate fuel at different temperatures.

'If you have a deviation of 0.5 per cent on, say, 2000 litres, that is 50 litres, so you are dead,' says Ulrich Baretzky. 'They are testing it, but not in how you test a car with vibration, dynamic and heat. You have to take that into account. If it is going in the wrong direction you need time to change it. If it goes wrong at Le Mans, how do you explain to the press that this little chip has screwed you?'

Audi has tested its car using a front splitter that does not conform to any regulations, but which develops downforce similar to that expected of the 2014 car and will run it at the Le Mans test day to gather information. 'The tyre partner needs information, grip levels, tyre loads and so on,' says Baretzky. 'You cannot wait until such a car is ready and then start to build tyres. An interim splitter would not be according to any rules, but would give you some information. It produces your wheel loads and aero loads that give you what you expect on the new car already. We are working on that, and there are components which will be used later, but this is nothing special.'

Thomas Laudenbach, former head of drivetrain at Porsche, has been recruited to head up a new department designed to improve the efficiency of the hybrid and storage systems, as well as the internal combustion engine.

'You have to see that with the introduction of the hybrid system you have a new quality of interaction between the combustion engine and the electric motors,' said Baretzky. 'Call it strategy, functions, strategy on how to drive, more power or economic – it is a learning curve that takes a long time. This movement started slowly and went on, and then you see that it is another world. It is something new for a mechanical engineer like me.

'The complexity of the system in the car requires more networking between the systems and how to combine them, and this is a completely new area of development. This is part of the battleground for the next generation of racing cars. The car is becoming more an entity of different systems.

'Before you had a chassis, engine, gearbox, tyres and that was it, roughly. Now you have a hybrid system, energy storage system and one or two computers, they have to make decisions, and you have to enable them. You have to make a lot of simulations or reflections. With every element included, the complexity grows by a factor of 10, and the elements that you can tune is huge. Then you cannot be sure that these systems cover all the possibilities that you have in the car.

'It is good that Laudenbach has a deep understanding of engines to optimise or create the best possible interaction between the electric motors and the combustion engine.

'He is in a completely new department that he is building up. It is a link between engine, hybrid and energy storage systems, to make them work in a perfect way. His job is to optimise the electronic and hybrid side. The more he can contribute to the performance of the car, the better.

'If you look at Toyota and the progress that they made in the last 12 months, we are far behind and that is visible.'

TECH SPEC

Model Audi R18 e-tron quattro (2013)

Vehicle type: Le Mans Prototype (LMP1)
Monocoque: carbon fibre composite with aluminum honeycomb, tested according to the strict FIA crash and safety standards
Battery: lithium ion

Engine:
Type: turbocharged 120deg V6, four valves per cylinder, DOHC, one Garrett turbocharger, mandatory intake air restrictor of 1x45.1mm diameter and turbo boost pressure limited to 2.8 bar absolute, diesel direct injection TDI, fully stressed aluminum cylinder block
Engine management: Bosch MS24
Engine lubrication: dry sump, Castrol
Cubic capacity: 3,700cc
Power: over 360kW (490hp)
Torque: over 850Nm

Hybrid system: electric flywheel accumulator, max 500kJ, WHP motor generator unit (MGU) on the front axle, water cooled with integrated power electronics, over 2x80kW

Drivetrain/transmission
Transmission type: rear wheel drive, traction control (ASR), four-wheel drive e-tron quattro from 120km/h
Clutch: carbon clutch
Gearbox: sequential electrically activated six-speed racing gearbox
Differential: limited-slip rear differential
Gearbox housing: carbon fibre composite with titanium inserts
Driveshafts: constant velocity sliding tripod universal joints

Suspension/steering/brakes:
Steering: electrical assisted rack and pinion steering
Suspension: front and rear double wishbone independent suspension, front pushrod system and rear pullrod system with adjustable dampers
Brakes: hydraulic dual circuit brake system, monobloc light alloy brake calipers, ventilated carbon disc brakes front and rear, infinitely manually adjustable front and rear brake balance
Wheels: OZ magnesium forged
Tyres: Michelin radial
Front: 360/710-18
Rear: 370/710-18

Weight/dimensions:
Length: 4650mm
Width: 2000mm
Height: 1030mm
Minimum weight: 915kg
Fuel tank capacity: 58 litres

With the improved power from the hybrid system and the improvements to the engine, it was inconceivable that the R18 would lap slower than last year, and so it proved. At Silverstone, the cars were up to two seconds per lap quicker, but used significantly more fuel, nearly 21 per cent more to go 1.5 per cent further over the course of the race.

There was clearly an increase in fuel consumption, admitted Baretzky after the race, but 'we had higher fuel consumption, but for a number of reasons, and one of them is speed,' he said. One of these is the increase in minimum weight to 915kg this year.

LAT

For Toyota, the increase in fuel consumption is a mystery and Pascal Vasselon went on record to say that it was like 'blowing it into the air'.

GOOD WEAR

What was really encouraging for Audi was its tyre management. At Silverstone, the cars were easily able to run double stints on the 2012-spec Michelin tyres, which it ran throughout the six hours, while Toyota struggled to do so and only really worked on the 2013 car. Even in 2012, Audi was only just able to run double stints on these same tyres. This year, the wear was so good that the team considered attempting a third stint in race conditions.

Michelin has worked with both Toyota and Audi to develop a tyre that can cope with the cold conditions at Le Mans, meaning that – should the race run without safety cars – the pace at night should be higher. With the 2012 tyres being run so comfortably, the 2013-spec tyres should be a step forward.

'It was not the latest development spec, because we tested so much that it became impossible for Michelin to produce in numbers,' said Jüttner of the decision to run 2012 tyres at Silverstone. 'The weather is different, the ambient and track temperatures are not too different to last year, but yes, it was encouraging.'

At time of writing, the Audi has yet to be seen against the 2013 Toyota TS030.

BLOCKED AIRWAY

Audi was undoubtedly compromised by the ACO's decision to now allow it to run the 'air hybrid' system that was 15 months in development and was intended for use in 2014.

'For next year you are allowed to use two energy recovery systems and we are working on this,' says Audi's Ulrich Baretzky. 'We made something that was too clever for the sport authorities. It was a kind of air hybrid, what I call a clever version. It was nothing to do with electricity. I am not happy that it was banned, but it was proven that it really was working and from an engineering point of view it was really OK and it has road car relevant.'

So why ban it? 'A good question – why not? It was a comparatively simple system, there was nothing complicated, and it was efficient. It was just that in a race environment it would have been a help. A turbocharger is also an energy recovery, but this was something different. We spent 15 months developing it, but for us now it is dead. It was just one of the projects, we also improved the efficiency and power of the engine. Even if this is the last season of this engine, you try to keep it competitive.'

The system is believed to work in the similar way to the Peugeot system announced in Geneva. A compressed air reservoir is charged by the engine cylinders during braking/coasting and then released on acceleration, eliminating turbo lag. This eliminates the need for batteries. 'This year, you will not see it,' said Baretzky. 'The rule-book will develop and the more recuperation will be allowed.'

The waiting game

Toyota has launched its 2013 TS030, but its sights are set firmly on 2014

BY ANDREW COTTON

Toyota's 2013 Le Mans car is so similar to the 2012 machine that there is no new model designation, despite a new tub, a more central seating position for the driver to improve visibility, and a new aero package that is aimed at reducing the sensitivity of the car to changing conditions.

Despite winning three races in 2012, Toyota has changed its overall philosophy towards the new car, making it more serviceable and built more for endurance than for speed. A regulation change – increasing the minimum limit by 15kg to 915kg this year – has helped as components have been beefed up. Meanwhile, accessibility to the suspension, and to vital organs of the car such as the alternator, have been improved.

'In Bahrain, we had a light fail, and had to change almost the complete side bodywork for that,' said John Litjens, chassis project leader. 'The alternator we couldn't change the position, but we can change the access to it and also the suspension, to make it quicker and easier to change as we try to reduce the damage to the monocoque in case of a barrier impact. At Le Mans, Audi had some accidents, changed the suspension and went back out again. We couldn't do that last year, but I hope we can this year. That was partly the philosophy for last year, and for sure that is the experience that you gather. There were still quite some Formula 1 philosophies in the first tub.'

