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M-powered

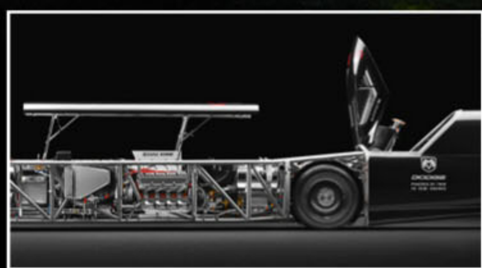
Controversial M8 brings BMW back to Le Mans

BRM's H16 folly

Why one of F1's most radical engines was a big time flop

Mazda RT24-P

Under the skin of dramatically updated Daytona prototype



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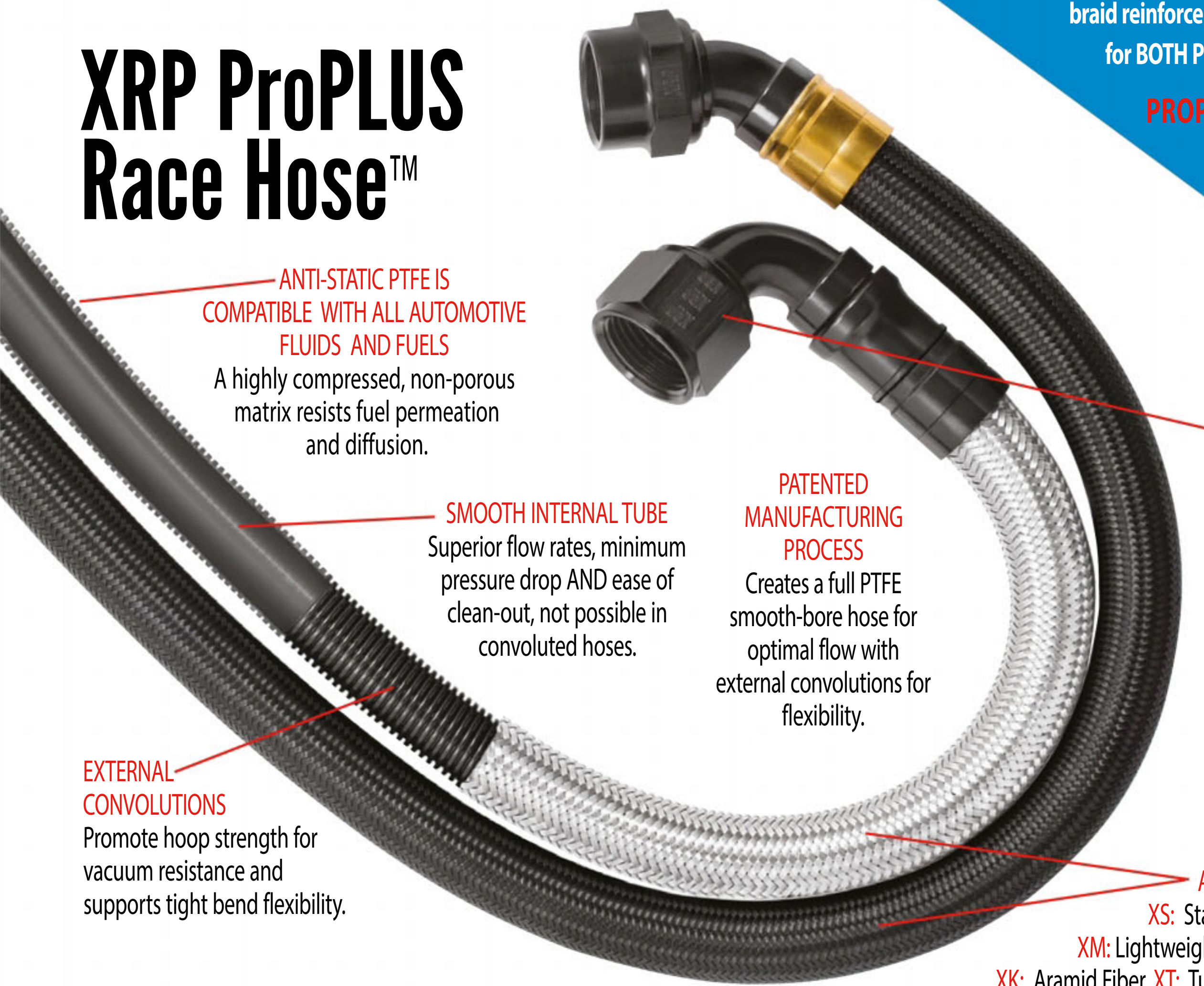

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You know the motorsport year has well and truly started when spectacular shots from the Dakar start to appear. This year Peugeot won, while BMW Mini (one of which is pictured here) could do no better than fifth

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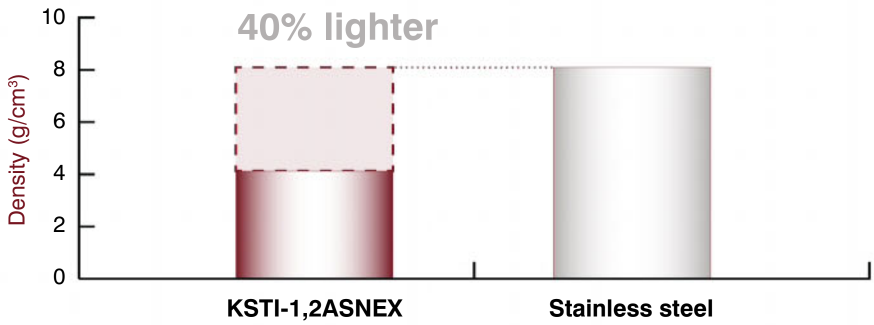
Typical Analysis

	H_2 (ppm)	0(%)	N_2 (%)	Fe (%)	C (%)	Si (%)	Al (%)	Nb (%)	Ti
Min.						0,30	0,30	0,10	
Max.	13	0,15	0.05	0,20	0,08	0,60	0,70	0,30	bal

Typical mechanical properties:

Tensile strength :	(N/mm)	min : 340
0,2 % yield strength:	(N/mm)	min : 215
Elongation:	(%)	min : 23

General Characteristics



Oxydation resistance in comparison to Titanium Grade 2

KSRI-1,2ASNEX
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Gr.2 pure Titanium
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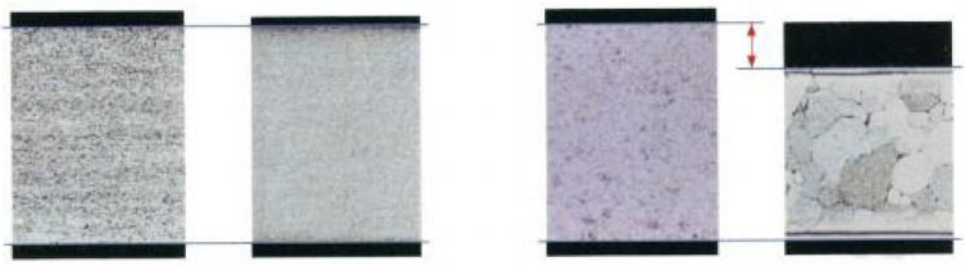
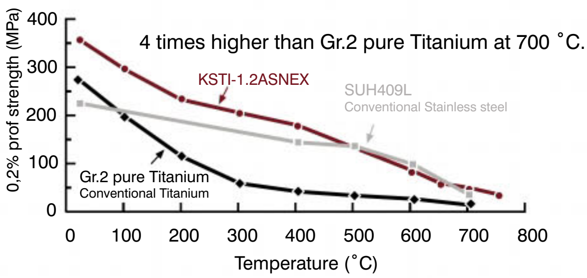
because of exfoliation of oxide scale



Before test   After 10 hrs at 800 ˚C   Before test   After 10 hrs at 800 ˚C

0,2% Yield strengh at higher temperature

(comparison Stainless Steel and Titanium Grade 2)

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Creative industry

Our columnist remembers some of the great F1 designers he has worked with

In last month's edition (V28N2) I marked 60 years in motorsport – my first event was the Sao Paulo Grand Prix at the end of 1957 – with a trip down memory pit-lane, recalling some of the great names and huge characters among the racing drivers I've worked with and known. This month, let's remember some of the great designers (and a team owner) who are no longer with us, that I've had the pleasure of working with and knowing.

Jumping past Colin Chapman, who has had enough written about him to make any story superfluous, the other huge influence for me was Guy Ligier, who caused me to end up living in France permanently after coming to work at the Ligier factory at Magny Cours. An ex-F1 driver who used to race Cooper Maseratis, he garnered unflinching loyalty from his team and was the embodiment of the 100 per cent racer.

He was French rowing champion in 1947 and played rugby at a high level – good enough to be in the France B team. When his rugby career ended he switched to racing, but on motorcycles, winning the French championship in the 500cc class on a Norton Manx LA in both 1959 and 1960, before moving up to car racing.

He also had a volcanic temper. A good example of this was at Hockenheim in 1989, when after qualifying on the fifth row and looking good for the race, our driver did about six practice starts on the way to the grid, with the result that the car was left stranded at the pukka start because the aluminium clutch hub had melted.

Swearing colourfully, Ligier then grabbed the design team and management, leaving only the truckies to look after the other car, and he drove us flat-out from the track back to base. Most of this journey I spent cowering in the front passenger seat, one of the most hair-raising experiences I have had on the road. We made it, but I still don't understand how. Ligier, which he set up and ran until his death at 85, attests to his passion for racing. It is still building cars. My hero, hugely larger than life. They don't make them like that anymore.

Grand designers

Of the designers, good friend Gerard Ducarouge looms large in my memory. A civilized gentleman, we used to have tea in my garden listening to Mozart on his return from the UK in the Lotus days.

I also remember Maurice Philippe fondly. He had a vast repository of stories from Lotus and De Havilland, designed his first car in 1955, called the MPS (Maurice Philippe Special) while employed developing the Comet 4 aeroplane. We both had our first love for aircraft and spent far too much time talking about planes rather than working on cars.

The good doctor

Then there was Harvey Postlethwaite – a genial organiser of teams with a knack of generating friends. After several years working with me at Fittipaldi Automotive he was head-hunted by Ferrari in 1981, where he did a version of our F8 model, so close that we used to call it the red Fittipaldi AKA the 126C2 (1982). It is amusing to think that Adrian Newey should have some of the kudos for Ferrari's 1982 Constructors' championship as a lot of the 126C2 aero was derived from his work on the F8D. The Doc, as Postlethwaite was known, gave Newey his first job after I had looked at Adrian's CV and pestered him into hiring him, even though he would take over my wind tunnel and aero duties. The kid was really good, as it has turned out.

XPB

Adrian Newey studies the Ferrari in 2012. Our man reveals that Newey actually had an influence on another Maranello F1 car 20 years earlier

I had a direct line from Reading to Maranello, when all the development we were doing on the F8D were often discussed with Postlethwaite as we had no pretension of beating the Scuderia with the state of our finances.

A stay at his house in 1983 whilst attending a Formula 2 race at Imola led to a visit to Maranello in the dead of night, at which point the sheer scale of what Ferrari had in facilities and equipment – a private test track behind the workshop, its own in-house foundry and a drawing office with 40 drafting boards at each side of the marble-floored room at a time when most of the British teams had around 80 people in total – led to me asking the very difficult question: 'Why didn't Ferrari win every race and every championship?'

To which 'Il Buon Harvey' would do a recap, in good Italian, of a Monday race debrief at the Ferrari factory, the loose and short translation of which would be 'politics, internal'.

The Buon Harvey name in Italian came from the racing team, who loved him. Reportedly, they were so incensed when he was replaced at the track by John Barnard – and the subsequent banning of the Lambrusco at lunch which came with this – that it led to a mysterious lack of performance and reliability of the red cars until he was brought back.

As a devoted fan of the local wine with my pasta, I cannot see Harvey approving of the 'great paddock drought of 1983'.

English Gardner

Derek Gardner is another I remember well. When we were having problems with the gearboxes in the BTCC Super Touring Nissan Primera he was brought in to sort out the issues. He was an acknowledged advanced transmission specialist and had arrived in Formula 1 whilst working for Harry Ferguson Research, designing the four-wheel-drive system for the Matra in 1969.

Always the perfect English gentleman, he would come down to the shop with his three-piece suit and tie with lovely cursive script design analysis, maintaining that a front-wheel-drive was not the way to go.

This resulted in a bet and when we beat the four-wheel-drive Audi in a race in 1998, he posed with a baseball cap with the brim turned backwards, one of my prized memories and prominently displayed on my 'I love myself' wall. I had the honour of working on some details of one of his projects, the Thomas Morse flyer SC4, a WWI three-quarter scale ultra-light plane that he built.

There are so many memories, not nearly enough space. And we have not even talked about Len Terry, Allan 'Mad dog' McCall and all the mechanics and crew members that have passed on, too.

It is the men who end up leaving me with my best memories of motor racing, not the racecars. Which is only right and proper.

The sheer scale of what Ferrari had in facilities and equipment led me to ask the difficult question: why didn't it win every championship and race?

The **vast** and the **furious**

BMW has had to jump through a few regulatory hoops but its rather large and quite controversial M8 GTE is now fully sorted and ready to race. *Racecar* traces its troubled development

By ANDREW COTTON

You can always rely on BMW to be different and while its rivals campaign regular sports and GT cars its GTE weapon of choice is the gargantuan M8

BMW's history with endurance racing has been somewhat chequered in the last 20 years in that, while it won the 1999 Le Mans 24 hours overall with the V12 LMR, one of the best-looking prototype racecars the world has seen, in GT racing the picture has been more complex.

From the M3 GT2, featuring a 4-litre V8 engine which did not exist in true production form, to its new car, the M8, which is based on the 7 Series executive saloon, the firm has often not had a car that fits with the traditional GT philosophy along the same lines as Ferrari, Porsche, Aston Martin or Corvette, with their sportscar derived racers. So it has consistently required the agreement of rival manufacturers to be given waivers to race – and the brand new M8 GTE is no exception.

Unveiled in road car spec at the Frankfurt Show in October, 2017, the base car for BMW's new racer is huge. But that size has almost proven to be its undoing, as major changes were required to the racecar, demanded by the FIA and the ACO after consultation with rival manufacturers, before it could even start to consider balancing its performance against its sportscar-fielding rivals.

By that October launch, of course, the car had already undergone some extensive test and development work, starting in early July at Germany's Dingolfing test track. There were some issues early on in the testing, with the flat crank engine causing vibrations that needed to be solved before proper testing could begin in earnest, but the biggest challenge, as usual, came from BMW's competitors, who were required to agree to the base concept. They left it as late as possible to do so, and cost BMW an estimated four months of development time.

The programme for the M8 is as large as the car itself. Two cars are entered into the full IMSA WeatherTech Sportscar Championship that started in January at Daytona, Florida, and there is a two-car entry in the FIA World Endurance Championship's so-called 'Super Season', that starts in May at Spa and runs through to the Le Mans 24-hours, 2019.

The four months of lost time put the team under immense pressure, and perhaps compromised the ultimate set-up for the car

The engine is based on the 4.4-litre unit that saw service in the M6 GTLM car last season, but capacity has been cut to 4 litres while BMW has also adopted a twin-turbo layout

There is some carry-over from the M6 GTLM that has previously run in both GT3 and GTE trim in the States, but much of the car is new. The engine, for example, is based on the 4.4-litre unit used last season in the M6, but with reduced capacity to four litres with a twin turbo layout. That meant that the company had to abandon its much-vaunted claim that 95 per cent of the race engine featured production car parts, and instead build a race-spec unit.

'Overall, on the engine side we started with the base engine that has also run in the M6 GT and GTLM and brought that down to four litres, with full accordance to the regulations and in that respect we also went away from the 95 per cent production parts concept to 30 to 45 per cent production based,' says BMW Motorsport director Jens Marquardt. 'It is still based on the production engine, but with very different components involved. We also changed the crankshaft, cylinder heads and everything and worked on efficiency and power. I think that we have done a pretty decent job.'

M-powered

The inlet system is completely different, as are the turbos and wastegates, but the changes and the installation led to vibration issues early on in the test programme. The company admits that bits fell off the car during testing, but the official line is that this was more down to a materials issue than the engine vibration. 'With the flat crank engine we encountered some vibration issues at an early stage that we had to address and solve,' says Marquardt. 'Other than [these] vibration issues, we have not encountered anything that I would consider to be a major issue. I think I have been really surprised, we have done a lot of work on the dyno.

'We have had [the vibration] in the M3 and in the DTM car so it is nothing that is unusual. It is down to the concept of the engine,' Marquardt adds. 'You can do a lot of simulation, but the vibration itself is not an issue at all; you can run that engine to death on the dyno with no issue, but when you have installed it into a car and you get into resonance issues, that's where you have to figure out, does it cause any other issues? We had much more vibration on the M3 GT2 than we have now, but they never caused natural same frequency issues. It might not be comfortable for the drivers when you are going through those resonance peaks, but it is not an issue that would hamper the performance. We handled the problem in a normal way.'

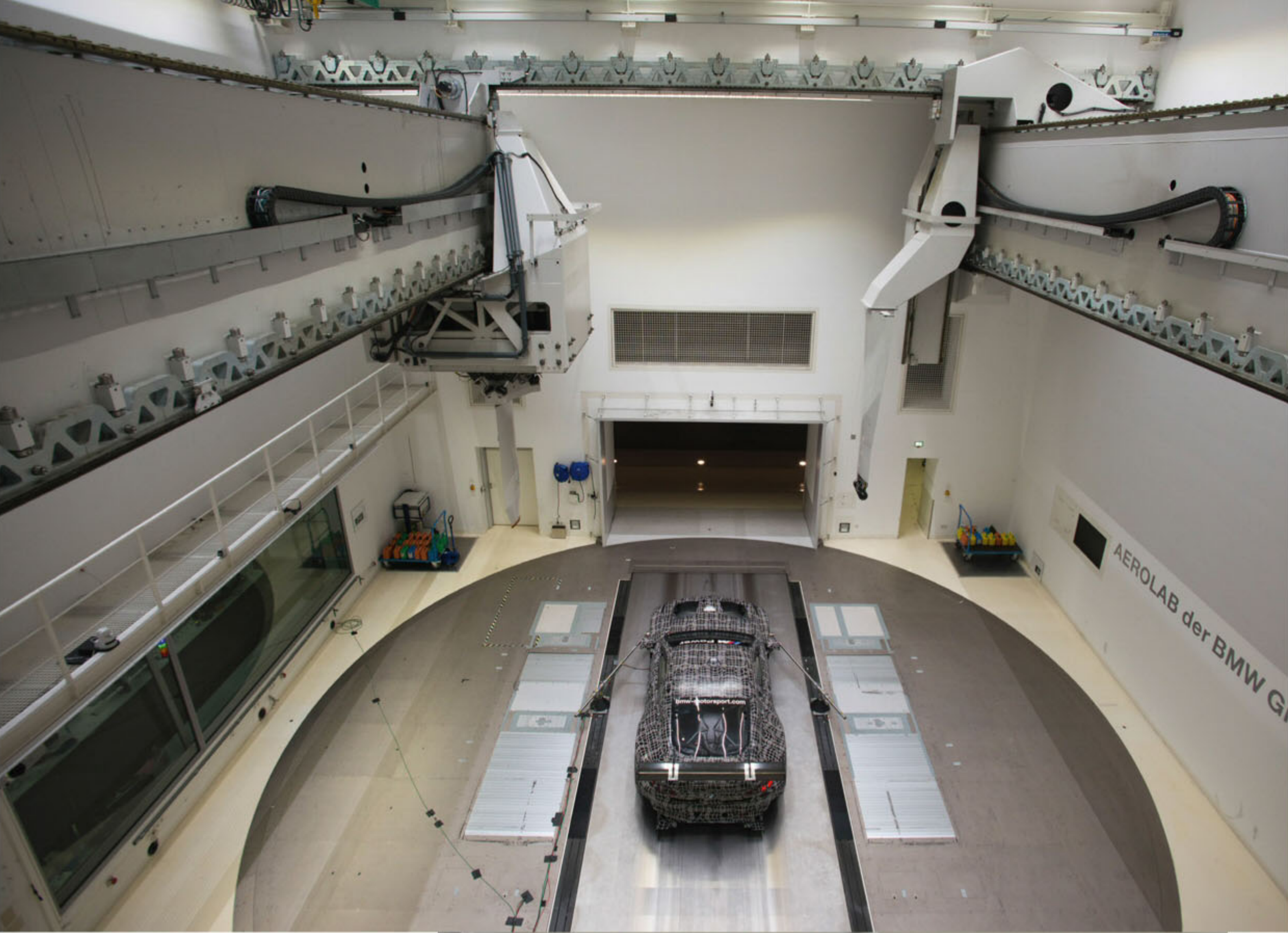
Unlike its rival Aston Martin, the engine bay is plenty big enough to house the turbocharged engine and there are no packaging dramas. 'Our engine bay is huge, there is no issue there,' says Marquardt with a laugh. 'The thing about the base car, it has a pretty big front. There is a lot of space under the bonnet that isn't used, especially as you drop the engine and move it as far back as you can. Intercooler-wise it is not an issue; cooling is not an issue.'