With the new tub, weight distribution has been a major factor, but the team has not opted to go with a carbon gearbox, similar to that used by Audi in 2012, despite the need to shift the weight as far forward as possible. 'In general, the balance is changed with the aero package,' says Litjens. 'You go as far forward as you can, but you have to be careful where you put the extra weight, and try to limit the damage of the extra 15kg.'

The rear suspension kinematics have also changed, although there is no all-new system. This was to improve driveability following feedback from the drivers, while the hybrid system has also been tuned to provide a smooth delivery of power. At the rear, the roll-out car of 2013 featured the Le Mans bodywork of 2012, complete with the narrow rear wing and without the huge rear wheel arches that debuted at Silverstone last year. However, the 2013 car will race with the wheel arches, and the team believes that it has made enough of an aero gain that it can run these flared arches at Le Mans. 'We were working on the details of the aero to make sure this doesn't affect the drag so much,' said Litjens. 'It looks as though we will bring it.' A high-downforce package will be introduced, but Litjens says that it will not be as significant as in the latter half of 2012.

One of the most noticeable differences between the 2012 racecar and the 2013 version is the nose, which is more similar to that rolled out at the start

of 2012. The tub used last year was designed to evaluate both front and rear hybrid systems, and the team raced with the compromised chassis. Now that it has settled on a rear-only solution, the tub has changed to reflect that, leading to a new, tightly controlled aero package. The new nose is lower, and the change means that the team will have to re-crash test the tub ahead of its first race.

'The major changes are invisible to the spectators,' said project leader Pascal Vasselon. 'The concept of the splitter, and what is facing the ground, is different. Last year was quite interesting. We lost more than we expected in the two scoops in the wishbone fairings. We went from the roll out-car with a conventional splitter to the racecar with an F1-like front end, and now we are more conventional again. We will upgrade the rear, and that will come later. At the moment we are still running last year's Le Mans aero. We are not targeting only efficiency, but we have targeted a more consistent front-end so that it is not so sensitive.'

"The major changes are invisible to spectators – the splitter and what is facing the ground is different"

The team will introduce the new car in race conditions at Spa in May, preferring the 2012 car at Silverstone, but the team still expects to challenge for the World Championship title. 'We can be favourite for six hours because we have done that, but at Le Mans we are still the challengers.'

On speed alone, the TS030 had an advantage over Audi's R18 over the shorter distances, but needed to open out a lead of around 50 seconds over the race distance to accommodate an extra fuel stop, despite carrying a larger fuel tank than the diesel hybrid (73 litres for a petrol hybrid compared to 58 litres for diesel). One of the regulation changes for 2013 is that the fuel stops will take longer, thanks to a reduced size of refuelling restrictor (25mm compared to 33mm for non-hybrid petrol cars, which also receive an extra 5 litres in fuel), again an offer to close the gap for the privateers. However, that could have far-reaching consequences for Toyota. Instead of having to open out a 50 second gap, it could have to open between 10 and 15 seconds more if the TS030 has to accommodate an extra fuel stop.

At Silverstone in 2012, the TS030 had to complete two extra fuel stops, but that was due to poor management of the fuel maps available, says Vasselon. 'It is a question mark for this year,' he said, although he admits that nothing is expected to happen this year. 'It is easier to restrict the size of Audi's fuel tank than to inflate ours, but at some point if we want to be balanced, why would we accept that we have to do one more pit stop?'

While cosmetic changes are minimal, Toyota's new philosophy for the 2013 car has placed more emphasis on endurance than speed

The new nose is lower than last year's model, meaning that Toyota will have to conduct new crash testing on the tub ahead of the first race in May

The TS030 was launched with the 2012 Le Mans bodywork. The team believes it can run its high downforce wheel arches at Le Mans

Eyes are firmly set on the 2014 regulations. Internal parts of the hybrid system will already debut in 2013 as the team works to improve cooling and deliver the full 500kJ of power in any temperature, having been forced to reduce power at Bahrain due to the high ambient temperatures.

'Performance stayed constant from the first test to the last race, but more tuning means better driveability or more smoothness, said Hisatake Murata, hybrid project leader. 'The 2014 system is being developed in the technical research centre now, but some small parts give us some idea [for next year's system]. Next year the hybrid system will change, and the power to weight ratio will increase. To produce 8mJ is a tough target, but we are trying now. We will have to have two motors. It is impossible to achieve this target with one motor. 500kJ is around 300bhp, so that is a good balance.'

That extra 300bhp, added to the 530bhp from the internal combustion engine (both quoted figures, so likely to have underestimated the true figure), makes this one of the most powerful racing cars around, when the hybrid system is active under acceleration.

Tyre performance will also improve, although Toyota says that it is not its strategy to come up with unique rubber for its cars. Toyota is working with Michelin to develop tyres that are better suited for low temperature running than in 2012, after both they and Audi struggled during the night. 'If you have to manage your track time, it is better to have an understanding of the existing tyres and engineer your car to use them than to use the track time to develop new tyres,' said Vasselon. 'Last year we started from an existing range and it showed a few voids, such as at night at Le Mans. We are developing the range, but there is no strategy to have different tyres.'

RULE RUCTIONS

Despite rumours that Toyota could pull out of sportscar racing at the end of 2013, the team has already started to develop the long lead time items for 2014, including the hybrid system, the tub and the gearbox, while the drivers are under contract for a further year.

Audi has hinted that it would like to see a change to the regenerative braking zones, which influence the outcome of the race, but project leader Pascal Vasselon dismissed the idea. 'It is a rule based on physics,' he said. 'It is a rule that is based on braking of more than one second, and more than 1g, and that is it. There is no room for negotiation. If it changes largely, we have developed our system for nothing. I don't see the point. The regulation is in place for two years, we have sized our system for this regulation, and it would not make sense to change it because Audi hasn't the power to generate 500kJ.'

Achieving the 870kg weight limit for the 2014 cars will be a challenge for the manufacturers, which will have to run two hybrid systems to achieve the target. Toyota has not developed a lightweight bodywork kit for simple durability. 'If you make it too light, with the pick up and dirt during the race, you throw away the bodywork at the end of the race,' says Litjens. 'For 2014 it will be far more critical with the 870kg weight limit. It was very early in the discussions to go to 750kg minimum weight, but if you do that, you say goodbye to hybrid systems. We are still at the bottom of the curve with hybrid systems, so it was too early.'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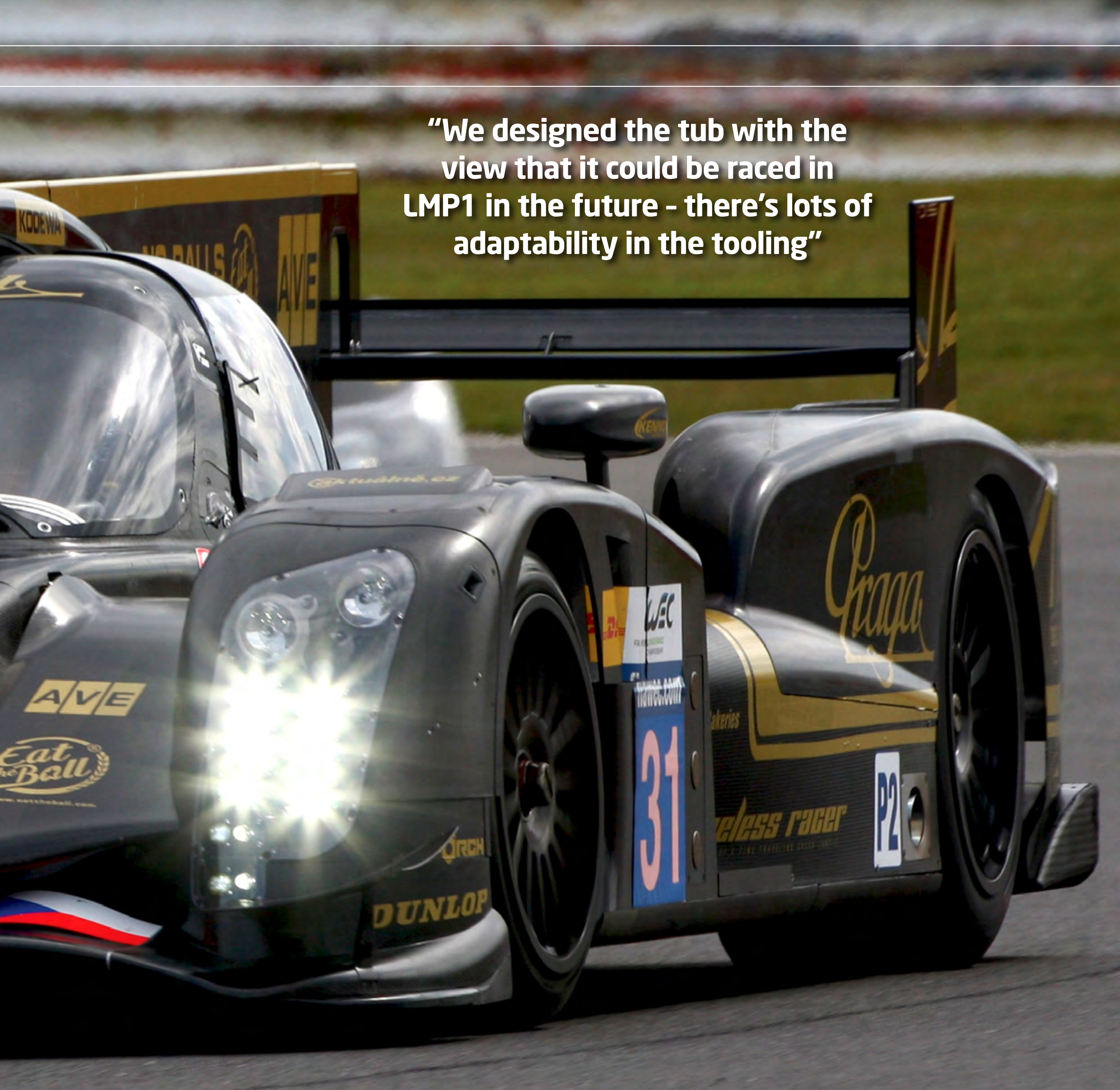
Playing the name game

BY SAM COLLINS

It has more in common with last year's HRT F1 car than anything bearing the Lotus brand, but the new T128 is a LMP2 contender with potential

"We designed the tub with the view that it could be raced in LMP1 in the future - there's lots of adaptability in the tooling"



The new Lotus T128 has a somewhat confusing name. It was not built by Lotus - though it is officially endorsed by the English firm - and has no direct relationship with the Lotus T128 which contested the 2011 Formula 1 World Championship. However, this Le Mans Prototype can trace its roots directly back to a 2011 Formula 1 car, just not the Lotus…

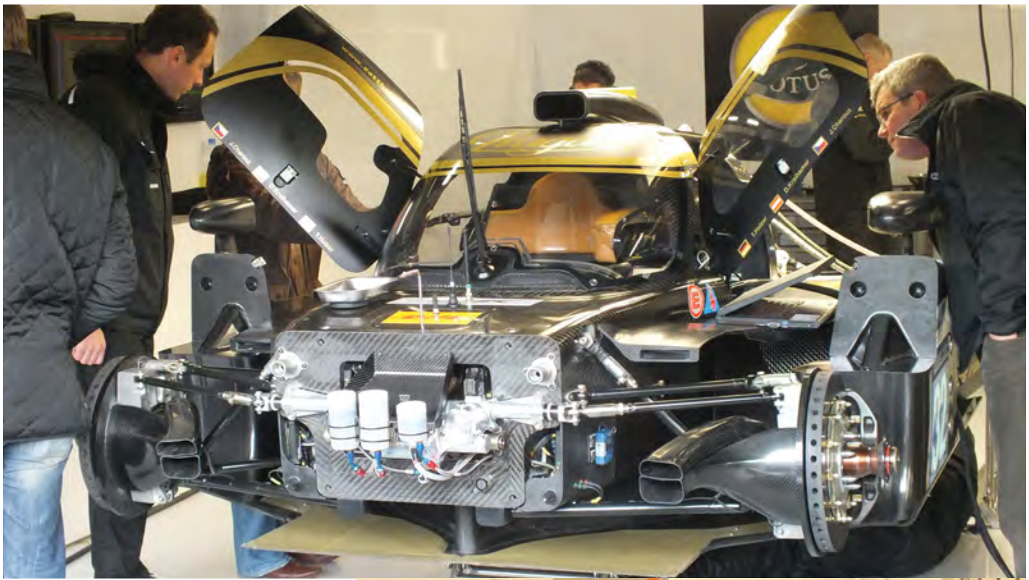
When the project first began, it was just to prove the capabilities of the company that instigated it.

'It was started by SCE Solutions based in Munich, Germany,' explains the company's founder Stéphane Chosse. 'We decided that we wanted to develop a Le Mans Prototype as a demonstration for what SCE could do. The idea was that we would sell the design study, but we were not successful at first.'

However, Chosse was also working with the HRT F1 team as chief of aerodynamics at the time, which brought him into contact with team principal, Colin Kolles. 'SCE Solutions acted as the aerodynamic department for HRT, and as Colin is a big fan of sportscar racing I told him about the LMP project,' he says. 'We discussed it, and in the spring of 2012 we decided to go for it. As a direct result of that we decided to create a bigger company called Adess GmbH - short for Advanced Design & Engineering Systems Solutions - and Colin gave us the opportunity to build the LMP and compete in WEC with the Kodewa team. We had the target of having two cars on the grid for the first race of 2013 at Silverstone.'

The new company had to take a design concept and turn it into a running car in around 12 months. Adess and SCE had all the capability required to design and develop the car in-house, but much of the manufacturing work had to be outsourced - the same approach taken with the HRT F112 Grand Prix car. 'Adess is primarily a design and engineering office. Like the F112, the car is manufactured by a group of companies, including the Kodewa team who make parts. Holzer Group makes some parts too. So we have a good group of companies integrated in this project.'

Kodewa had secured backing from Lotus to compete in the LMP2 class of the World



The Lotus features torsion bar front suspension, not seen on an LMP2 design since the Porsche RS Spyder

Bodywork consists of carbon sandwich composite panels, with quick release nose, rear diffuser, wheel arches, rear end and rear wing

Endurance Championship – it ran a Lola-Judd in 2012 and has a licence to use the Lotus brand in 2013 and 2014. This is why the the new LMP2 is branded Lotus instead of Adess or similar.

Early in the car's development, Chosse decided that the car would have to be a coupe instead of a roadster. There was also an eye on the future with the design of the monocoque. 'We had a few targets with the car,' he said. 'One of the first things we decided was to build the monocoque to the 2014 LMP1 technical regulations. Firstly because we want the car to be sold all over the place in a few years, so the monocoque has to be state-of-the-art. From a performance point of view we absolutely wanted to go for a closed car because LMP1 in the future will only be closed, and we think that in the medium term LMP2 will be the same.' The 2014 LMP1 regulations place the driver higher and further forward in the car and give the drivers greater visibility. The T128 is the first car to be built with a new specification monocoque. 'We have designed the tub with the view that it could be raced in LMP1 in the future, so we have designed a lot of adaptability into the tooling to allow us to go for the top class in future.'

Aerodynamic development was another one of the priorities of the Adess engineers. 'Another driver for a closed car was the aero,' explains Chosse. 'We have done a full aero programme with this car. With our common work with HRT we have taken the same approach with an F1-style programme. We have a wind tunnel model and extensive CFD work has been conducted.'

Wind tunnel development was conducted at 50 per cent scale using the commercially available wind tunnel at Mercedes GP in Brackley, England with a maximum air speed of 50m/s. The CFD development was conducted in-house using CD-adapco Star-CCM+.

The front end of the car is not dissimilar in concept to the Audi R18, with a high nose. 'We had a very close look at what the other manufacturers are doing. On these LMP cars you have basically two concepts with the splitter, a semi-open car like the Audi R18, or a closed car like the Oak Pescarolo. We did a lot of evaluation of this in the wind tunnel, but at some point in your development you have to take a route and decide what to do. We decided for a semi-open design,' says Chosse.

One of the main focuses for the car's design was making it useable for the amateur drivers, as it is hoped that the car will be sold to customers.