Power is delivered to the rear wheels through an Xtrac gearbox, the company choosing to switch from Ricardo, which continues to supply the GT3 customer car. BMW felt that the Xtrac gearbox offered 'more potential in the current package than we had in the package in the M6,' Marquardt says.

On balance

The M8 weighs in at 1220kg, down from an estimated base weight of 1800kg of the road car, and races at 1250kg, heavier than the previous car by regulation, while it also has smaller air restrictors on the smaller-capacity engine. BMW says that this contributed to its apparent lack of speed in the 'ROAR before the 24' event, and after extensive analysis, the BoP table for the race saw an increase in power, less weight, a larger fuel capacity and faster refuelling.

The M8 has had to undergo the usual balance of performance testing, at Daytona in December and January. However, IMSA started with all new cars in a conservative set-up and will need a season of running before they are able to balance the cars perfectly.



The auto BoP that will be used in the FIA WEC will cause more of an issue as there is only the test session in France in April, and the Spa 6 hours in May, to see the car in full race trim ahead of the Le Mans 24 hours in June. The FIA's method of balancing the performance is to rely on the manufacturer to explain how much better or worse the new car will perform, and that information will form a baseline. Also available to it will be the data collected by IMSA from the Daytona and Sebring races.

Raising issues

Bringing such a car to GT racing has led to the usual gamesmanship from BMW's rivals, who recognise the importance of having the name in the series while not necessarily agreeing to the base concept. BMW worked with the FIA in the early stages of development to produce a concept that would be acceptable to it in terms of the BoP, but having lowered the car to the lowest possible level, it was then required that the car be raised slightly. It was not an innocuous decision; rivals deliberately waited until the last minute, and completely compromised all the aerodynamic work that had already been conducted on the car.

'It is the typical game,' says Marquardt, although it is a game that clearly rankles with him as it cost time, performance and money. 'It

The M8 has had access to BMW's mighty resources including its huge Aerolab wind tunnel (top) but the aerodynamic effort was massively set back after a late decision by rule-makers and rivals to ask BMW to raise the ride height of the car

'With the flat crank engine we encountered some vibration issues at an early stage that we had to address and solve'

Much of the early testing was conducted with an adapted M6 GTLM, which allowed the team to evaluate key components for the M8 GTE

The WEC has adopted IMSA's pit stop rules, allowing refuelling and tyre changes simultaneously; emphasising slick pit-work

is competition. Our approach is to be as open as we can with everyone with the FIA, ACO and IMSA, and the other competitors. It doesn't help anyone if you pull the rabbit out of the hat, and then the rabbit doesn't walk. Obviously the car has a certain frontal area, and the FIA wanted us to be in a certain window so that they could balance us properly and so we made proposals, had a pre-agreement and worked towards that, and then it turned out to be not acceptable to the FIA. We had to redo it to what they said was [now] acceptable for them, and that cost four months, and a little bit of money, and that was not a small amount of work, which is why it cost us four months.'

That four months of lost time put the team under immense pressure, and perhaps compromised the ultimate set-up for the car as key decisions had to be reached quickly and without the usual analysis. 'We have tried to be as early as we could, and obviously not everyone responded as early as they could, which is normal,' says Marquardt. 'With regard to the discussions, we have good ones with the FIA and ACO and everyone involved regarding calendar changes, and homologation changes; we can make our lives easier if we do a slightly different process where you get concept approval, intermediate approval and then final approval. [The current system] puts a lot of work onto the people that we are responsible for, no matter what manufacturer, and we have to keep the workload, which is already high on them, to a reasonable level. It doesn't help if you delay things artificially and make things more difficult. It increases the workload, brings the cost up and it doesn't make the racing any better.'

Motive 8

BMW had not yet reached the stage of building parts for the car and so it was not all bad, but the company had to ditch all of its aero work and start again. 'Everything that we did before went into the bin, and once the concept was approved we could really start to work on the aero design and everything,' says Marquardt. 'We were not far enough yet that we had to make things again, and we didn't have a final concept, but we were already quite advanced and had some ideas and those we had to scrap.' The team was helped here by extensive use of rapid prototyping and 3D printing.

Work on the aerodynamics relied on a new algorithm that allowed a significant increase in CFD calculations, thus making it possible to use greater computing power to increase the number of possible simulations, before progressing to the wind tunnel. The same 3D measurement technology that was used on the BMW M4 DTM is also used on the BMW M8 GTE. The measurement system provides the perfect quality control once the racecar has been assembled. With such a complex car as the BMW M8 GTE, which is built completely by hand, it is essential that all the dimensions are correctly adhered to and implemented.

Delayed testing

The enforced delay meant that the car had to test later in the year than originally planned and in less than ideal conditions. However, much of the early testing was conducted with an adapted M6 GTLM, which allowed the team to evaluate key components for the M8 GTE.

The car struggled for outright pace during Daytona testing. BMW plans to field two M8s in IMSA plus another brace in WEC

Suspension is conventional double wishbone set-up with 4-way adjustable shocks front and rear. Car body is composite

Work on the aerodynamics for the M8 GTE relied on a new algorithm that allowed a significant increase in CFD calculations

'If you ask the engineers, it was a disaster, too late, and they always need three more months,' says Marquardt. 'I have to say that if we would not have lost the four months a lot of things would have been easier. Better? I don't know.'

'We had to cut a few corners,' Marquardt adds. 'Whatever issue we had, we couldn't examine the options of maybe A, or B, or C, as you normally would do, and find the best in terms of performance or efficiency. If we had an issue, we had to then decide what will solve the problem, and get it done, maybe not done in a fancy way, but just to solve that problem. We have managed very well to resolve the issues that came up and so far we haven't encountered anything major that I can say is down to not having the time to sort things properly, so it is only things like the body fit on the car and small pieces like that.'

Jens Marquardt says the four-month delay after the late ride height change decision meant BMW had to alter its approach with the M8

BMW has switched to Bosch electronics, leading to a very different cockpit layout, plus the rear view camera and collision avoidance system that was developed by Corvette and has since become widely adopted in GT cars. The system is able to recognise different classes of car, and their closing speed, aiding the driver in identifying where and when they will be passed. Audio warnings in the earpieces are also available in the Bosch system. 'We also felt that we had more potential upwards with regards to functionality processing capabilities and so on with Bosch,' says Marquardt.

Safe seat

In terms of driver safety, BMW has, like Porsche, fixed the driver seat and the adjustability of this now comes from moving the pedals via a spring-loaded system, rather than an electronic system. The driver seat has moved closer to the centre of the cabin, although this movement was restricted by the transmission tunnel.

'We have moved the driver seat as much inboard as you can in accordance with the regulations, but in our case, we have the transmission tunnel and that puts limits on what you can do,' says Marquardt. 'The tunnel is sacred and there is no modification allowed in this area at all. Even though there are other racecars without the tunnel now, I don't know why [the GTE regulations are] so strict on those things, because moving the driver to the centre only helps safety and doesn't have much impact on performance. People tell you about polar moment and all of that, but if you calculate the potential lap time gain for moving the driver 10cm inboard, it is not even visible. But, in terms of passive safety, we have done everything that we could.'

In the cabin the seat is fixed, with the pedals adjustable, while it has also been moved a little closer to the centre of the car

Hot laps

One of the major issues faced by the team is the car's large greenhouse, the cockpit area that needs to be air-conditioned to a maximum temperature at the hot races. Porsche faced a similar problem and rectified it with a screen that effectively cut the cockpit in two and reduced the volume of air that needed to be cooled. BMW considered a similar solution, but then abandoned the idea. 'You have to work a lot at blowing air onto the driver,' says Marquardt. 'To get such a big volume cool is one thing, but to get flow is the main thing. It's completely different to a road car. We looked at splitting the cockpit, [but] we found more improvement with cooling the drivers. The cockpit temperature is one thing, but if a driver doesn't feel cool, it doesn't help things.'

BMW has decided to bring something completely different to GTE. For now, it has pulled the rabbit from the hat. Whether it walks the walk has yet to be seen.

TECH SPEC

Chassis/body: Composite body with carbon core and DMSB-approved safety roll cage; CFRP outer shell with quick-change concept.

Engine: V8 engine with BMW TwinPower Turbo Technology; 3981cc; 8-cylinder; 90-degree V angle; bore x stroke 899mm x 80mm; cylinder spacing 98mm; engine speed approx. 7000rpm.

Transmission: 6-speed sequential motorsport gearbox; electric paddleshift system; limited slip differential; CFRP driveshaft; Sachs carbon clutch.

Suspension: Double wishbones on front and rear axle; 4-way adjustable shock absorbers at front and rear; anti-roll bars with quick adjustment.

Electronics: BMW Motorsport in-house developed software functions for engine, gearbox and driver assistance; steering wheel with 16 buttons and seven dials; rear-view camera system with object recognition; high-performance headlights with OSRAM LED elements; live telemetry system for vehicle monitoring during races.

Wheels: BMW Aero rims: 12.5x18in on the front, 13x18in on the rear.

Tyres: Michelin, 30/68 R18 on the front, 31/71 R18 on the rear.

Dimensions: Length (without rear wing) 4980mm; width (without mirrors) 2046mm; width (with mirrors) 2224mm; height 1212mm; wheelbase 2880mm.

Take two

Mazda had a troubled DPi debut last year but for 2018 its car has been partly redesigned and will now be run by crack sportscar outfit Joest. But is this enough to turn the RT24-P into a race winner?

By ANDREW COTTON

The Daytona 24 hours in 2017 saw the competition debut of Mazda's DPi car, powered by a 2-litre, 4-cylinder turbo engine built by AER, which was housed in a chassis designed by Riley Technologies and Multimatic Motorsports. The RT24-P promised much, but somewhere between the drawing board and the track problems arose, and it's fair to say that the car never fulfilled its potential.

The relationship between Multimatic and Riley began when Larry Holt, the vice president at the former and also its motorsport boss, was approached by Mazda to find a way into the IMSA series. Holt was not at all keen on building his own LMP2 chassis, which would have been eligible in the WEC and IMSA as well as the Asian Le Mans Series eventually, despite the promise of far-flung customers this could mean. He figured the numbers just didn't add up. But when Riley was awarded one of the four contracts to do so, it was a match that made sense. The two US entities had worked together in the past, and knew each other well.

Multi's task

But now Multimatic has taken on sole development of the chassis, and put former Lola designer Julian Sole on the case. Meanwhile, with Joest looking for another racing programme following the cessation of the Audi WEC project, the opportunity arose to drop original car-running team SpeedSource in favour of the famous German team, which has now re-opened the base in Atlanta that it had used in its Audi ALMS days.

'When the project started it was a joint project between Riley and Multimatic and they managed it,' says director of Motorsports for Mazda North America, John Doonan. 'That was between them as technical partners. From our standpoint, what we have now is a complete transformation. Whatever gets us to victory lane, that's what we need to do. The Mazda brand deserves to be at the sharp end of the grid.'

‘I want to be in the hunt for wins come the latter half of the season, and surprise some folks in the championship fight too’

The Mazda RT24-P (pictured at the Daytona test) might look the same as last year’s version, but Multimatic and Joest have further developed it

One of the first DPi Mazdas was delivered to Joest’s workshops in Germany, and work immediately began in turning it into a competitive car. That process included a general tidying of the cockpit and particularly focussed at the rear of the car in terms of cooling and suspension layout. ‘I saw the very old car that came to the workshop in Germany and is still there,’ says team manager Ralf Juttner. ‘It was a shock to see that. This is still not what a racecar should look like; that was a nightmare. Looking at our situation now, hats off to SpeedSource that they ran with two racecars at all, but why didn’t they use the second half of the year to clean up what was obviously a ‘get it ready somehow’ car? There was no cleaning up process. For example, they had a drinks system in it, welded aluminium. [Drivers] Jonathan [Bomarito] and Tristan [Nunez] were in Germany with us, and I asked how much are you drinking in the stint? They said not much, because it doesn’t work anyway. It looked like a small nuclear power plant!’

Joker in the pack

This was not a normal development cycle, either, as the original car was homologated for four years following its introduction in 2017, and there were no written rules about what was allowed under the ‘joker’ system of development. That meant Multimatic had to submit its plans to the ACO and FIA, and receive permission for what it was allowed to do.

On top of that was the added complication that the ORECA chassis was the baseline car for performance, and that changes to the Multimatic chassis could not make it faster than this, the only one of the four cars that was not allowed to play its joker. ‘We all have our performance window that we are allowed to use, and that is limited in the rules,’ says Sole. ‘You are allowed to do a joker but not to gain performance over the lead car. That is a difficult rule [to work around]. The point is to have an impact on performance or you wouldn’t do it.

Radiators are blanked off for the cold temperatures at Daytona. Ironically, overheating was a big problem for the car last season

The front end of the car has seen very little development over last year's version. This is partly because major changes to the suspension here would have meant knock-on changes to the tub, entailing another crash test

The RT24-P is subjected to IMSA's scrutineering. Winter development was tempered by the complicated joker system

The purpose of the rule was not to promote development to knock others down. You are not allowed to go faster than the ORECA, but you can use your joker to level the playing field.'

The team kept the Life Racing ECU that comes with the AER engine, and the Motec electronics rather than the more standard Cosworth electronics chosen by the other manufacturers. The work then started with the electrics within the racecar, and already there was some weight saving to be found there. 'There was a lot of cabling that came out of the old car,' Sole says. 'Electrically it is still the same Motec system in the car, but the cabling is all quite different. I would hope that people would look in and say that it was all a bit more thought out now. The wiring loom had cables that came up and down the car before it reached the point it was supposed to go to.

'As an update, stripping the wiring looms out, positioning the boxes and getting the wiring to go from A to B, we probably lost 10kg,' Sole adds. 'If you took into account fluid and plumbing you would find a similar amount, maybe more, some of it as a function of the car not cooling properly and then systems added to make it cool, there were lots of split radiators, pipes going across the car that had to be added.'

Hot and bothered

The overheating issue on the original racecar Sole mentions above had led to some rather unusual solutions. The radiators were stood up in the sidepods, with a reduced size compared to when the engine ran in a Lola. So the first job was to improve the internal design and airflow.

'I heard even with temperatures like this [speaking at a freezing cold Daytona at the ROAR before the 24 test in January], they would have struggled with the old cars,' says Juttner. 'They ran that engine in the Lolas, and they were on the limit, and then Riley made the radiators 70 per cent the size of the Lola. We have gone for bigger radiators. The radiators were standing on the left, and behind that was the big inlet for the turbo, so 60 to 70 per cent was blocked. The car that we received in Germany, they had a constantly blowing ventilator for the radiator to survive somehow. Now they are angled, bigger, and the inlet configuration is different.'

Sole confirms that this is where the main cooling issue lay. 'There was general blockage all the way through the back end of the car where there were plumbing and dry breaks on the side of the gearbox that were blocking the exit from the radiators,' says the Briton. 'We have angled the radiators to get the area up. The oil coolers moved – they were originally piggy backed on the radiators and they are now fed around the rear of the car through the brake duct area. It was lighter, it has its own air feed now so is more efficient. It [was] getting better by the time we finished last year, but it wasn't cooling properly even at the end [of the season].'

There were not only changes made to the size and the angle of the radiators; the front of the sidepod was also modified to bring more air in through the radiators, air which then had to be expelled efficiently. 'When you increase the area of the radiators you need to increase the flow through the radiators as there is no point in just increasing the area,' says Sole. 'That, all hand-in-hand with making the cooling system work, has worked out well. It has been an impressive gain in cooling.'

Rocker role

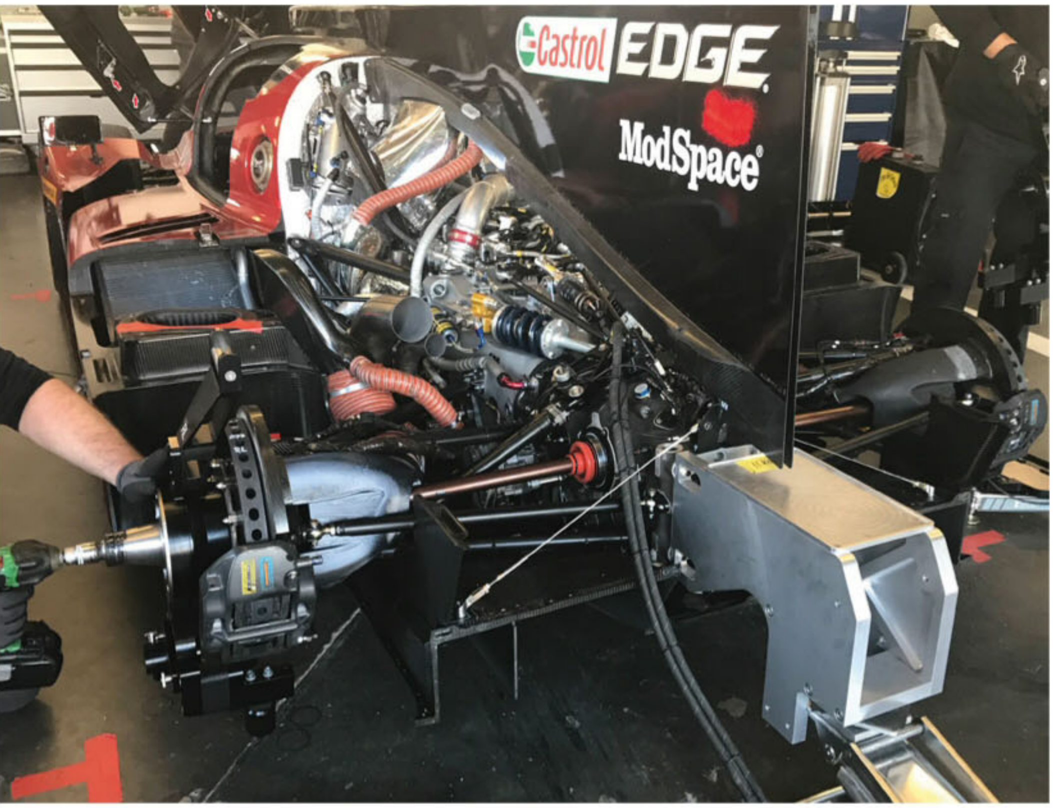
It was not only the cooling system that was developed at the rear of the car; the suspension was also redesigned. The original car had the spring separated from the damper, acting with a rocker running a longitudinal pivot and dampers running across the car. 'We have turned that around to a more conventional rocker pivot installation pushrod with the dampers longitudinal now,' says Sole.

'The efficiency of the structure around that area is massively improved, and there is a massive chunk of weight out of the car, and it is stiffer,' Sole continues. 'It was not a small task, as it affects the bellhousing and main case, so it is a big change to make. When we really kicked off and were going at this in anger, we

Joest Racing has particularly focussed on the rear of the racecar in terms of the cooling and the suspension layout

‘If you lose a wheel speed sensor how do you carry on and not then run into trouble with traction control and speed limits?’

Much of the work has been focussed on cooling. The original car had the radiators stood up in the sidepods but these have now been made bigger and placed at an angle, while there’s also been an effort to improve the airflow going through them



Switching to a more conventional rocker pivot installation pushrod, with longitudinal dampers, has not only helped to stiffen the rear but has also taken weight out of the racecar. The suspension mods had to be worked around the Xtrac transmission

were late in the day, so it amounted to a lot of work in a short space of time.’

The suspension pick-up points were pretty much unchanged although the kinematics have been improved. The Xtrac gearbox largely dictated the options open to the team regarding the rear suspension, while the tub design dictated what was possible at the front.

‘At the front, the suspension is similar, with the spring and damper separated,’ says Sole. ‘The rocker ratio to the spring and damper was an improvement for kinematics. You are fairly limited in the space that you have got because you are limited with the tub. We looked at different suspension options on the same tub, but it is difficult to do and then say that you are using the same structure and not do a crash test. We got to the point where we would have to re-crash test the tub and that was not an option.’

But there was some inadvertent crash testing, as Nunez lost control of the car at Daytona in testing in late 2017. ‘We still don’t know the cause of the accident,’ says Juttner. ‘It was just after the kink before the second hairpin, way before he hit the brakes. This is now a different tub. The problem is that he went into the guardrail on the left hand side, and there was earth behind it. It didn’t move. He [effectively] went into a solid wall, without tyres,, and that didn’t help the parts situation.’

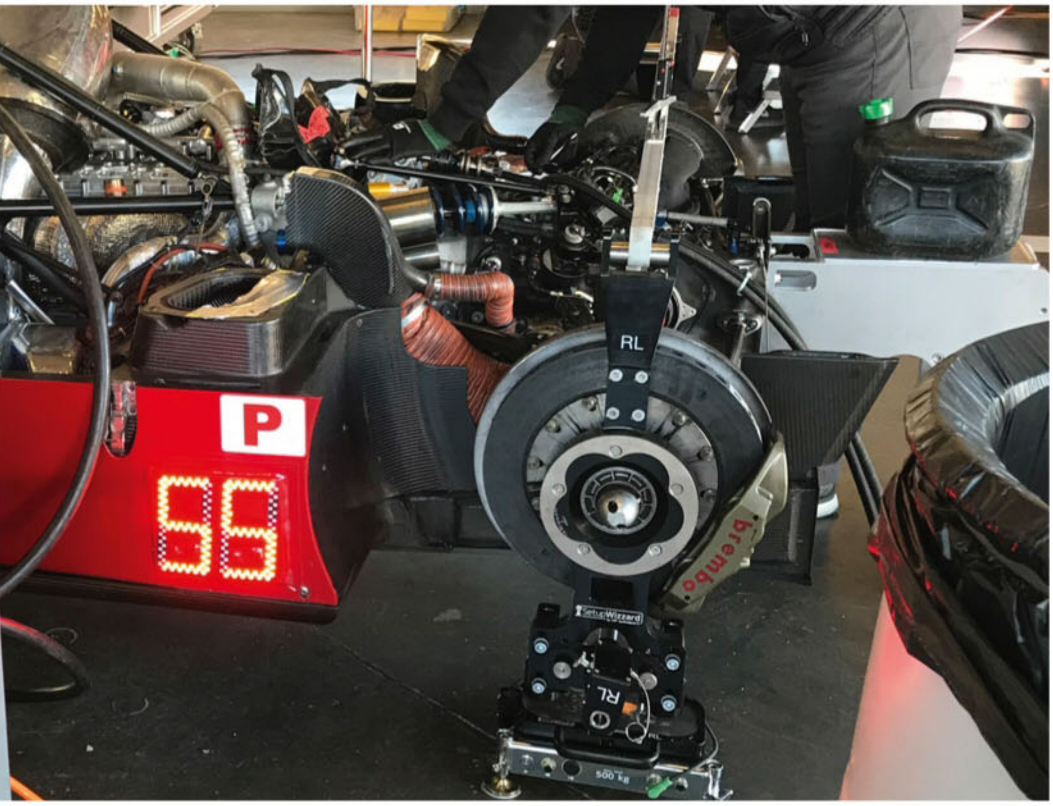
Parts issue

Parts are currently the major issue for the Joest team, and this is not helped by the supply by Multimatic of a racecar to the BAR1 Motorsports team for the 2018 IMSA season. The BAR1 car itself is the chassis that ran at Le Mans last season, but the rush for spare parts has left the teams short, and BAR1 was struggling to get the full upgrade package in time for the test session for the Daytona 24 hours.

‘People concentrate on the bigger parts, but we are missing the smaller parts, like the bushes for the bearings into the clevis for the gearbox,’ says Juttner. ‘We are way behind on the parts numbering lists. Things that are usually done in an hour take a day. We had pushrods without strain gauges, and when they arrived [at Daytona] they were late and you need to have them because how can you make an aero test without strain gauges? On the 55 car we lost the first session [of the ROAR before the 24 test], because updated uprights arrived, and we did not know whether to run the old ones, which is not the spec you will race. But then you put the new ones in and you find out that the brake shrouding does not fit.

‘That is the narrow bit of the whole process,’ Juttner adds. ‘We were supposed to have a test

'By stripping the wiring looms out and repositioning the boxes, and getting the wiring to go from A to B, we probably lost 10kg in weight'



The engine is still the AER-developed 2-litre, 4-cylinder turbocharged unit that proved reliable last season. Joest has worked hard on making it even more reliable. The braking system was developed last year by Mazda and former team SpeedSource

TECH SPEC

Mazda RT24-P DPi

- **Class:** Prototype made to Daytona Prototype international (DPi) rules and regulations for IMSA WeatherTech Sportscar Championship.
- **Chassis:** Riley Mk 30, developed by Riley Technologies and Multimatic Motorsports.
- **Engine:** Mazda (AER) MZ-2.0T; 1998cc; bore x stroke: 90mm x 78mm. Power: 600bhp. Max revs: 8500rpm.
- **Camshafts:** Dual overhead.
- **Valves:** Four per cylinder.
- **ECU:** LIFE Racing.
- **Turbo/Intercooler:** Garrett Motorsports, air-to-air intercooler.
- **Fuel Injectors/pump:** Bosch Motorsport.
- **Fuel rail:** AER.
- **Transmission:** Xtrac 6-speed sequential with paddleshifters.
- **Suspension:** Independent double A-arms.
- **Dampers:** Dynamic DSSV.
- **Brakes:** Brembo/Hitco carbon discs.
- **Tyres:** Continental Extreme Contact.
- **Front tyre size:** 320/680/R18.
- **Rear tyre size:** 325/710/R18.
- **Wheels:** Motegi Technomesh, forged aluminium.
- **Fuel:** IMSA E20.
- **Fuel Capacity:** 75 litres (19.8 gallons).
- **Length:** 4750mm (15.41ft).
- **Width:** 1900mm (6.23ft).
- **Wheelbase:** 2950mm (9.67ft).
- **Weight:** 930kg (2050lbs) without driver or fuel.
- **Top Speed:** Approximately 200mph.

car and two racecars, plus spares, and suddenly there is another team with a car that also needs spares. They started with five sets of parts, which is already a small number for us, and it doesn't help that they now need to provide another one.'

Power points

The main talking point on the car is still the small capacity turbocharged engine, an element that was reliable throughout 2017 despite the unusual cooling arrangements around it, yet a component that Juttner still describes as 'a delicate machine'. The team blew up an engine in testing at Sebring, causing a small fire, but it is still confident that this powerplant will now work well throughout the season. 'We had to give the engine a better surrounding, which is now the case,' says Juttner.

The drivers report that there is very little vibration from the engine, perhaps surprising given the loads that it was under in the various conditions of the IMSA series. But the engine does vibrate, as the team can see cracks and has suffered failures, but that can be rectified before the rigours of Sebring in March.

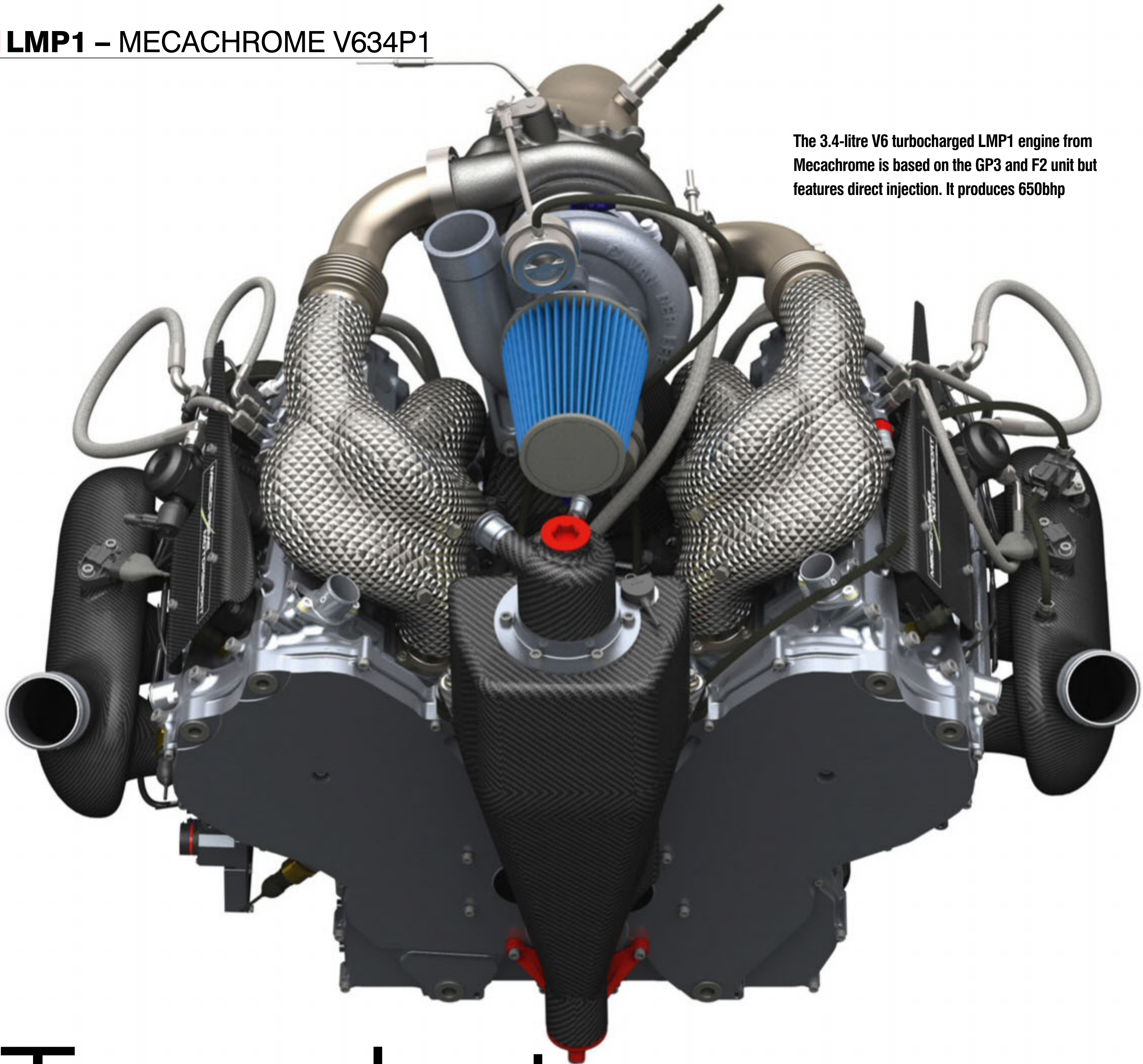
'We had starter motor issues, but that was the wiring of the solenoid to the motor,' continues Juttner. 'The electronics on the car in general haven't been that bad. The only thing is the failure modes. If you lose a wheel speed sensor, how do you carry on and not run into trouble with traction control and speed limits? There are still some open issues there, and then you try to address that, but in general the electronics are not too bad.'

Joest's Mazdaplan

In terms of the aerodynamics, the car is pretty much as it was in 2017 with only minor changes to the sidepod to improve airflow, coupled with some changes to the front splitter that are also seen on the base WEC car. The brakes are the same as last year following development by both SpeedSource and Mazda.

But Juttner says he would love to have more time to develop the car: 'Two or three months of time … There is still a lot that we could do but don't have the time,' he says.

As for Mazda itself, despite a disappointing 2017 season the company has not set itself any official performance targets for this year. 'No one at corporate has said you have to win this many races, but for me, my role at Mazda and for the people who worked so hard, we need to win multiple races, and I want that for everyone,' concludes Doonan. 'I want to be in the hunt come the latter half of the season and surprise some folks in the championship fight too … But everyone here will say the same thing.'



The 3.4-litre V6 turbocharged LMP1 engine from Mecachrome is based on the GP3 and F2 unit but features direct injection. It produces 650bhp

Transplant surgery

Developing the F2 V6 for use in LMP1 took a great deal of engineering nous and some serious technology, as *Racecar* discovered when we delved into the inner workings of Mecachrome's V634P1

By GEMMA HATTON

The 2018 LMP1 grid was looking rather bleak until Ginetta declared that it would compete, claiming the first privateer spot. This was followed by the news that Mecachrome would supply it with 650bhp in the form of a 3.4-litre V6 turbocharged, direct injection engine.

This LMP1 concept is an evolutionary step from the V6 already raced in both GP3 and F2, with the former naturally-aspirated and the latter a turbo with port injection. 'After the first GP3 and Formula 2 tests, we realised that this engine could be a good base for an LMP1 car. Not only could this V6 meet the power demands of LMP1, but direct injection was also feasible and it met our cost objectives,' says Bruno Engelric, managing director of Mecachrome Motorsport. 'The current WEC regulations are driven by fuel restrictions of 110kg per hour, so the only way to increase performance is to try and burn as lean as possible. Therefore, you need to guarantee that each droplet of fuel is burned with the maximum amount of air, and this is best achieved with direct injection.'

The direct injection system and the consequent redesign of the cam cover and combustion chamber is undoubtedly the biggest difference between Mecachrome's LMP1 engine and its single seater variants. In addition to maximising power through lean combustion, it is also crucial to ensure that the fuel and air mixture is prepared effectively. This requires an array of strategies using specialised injectors and spark plugs as well as techniques to initiate swirl and turbulence, which all work together to help burn the lean mixture,

TECH SPEC

Mecachrome V634P1

Cylinders: Six; four valves per cylinder; finger follower actuated valves.

Turbocharger: single, in 'hot vee' configuration; 180-degree twin scroll turbine.

Injection: direct and port injection system.

Combustion: lean burn combustion system.

Displacement: 3396cc.

Engine construction: 95-degree vee angle; full stressed engine construction; high strength aluminium fully machined crankcase, sump (dry), timing drive cover and cylinder head covers. High strength steel wet liners.

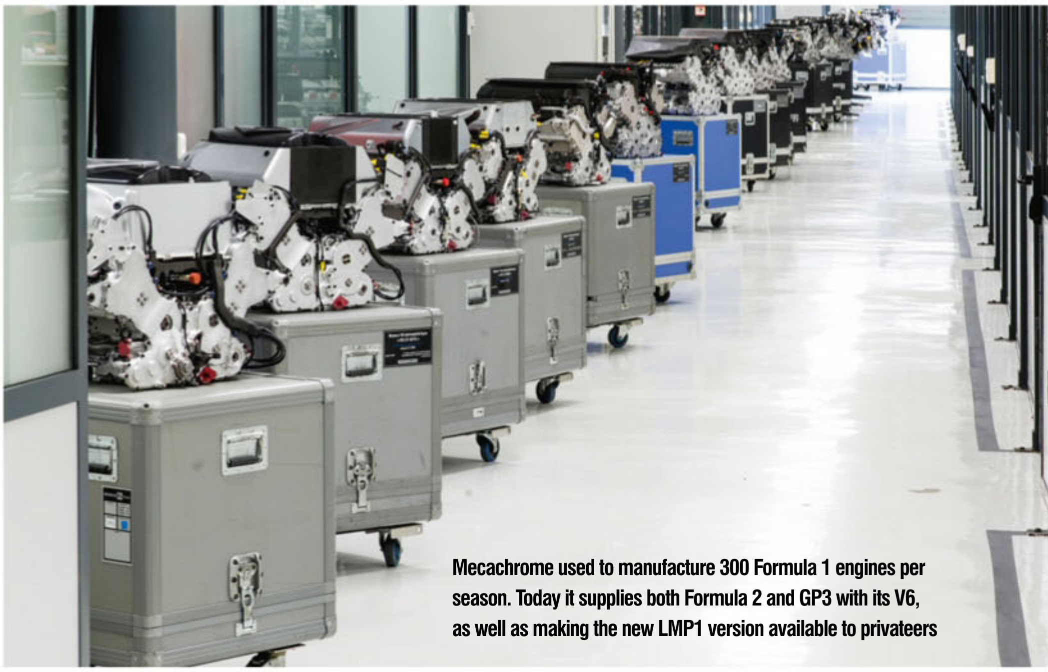
Bore x Stroke: 96mm x 78.2mm (3.78in x 3.079in).

Electronics: Bosch MS6.4 ECU.

Max revs: 9000rpm.

Peak power: (with 110kg/h WEC fuel): 650bhp at 7000rpm.

Max torque: (with 110kg/h WEC fuel): 650Nm at 6000rpm.



Mecachrome used to manufacture 300 Formula 1 engines per season. Today it supplies both Formula 2 and GP3 with its V6, as well as making the new LMP1 version available to privateers

'We have eliminated 90 per cent of the risks of the first order of knock in the LMP1 engine'

which otherwise would not be possible. These strategies were concluded from a wide range of test programmes conducted with Bosch, which specialises in direct injection systems.

Lean burn

'The dream of an engine engineer working in this area of lean burn today, is to be able to burn as a diesel, and do that more or less automatically – a sort of auto combustion,' says Engelric. 'To do that right, firstly you need to have direct injection, then you need to use spark plugs with pre-chamber and you need knowledge of the right set-up. But there are no fixed rules that guarantee you the best result with one attempt. Why do you think F1 teams spend so much money on engine testing? They know what they want, they know the rough direction to go in, but they have to experiment with a trial and error approach.

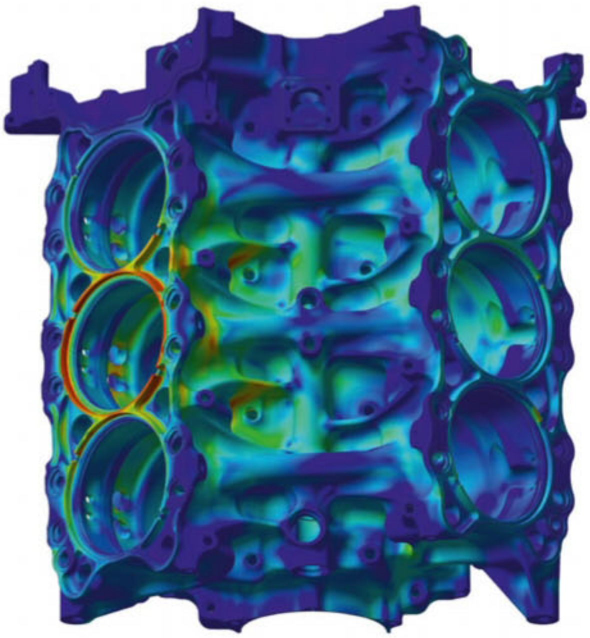
'The talent of the engineer is to extract the knowledge from the results of each test, and build understanding,' Engelric adds. 'We know that swirl, tumble and pre-chamber all help with the combustion, but it is still an area that requires a lot of experimentation to gain that last five per cent of efficiency, and that is where you can easily explode your budget. For us, it makes no sense to spend all our money in this area, it is a constant fight between the technology we want to develop, the budget of a privateer team, the racing we want to create and the profitable business we want to be.'

Another factor that required careful consideration when redesigning the combustion chamber was controlling the area where knock is most likely to occur. This can be done through ensuring smoother geometries, higher squish (the sudden turbulence of the air and fuel mixture as the piston approaches TDC), and instigating turbulence in the knock-prone regions to create conditions that minimise the likelihood of such an effect. The electronic control systems have to be capable of not only detecting the beginning of knock, but also have the correct mapping to react and prevent any development of knock.

'The key is to push this limitation as far as possible, whilst using electronics to control the moment that you start to see this phenomenon because you know that it can destroy your engine,' says Engelric. 'We have eliminated 90 per cent of the risks of the first order of knock in our current LMP1 engine, whilst achieving the level of power possible from the fuel limitations by managing the introduction of direct injection.'

Structural role

A further consequence of switching to direct injection was that the cam cover required modification as the high-pressure pump was now driven by the camshaft. Furthermore, the engine plays a much more structural role in a prototype racecar as opposed to a single seater. 'This means we have to achieve much higher stiffness with our LMP1 engine compared to F2. In F2 we have four points to fix the engine to the chassis, however for LMP1 we have a total of six attachment points, two of which are by the cam cover,' explains Engelric. 'We have used FEA to analyse the stiffness as well as the fatigue stress of the parts to guarantee that our new components never fail under the stresses we see during the life cycle of the engine. With this new design we have improved the stiffness of the



FEA analysis was used to optimise the stiffness and stress of the components, such as the cylinder block, as shown here. The result is a 40 per cent increase in the stiffness of the engine

engine by 40 per cent, which is essential for such a car and why we redesigned the cam cover.'