'One of the criteria during the programme was to make sure the car was safe and stable in high-speed corners, with a low ride height sensitivity,' Chosse continued. 'We took this approach because with gentleman drivers there is more time to gain than there is from a professional driver getting the ultimate pace. Our reference car was the Lola B08/80 coupe that the Kodewa team ran last year, but this car was a real blank sheet of paper. We have done very little comparison work with the Lola so far, but we plan to. At Le Mans we will have a real Le Mans aero kit on the car – the team takes that really seriously, but will show that there is a lot you can do within the cost cap.'

Under the 2014 rules, LMP2 cars must not sell for more than €440,000/$570,000 making it very difficult to make a profit from a highly developed car. Indeed Chosse explains that the priority with the T128 is initially not to

SOFTWARE SOLUTIONS

The engineers at Adess employed several HyperWorks tools in the T128 project, including HyperMesh, the meshing tool of the suite, to create finite element models; RADIOSS for linear and non-linear analysis, especially for crash test simulations of the front structure of the car; then HyperView to post-process the results.

'The bodywork panels of the car are made of lightweight carbon sandwich composites and it has a carbon composite monocoque as well,' said Stéphane Chosse, founder and CEO of Adess. 'Altair's HyperWorks suite is crucial in handling the crash event simulation of all safety-related parts to make sure that they meet all the crash and stiffness regulations, while keeping the car as light as possible. We are very satisfied with the results we get from HyperWorks and feel confident that it is the best solution to meet all of our engineering needs as well as external requirements. In addition we are also happy that we found a software provider who is an expert in the area of composite simulation.'

With the results achieved in the development of the T128 racing car, Adess is planning to continue working with Altair and HyperWorks on current and future projects including its 2014 F1 car design. It also intends to apply the optimisation tool OptiStruct to optimise composite parts to further improve the lightweight and stiffness characteristics of its racing cars.

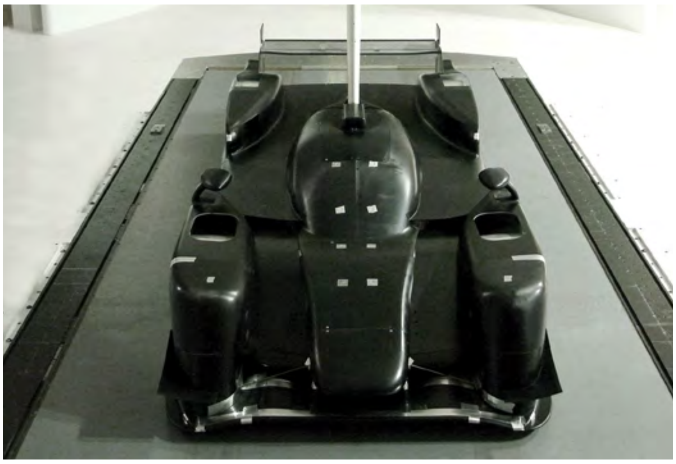
make a profit from selling cars, rather to show what it can do.

'The target of the project is to demonstrate the performance of the car,' he says. 'We are certain that the car will be competitive and this is a multi-year project. There is also the balance of performance, so we do not want to do anything stupid. So we are not developing the car for outright performance, but also to ensure that a gentleman driver feels comfortable in the car.'

The overall design of the T128 is a departure from what is normal in LMP2. Indeed, some in the WEC paddock have been overheard saying 'that is not a sportscar – it's a Formula 1 car', and they are not far from the truth. 'A lot of people working on the project have been involved with F1 very recently. I'm still involved personally,' says Chosse. 'On the Kodewa side of things, they've worked in F1 before too with HRT, Jordan, Spyker and Force India. When you have people like that, you end up with a lot of creativity and F1 inspiration. With the Toyota you will find the same approach.'

This F1 inspiration is immediately evident with the nose of the car removed. The tub has a raised nose with aerodynamic concepts that appear, visually at least, to come straight from the open wheel design textbook. Torsion bar front suspension, not seen on an LMP2 design since the Porsche RS Spyder, only adds to this.

'We went to torsion bar suspension at the front for reasons of performance,' says Chosse. 'Compared to our competitors our tub is much smaller and we have to package everything, so a torsion bar



Aerodynamic concepts appear to come from the open wheel design textbook. A full aero programme was undertaken, adopting an F1-style approach

was the right direction.' At the rear, torsion bars are not used but the suspension still has some single-seater design elements including a neat third element. 'It's not torsion bar suspension at the rear, though there is also clear F1 inspiration in this area,' he continues. 'We had great freedom at the rear as we did not use an off-the-shelf transmission. Instead we have a bespoke transmission from Hewland. It was very important to us that we did not just replicate what others had done – we wanted to go our own way. The car was developed in late 2012, so we wanted something more modern and we have made a big step in this area. It adds a lot of value to the car. A lot of attention went into keeping the weight down at the rear to achieve our target weight distribution. It is a magnesium case with an aluminium bell-housing. Although we have our own case, the off-the-shelf transmissions also have quite a range of pickup points, so it's not a great advantage in that respect, but with this transmission the pickup points are exactly where we want them.'

Powering the T128 is the Judd HK 3.6-litre V8, albeit wearing the branding of Czech firm Praga. 'The team last year had some difficulties with Judd last year, but decided to stand by them,' Chosse explains, 'We feel Judd is a very reliable partner and the team is very happy to have them with us. The regulations state that there must be two engine installations, so we integrated the NISMO engine as well as the Judd. The NISMO has very similar installation to the Judd HK.'

The two Kodewa-run T128s debuted at Silverstone for the opening round of the 2013 WEC. Things didn't run all that smoothly however, and neither car was classified, but the team is hopeful they'll be much stronger at Le Mans.

'Everything is new and that takes a lot of courage,' concludes Chosse. 'If you look at the rest of the LMP2 field, the cars are older with chassis dating back to 2006 and 2007 in some cases. This is a really nice product – I hope we can sell some. We want first to demonstrate its potential, then see a few customers next year.'

TECH SPEC

Lotus Type 128

Class: LMP2

Chassis: carbon fibre monocoque to LMP1 2014 regulations

Engine: Judd HK 3600cc N/A V8

Bodywork: carbon sandwich composite panels, quick release nose, rear diffuser, wheel arches, rear end and rear wing

Suspension: double wishbone front and rear with pushrod-actuated dampers

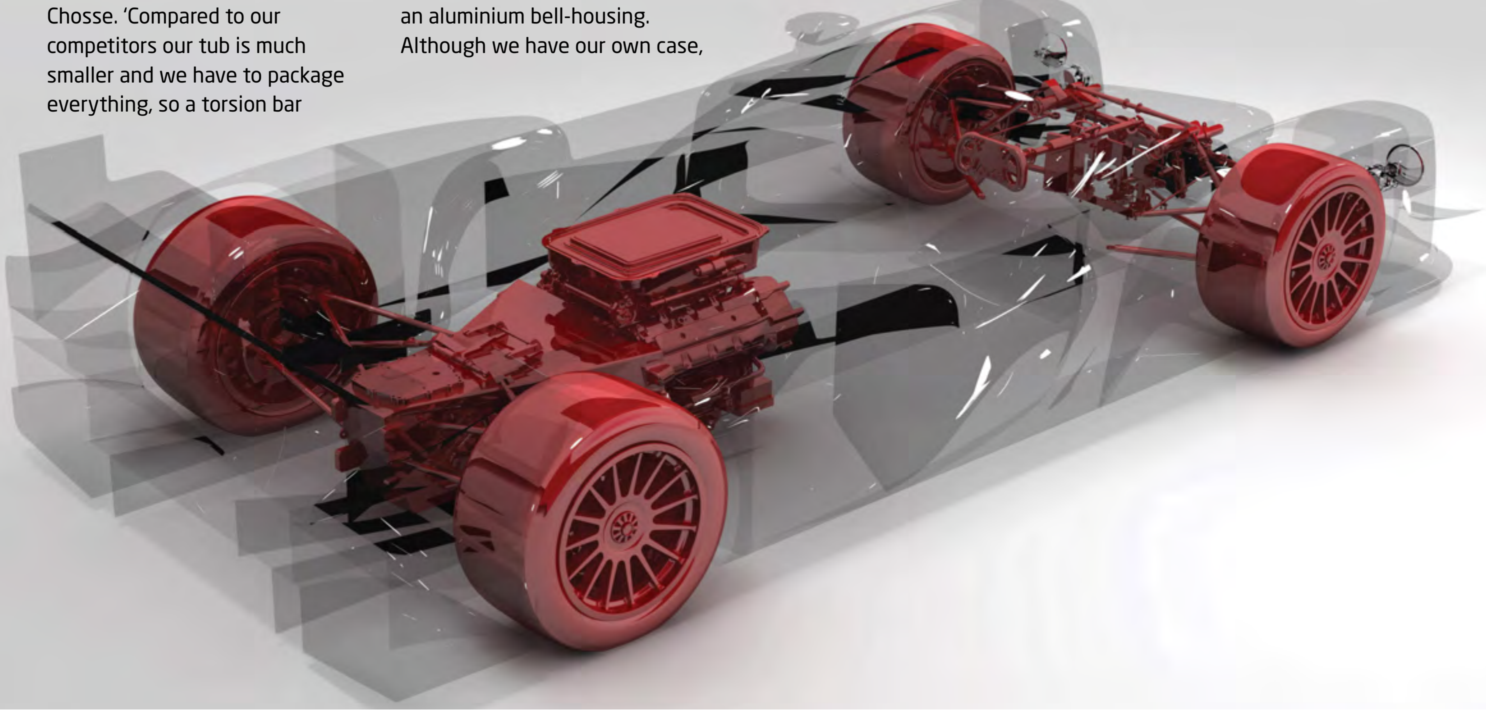
Transmission: Hewland TSLM 200 six-speed sequential