Aside from the direct injection-related redesigns, the LMP1 and F2 engines are very similar; sharing approximately 90 per cent of the same components including the block, head castings, crank and conrod. 'The total distance raced in a full season of F2 is around 8000kms, Le Mans is around 7000kms. Our engine has already done a full season of F2 on the dynamometer, so we are not far away from completing Le Mans,' Engelric says. 'Of course it is somewhat different because at Le Mans, you start and never stop, but the majority of the larger parts will all work the same way for Le Mans as they do in GP3 and F2. The more critical parts, such as the pistons, valves and

'You need to guarantee that each droplet of fuel is burned with the maximum amount of air and this is best achieved with direct injection'

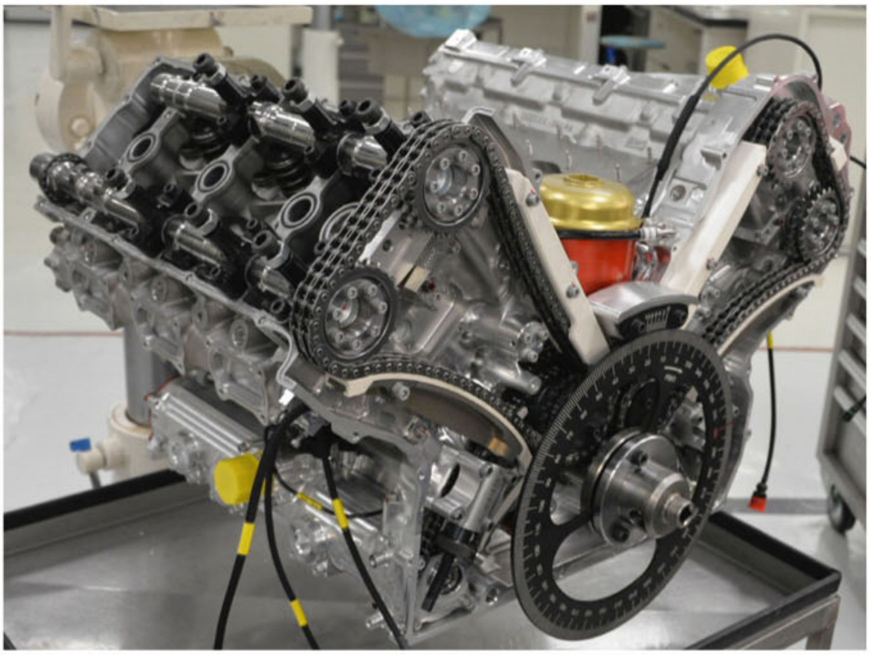
other valve-train components need to be re-evaluated to guarantee they can survive Le Mans and the WEC season. But if we had started designing this LMP1 engine from scratch, I am pretty sure we would have arrived very close to the design we have today. The V6 is a good compromise and the single turbocharger in the centre fits well with the installation of the car.'

Solid as a block

In the past, Mecachrome used to produce approximately 300 Formula 1 engines per year and although it still has that capacity, the continuous drive for reliability has resulted in categories such as F2 now only requiring 30 engines. However, the efficiency of the manufacturing process remains vital in maintaining business growth and this has been another area of improvement. Rather than utilising cast engine blocks, like some of the current Formula 1 engines, the only cast components are the cylinder heads, which are made by Grainger and Worrall, everything else is fully machined from solid.

Of course, machining an engine block from a billet of aluminium costs much more, but Mecachrome felt this necessary to guarantee quality. 'This is really a racing engine, it is not based on a mass production version. The crank, for example, is completely unique because it has been fully machined from raw material bar, so we have invested in quality,' Engelric says. 'Casting is one of the oldest technologies and I'm sure you could find tools that have been cast thousands of years ago. But the process is extremely complex and although it allows you to create any shape, the quality is dependent on sophisticated techniques to ensure uniform temperature gradients during solidification. Whereas with a raw billet of aluminium, you know the quality, because it is simply raw material that has been extruded, rolled, pressed.'

The turbo is mounted in the centre of the vee. New compressor and turbine could be developed after Le Mans



LMP1 engine shares approximately 90 per cent of its components with current Formula 2 V6, including the block, head castings, crank and conrod, but has been modified to cope with the different demands of WEC

Private income

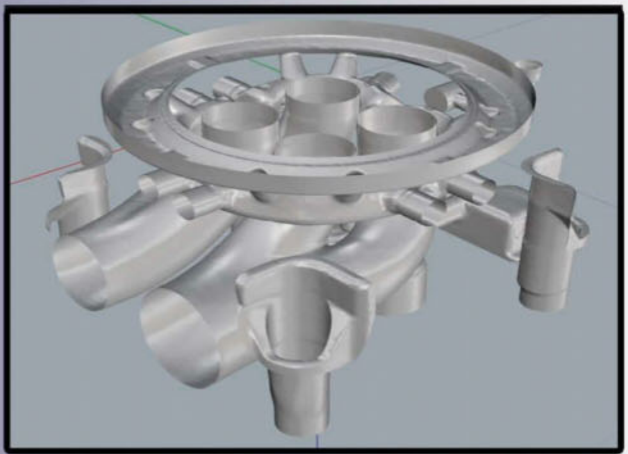
The driving philosophy running through the design of the engine was to meet the targets set by its privateer customer, Ginetta. 'I would say we have done the first step in achieving the sufficient level of power required by Ginetta to fight at the top,' Engelric says. 'We have met our target of 650bhp, which we believe will guarantee it will be at a good level and competing with the Toyota. It's not necessary to bring an engine with more power because the rules will kill you in fuel to put you back to that level and it makes no sense to spend money if we're already at the level that the rules want us to be. However, if this is not the case and our competitors are better than us, then we need to improve and make a second step in development and this will happen after Le Mans.'

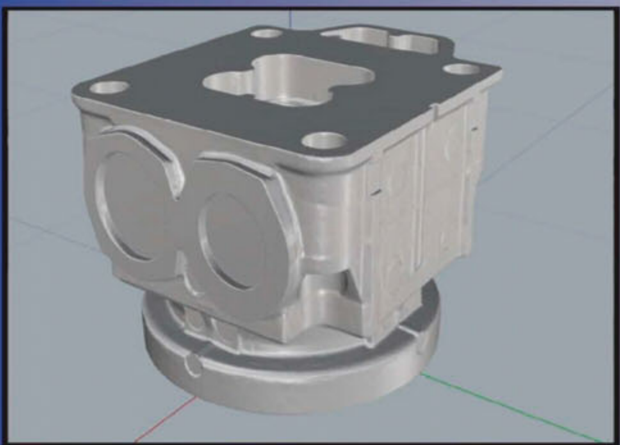
Planning ahead

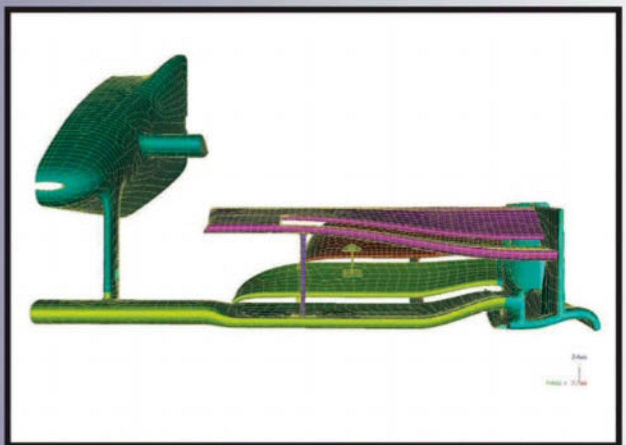
Mecachrome already knows where to focus its development if it needs to improve performance. The analysis has already been completed and some designs have already been started, it is simply a case of pushing the '*Go*' button, if necessary, after Le Mans. The first area that will be focused on is optimising the combustion process through utilising spark plugs with pre-chamber and other new components that will be developed in parallel with new jets and geometries.

'This is still an area that we need to continue developing on the test bench,' Engelric says. 'This is what all the F1 teams do; they have full development programmes focusing on combustion chamber design and are continuously testing new techniques. Over a year they may only improve efficiencies by one or two per cent, but if they achieve that for three years, it can be as much as six per cent and six per cent of 700bhp is 42bhp, which is a lot of extra power. The efficiency of today's F1 engines we could only dream about 20 years ago. But to achieve that, you have to spend a huge amount of money in these areas and this is what the FIA

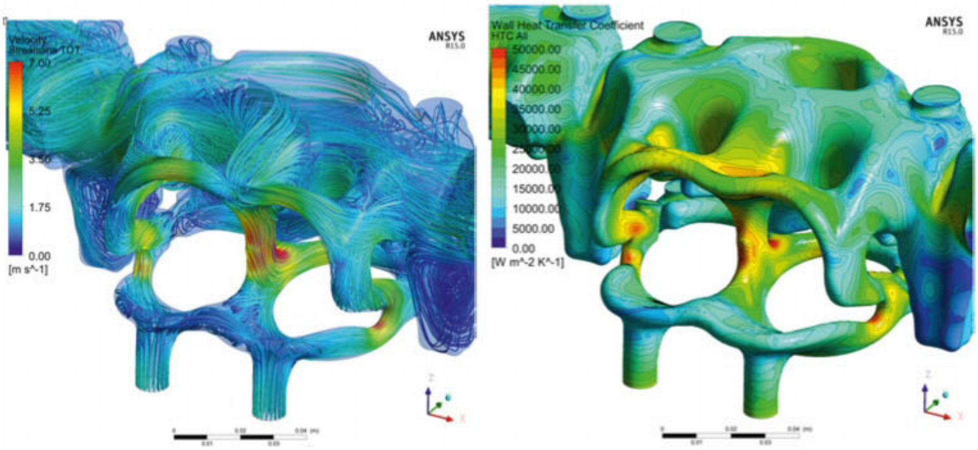

FARO



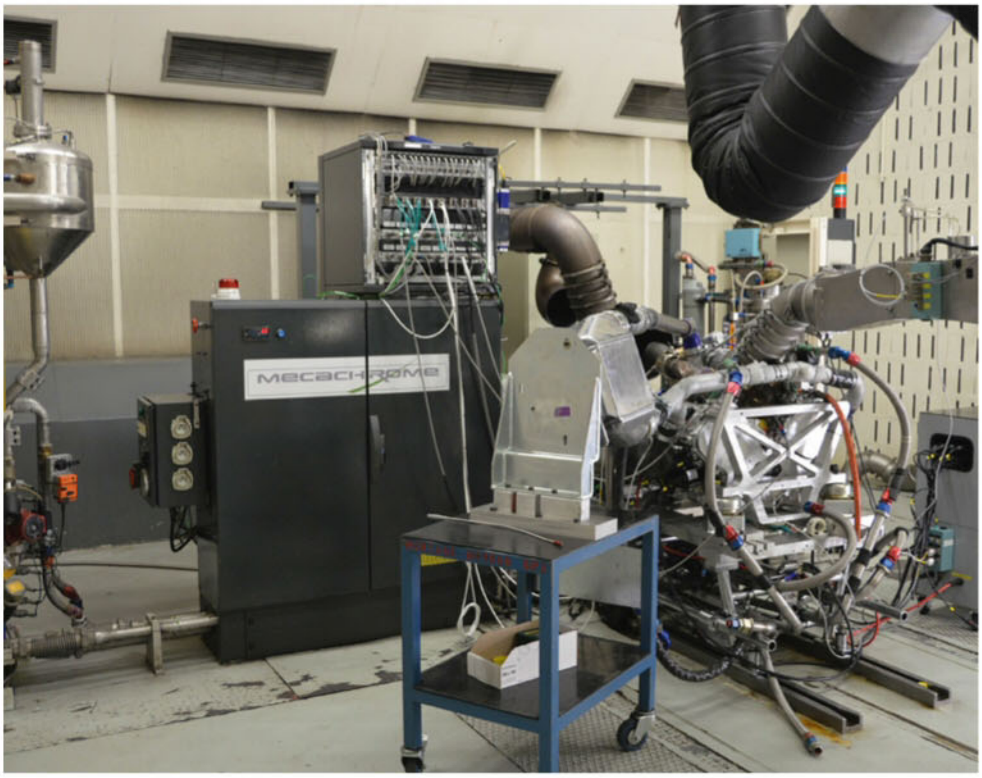




Machining an engine block from a billet of aluminium costs much more, but Mecachrome felt this was necessary to guarantee quality

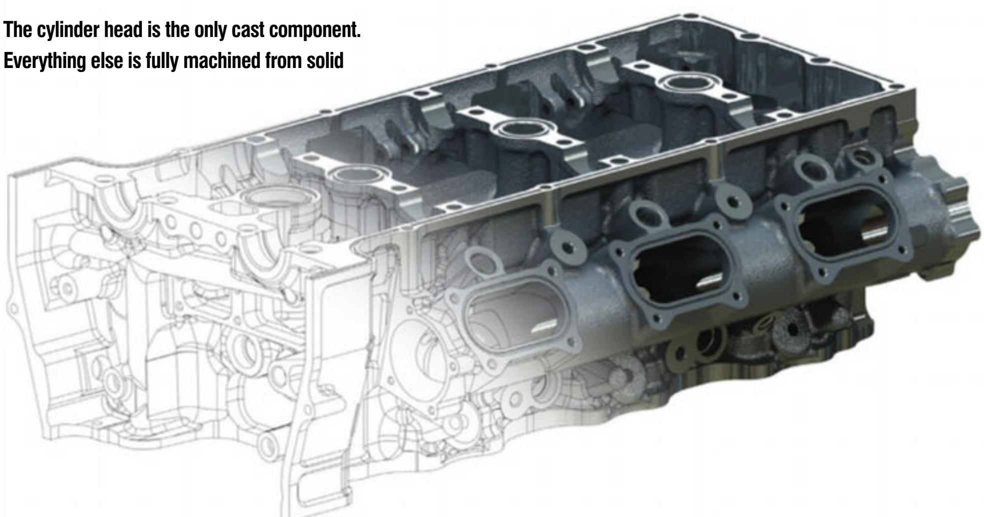


Left: Velocity streamlines showing flow of water around cylinder head **Right:** Distribution of wall heat transfer coefficient



Experimenting on the test bench is where manufacturers make the small hikes in power that add up to big gains over time

The cylinder head is the only cast component. Everything else is fully machined from solid



and ACO want us to avoid, because they know we can easily burn our budget.'

The other area of development lies within the turbocharger. Currently, the LMP1 turbo system was developed in conjunction with Van Der Lee and includes a redesigned compressor and turbine compared to the F2 version. However, this second phase of development will also include using newer materials and modifying the geometries of both the compressor and the turbine.

'With lean burn, you have to increase your airflow into the engine and that is now defined by the compressor and the turbine. If you know you want 10 per cent more airflow because this will meet your targeted power level, then you need to distribute more air for each engine speed,' Engelric says. 'After Le Mans we will have better experience in terms of defining the exact mapping of the turbine and compressor that we need for the second development step. Then we will have two options: either we find the exact compressor and turbine wheels on the market, which would be a miracle, or we create them ourselves, and that is a big investment.

'What people have to understand is, we are trying to develop technology that is driven by politics,' Engelric adds. 'All our engine engineers would love to develop the most technically advanced engine, but I have a business to run and salaries to pay. So I either have to explain to the engineer the solution without that technology, or I have to find the budget.'

Money and power

'If you were to give Andy Cowell [boss of Mercedes HPP] this 3.4-litre engine limited with 110kg of fuel per hour, he would probably design an engine that could achieve another 100bhp,' Engelric says. 'But to do that, he would have to go to his board and ask for some money which is probably much more than Ginetta ask to race the car for a season. Different levels of racing can afford different levels of technology. F2, for example, cannot afford to use direct injection because one DI injector is the price of the whole injection system currently in F2.

'To lease a Formula 1 engine for the second-half of the grid teams, you are talking about more than €10m per car, per season [for around 20,000km per year, per car]. The engine lease for the Super Season of an LMP1 private car is much lower, less than €1m [for around 25,000km per car]. When you calculate the ratio price per km, you quickly realise where the real difference is between Formula 1 and LMP1 [for privateers]. For sure, technically we could manufacture a more powerful engine, but not at the budget the privateers could afford, and this has been our daily challenge,' Engelric says.

Private enterprise

Ginetta is one of a growing band of privateer LMP1 entries gearing up to take on Toyota in the WEC – *Racecar* was at the launch of its G60-LT-P1 to check out this car's top-flight prototype credentials

By ANDREW COTTON

Ginetta has fought for its place in the top tier of WEC, staving off a plan to introduce an LMP2-plus concept

Ginetta finally took the wraps off the car that it hopes will win at Le Mans, the Mecachrome-powered G60-LT-P1, at Autosport International in January. The new LMP1 was unveiled by Ginetta chairman, Laurence Tomlinson, technical director, Ewan Baldry, and Graeme Lowdon, who confirmed that the intention was for Manor Racing – of which he is sporting director – to run the car alongside an LMP2 entry in the FIA World Endurance Championship.

Following the withdrawal of Audi and Porsche from the WEC, leaving Toyota as the only major car manufacturer involved in LMP1, Ginetta has fought for its place in the top tier of the series, staving off a plan to introduce an LMP2-plus concept that would have seen an LMP2 chassis with more open tyre, engine, aero and driver grading parameters than the second-tier prototype class.

Ultimately, this plan was shelved, in no small part thanks to the politicking by Ginetta and the other chassis manufacturers who had already invested in designing and building new machinery. No one is willing to say how close the concept came to reality, but there was certainly backing from many quarters for it, given that both ORECA and Dallara build LMP2 chassis already, and Ligier had a strong and long-standing desire to go into LMP1 and compete for an overall win at Le Mans.

Non-plussed

'I think that the ACO backed us for sure,' says Baldry. 'At one point we were concerned that there would be this LMP2-plus thing coming along and we had to lobby hard, but at the following [Technical Working Group], I felt that we were protected. The ACO were worried and did have this LMP2-plus idea, and I can understand their thinking at the time, but I am pleased that they backed us; there was a lot of behind the scenes lobbying saying that they have to stand by Ginetta and others that are putting their hands in their pockets.'

By then, Ginetta was already far down the route of designing its LMP1 car, having announced most of the key suppliers and concept at Silverstone in April, 2017, and was committed to the project. The LMP2-plus plan would have meant losing Ginetta from the series completely, as it had started its programme based on a guarantee that LMP1 privateer regulations would be fixed until 2022.

'We got Andy Lewis on board early, who had been working at Williams Advanced Engineering on another very successful LMP1 car, and as a result of that, he already had in his mind a direction that he wanted to go,' says Baldry.

High nose

One of the first striking things about the car is its high pedal box. 'Early on in the project we CNC cut an MDF mock-up that had an adjustable footbox height and we had a range of drivers who sat in it and really decided what the limit was in terms of how high to go,' says Baldry. 'Although I have never measured the others, it is not as high as the last iteration of the Audi LMP1 that never raced, but it is higher than the Porsche and I believe it is also higher than the Toyota or any of the LMP2 cars.

Ginetta's new LMP1 was shaken down at Leeds East Airport in January. Its high nose, higher than the Toyota and all the LMP2s it says, is designed to give air a clearer flow to the racecar's front diffuser exits

'It is all about giving you the best possible front end,' Baldry adds. 'We have quite a different concept to the Audi here in the way we deal with the front end of the car, and closer to what Porsche and Toyota have done, but it is about giving clean passage at the exit of the front diffuser sections. Making rear downforce is relatively easy because you have the rear wing, although the diffuser is controlled, but for the aero guys it is about getting the front end good, and then balancing the rest with the other things that you have got.'

Inside information

With the high nose, the front suspension kinematics were more challenging, but personnel with previous experience helped to shortcut this issue. 'With the high nose, you have to attach the wishbones to the tub somewhere, but we had a good bit of data on that from one of our employees who was working somewhere else before. We also had Paolo [Catone, who designed among other things the Peugeot 908] involved too, so we spent quite a long time in the iterative loop to get the suspension kinematics how we wanted them, but it wasn't hugely challenging,' Baldry says.

The car weighs in at 750kg, we are told, and its tub is significantly lighter than an LMP2 chassis, thanks to heavy investment by Ginetta in structural analysis and material choices, which the team estimates has saved 30 per cent of the weight compared to an LMP2 car in terms of bodywork. One of the key weight saving devices used is the integration of the Zylon panels to the tub, offering structural rigidity as well as lighter weight. 'Normally you would bond the two together, but with ours it is co-laminated within the structure which means that you get the structural performance from them as well, so whereas they would normally be an impact panel, in our car it completes the structure of the tub, and there was a massive weight saving there,' says Baldry.