Brakes: Brembo carbon/carbon with aluminium caliper and in-cockpit quick balance adjuster

Steering: DC Electronics EPAS

Electronics: MoTeC EDL3, multifunction F1-style carbon fibre steering wheel with integrated LCD display

Fuel system: ATL tank with Stäubli refuelling valve, electronic lift pumps and catch tank



BoP buster

After a season of adjustments in the boardrooms of the rule-makers, Ferrari has taken steps to make its GTE car even better for 2013

BY ANDREW COTTON

The main update for the 458 is aerodynamic. The Ferrari has a wider front cross section compared to the Porsche, and has a lower top speed, which had to be increased without compromising fuel consumption

The GTE category is something of an enigma. It often provides the best racing in an endurance racing field, has the support of Ferrari, Porsche, Aston Martin, General Motors and BMW, with others waiting to join in, yet the ACO has long insisted that costs are rising out of control, and need to be curbed.

As the category goes through a process of adjustment, manufacturers are piling on the pressure to maintain the status quo. Porsche will this year develop the 991 in competition in the World Endurance Championship. In October 2012, General Motors unveiled the C7, which will eventually replace the C6, while in February, BMW unveiled the Z4 that replaces the old M3. McLaren will not race a GTE version of the MP4-12C this year, but there is little doubt that one is coming.

Ferrari, meanwhile, having produced a winning car in 2012 with its 458, victorious at Le Mans and in the WEC, has updated the 458 in 2013, with an emphasis on aerodynamic development to reduce the effect of having a wider nose than its rivals, and to negate a reduction in fuel tank size mid-way through 2012, placing the emphasis on fuel economy.

Timing is important – the FIA regulations permit one evolution per period of two years, rather than one per year, so Ferrari has to get this right in the face of increasing competition.

Ferrari's drivers have long felt that the balance of performance measures were working against them. Aston Martin, for example, did not have to run a Gurney flap at Le Mans, and ran with five litres more fuel, while the Ferrari's capacity was reduced by five litres, which took away its ability to do a six-hour race on fewer stops than the rest of the GTE pack, though the 458 was given a 15kg weight reduction. The 458, which features a direct injection engine, has worked on the electronics to improve fuel economy and try to get back some of the lost performance.

"The Ferrari's fuel tank was reduced by five litres, effectively taking away their ability to do a six-hour race on fewer stops"

Ferrari's drivers reported that the Porsche, with its faster speed on the straights, was able to reach the braking zone ahead of the LMP2s more easily than the Italian factory's cars

At the rear, the bumper has been redesigned to improve the extraction of the air and to make the diffuser more efficient. The wing now has a different profile and features the mandatory 25mm Gurney flap

During 2012, Ferrari drivers complained that their cornering speed, a strength over their rivals with a mid-engine layout compared to the front-engine for the BMW, Corvette and Aston Martin, was being compromised by the LMP2 cars, which could more easily pass just ahead of the braking areas, but badly driven ones were slower in the corners and tripped up the 458s.

The FIA changed the bodywork regulations for 2012, and increased the permitted width of the GTE cars by 15cm across the front wheel arch to accommodate a larger front tyre, and also increased the size of the rear wheel arches. The overall width, not including the rear-view mirrors, is 205cm, which was not necessarily a bonus for the Ferrari, which already had a larger snout than the Porsche or Aston Martin, and consequently had an aero disadvantage. The aero work was aimed at making the car more stable, less sensitive to the variation of the ground clearance to take maximum advantage of its already very good downforce.

In order to reduce the drag, Ferrari has redesigned the bumper, which is now closed immediately over the splitter. The splitter has also been redesigned, a second dive plane has been added to each side, the openings of the bonnet have been reduced, while the wheel arches are more rounded.

In order to make the car less sensitive to the variation of the ground clearance, a small channel has been opened up on the central lower part of the front bumper (in the middle of the splitter), which reduces the pitch sensitivity. For the same reason, the suspension has been slightly modified, but the geometry is unchanged.

At the rear, the bumper has been also redesigned to improve the extraction of the air and to make the diffuser more efficient. The wing has a different profile and features the mandatory 25mm Gurney flap.

The new contender

Aston Martin's updated GTE entry has rivals worried

The new GTE model features brand new side sills, added to counter the problem of having the exhaust running down the side of the car

The new GTE challenger from Aston Martin launched in London in February, and the car raced for the first time in the opening round of the American Le Mans Series at Sebring in March. It was immediately impressive.

Under managing director and team principal at Aston Martin Racing, John Gaw, the team has changed upwards of 30 per cent of the car to make it more driveable, and faster.

One of the main issues with the car last year was the speed at which it reached its V-max on the long straights of Le Mans, Shanghai and Fuji. It was allowed to run at Le Mans without a Gurney flap, had a larger fuel tank and less weight than its rivals, all measures that the new car has been allowed to keep.

Yet it still is a draggy car, despite a new rear wing that has been introduced throughout the GTE field. The Aston runs this year with a minimum weight of 1205kg, five lighter than the Porsche 991 and 55kg lighter than the BMW Z4 that races in the ALMS only. It has a larger air restrictor, at 29.7mm, 1.4mm larger than the Ferrari 458, runs at Le Mans without a Gurney, and it carries10 litres more than the Ferrari, five more than the rest of the contenders in the GTE field with a 95-litre tank.

Since 2011, the car has also been given a performance waiver, and runs 5mm lower than the other GTE contenders.

The Prodrive team has modified the suspension, and taken weight out of the car (although the BoP adjustments means that it runs 10kg heavier than last year), making the car more driveable in the corners. 'It is not a good aero car, which is why the air restrictor is bigger, and then we use more fuel,' says Gaw. 'It is a torquey engine so we are good out of the corners.'

The side sills are new, due to the problems of running the exhaust down the side of the car and having a body made from aluminium, a metal that is very good at conducting heat.

'Last year we proved how fast and reliable the car was, and our two GTE Am entries will pick up where the Pro car finished with victory in Shanghai last year,' added Gaw.

'Overall, around 30 per cent of all components on the 2013-spec Pro cars are new, which makes for a significant improvement. We looked at specific areas where we could take weight out of the car and redistribute it to a better location. We have also revised the suspension, which has not only improved the handling but – when combined with the new fly-by-wire throttle allowed under this year's regulations – makes the car easier to drive.

'Our aim is to win at Le Mans and in the WEC, and we are particularly pleased to welcome such a professional driver lineup to Aston Martin Racing for this centenary year.'

NO FRILLS, NO FUSS, JUST RACING

BY SAM COLLINS

Greaves Motorsport is one of those organisations that tends to get overlooked, but it is rapidly becoming a major player in international sportscar racing. Its roots can be traced back to club racing in the UK. Entrepreneur and amateur racer Tim Greaves acquired one of the first Radical Sportscars ever built, which he campaigned in the 750 Motor Club Sports 2000 series in 1998.

Greaves saw the potential of the fledgling racecar constructor and invested in the company. That injection of cash enabled it to grow into what is now one of the worlds biggest manufacturers of racing cars, with well over 1,000 vehicles built in 15 years. The majority of those cars were for amateur racers and Greaves wanted to take the brand to the next level, giving those club racers the ultimate goal to aspire to; Le Mans. The company engaged Peter Elleray to design the Radical SR9, hoping that he would be able to repeat the success of his earlier creation, the 2003 Le Mans winning Bentley. It finished Le Mans at the first attempt.

Greaves Motorsport (then known as Team Bruichladdich Radical) made its début in international motorsport during 2006. The team acquired the chassis SR9-002 in mid season and then ran a limited campaign in the 2006 Le Mans Series plus the final round of the American Le Mans Series at Monterey. The car was powered by an in-line 4 cylinder AER 1995cc turbo and ran on Dunlop tyres.

The Radical was retired from duty at the beginning of 2010, Greaves had disposed of his holding in the company, and changes to the technical regulations had made the pre cost cap SR9 uncompetitive. The project was mothballed while Greaves retained the rights to the design. The newly renamed Greaves Motorsport acquired a brace of new Zytek 07S chassis.

Despite winning at Le Mans in 2011 and picking up the Le Mans Series title in the same year, people tend to forget about team. That, I thought, was a little unfair, but I knew little about the outfit myself, so shadowed them throughout the 2013 RAC Tourist Trophy meeting at Silverstone.

As seems to be the way with everything in the team the garage was neat, functional, efficient and effective. It's perhaps a good

Greaves 3D Engineering has developed its own range of garage and pit equipment. The kit will be used by Aston Martin, and others, at Le Mans, in the WEC, and other racing series

metaphor for this team. That's not to say it was basic; via its partner company Greaves 3D engineering, the team has developed its own range of garage and pitlane equipment. The kit will be used by the works Aston Martin at Le Mans this year.

Perhaps it is because of the team's background, but this is a proper engineer's team, which has some big ambitions, even though it does not shout about them. I was surprised to find Sergio Rinland in the garage at Silverstone. The team was running both of its cars that weekend, one in the six-hour Tourist Trophy race, and the other in the three-hour ELMS event, both with the same driver line up. Rinland was focussed on the ELMS car while the team's regular engineer looked after the car running in the TT. But with both being identical the team found itself shuttling between Silverstone's two distant pit complexes. A far from ideal scenario, but with each race having separate practice sessions it allowed the team to run it as one continuous test. A pragmatic approach, which I later discovered was typical for the team.

I noted with interest that the engineers manually entered data for each lap the car completed on track, despite the fact that Cosworth's software (run on the Greaves car) can do this automatically. It is a method that the team believes helps to understand what the car is doing. It is important for engineers in the LMP2 class to understand the car themselvesas by regulation they have to run at least one amateur in the car, so they cannot rely on the same quality of driver feedback as you would find in LMP1 or in the GTE-Pro category.

I noted that the engineers manually entered data for each lap the car completed on track to help their understanding

Greaves has not only developed its own pit equipment, it had also been quietly developing the car itself, when I saw the images of the cars shake down ahead of the Le Mans test day it was immediately apparent that the front of the car had been redesigned. It seems to me that Greaves drove the update of the car, rather than Zytek. That desire to develop a car in-house makes the team an ideal partner for a manufacturer of the new breed of LMP's that are being introduced next year. What will the team do? Nobody is saying yet. But first there is the small matter of the Le Mans 24 hours this year. Greaves probably has the best driver line up in the class but has as usual been largely overlooked, but they are quietly hoping to change this by 3pm on Sunday 23rd June.

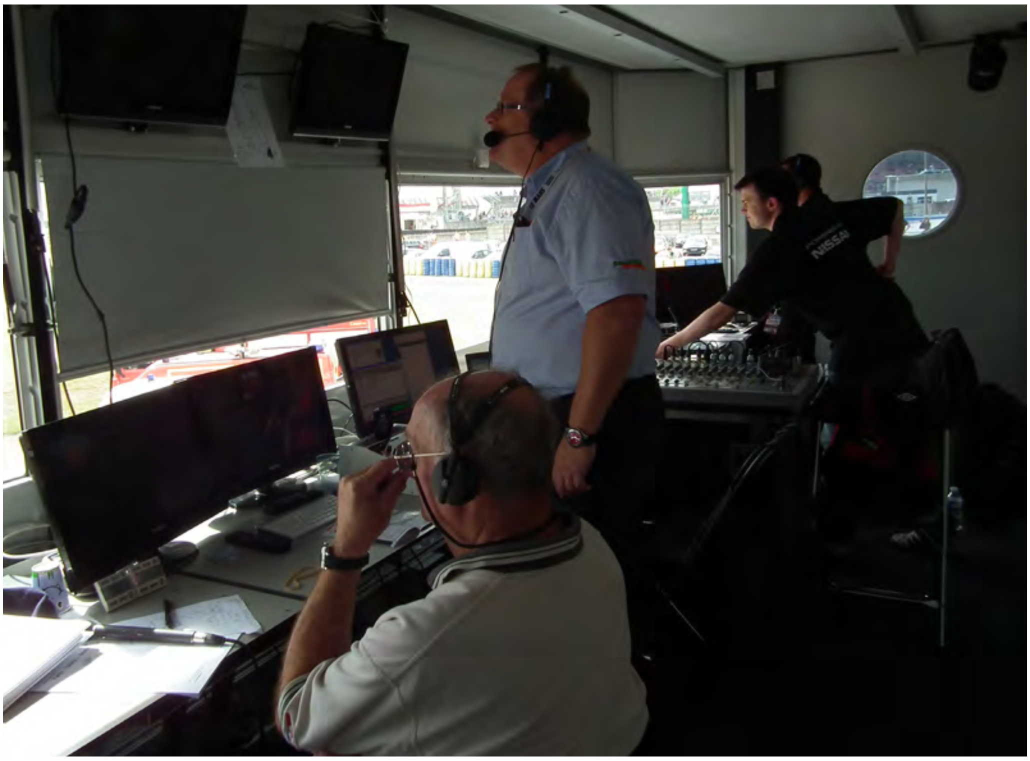
It's not JUST Radio Le Mans

The world's greatest race, once a year, one week, one radio station, how hard can it be? Even if it was *just* Le Mans, Radio Show Limited produce over 50 hours of live broadcasting that in 2012 attracted over six and a half million visits to the www.radiolemans.com website.

The truth is, of course, that Le Mans 24 hour is the jewel in the crown of the endurance year. However, as far as RSL is concerned, it is complimented by smaller but no less sparkling gems throughout the season.

Many Le Mans fans don't realise that the same team that put together their favourite radio station at La Sarthe are on duty at other events, all broadcast live and free at Radiolemans.com, on FM at the tracks, and often on broadcast TV and streaming video too.

In 2012, Radio Show Limited covered five 24-hour races, one 12-hour, seven 6-hour races, plus 50 two-hour weekly shows, adding up to around 300 hours of live broadcasting from eight countries on four continents. Already in 2013, the same voices you fall asleep to at Le Mans have covered events in Dubai (Dunlop 24 hours), Australia (Liqui-Moly 12 hours), USA (Rolex 24 hours), Italy (Imola 6 hours), Germany (Nurburgring 24 hours), Belgium (Spa 6 hours), UK (Silverstone 6 hours, two hours of British GT), and a mere eight hours of Le Mans test day where RSL were the only live broadcasters.



Broadcasting from the studio is a dedicated team of professionals, joined once again by Racecar's Sam Collins

So why is the RSL team so much in demand? Clearly the passion, enthusiasm and knowledge of the presenters are very important. But beyond that, Radio Show Limited are the world experts in producing 'integrated broadcast solutions' suitable for use in multiple media outlets. At the 24-hour races in Dubai and Daytona, the team were broadcasting simultaneously as international live TV sound, local and global Internet radio and the track PA. Combined with significant cost savings over setting up several different operations, broadcasting this way provides a continuity of message for the event and sponsors that cannot be delivered any other way.