The car weighs in at 750kg and its tub is significantly lighter than an LMP2 chassis

The Ginetta team inspects the 650bhp Mecachrome V6 turbo engine that propels the new privateer prototype. Xtrac supplies the gearbox, said to be a step up from its LMP2 transmission – this has helped Ginetta to keep the weight of the car down

With engine supplier Mecachrome signed up early (see page 24), the Ginetta LMP1 was designed around the French-manufactured engine, which led to further weight saving. There is no integral bellhousing which is a further weight saving for the car. The gearbox itself, which is from Xtrac, uses higher grade materials than those used in the LMP2 gearboxes, saving further weight, and the cluster has been rotated, the team tells us, bringing the weight further forward in the car. 'We are lighter on the gear cluster because we have gone for the next level up compared to the [Rebellion] R1 and the LMP2s, which has allowed us to save weight,' confirms Baldry.

One of the key issues around a privateer car is the tyre selection, and Rebellion particularly struggled with the front tyre supplied by Michelin following development with the four-wheel-drive hybrid cars from the big manufacturers. That meant less energy through the front tyre, and so, particularly at night at Le Mans, and in other cold temperatures, the team struggled for front-end grip.

Tyre options

The tyre choice for Ginetta's LMP1 has not yet been set, and will be decided by the team, but both Dunlop and Michelin have confirmed that they would develop a customer tyre for the racecar. 'We have liaised with Dunlop and Michelin, and we have shared kinematic information with them,' says Baldry. 'In both cases they have made the case that they won't be churning out a hybrid tyre and they will make a tyre specifically for this purpose.'

Megaline provides much of the electronic components in the car, including the e-clutch, gearshift mechanism and steering wheel internals, allowing it to be fully configurable, while Bosch takes care of the management systems, including the PDMs and data logging.

There is not much provision for the proposed hybrid system that the FIA wants to introduce to all cars under the new regulations when they are introduced, but Baldry thinks that not much will be needed to adapt to an off-the-shelf system.

On track testing has now begun, with unlimited testing allowed until February 9, and then strict limitations on the number of days ahead of the first race at Spa in May.

TECH SPEC

Ginetta G60-LT-P1 LMP1

Chassis: Carbon-fibre and aluminium honeycomb monocoque.

Body: Composite panels.

Engine: Mecachrome V634P1 95-degree V6; turbocharged. Power, 650bhp. Torque, 650Nm (see page 24).

Gearbox: Xtrac 7-speed.

Suspension: Double wishbones; pushrod actuated springs and dampers; anti-roll bar.

Steering: Rack and pinion.

Brakes: AP Racing carbon ceramic discs.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Dodge bullet

It has two 2500bhp Dodge engines, a super slippery 13-metre long body, and its builder is confident it's set to become the fastest 'car' in the world. Meet the Target 550

By SAM COLLINS

'Nobody who competes in Land Speed Records is really competing against another person. They are competing against a number'

The Target 550, as the name suggests, has been designed to hit 550mph. But its first mission is to break the current wheel-driven Land Speed Record of 458mph, a speed it could possibly reach at Lake Gardiner in Australia in the spring of this year

There is an overused expression, often heard when extreme projects are launched. It was first applied to mountaineering, in response to a journalist asking George Mallory why he wanted to climb Mount Everest he apparently replied 'because it's there'. Marlo Treit gives the same answer why he wanted to beat the record for the fastest car in the world. And now his twin-engined streamliner, Target 550, is about to take a big step towards this goal.

In the mid 1960s the outright Land Speed Record split in two with jet propelled cars treated separately to those with driven wheels. While the jet cars evolved into wingless jet fighters (literally in the case of the North American Eagle) and the overall record almost doubled since the split, the wheel-driven record has only crept up from just over 400mph to the current mark of 458.440mph, set by the late Don Vesco's Turbinator in 2001.

Treit has been in pursuit of this wheel-driven record for decades. 'I started drag racing with a motorcycle in the late 1950s', he says. 'My mentor back then was a guy called Pat Connelly who was the cam grinder for BSA and Triumph, and did all the work on English motorcycles which needed to be pumped up a little bit. I had built a twin-engined motorcycle and it proved to be very effective in drag racing. Pat then tapped me on the shoulder and said "you should take this thing to Bonneville".

At that time Treit was not overly keen on hitting the salt at any speed. 'I was not all that interested in going, but he convinced me and got me an invitation to run the motorcycle there. At that time it was an invite only event with SCTA [Southern California Timing Association], with only 25 motorcycles running each year at speed week. I ended up breaking a record, and from then on I ran motorcycles at Bonneville for the next few years until I was drafted into the military. I sold all my motorcycles and never went back to them.

'When I came out of the service, I built a drag car for the first time, but I soon found out that drag racing with a car was very expensive,' Treit adds. 'So I went on to build an exhibition car with a commercially available turbine engine. I lobbied SCTA to let me run that turbine engine at Bonneville and they turned me down, so I dropped a Mazda engine into the car and ran it as a Lakester and that became the fastest rotary powered car in the world for a few years.'

TECH SPEC

Target 550 record car

Chassis: Tubular 4130 steel with one-eighth inch wall thickness.

Engines: Twin Dodge 510ci Hemis; Whipple superchargers; Mallory Magnetos; Waterman fuel pumps; Webster heads; KB billet crankshaft; RCD pulleys.

Transmission: B&J 4-speed planetary transmissions both being shifted simultaneous via controls at steering wheel; Crower triple plate clutches; Halibrand front and rear housings with Arrow ring and pinions 1.5 to 1 with shafts made by Lenco; gear ratios: 1.45 / 1.30 / 1.25 / 1.0.

Wheels: 18in with 1.5 degrees camber.

Deceleration: Willwood brakes: quad parachute system by Stroud: airbrakes.

Frontal area: 8.61sq.ft.

Length: 43ft.

Width: 36 inches.

Height: 42 inches.

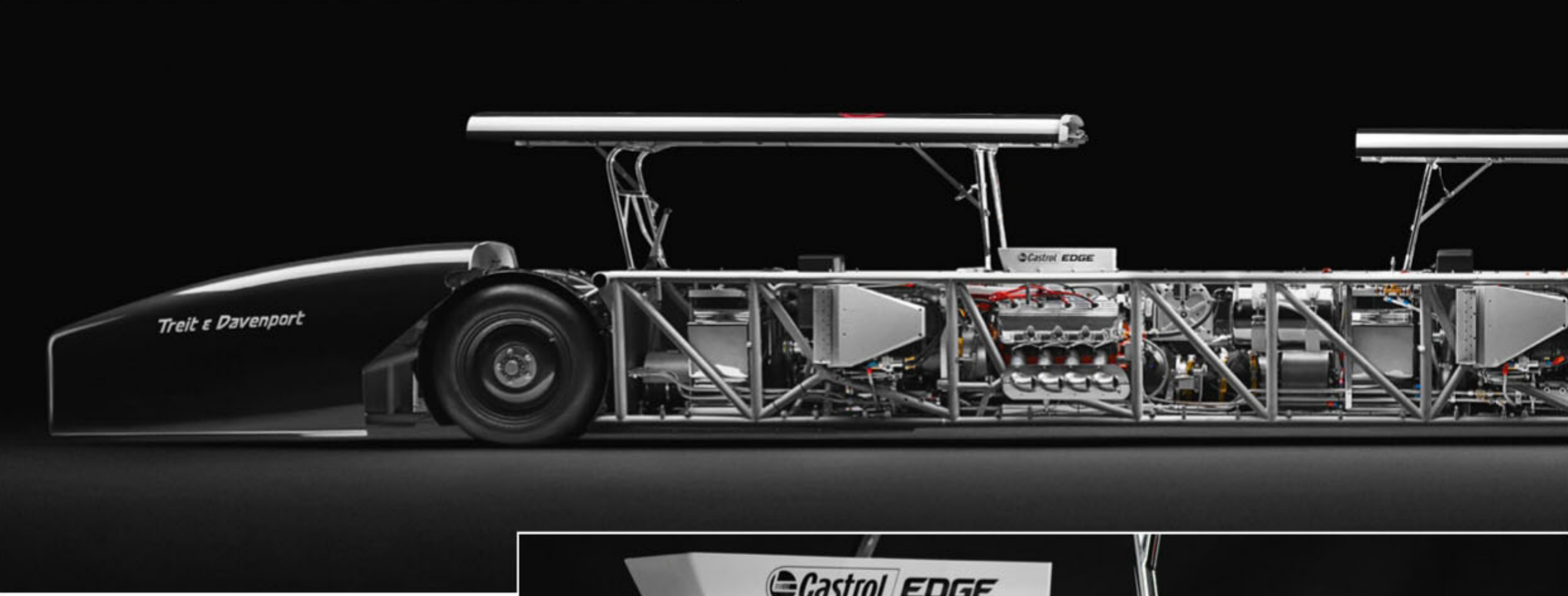
Need for speed

From that point on Treit discovered a love for speed records, and also found that it fit with his lifestyle far better than drag racing. 'At that time I was working, I had a family and the idea of only having to prepare for one event a year was a lot more attractive than going racing most weekends of the summer in financial terms,' he says. 'So over the years I kept going to Bonneville, I had a few partners over the years and different cars. In the 1980s I built a streamliner that did 308mph which was pretty close to the record for that type of car. I aimed to go for the record the following year. I improved the engine and on the first pass I crashed and completely destroyed the car. I still wanted to build a faster car but at that point I decided it might be a better idea to let someone else drive.'

It was at this point Canadian drag racer Les Davenport took on the driving duties, and the concept for the car which became Target 550 began to take shape. 'The vision of this car was clear in my mind in 1985, but it was 1998 before the project started to get off the ground. But by that time I had accumulated a war chest of parts and ideas to start the build,' Treit says.

Car concept

The vision he had was for a long twin-engined car, with four driven wheels and a sturdy tubular steel chassis. While most of the mechanical components would be located between the front and rear axles the driver would sit in a pod just behind the rear axle. While the design evolved as the years passed its overall concept remains the same to this day. 'Over the years I have discovered that two engines are better



than one engine, the same way a V8 is better than a 4-cylinder, you don't have to strain the engines as much,' Treit says. 'But with two engines the chassis needs to be substantially more secure, so that is why it is how it is.'

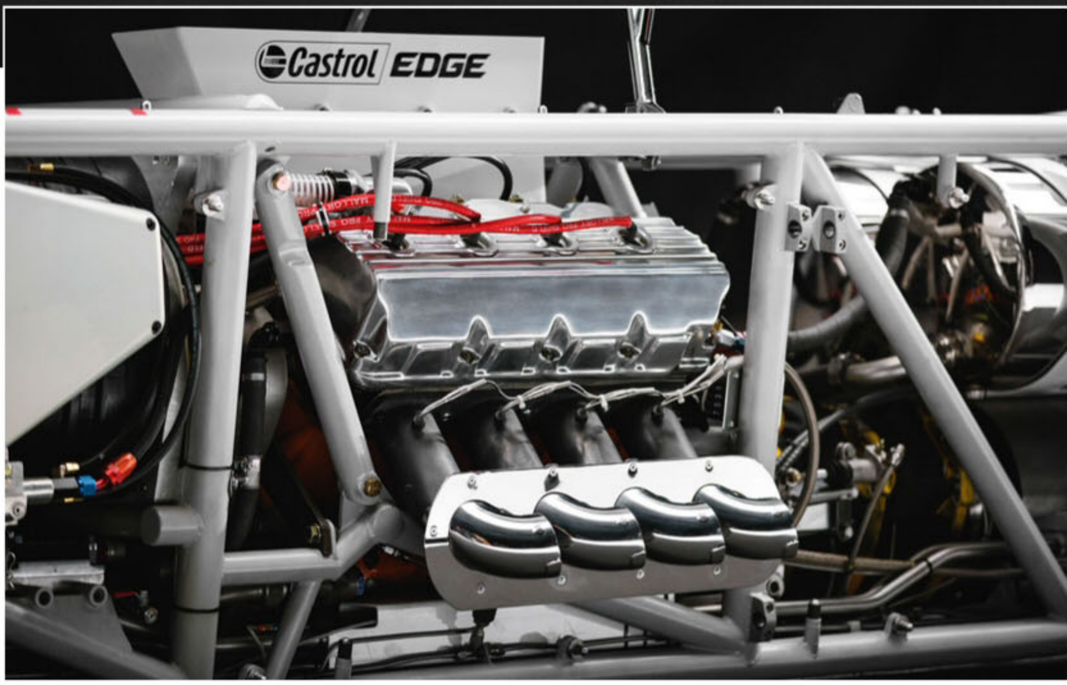
Dodge call

For a man who proudly claims to have been a 'Ford guy' the choice of twin Dodge V8 engines perhaps seems counter-intuitive, but this was the product of practical considerations. 'I'm still a Ford guy, but unfortunately there are no aftermarket Ford engines suitable for this project that have the broad spread of parts available that the Chrysler Hemi does,' he says. 'I'd love to have 427 OHC Ford engines in the car, but to get the parts needed I would have to spend $100,000 to $200,000 more on each engine. The 426 Hemi has a dozen companies making very good parts. They are still using the same basic bore centreline and same crank as in 1972. It is relatively bulletproof. If I need a head gasket there are 10 companies making them, with the Ford there are none, you have to make it yourself. I already make enough stuff myself.

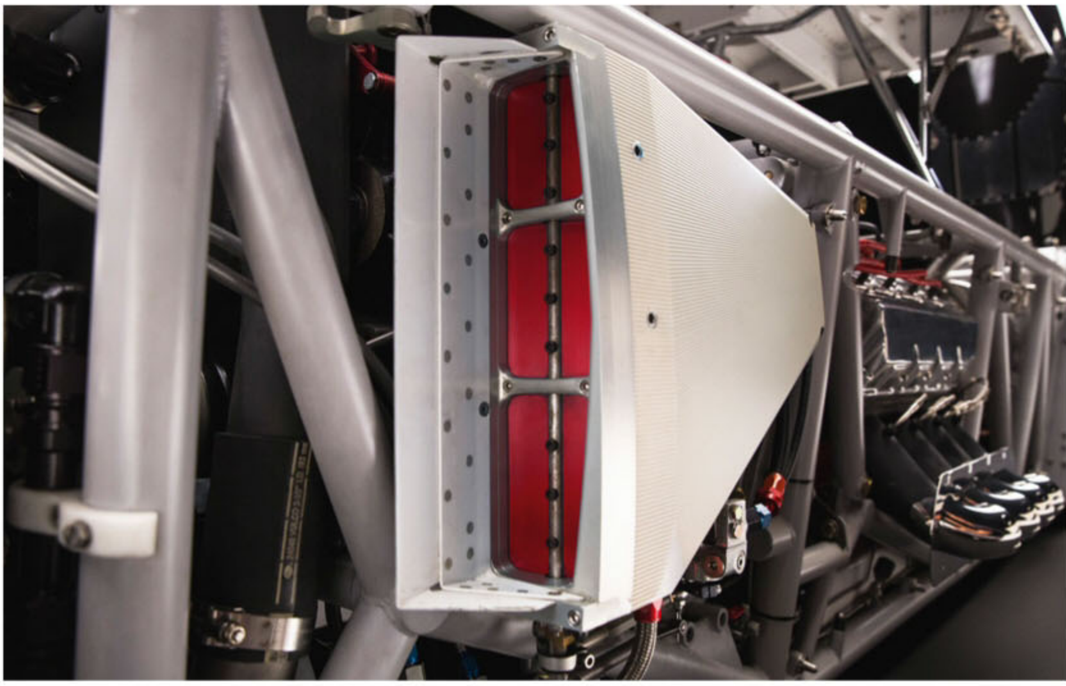
'The Hemi engine supercharged and running on alcohol is an easy engine to make performance. Having used it for so many years we know the cycle life of parts, so, for example, we change the rods after every 10 runs. I still run water in the heads, I could actually detune these engines and run them on the street.'

Despite that claim it's clear these engines are far from standard. They are fitted with Whipple superchargers, KB billet crankshafts, Mallory magnetos, RCD pulleys and Waterman fuel pumps, with many internal changes, too, while the heads have been extensively reworked by Webster. Each powerplant produces around 2500bhp at 7500rpm, giving the Target 550 around 5000bhp, while each engine has around 1800ft/lbs of torque at 6800rpm.

As the car is four-wheel-drive and twin engined it might be expected that the front wheels are driven by the front engine and the rears by the rear. However, this is not the case.



Motive power is courtesy of a pair of old fashioned Dodge Hemi V8s, providing a combined 5000bhp. They have KB billet crankshafts, Mallory magnetos, RCD pulleys and Waterman fuel pumps, while the heads have been extensively reworked



Supercharger intake. The Whipple superchargers can be adjusted to make up for power loss at altitude. High altitude means low air density and hence less drag and the team hopes to run on the very high Bolivian salt flats at some time in the future

The Target 550 is just over 13 metres long and features a cockpit pod aft of the rear wheels

‘Over the years I have discovered that two engines are better than one engine’

The twin engines drive a side shaft running down the right hand side of the car. The only time they rev at a different RPM is when the clutches slip, beyond 4000rpm on a run they behave like a single unit

‘The two engines are tied into a side shaft running down the right hand side, there are Kevlar timing belts between the back of the transmissions over to this layshaft, the front engine’s only connection is to that shaft,’ Treit says. ‘The shaft goes past the front engine to another belt box which drives the front pinion which is on the centreline of the crankshaft. The rear engine also has a belt box behind it and also goes to that shaft, but it also has a through shaft which goes to the rear drive unit.

‘Theoretically we could disconnect the rear engine and the front engine would drive all four wheels or the rear could drive all four alone,’ Treit adds. ‘With the two engines mated like this the clutch slippage is the only time the engines are at different RPM. As soon as the clutches lock up at around 4000rpm both engines run at the exact same speed. I had assumed when building the car that this would be the area where problems would occur. On my twin-engined motorcycle the chain between the engines took a horrendous beating, but on this car the system has been absolutely trouble free.’

Geared up

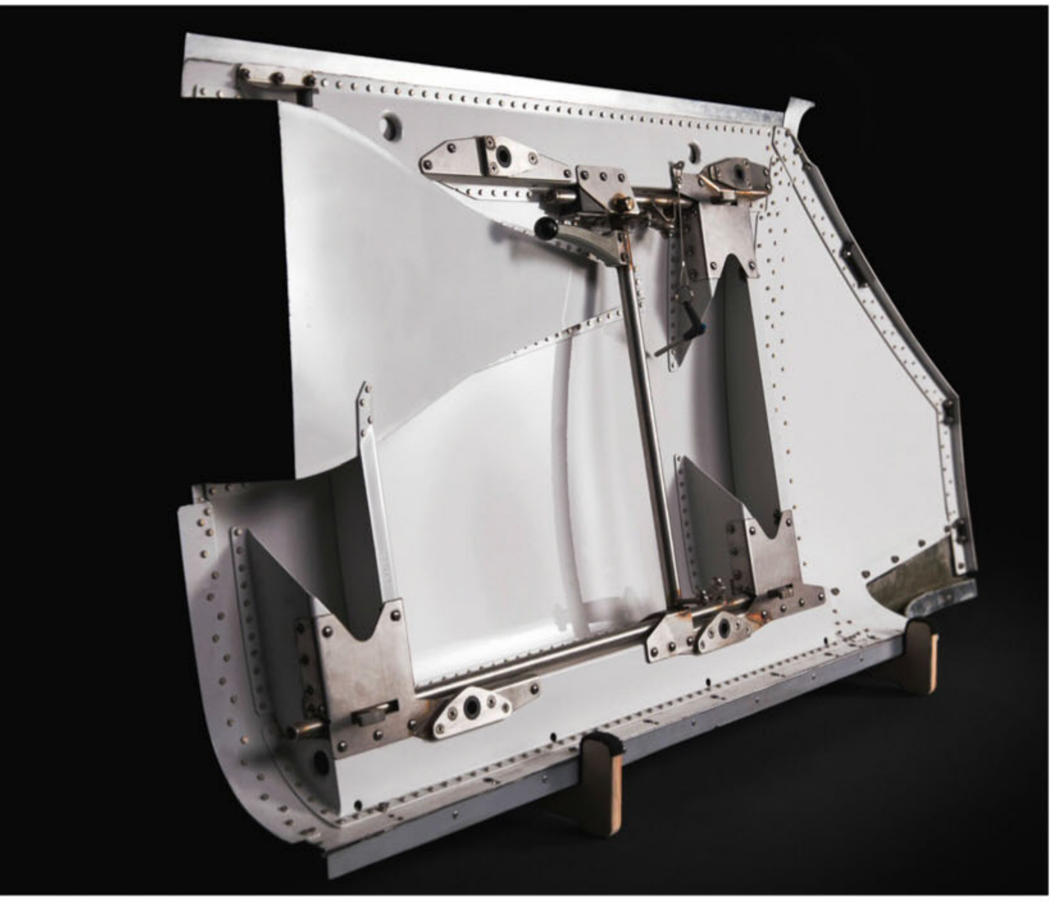
Some of the transmission components have seen use in other racing fields including Top Fuel drag racing and high level single seater racing. ‘The differentials started out as Halibrands used for Champ Cars, and they are the last aluminium castings that Halibrand made while it was still in business. They were purchased for this car back in 1992,’ Treit says. ‘Arrow Gears made the gears and the car has a 6-inch pinion and a 9-inch ring gear, so it has a 1.5:1 ring-and-pinion ratio. With the quick change, it’s possible to get the ratio down to .75 or up to 3:1.’

But for a car to go over 400mph it requires more than just sheer horsepower and a strong chassis, it also needs a good aerodynamic package. To develop this Treit turned to Dr Michael Seal, then the director of Western Washington University’s Vehicle Research Institute. A 10 per cent scale model was made and tested in the university’s own wind tunnel.

‘That was a real learning curve,’ Treit says. ‘We had to rework the front end a number of times. That’s where the name of the car came from. When the guys there asked me how fast I wanted to go, I said 550mph. With many small modifications to the design we found that it was possible to do that speed.’

The ultimate design which emerged from the university’s wind tunnel for Target 550 was a very long (13.1 metre) car with a frontal area of 8.61sq.ft (0.8sq.m). It also has a 1.5-degree

For a car to go over 400mph it requires more than just sheer horsepower and a strong chassis, it also needs a very good aerodynamic package



The body panels are constructed to be firmly attached during the run yet easy to remove for maintenance. They have been compared to the door on a safe, yet the force of an explosion caused by a malfunction still managed to blow off some panels

Airbrakes deployed. Most of the retardation actually comes from parachutes fired out from the rear of the car. There were problems with these at early tests due to the disturbed salt that was thrown up behind the record car chewing up the chutes

included angle on the sides of the bodywork, front to rear, for additional stability.

One area that the aerodynamic team had to consider, in conjunction with Treit and the engine builders, was the impact of altitude on the car's performance. Bonneville sits at almost 1300 metres above sea level, which gives a relatively low air density, reducing drag.

'At Bonneville the density altitude is around 7500ft,' Treit says. 'I think we can run up to 500mph at 8-10,000ft, but we will have to go to a venue in Bolivia [where there are salt flats at an even higher altitude] to get that final 50mph. On the worst day they had, the density altitude was 13,500ft. Since the car is supercharged we don't have the power loss which comes as a result of altitude; we can adjust it to cope with the effect of density altitude.' The team intends to go to Bolivia if the funding can be found.

Chute out

With this getting up and running properly in 1998, Treit expected that it would be a five year project, but ultimately it would be 2012 before the car was ready to run. When testing began lessons started to be learned straight away, and one in particular, as Davenport struggled to stop the car on the salt at Bonneville. 'It's got the best brakes that money can buy from Wilwood, the rotors are good for 7000rpm, and I would say the pads are good for about three seconds,' Treit says. But most of the braking force comes from parachutes fired out from the rear of the car after each run, and something was going wrong with them on almost every single run. 'Our airflow is so good that the air gathers together behind the car, about 40ft back, just from the vacuum from the tunnel under the front and rear wheels. The front end has 900lbs of downforce and the rear 800lbs at 400mph. So when the salt is loose, it's like shaking a salt shaker on a table, and all those hard crystals are sucked up, and it just ate away nine chutes. Because of that we had to change the deployment system from a centrally mounted pod to two pods side by side and hopefully they will bump each other and leave a gap in the middle for the salt spray.'

Into the unknown

The tyres were also an interesting area, as no wheel-driven car has ever exceeded 500mph, let alone 550mph, so there is little knowledge of how they would perform on salt at such high speeds. 'In testing we have run Mickey Thompson tyres, but for the record runs we have the option of both those and Goodyears,' Treit says. 'There is a gentleman in Montana with a tyre spinning machine and he has spun the tyres at 550mph and they have not disintegrated.

The tyres were an interesting area as no wheel-driven car has ever exceeded 500mph, let alone 550mph

The dash tilts up to allow the driver easier access to the cockpit. Canadian drag racer Les Davenport took over the driving duties after car builder Marlo Treit crashed a previous record racer

Many of the parts on this record car are pleasingly low-tech, such as this hand-operated lever for the wheel brakes. The brake system features Wilwood discs and pads that last for just a few seconds

That also gives us the growth rate with speed, from that we mount them in pairs. The tyres are all laid up by hand so there is some variance, a tyre with a 92in static roll out, for example, may after one run grow to 96 inches, maybe 94. So we make one run with the tyres and then re-measure them and use them in pairs. This means we don't end up with two 96in tyres on one side of the car and two 94in tyres on the other.'

Testing drama

Testing also highlighted manufacturing issues with some components on the car, notably during one test run in 2014. 'We had the most catastrophic failure that I could ever imagine,' Treit says. 'The superchargers have rotors machined from magnesium billet. They are a screw blower, rather than an air beater blower like a Roots, so they are actually a real compressor. On drag race cars, the blower sits on top of the engine. For this application, the blowers are down in front of the engines to keep the height down so the driver can see. The blower on the front engine at this test somehow picked up a harmonic vibration. With these blowers the shafts that go into the rotors are pressed in from both ends, it's not one continuous shaft all the way though and there is a friction mechanism to time the rotors. For whatever reason, the blowers came out of time and they scrubbed each other, so there was a lot of powdered magnesium in the intake system. The magnesium went through the intake system and into the combustion chamber, where it ignited and then went out the exhaust. There was no problem with that except that these engines have a lot of overlap at the top of the exhaust cycle, and the magnesium was still on fire in the combustion chamber as the piston tracked back up through the intake stroke. The engine sneezed and blew a gasket out of the intake side. It happened so quickly the crew didn't pick it up.

'After the run, the crew checked the car and everything looked fine,' Treit continues. 'Everything turned over well, so they went out and made another run. This time the sneeze was more noticeable, because the rotors were getting further out of time. The engine compartment from the water tank forward was filled with magnesium dust, and when it sneezed the next time, it blew off several body panels. Now these body panels are hooked on like the door of a safe, they are latched, ribbed and riveted. It takes a huge explosion to dislodge a panel. The force of the explosion ballooned the nose by two inches!'

Salt shaker

With lessons learned Treit decided to push the car as far as it could go at Bonneville. But a problem which did not exist when Treit started the project then made itself abundantly clear. 'The car was designed to run on a course at least 10 miles long at Bonneville,' Treit says. 'It is the heaviest of the high speed cars and there was no thought that it would need suspension because the salt was smooth and in good condition. Or at least it was when we started the project.'

But in recent years the condition of the salt at Bonneville has degraded significantly and Davenport discovered first hand just how bad it had become. 'He was bouncing around in the car like a pea in a whistle, he did not know which mile marker he was at,' Treit says. 'We have a tattle-tale on the throttle position on the dash, the car was bouncing around so much that on one run the driver's throttle position moved from 20 per cent to 50 per cent 10 times during the five or six seconds he was accelerating from 360mph up to 390mph.'

The pounding that the Target 550 was sustaining meant that parts were starting to fail, and it was becoming clear that it would not be possible to break the record at Bonneville. 'My car is not suspended, it is also full time four-wheel-drive. If a wheel bounces the other wheel and tyre has to take the full power and torque. That has seen us break things that Top Fuel drag cars don't even break. Some of the shafts we have broken are huge,' Treit says.

As a result Treit turned his attention to Lake Gardiner in Australia. 'The salt looks so smooth you could play snooker, it's that hard and that smooth there,' he says. 'You can spin a tyre on the salt there and you get a black mark on it, that is what Bonneville used to be 20 years ago.'

For the record

The fastest wheel-driven car to ever run in Australia was Donald Campbell's Bluebird CN7 in 1964 with 403mph, a mark that Treit is keen to improve on when he runs Target 550 in the same country in the spring of 2018. 'Campbell's 403mph, [Don] Vesco's 458mph or [George] Poteet's 430mph, I don't much care about those numbers, they have very different styles of car,' he says. 'Vesco and Poteet are both fully suspended, my car is not. Land Speed racing is about one's own personal best. There are people with 50cc motorcycles, steam powered cars, through all the classes nobody who competes is really competing against another person. They are competing against a number, and that number is their own personal best. I'm hoping to slide by Campbell's record. Nobody has ever run much more than 330 or 340mph at Lake Gardiner, but with luck we should be able to do more than that. The density altitude at Lake Gardiner will never be over 2000ft as the lake is just 300ft above sea level. I think we may still be able to get pretty close to 500mph, depending on the course and the conditions.'

While the car is already looking well capable of breaking the record, Treit's team is still a small effort and is constantly looking for additional funding so it can achieve its target. And while the outright wheel-driven record may well fall in Australia, you can be sure Treit will still be looking to hit that target of 550mph.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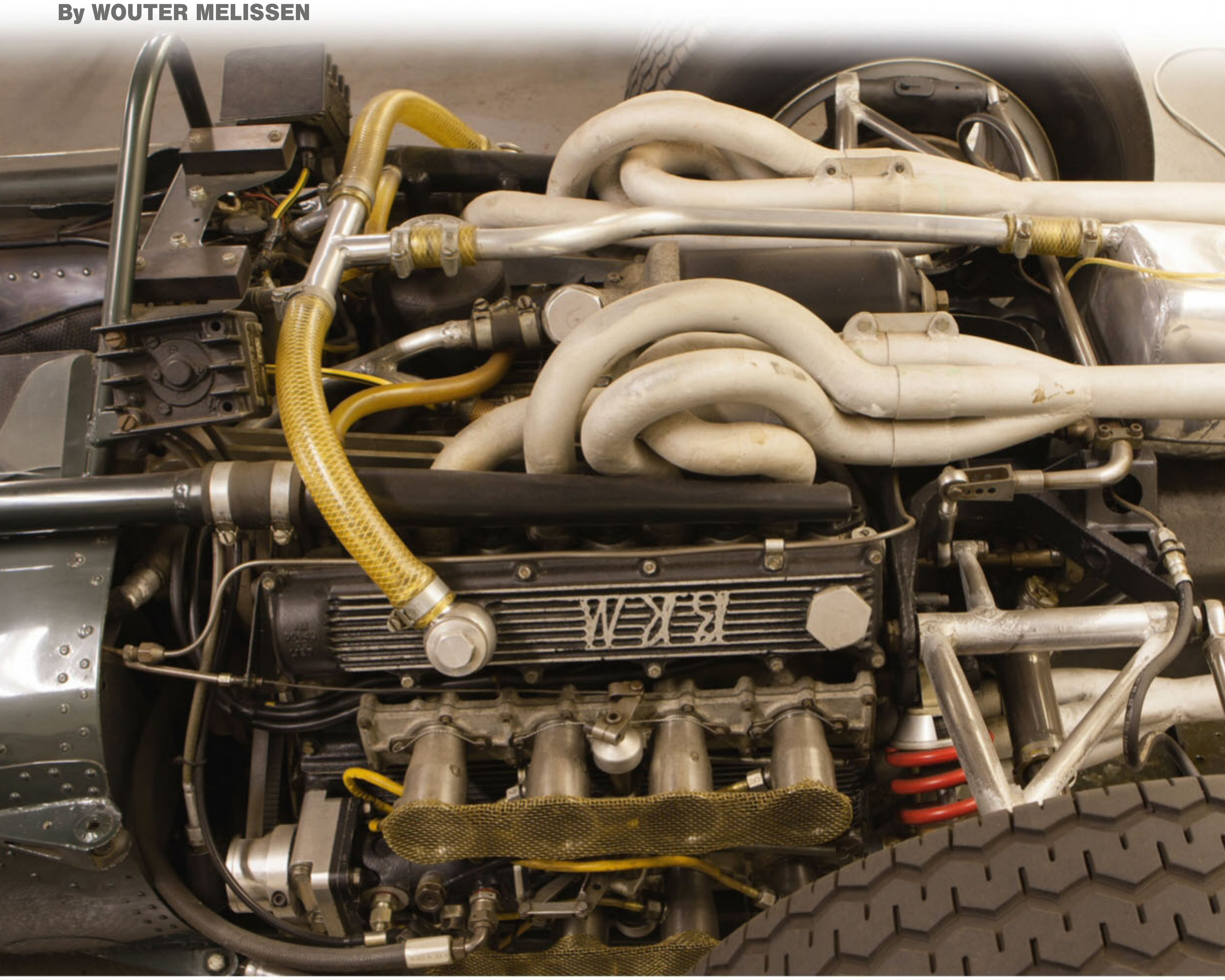
H-bombed

As glorious Formula 1 failures go BRM's H16 engine is right up there – but why did a concept that looked so good on paper fail to deliver on the track? *Racecar* investigates

By WOUTER MELISSEN

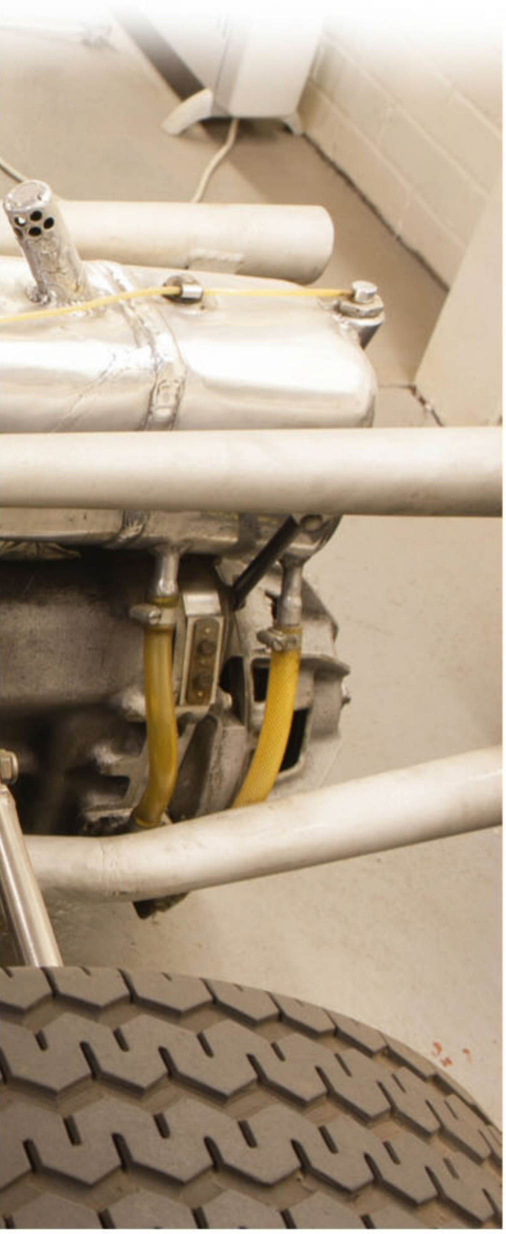


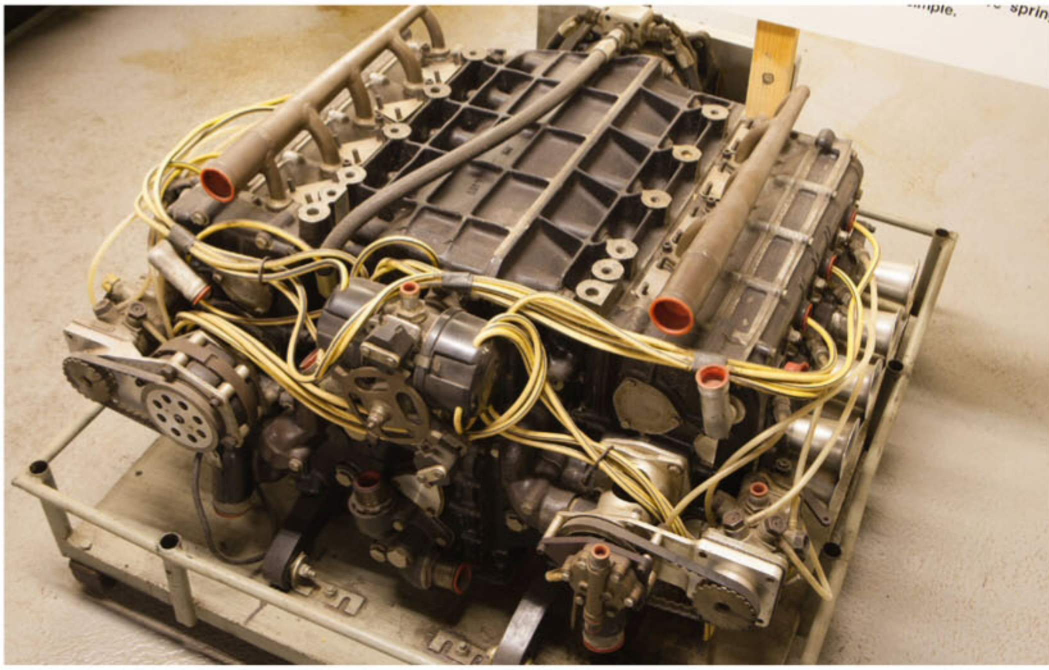
More akin to an H on its side, the H16 was built up of two flat-eight engines stacked on top of each other

British Racing Motors (BRM) had an inconspicuous entry into Formula 1 back in 1950 with the highly anticipated but ultimately unsuccessful V16. Such was the disappointment of the crowd after the car stalled on the start-line at its debut that driver Raymond Sommer was bombarded with coins. While Juan Manuel Fangio did manage to score non-championship wins with the temperamental V16, BRM only became a force in the Formula 1 World Championship as its cars became more conventional. The team particularly excelled in the sport's 1.5-litre era (1961 to 1965), using a high revving P56 V8 engine.

But for the 1966 season the displacement limit was raised to 3-litre and BRM responded with what would become known as the H16 engine. More akin to an H on its side, this engine was built up of two flat-eight engines

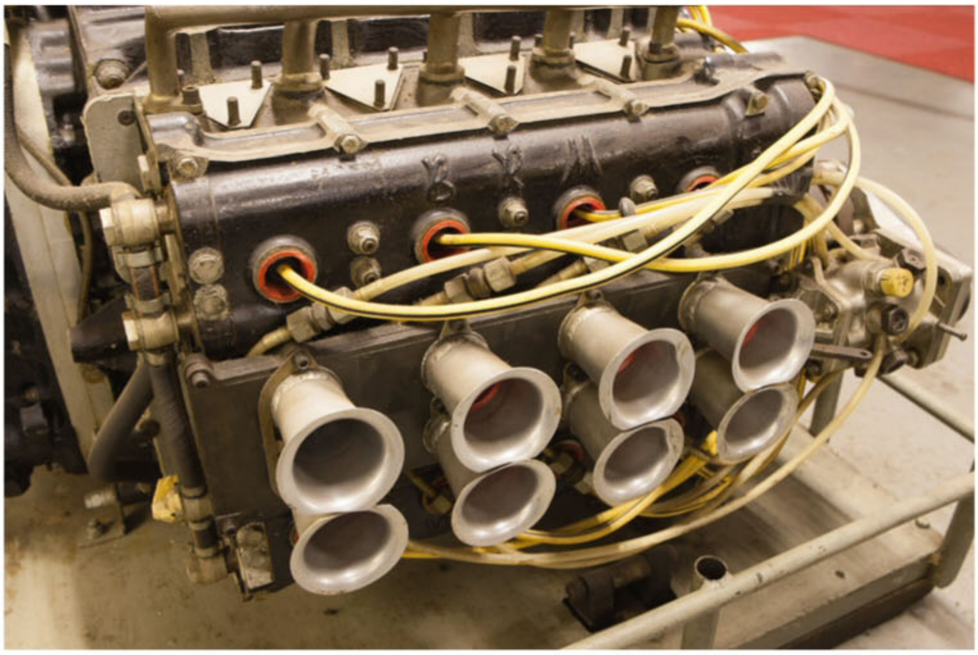
Main picture: When the new 3-litre formula arrived in 1966 BRM rose to the challenge with its radical H16; but the engine was too heavy and unreliable **Right:** The architecture of the unit is clear here, with two flat-eight engines mated together. BRM had hoped for 600bhp but only achieved 420bhp at best





stacked on top of each other. As BRM struggled to get the unconventional engine race-ready, observers were quick to conclude that the Bourne-based company had returned to its bad old ways by cutting one too many corners by grafting two of its existing V8 engines together. Yes, as it turned out, the decision to develop the troublesome H16 had actually been well thought through and some alternative solutions had also been seriously considered.