Radio Show Limited are the world experts in producing 'integrated broadcast solutions'

Underlining the relevance of RSL strategy, the FIA World Endurance Championship has appointed Radio Show Limited as their Global Audio Partner and official English language broadcaster. In addition to the trademark live Radio coverage via Radiolemans.com, interfacing with the TV production company to provide International TV sound, feeds to WEC partner Internet TV services, local and track radio and PA, is a technical challenge that has become an every-day requirement for the team.

The event and sponsors get access to a huge global audience on Radiolemans.com, TV companies get informed commentary originating trackside and the endurance racing fans get coverage from people who are immersed in the sport. Top quality coverage, FREE to the listener (or Internet viewer), with no geo-blocking on the audio, is still the absolute commitment of Radio Show Limited.

So whether you are a first timer or a seasoned veteran, listen to Radiolemans.com outside of June. We think you will like it.

The holy grail...

The year is 2002, and our hero is working for the Pescarolo team at the Le Mans 24 hours, following his ambition to win the great race. Ill-equipped to take on the teutonic might of Audi, he resorts to great tubs of lard, and coffee, to pursue his impossible dream...

It being June, one has found oneself at Le Mans, as one does, and to the obvious question; 'why go to a relatively small town on the plains south of Paris, and subject oneself to unremitting lack of sleep, noise and the almost obligatory consumption of rillettes; Le Mans' other claim to culinary fame, for almost a week ... I can give only one justification -Because it's There...

After the late fray at Sushi Gulf when Hondas and Toyotas were my incubi, going to France brings the novelty of competing against Audi, the modern day Teutonic juggernaut, which operates on the principle of 'why do something subtly when you can bludgeon it to death?'

No fault of theirs that they are more than adequately funded but a bit disheartening for the other competitors and as Marx (Groucho) used to say, 'Glory is directly proportional to the might of your opponent.' Or would have said if he knew I might quote him. Never mind, I digress.

Tuesday

Arriving at Le Mans on Tuesday to catch up with team and see our major bodywork evolution; was a bit disturbed to find out only wind tunnel work on car had been at full-scale St Cyr, with no boundary layer control or moving belt, and no figures for fuel consumption either. A bit of an oversight, as pit stop tactics rather important for long distance racing, and so prepared to jump into qualifying on Wednesday and Thursday.

Renewed acquaintance with rillettes, which can only be compared to small bits of meat (pork or beef? We might never know), shredded, probably by dropping pig, or calf into 50 gallon drum and tossing a couple of hand grenades in together, and afterwards slopping in (I use the word advisedly) 20 gallons of melted lard.... No wonder you will find no mention of rillettes in the Guide Michelin ...

Wednesday

In qualifying I was a bit bemused to find car barely reaching 308 kph on straight, rather slower than last year's 324kph.

I know we were supposed to have gained a couple of horsepower but not to that amount; it seemed to me we had done a bit of reverse engineering, and handling as well as a ripe pumpkin to boot.

Worst case scenario exceeded by a mile as at stroke of midnight when practice ended found our pumpkins were 19th and 22nd on grid, 19 seconds behind pole.

To further sweeten my day, I still had to drive from Le Mans to Jouet to be up at 9am to go to dentist and fit new crown, not a very cheering prospect as pain loomed on horizon. Trip accomplished in new record time of two hours and 18 mins. It's incredible how rental cars are faster than personal cars, and immune to valve bounce.

Thursday

Trip back to Le Mans at midday taking a ponderous 4hrs, 30mins, courtesy of playing chicken with EuroTransport forty-tonners and escargot-like county bumpkins driving on narrow back roads.

A remarkable number of said bumpkins and Euro Truckers seemed to know me, as they waved fists and flashed lights cheerfully as I went by.

Definitely not very gruntled on arrival, but at end of second practice had improved time by 11 seconds, and first car in team, but still 17th on grid, mmm... maybe time to go back to drawing board (really and truly, this car had never sullied a CAD screen in its present incarnation.)

Meanwhile having brought along 40X zoom 4.2megapixel digital camera to take photographs of details on cars I found delightful side effect of being able to photograph unsuspecting females from the south side at incredible amounts

of magnification, and discovering two unpalatable truths of photography: 1. Very difficult to focus on gluteus globes in crowd as innocent bystanders keep getting in the way and 2. Very disappointing to discover most of the Hawaiian Tropic girls have cellulitis. I now understand the need for PhotoShop.

Having a monk-like dedication to my chosen calling, the lack of pulchritude in the paddock would not distract me.

Friday

Friday spent in getting cars ready for race, and of course consuming some more rillettes, found aftertaste could not be erased even by bad espresso, and in sudden flash of brilliance akin to Paul's illumination on road to Damascus decided did not need to eat rillete sandwiches, despite a lard dependency acquired during previous days.

Work finished at 1am. Let's see, three hours sleep on Wednesday, four hours on Thursday, will have to get up at 6am on Saturday as warm-up at 8, and then race starts at 4 and goes on for 24 hours, and leave for Tokyo Monday afternoon... and then Kuala Lumpur Wednesday morning (note, after visit to Rillettes Anonymous, go by psychiatrist and check sanity. Is lard A MIND WARPING SUBSTANCE?)

Saturday, RACE DAY

We of course had a slightly less ambitious plan, soldiering on sedately and surprised to find race pace as fast as qualifying laps, had un-reverse engineered car enough to gradually creep up lap-charts to find ourselves in top ten after sundry cars fell foul to gravel, punctures, bodily contact with gaggle of Porsche GT3s.

Felt distinctly in 'vulture mode' as carcasses of faster cars littered landscape, awwwrk, he said, flapping wings...

Also quite sure holed piston problem we had in simulation would not repeat, as fuel consumption showed Sodemo had taken the safe route and were cooling piston crowns with fuel. Oh well, at least the photographers would have some spectacular shots, what with the metre long flames on overrun, but 12 lap stints max...

Of course, such happiness was fatal, as flat bottom started detaching around midnight, prompting one hour and 8 minute pit-stop to change floor and re-design whole attachment system on car #7 (Bourdais, Lagorce and Bouillon), now down to 29th, whilst Ortelli/Helary/Katayama #18 lapped serenely into 11th.

But, wait, dear reader, will our heroes trundle on during this late-spring velvety night with no problems?

Of course not! The great god Murphy will not be denied! Before halfway 4am witching hour sudden cry from telemetry suggested all was not well, alas left-hand bank camshafts had decided to go their own way, having taken the high road.

Quick radio message suggested to Helary to park car pronto, as engine was coughing up blood. Do not pass go, do not collect $200.

Much to our surprise, we noticed dot representing car on telemetry around Mulsanne, when we thought car parked at start of straight, even more surprised when car swung into pits, emitting what driver described as "un bruit infernal mechanique..." quickly called in priest for last rites, and wagged finger at driver, remembering a misquote by PT Barnum viz. 'It is impossible to underestimate a driver's intelligence...'

Did not make many friends in paddock either as the oil slick from start of Mulsanne Straight ended right in our pits. It didn't need a triple digit IQ to deduce who was responsible for 12 lap safety car whilst ACO minions scattered cement dust like grooms at a Mafia secret funeral...

Rest of race a bit of an anti-climax, quietly finished 10th a couple of laps adrift of 9th and a couple of laps ahead of 11th. Thankfully the press were agog at Teutonic steamroller and mourning demise of MG's and Bentley gallantly (their description...) finishing 4th and not noticing our discomfiture, specially as Oreca Dallara-Judd finished 5th (Erik Comas)& 6th, thus assuaging Gallic press...

And so to home, feeling severe lard withdrawal symptoms, now also compounded with caffeine poisoning... good thing the '60s had hardened me to multi-drug use....

Rest of day and following morning spent in zombie-like state.. until embarking on trip to Tokyo.... My god, twelve hours without lard!! Would I find a lard dealer in Tokyo?....