The first Formula 1 car to pack the H16 was BRM's 1966 entry, the P83. Note the routing of the water pipes outside the car

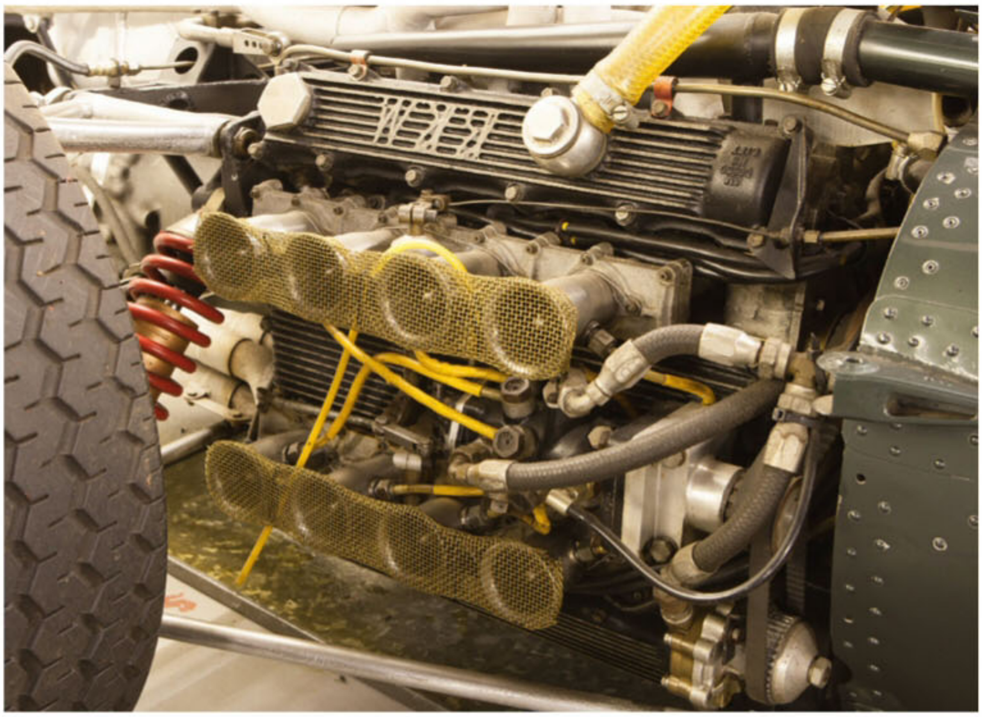


BRM's old V8 engine had inlet ports between the camshafts. This allowed the H16's intake trumpets to stick out of the sides

The Repco V8 Formula 1 unit produced not even 300bhp, but it did so very reliably and weighed over 200lb less than the H16

Indeed, well ahead of the proposed rule changes the BRM design team, headed by chief engineer Tony Rudd, considered all the available options. For obvious reasons a 24-cylinder was quickly discarded. A 3-litre V8 was given some more consideration as it would be the lightest and most compact option, but the engineers feared it would not be able to rev high enough to reach the power figures they estimated would be required in the near future. This left a 48-valve V12 engine that was the choice of engineer Harry Weslake, who ran BRM's remote advanced projects study office in Rye, Sussex, or the H16 engine that was favoured by Rudd himself, who worked at BRM's main facility in Bourne, Lincolnshire.

Design studies for both were made and various options considered but eventually the H16 was given the green light early in 1965. The studies had found that while the H16 engine would obviously be more complex and heavier (380lb *vs* 360lb for the V12), the potential output of as much as 600bhp in 64-valve form would provide sufficient compensation. Another advantage of the 16-cylinder design was that the engineers could use the valuable lessons learned developing and running the successful P56 V8. It was also found that the V12 would be too long (30in compared to 24in) and that due to its compact design the H16 could be used as a fully stressed member of the chassis. Weslake did continue with the development of his V12, which would eventually power Dan Gurney's Eagle to victory in the 1967 Belgian Grand Prix.



One of the H16's unsung legacies is that it was the first engine to be used as a fully stressed member; before the DFV in '67

This P115 (at Goodwood Revival) was raced five times by Jackie Stewart in 1967 but it never made it to the chequered flag

Bourne identity

The initial plan while creating the P75, as it was officially called, was to use as many components, including conrods, pistons and cylinder liners, from the existing V8 engine as possible. Developed and raced for five seasons, this was a well-honed unit and produced a very reliable 220bhp during the 1965 season. What was bespoke for the new design was the cast-aluminium block and heads, which were effectively two flat engines stacked on top of each other with two crankshafts connected by gears to a central output shaft.

A crucial feature of the latest evolution of the V8 engine that had allowed the H16 even to be considered was the relocation of the inlet ports to between the camshafts. This allowed the intake trumpets of the engine to stick out the sides. The exhaust ports were in a more conventional position at the top and bottom of the engine. The original design included the use of a single intake camshaft that would actuate both the top and bottom valves on one side of the engine. This would mean another benefit of using the unconventional layout and allow for an even more compact design.

As it turned out, this would make the design too compact, and would have the crankshafts running too closely together. A wider valve angle could have sorted this issue but the designers were actually looking at getting a narrower angle. In the end it was decided to give each bank of four cylinders a separate intake camshaft despite the added bulk. To free up room for the additional camshaft, the valve angle was narrowed, which in turn led to a slightly wider bore. As a result, the pistons of the V8 engine could no longer be used.

Bourne again

With the design finalised it was time to cast the major components. The engine block was cast in aluminium in two halves, split vertically down the middle. The decision to cast the pair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There was a belief held at that time that longer conrods would provide a performance improvement due to reduced side loads

The complex H16 needed an array of pulleys, cams and gears to get it to function correctly and all this just added weight to the unit

of heads on each side as one piece proved troublesome. The heads were designed this way to increase stiffness and ensure a leak-free flow of coolant between the top and bottom heads. Foundry problems, however, delayed the production of the prototype engine by a staggering six months and measures to sort out the issues added a further 44lb to the weight of the prototype engine. The vertical split in the block was not straight down the middle and the 2.5in offset allowed the crankshaft and bearing assembly to be built up in one half before the case was sealed.

Crank call

At the rear of each crankshaft a single gear was fitted to connect it to the output shaft of the engine. The gear was connected to the crankshaft with a torsion shaft. This provided some play, which allowed for a slight misalignment of the two halves of the engine. At the other end the top crankshaft was connected to the Lucas ignition system and a pair of distributors. The lower crankshaft powered the eight camshafts through an array of gears and also drove the two oil pumps.

BRM P83 (8302)

The second of three P83s built, this example was first raced by Jackie Stewart in the 1966 Italian Grand Prix at Monza, but the H16 engine expired just a handful of laps into the race. It was then raced three more times that year by Graham Hill, but he failed to reach the finish on each occasion with this car. Underlining that the drivetrain and car were more reliable in 1967, Mike Spence was a regular finisher with this chassis that season. His highest finish was fifth, but he achieved this in five grands prix and also placed sixth twice. Last raced at the 1967 Mexican Grand Prix, where Spence – of course – finished fifth, this BRM was eventually sold to the late Tom Wheatcroft and displayed for many years in the Donington Grand Prix Collection Museum.

Halfway through the development of the H16 engine, BRM owner Alfred Owen decided that his cars should also compete in the Tasman series in Australia and New Zealand during the 1965/1966 off-season. He sought additional exposure in the lucrative market for his Rubery Owen company. Different again from the 1965 Formula 1 regulations, the Tasman series was open to single seaters with a displacement of up to 2.5 litres. The existing cars could be used but Rudd was tasked to enlarge the V8 engines to the maximum allowed by the blocks, resulting in a swept volume of up to 1916cc.

Bad vibrations

Developing these Tasman engines also took valuable time away from creating the new F1 unit, which was finally ready for testing on January 23 1966. The first engine ran for seven minutes at 2000rpm before the dynamometer propeller shaft seized. This in turn required a week-long rebuild of the engine, which delayed testing further. This happened several times more before the cause was finally discovered. A vibration was the issue, which Rudd initially believed was caused by the exhaust and intake valves tripping over each other. This was deemed to be physically impossible, but has since been regularly repeated and is now seen as one of the engine's major shortcomings.

The actual root of the problem was a lack of inertia of the crankshafts, in particular that of the top one, which relied almost solely on its own weight and that of the bottom one to maintain motion between firing cycles, instead of a conventional flywheel. This was addressed by adding 2lb steel discs to the four balance weights on each of the two crankshafts. While this finally allowed the engine to rev over 10,000rpm without a problem, a further 16lb had been added to the mass of the already very heavy H16. In fact, it weighed in at a staggering 586lb at this point, compared to the 260lb of the V8 and the 460-480lb the engineers had estimated the engine to weigh after starting the development proper. To make matters worse, it also could produce no more than 400bhp reliably; far less than double that of the V8.

Monte Carlo and bust

Despite this considerable under-performance BRM brought one of the H16 engines to the opening round of the 1966 World Championship; the prestigious Monaco Grand Prix. It was bolted to the new BRM P83 grand prix car as a fully stressed member. Graham Hill ran the car briefly in practice but was quickly sidelined due to an issue with BRM's bespoke 6-speed gearbox. For the rest of the weekend

The one successful design feature carried over from the BRM H16 engine was its use as a fully stressed member of the chassis

Early 3-litre F1 cars were noted for their elaborate exhaust layouts and the P115 was no exception with its under-and-over approach

he switched to one of the 2-litre Tasman cars also used by his team-mate Jackie Stewart. BRM was not the only team to run interim cars as Team Lotus, also awaiting the BRM H16 unit, and Ferrari also raced Tasman cars. There were also true 3-litre cars on the grid with Ferrari and Maserati running V12s and Brabham a relatively straightforward Repco V8 that was based on an Oldsmobile production engine. John Surtees had proven fastest in practice with the single 3-litre V12 Ferrari available, but Jackie Stewart managed to win the race with his tried and trusted 2-litre engined BRM.

Lotus position

After the H16 engined car had failed, Lotus' Colin Chapman came to the BRM pit to have a look. His was more than a passing interest as his team had ordered H16 engines, which it was going to use for the rest of the 1966 season. He soon saw just why the gearbox had failed; the clutch was mounted the wrong way round. Instead of connecting the heavy drum to the engine, which would have also helped with the inertia issues, it was connected to the gearbox. This meant that the gears continued to move even in neutral and with the clutch disengaged, destroying them within a few laps.

The first H16-engined Type 43 Lotus appeared at the French Grand Prix where the engine's sheer grunt should have helped. Peter Arundell, however, started the race at the back of the grid and had already pitted during the opening lap with a rough running engine. He went out several times more but with no luck. Ironically, perhaps, the race and the World Championship that year was won by Jack Brabham, who had chosen to run the simplest 3-litre engine on the grid. His Repco V8 with a single overhead camshaft produced not even 300bhp but it did so very reliably and weighed over 200lb less than the H16 engine.

There was a small silver lining for the whole H16 project as Jim Clark actually managed to win the 1966 United States Grand Prix at Watkins Glen with his Lotus 43 BRM. This was more a testament of his incredible skill and a case of a lot of luck, though. In practice Clark had already blown the engine allocated to him and BRM could do no better than loan Lotus its spare H16. Not race-worthy at all, it actually already leaked oil on the grid and the Lotus mechanics did their best to divert the eyes from the officials away from the drips on the track. They were successful and Clark would go on to take the H16 engine's only grand prix victory.

Despite the disappointing results during the 1966 season, Tony Rudd continued the development of the engine. Among the first major changes was the introduction of an eight-throw, two-pin crankshaft to find a more permanent and above all a lighter solution for the vibration issues. This allowed the engine to run as a single 16-cylinder instead of two eight-cylinders. First used late in 1966, at the Mexican Grand Prix, these Mark II crankshafts were not an immediate improvement as they caused conrod failures.

The long con

By the March of 1967, the engines were running relatively reliably but during bench tests the BRM engineers never recorded over 420bhp. One of the problems was tracked down to the conrod lengths, which had been set in stone early in the design phase back in 1965. At that time, BRM also developed a four-cylinder engine with similar length conrods. The belief prevalent at that time was that longer conrods would provide a performance improvement due to reduced side loads. However, shortly thereafter, it was actually found that the adverse effects were actually larger. By that time the design of the H16 had been finalised and could not be changed.

Having recognised all the shortcomings of the original H16 design, Rudd returned

BRM P115 (1151)

For the 1967 season BRM built one brand new car for the H16 engine. It was slightly lighter and featured a revised cooling infrastructure.

That season it was raced by Jackie Stewart on five occasions but he never managed to reach the finish. Mike Spence also tried the car at the opening round of the 1968 season but again was forced to retire before the end of the race. Like many of the BRM cars it eventually ended up in the Donington Grand Prix Collection museum. In more recent years it was restored to full running order by specialists Hall and Hall.

In 2016, the car was demonstrated for its new French owner by Hall and Hall's Andy Willis during the Goodwood Revival celebration of the 50th anniversary of Formula 1's 'Return to Power'.

A new version was to feature simpler castings to reduce the weight and also boast four valves per cylinder to improve the performance

to the drawing board to create a much-improved successor. This engine would feature much simpler castings to reduce the weight considerably and also boast four valves per cylinder to improve the performance.

Among the changes was a completely revised head with narrower valve angles. These meant that the intake ports could be moved to the outside of the heads with the trumpets mounted between the top and bottom heads. Only the spark plugs were still placed between the camshafts. One such 64-valve engine exists today as a display piece, but it was never raced in anger.

Dropped H

Disappointed and somewhat embarrassed by the lack of success and realising the sheer weight of the H16 engine would always remain an issue, Alfred Owen decided halfway through the 1967 season to use BRM's newly developed P101 V12 powerplant instead. Originally intended for use in sportscar racing, this V12 bore no direct relation to the engine proposed by Harry Weslake two years earlier. It was a straightforward design with two-valve heads but at least it worked. The V12 made its grand prix debut powering a McLaren early in 1967 and would go on to form the basis for BRM's Formula 1 engines for a decade.

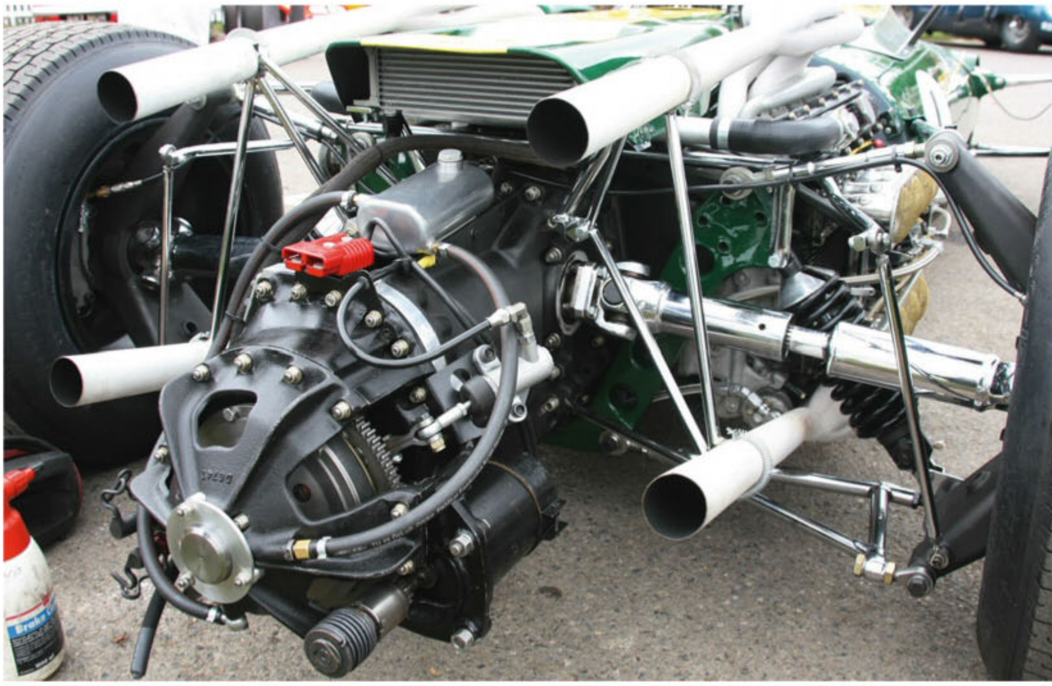
The Bourne legacy

With hindsight, it is easy to say that BRM made the wrong decision to go with the H16. The fear of the potential performance of its rivals in Formula 1 pushed it towards the more complicated solution that may have had the most potential in the long run, but certainly cost the team a shot at immediate success.

Had BRM spent the resources to develop the Weslake V12 or even the more straightforward P101, BRM would have been an instant title contender during at least the first two years of the 3-litre era. Instead, the Brabham Repco team won the drivers' titles with its very modest V8 engines.

The one design feature carried over from the H16 was its use as a fully stressed member of the chassis. Erroneously, this innovation is often credited to the altogether more successful Cosworth DFV V8 that was introduced in the back of a Lotus 49 in 1967. Today it is hard to imagine a purpose-built, top-level racecar that does not use its engine as an integral part of the chassis.

Special thanks to Rick Hall of Hall and Hall for the access to the H16 engine and the BRM P115, and for the excellent documentation provided on this subject.



The BRM H16 engine scored its only grand prix win, the 1966 US GP at Watkins Glen, in the Lotus 43 that is pictured here

Lotus 43 BRM (43/1)

Two Type 43 models were built by Lotus for the BRM H16 engine. This car was entered twice for Peter Arundell halfway through the 1966 season before being entrusted to Jim Clark for the Italian GP. Monza suited the sheer power of the engine and Clark managed to set the third fastest time in practice. He had a bodged start and eventually started the opening lap in last place and then retired shortly thereafter. The next outing was the US Grand Prix at Watkins Glen where all the pieces did fall into place and Clark managed to score the only grand prix victory with an H16 engine in this very car.

After its F1 career it was fitted with a Ford small-block V8 and raced in F5000. It is now owned by a Jim Clark enthusiast, who had it restored by Classic Team Lotus to full running order. The engine was rebuilt by specialists Hall and Hall and the engine pictures in this feature are of that unit.

This car was not rebuilt with the intentions of it being raced, but it has been demonstrated at the Goodwood Revival by its owner and by Dario Franchitti.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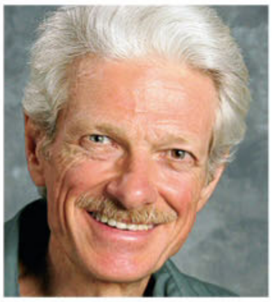

Suspension tweaks for the Mazda MX-5

How to set up the popular sportscar for US autocross events

QUESTION

I am autocrossing [fast US autotests] with my son in his 2015 Mazda Miata [MX-5] in C-Street class and wondered what to do to go faster. The SCCA requires sticking to the stock wheels but tyres are open so we went from 205/50R-17 to the 225/45R17 BF Goodrich Rival S1.5 tyres and everything else stock. Our camber is the stock -1.5 degrees front and rear, as are all of the other wheel alignment settings. The shock absorbers and the springs are also stock.

The front tyres look like the negative camber is not enough as there is a residue of tyre 'clag' [rubber build up] halfway out the tread after a competitive run.

The C-Street rules allow a double adjustable shock and alignment (I think) is open. My son purchased a fancy coilover shock absorber set but the springs are not stock items and therefore it's illegal. I am thinking we might fit the original springs on them and use the adjustability to lower the car as well.

I'm not sure of other options in the SCCA rule set. What do you recommend?

THE CONSULTANT

I have not had clients running this car in this class, and I expect that others have amassed considerable experience with it in this application, since the car is so popular. However, I think I can offer some useful thoughts having had a look through the rules.

It's unclear, but you might be able to use aftermarket shocks and get adjustable ride height and damping that way, but you do have to use the stock springs. When you lower the car you will get some more negative camber just from that, and your front view swing arm length will decrease, which will give you somewhat more camber recovery in roll.

You probably want to run the car as low as you can. If you drive it to and from the event, you may benefit from adjusting it lower at the event itself and then raising it again for the journey home. I would recommend having travel indicators on the shocks so you can see if you are bottoming out.

If you adjust the car to be lower at the event, it's probably advisable to align it and set wheel loads at competition ride height and then raise it equally at all four corners for use on the street, making a note of how many turns on the collars you have between the street and the competition settings.