Worse still, drug smugglers face the death penalty in Malaysia, so definitely no rilletes in Malaysia. Nothing but to go cold turkey

Tuesday

Not amused to find day cold and drizzly, 16 deg, definite let-down after Paris at 35 and 200% humidity (OK I exaggerate a bit...), went through usual motions and found myself at office by 4pm, found everybody at same desks, wondered briefly if, workaholic as they are, they had not moved since my departure.

Brief pang of longing for lard, wandered upstairs to workshop, greeted by mechanics with brief rendition of Spam, Spam, Spam, and reassured by them that despite Mizuki-san's refusal to get involved with paperwork required to transport espresso machine to Malaysia, they had smuggled said machine in car. Bliss, also meant would not have to find lard dealer in Kuala Lumpur, as can get caffeine fix...

Cars had left by sea two weeks before, but still managed to stagger on at work till 11pm; papers had been breeding on my desk, ruthlessly cut through foot-deep stack still there by 22h50 by dipping whole lot into shredder, in assumption that anything important would turn up again. On arrival at flat scrabbled to prepare suitcase with team gear for Sepang and snoring by 1am. Awake at 5am, zombied under shower and went to station to catch Narita express and flight to Kuala Lumpur.

Flight a blur, 9 hours just whizzed by as still comatose,

not to speak of lack of lard stimulant... obviously not a day to practice neurosurgery.

Felt briefly murderous as stewardess woke me up so as to put seatback in upright position, some sort of weird fetish they have, apparently the landing gear cannot extend if seats are not in upright position.

Weather; hot, humid and overcast. Everything going well until Nemesis struck again, major disaster, coffee machine installed, mineral water acquired, but NO COFFEE POWDER, not available around track, as track tacked on to side of international airport, as was hotel we were in, but nothing else.

Coffee machine at hotel (reasonable espresso, 3.5 out of 5 score) fed with beans, which it then ground in situ for tincture... not usable by my machine....

Mizuki-san dispatched on search mission and came back with Nescafe. The horror! Qualifying looming up and no coffee.... No lard either.... Such are the results of American imperialism, land where non-alcoholic beer and de-caffeinated coffee originated, rather think they will come a cropper when trying to introduce aspartame flavoured sweet-and-sour low cholesterol pork in China.

Next morning we were only car to use both sets of tyres in morning qualifying sessions, as judged afternoon was going to be too hot, but Eric made uncharacteristic mistake on second set at last corner (poor chap, also in caffeine deprivation, but being French, OK in the lard department).

At race start discovered we had forgotten to take giant magnet from front of car, said magnet working mysteriously only on Hondas, Eric managing to clout two Hondas at first corner emerging out of corner in fourth place, and although couldn't match lead Honda's pace merrily motored slowly reeling in third place Michelin-shod Toyota.

Sun reflection shining on glass-fronted pits started burning back of knees, and no lard to rub on scorched skin, making proposed day off at the pool on Monday a perilous affair.

Galileo was right; the earth does move around the sun, this was uncontrovertibly proven when after being very canny and having got out of sun and sheltered under pool parasol from 11am onwards, promptly fell asleep, and the dastardly earth spun around its axis, therefore exposing my left leg (only) to the sun.

After pit stop, Masami continued run, but after a bit of a spurt in opening laps was in second place, placing us in a bit of a quandary as that would involve getting 30 kgs of success ballast, and no way we would catch leading Honda despite Honda magnet on nose of car, and also noting after spurt car was beginning to oversteer a bit, allowing Michelin Toyota, which had disposed of Bridge Toy we had overtaken a couple of laps earlier, to start catching us at 0.6 seconds a lap. He would not be a problem as we knew from long runs that it would fade quickly, maybe even needing an extra pit-stop.

My suspicion was quickly confirmed, as check of inventory showed Toyota magnet not in pits, only place it could be was in car boot, this of course led to Toyota being irresistibly drawn towards us, and of course, a slight brake test by Masami ended in tears; he not being aware of magnet, so backwards into gravel trap with a bobtailed Skyline, now a couple of dozen centimetres shorter...

Restarted from gravel trap, but with missing left rear fender and rear wing leaning to one side and a fuel leak you could file under major; got promptly on radio and suggested to Masami he'd better park it quick if he intended to go back to Japan only with sunburns.

Meanwhile Satoshi kept on motoring and duly arrived 4th, leaving us with respectively 16 and 18 points, leading Honda now at 43, and with 4 races to go championship prospects now very dim; I blame it of course on the lack of coffee, and am sure lard could have helped us also, but there you go.

So there we are dear friends. I then arrived at Tokyo to see unnerving sight of thousands of Japanese wearing Brazilian football team regalia...it being World Cup time. Despite it all, I considered this last to be surreal..

RICARDO'S RECIPE DE JOUR

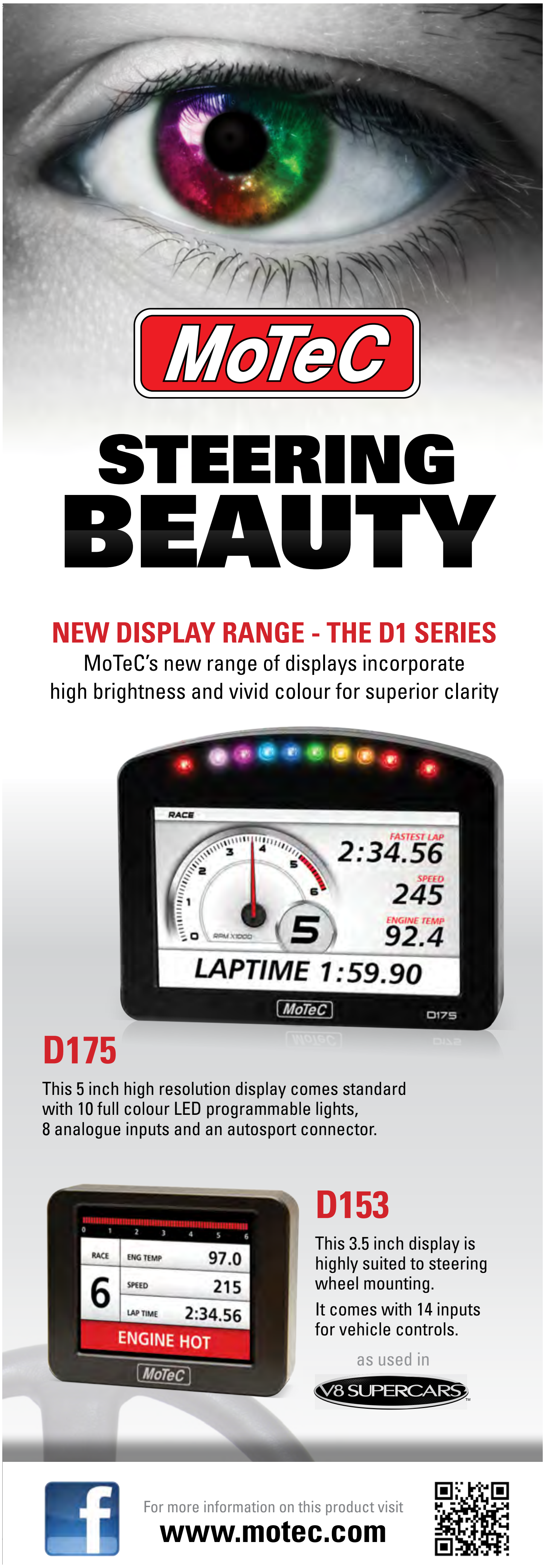
to the might of your opponent." Or would have said if he knew I might quote him...(*)

RILLETTES

A kind of pâté made from meat, such as pork, rabbit, goose or duck, which is cooked in seasoned lard, then shredded and pounded to a smooth paste. The paste is then packed into a terrine or into ramekins and served as a cold hors d'oeuvre, to be spread onto toast or bread.

LARD

Lard is pig fat in both its rendered and unrendered forms. Lard was commonly used in many cuisines as a cooking fat or shortening, or as a spread similar to butter. Its use in contemporary cuisine has diminished; however, many contemporary cooks and bakers favor it over other fats for select uses. The culinary qualities of lard vary somewhat depending on the part of the pig from which the fat was taken and how the lard was processed.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