Bump steer

You will want to check bump steer. You don't want much bump steer if you want to be able to change ride height without resetting toe. Note that caster affects bump steer. Adding caster moves any car toward roll oversteer, with toe-in as the suspension compresses. You may want to run more caster than stock, to reduce understeer. You may find that there's a conflict between running optimum caster for best cornering and minimising bump steer. In such cases, it is sometimes advantageous to bend the steering arms a little. That probably is not strictly legal for the class you run in, but in small amounts it's hard to detect. One possible procedure would be this:

1. **Find the caster setting that gives you the least bump steer.**
2. **At something close to static ride height, measure the height of the tie rod end. Perhaps use a scissor jack or other adjustable support to enable you to easily reset the tie rod end to that height when you bend the steering arm.**
3. **By testing it, find the caster angle you want to run.**
4. **With that caster in the car, heat the steering arms to cherry red as far from the tie rod end as possible and bend them down to the desired position.**

If you only use the car for competition, you can live with some roll oversteer for autocross. In any case, the above procedure can be used to minimise bump steer when running increased caster with a wide variety of cars, in the absence of built-in bump steer adjustability. It is also sometimes possible to add Ackermann by bending steering arms, but not on the Mazda Miata as the tie rod ends can't go any further outboard because the brakes are in the way.

You are allowed to change one anti-roll bar. As a rule, autocross rewards a somewhat freer (that is, more oversteering) set-up than most other types of events, due to the many

Oversteer is a good thing in the world of US autocross with its plethora of tight turns – and the MX-5 is a nice car to slide

You may find that it helps to use relatively stiff low-speed damping at the rear

small-radius turns. Therefore, it may work well to use a stiffer, adjustable rear bar.

It is desirable to dyno both your aftermarket shock absorbers and your stock ones, so you know what you have got and know how the adjustables actually respond to adjustments.

You may find that it helps to use relatively stiff low-speed damping at the rear. This will tend to add oversteer on turn entry and also add understeer on the corner exit.

The tyres you're using are barely suitable for daily driving. They will wear fast if used for that. If you use them only for competition, it is advisable to wrap and bag them between events. Wrap the tread with cling wrap and put them in contractor trash bags. The tyres will still harden over time, but not as much. The compound will polymerize, but there will be less evaporation of oils and solvents.

The treads are moulded pretty shallow, so there's probably not much to be gained by shaving them, but others running them should be able to tell you better than I can. Camber cutting is specifically prohibited. However, I don't see how camber wear can be prohibited. I suppose you could have some old car specifically set up to produce camber wear.

As with any car, tyre inflation pressure needs to be right. With a Miata, chances are that the same pressure will work well for fronts and rears. If you're able to do it, skid pad testing is definitely the best way to optimise both inflation pressure and camber.

Failing that, just have that adjustable rear bar set soft, or even disconnect it, so that the car understeers, and find the front tyre pressure at which it understeers least. You will find that this interrelates with camber to some degree. With less extreme static camber, the optimum pressure will be a little higher.

Finally, there may be a little extra speed available from optimising the driving position. It helps in autocross to have the driver's eye level fairly high to facilitate the accurate car placement that is vital in such events.

Camber compensators

The aftermarket swing axle modification that was good enough for Porsche

Camber compensators were originally marketed for swing axle cars such as the Porsche 356 (pictured). They add stiffness in ride or heave

QUESTION

In discussions about early Corvairs and other cars with swing axles, I've found out about a device called a 'camber compensator'. It's a kind of leaf spring under the rear end that is supposed to keep the rear wheels from tucking under the car. But do these things actually work? And, if so, what exactly do they do?

THE CONSULTANT

The camber compensator is essentially the opposite of an anti-roll bar, or sway bar. It adds stiffness in ride or heave (synchronous wheel movement) and not in roll (oppositional wheel movement), whereas the anti-roll bar does the opposite. It doesn't cure the jacking completely but it reduces it.

It accomplishes this without increasing rear load transfer, which would be the result if we used stiffer springs or droop limiters instead. When pre-loaded, it can also serve to lower the rear suspension and add a bit of static negative camber.

It was originally marketed by EMPI as an aftermarket improvement for Corvairs, VWs, Porsche 356s, and maybe some other cars with swing axles. In 1964 both Chevrolet and Porsche added it to their cars as standard equipment. That was the last year for both the swing axle Corvair and the Porsche 356.

Mercedes had a coil spring on their swing axles that did the same thing. It had that as early as the 1930s. Triumph achieved a similar effect on the Mk III Spitfire with the 'swing spring' which used a flexible mount for its transverse leaf spring, which was the only spring the car had at the rear.

Volkswagen had a torsion bar version on early Type 3s. All sorts of variations on the theme have appeared on Formula Vees.

CONTACT

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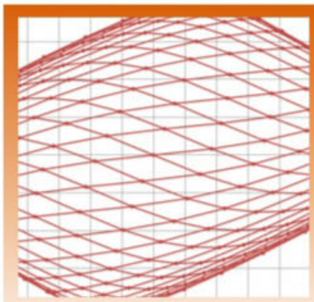


Slip Angle provides a summary of OptimumG's seminars

Formula Student 101

Building a Formula Student car? Then you need to read OptimumG engineer Claude Rouelle's 101 top tips for teams chasing FS glory. In Part 1 of this new mini-series he runs through his first 25 points

It's a mistake to study successful Formula Student cars before you start your design process; it could cramp your creativity

Besides his leading role at vehicle dynamics consultancy OptimumG, Claude Rouelle often offers his services as a design judge in many Formula Student competitions.

Rouelle started his 40-year racecar engineering career by designing and building a racecar and a wind tunnel. It was his engineering degree master thesis. The challenges he faced then were quite similar to those faced today by students building a first racecar. In this new mini-series Rouelle offers some advice on engineering and team building for Formula Student teams; though many of these tips are also applicable to professional race teams.

1. To finish first you must first finish. Think reliability before you think performance.

2. Accuracy, relevance, usefulness, meaningfulness, repeatability are five words that should be part of your everyday engineering vocabulary.

3. There are two rules with software use. Rule 1: You cannot make the software work unless you read the user manual/help file (and, ideally, some good case studies) from start to finish. Rule 2: Nobody reads the user manual. The same goes for the little sensor spec sheet.

4. The best way to predict the future is to look at the past. Often the best simulation and performance predictions are provided by the exploitation of previous data collected during previous races and on-track or in-labs tests.

5. There are three main goals you need to always keep in mind during your Formula Student concept phase: minimum weight, lowest centre of gravity, minimum yaw inertia.

6. A low inertia goes against stability but helps with control. The low limit of stability is mainly dependent on driver skills and speed. The reality is that inertia is always too big on a Formula Student car. Want proof? Look at the low mass and shorter wheelbase in karts. Besides, the best way to make a light car is to make a short car. I do not see any reason why you would not build a Formula Student car at the minimum legal wheelbase. Ergonomic and short cars are possible. I have seen many Formula Student cars with the minimum wheelbase

A low inertia goes against stability but it does help with control

where a 1.8m 90-kilo driver can easily sit and comfortably drive the car.

7. Ergonomics is fundamental. It plays a huge roll in the driver's ability to feel and control the car. Head, shoulder, ribs, hips, side, legs, heels, support is too often neglected. If, when you turn the steering wheel 180 degrees, the driver's hands rub his legs, or his elbows hit the chassis, he won't be able to get the most out of the racecar. You wear a cockpit like you wear a suit. A wood mock-up cockpit tested by your drivers will teach you more than any CAD software with dummy drivers.

8. If your steering torque is more than 5Nm, you will need to hire Arnold Schwarzenegger to drive your racecar. As a reference, most passenger car steering torques are in the 3Nm region. It is a pity that the majority of Formula Student teams do not simulate or measure the steering torque.

9. When you go to a job interview, you need to dress for the job you want, not the job you have. Same for design. Flip flops and dirty T-shirts are not the best clothes to impress design judges.

10. The gods of mechanical engineering are never with you. Mistakes keep being added to each other, and they do not cancel each other out. You must remove phrases such as 'this compensates for that' from your brain.

11. There are some numbers you should naturally know by heart, not because you memorised them but simply because you played with them so often: weight distribution, anti-roll stiffness distribution, wheelbases, tracks, motion ratio, damping ratio range, etc. If you must look for this kind of basic information in your binder during a conversation with a design judge, it sends a signal that you are not in control of your work.

12. In terms of project management, you must think about your racecar concept, simulation, drawing, machining, and assembly as an aeroplane that must land. If you keep flying your plane and run out of fuel, you crash. Similarly, a fantastic car design that is not finished on time won't help you. There must either be a dictator or a common agreement to have each car part finished on time. Winning starts at the workshop with on-time and on-target design achievements.

13. It is possible to create a car that is both stiff and light. The best way to achieve this is to keep in mind the lessons of Darwin: Form *follows* function. First, function and second, form, not the other way around.

14. Start any new Formula Student project with two separate brainstorming sessions that answer these simple questions; what makes a great team and what makes a great car. Make the wildest dream list of what defines an ideal team and a perfect car. Then, and only then, be reasonable and choose the goals that are within your team's means.

The three main goals you need to keep in mind during your Formula Student project's concept phase are keeping the car weight to a minimum, with the lowest possible centre of gravity and minimal yaw inertia

Cockpit ergonomics are a crucial part of the Formula Student design process. Your driver must be able to feel and control the racecar properly and it is important that no part of the chassis restricts movement

I do not see any reason why you would not build a Formula Student car at the minimum legal wheelbase

If you don't know why you win, you won't know why you lose

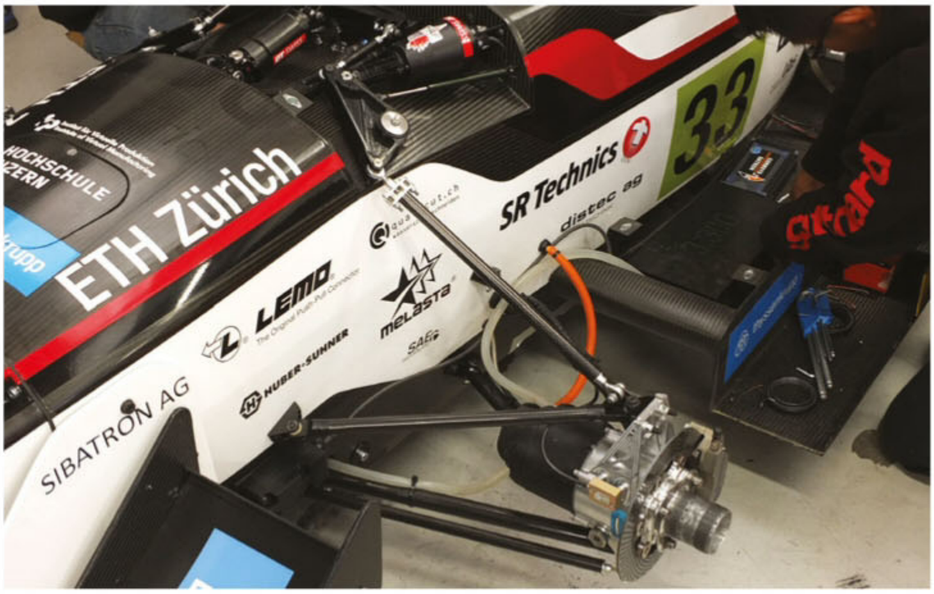
15. The worst thing that you could do when you start to design a Formula Student car is to look at other existing car pictures or videos on the Internet. Do not let pictures of other racecars influence you. Looking at other cars restricts your creativity and your ability to think function then form. Once your car has been designed, *then, and only then*, look at other racecar pictures, and if necessary, modify your own drawings.

16. You need to think SMART goals, an acronym that stands for Specific, Measurable, Attainable, Relevant, and Time-bound.

17. If you don't know your strengths, you don't know your weaknesses. You get your car out of the truck and you are the quickest all weekend. Good. Then two weeks later, conditions are different: it rains, or the circuit is bumpier. You get lost. If you do not know *why* your car was that good two weeks ago, you won't know *how* to fix it when it under performs. To put it another way; if you don't know why you win, you won't know why you lose.

18. A design judge will be expecting you to demonstrate how you chose your suspension rod ends and tube sizes, hub and upright shape and material, etc. with load case studies from tyre to chassis starting with simplified tyre load in longitudinal acceleration (braking and acceleration), lateral acceleration (cornering), vertical load and acceleration (mass, weight transfer, aerodynamic forces and moment, and bumps), and then a combination or all of any of these, and finally with track replay. Without this, you take the risk that any designed part will be either over engineered (too heavy) or under engineered (too weak).

A common error with Formula Student teams is not simulating or measuring steering torque, making the car hard to drive on the handling tests. This needs to be no more than 5Nm; road cars are around 3Nm



All parts need to be lightweight and the only part that is too light is the one that breaks. You need to figure this out with intelligent design and FEA. Go lighter until it breaks and then go one step back

19. Formula Student teams cannot use the same safety factors as in the passenger car industry. Do not compare cars that are run 2000km a year (for the most organised team running several competitions) and cars that are supposed to be reliable without any major issue for 100,000km.

20. There is only one definition of a 'too light' part: that's when it breaks. Do the best you can with intelligent design and FEA. Go lighter until it breaks, then go one step backwards.

21. You need to look at your racecar assembly as well as each car part and wonder 'if something breaks, what will it be?' If you know the answer and you don't do anything about it, that is just insanity, because there is a great chance that once you are on the race track that part will break. Analysis. Awareness. Communication. Action.

22. If something broke on your car and you do not do anything about it because you do not know why it broke, there is a big chance that part will break again. Worse, if you know why that part broke and you don't do anything about it, that is laziness.

23. Not having a Plan B, and ideally a Plan C, for any car part failure during its development phase demonstrates a lack of either imagination, objectivity, or preparation. Example: you test your new racecar and after a few laps, your front wheel hub breaks. You will now do a failure analysis, redesign, reordering the material if you do not have it in stock, re-machining … You could lose several weeks during which your engine and your aero are not developed. Now, imagine having a Plan B: you can mount last year's uprights on the new car. During that time, you can at least continue the other car parts' reliability tests.

24. Einstein said that 'Intelligence is the ability to find a solution to a problem you never encountered before. Insanity is doing the same thing over and over again and expecting different results.' I am also convinced that the biggest thing that slows down our ability to develop our intelligence is our inability to control our emotions. Control, not suppress.

25. 'We cannot solve our problems with the same thinking we used when we created them' (again Einstein). No more comment needed.

Next month: *Don't miss points 26 to 50*

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Reducing the drag on a Formula Ford

The hillclimb Swift returns to the wind tunnel for an aero appraisal

A year ago we featured the author's Swift SC92F Formula Ford, in part to celebrate the category's 50th Anniversary, but mainly to look at the effects of a wide range of drag-reducing modifications.

By 1992, the year this car was built, Formula Fords were very sleek but, in its current UK hillclimbing guise, the reduced cooling requirements of this Swift, compared to circuit racing duties, had seen the radiator inlet duct aperture two thirds covered and the outlet up to half covered. We saw in our January 2017 edition (V27N1) that these aperture reductions shaved off some useful increments of drag.

Our February 2016 (V27N2) piece concluded that 'there wasn't time to try … a reduction in frontal area by narrowing the sidepods', but this formed the basis of a winter 2016/17 project. Hence 25 per cent shorter radiators were provided by PWR Performance Products using up to date cooling core design, and the author fabricated narrower, ducted sidepods to house the radiators.

Frontal area was reduced by three per cent, and it was hoped that this, combined with the smaller radiator core area, minus the likely increased pressure drop arising from the narrower angle of the radiator to the onset flow direction, would add up to at least a three per cent reduction in drag.

Trap speeds in competition were compared to see if a measurable gain had been achieved, with the mean of the best of meeting finish line speeds at one indicative venue rising from 88.3mph in 2016 to 89.6mph in 2017, and season's best trap speeds rising from 89.6mph in 2016 to 91.4mph in 2017. Track and driver variability prevented any improvement on 2016's best elapsed time at this venue, but running at higher speed on the faster reaches of the course must have yielded a time benefit, other things being no worse than equal.

MIRA kindly gave us the opportunity to evaluate the new configuration in the full-scale wind tunnel, and the data are given in **Table 1**, relative to corrected values from 2016's session. Coefficients multiplied by frontal area have been used because they are directly proportional to the measured aerodynamic forces (at any speed) and eliminate any variation in the 'bare' coefficients arising from the changes of frontal area.

The drag reduction relative to the 2016 baseline configuration amounted to 5.5 per cent, and relative to the 2016 set-up with the radiator ducts partly taped over, which reflects the configurations in the trap speed comparison, was exactly two per cent, a little short of the apparently over-optimistic three per cent but still a useful improvement. Cooling was actually slightly more effective than previously, even when ambient temperatures exceeded 31degC, testament to the cooler design and effective ducting.

Engine inlet

A further upgrade was introduced part way through the 2017 season; the engine inlet was changed to a flush NACA duct (sized to feed the engine over the rpm and speed range

Table 1: The effects of fitting narrower sidepods and shorter radiators

	CD.A	CL.A	CLf.A	CLr.A
2016 Baseline	0.4976	0.1768	0.1408	0.0360
Old sidepod apertures taped	0.4800	0.1592	0.1312	0.0280
2017 sidepods and radiators	0.4704	0.1360	0.1092	0.0264

The 2017 configuration was creating more than 25 per cent less lift

The hillclimb Swift SC92F in 2016 baseline configuration with the original sidepods fitted

The early 2017 narrow sidepod configuration. Frontal area was reduced by three per cent

The Swift's original scoop duct to feed the engine inlet was an obvious drag generator

The mid-2017 upgrade featured this NACA duct engine inlet, which was sized to match the rpm and speed regime encountered. This reduced the car's drag by a further 0.6 per cent

Satisfactory flow into and out of the radiators is revealed here with the use of wool tufts, although the flow ahead of the lower inlet did seem to prefer to go under the car

Table 2: The effects of changing the engine inlet duct

	ΔCD.A	ΔCL.A	ΔCLf.A	ΔCLr.A
With new duct	-0.6%	No change	-2.3%	+7.6%

Table 3: The effects of removing the engine cover

	ΔCD.A	ΔCL.A	ΔCLf.A	ΔCLr.A
Without engine cover	+8.3%	-17.4%	-7.4%	-57.6%

encountered) rather than the original large scoop duct. The season's best trap speeds were actually achieved after this modification was installed. So how did the drag alter with the new engine cover and inlet duct? **Table 2** gives the 'delta' values, or changes, in percentages, and another 0.6 per cent drag reduction was achieved. This compares to the 1.0 per cent drag reduction found in the previous session by affixing a fairing in front of the scoop duct, but that modification allowed no air at all into the duct, so a 0.6 per cent drag benefit that still allowed the engine to inhale seemed reasonable. This saw a cumulative drag benefit when combined with the new sidepods of 2.5 per cent compared to the configuration run in 2016, or 6.1 per cent compared with the 2016 baseline configuration.

Lift and grip

The attentive reader will have noticed how the lift values changed on the Swift with each of these configuration changes. Compared to the 2016 baseline, the end of the 2017 season configuration was creating more than 25 per cent less total lift. How would that translate into forces at the tyres, and would it provide increased grip at relevant speeds?

With driver aboard, the front and rear static weights were estimated at approximately 204kg front and 306kg rear. At 100mph the measured front lift value dropped from 17.5kg (force) in 2016 to 13.0kg in 2017, a reduction of 4.5kg. This amounts to an effective increase in weight on the tyres of 2.4 per cent at 100mph, which crudely translates to 2.4 per cent extra grip at that speed. This would scale down by the ratio of the speeds squared, to 64 per cent of this figure in an 80mph corner, as encountered in reality, amounting to 1.5 per cent extra grip. This could be tangible. The change in rear lift approximates to around 0.23 per cent more grip at 80mph, which seems negligible, so compared to 2016 baseline configuration the racecar should now be slightly more tail happy in fast corners, which does tally with driver feel.

Take cover

Our last run saw the engine cover removed, and **Table 3** provides the results as delta values in percentages relative to the values with the new engine cover. The change in drag met expectations (and hopes) with 8.3 per cent more drag being created without the engine cover. This met with theory and demonstrated the worth of carrying the extra weight of the cover in tidying up the flow over the rear of the car. The change to overall lift looks fairly significant but amounted to around 2.9kg at 100mph.The change in front lift was equivalent to about 1kg at 100mph, while the apparently big percentage change in rear lift represented 1.9kg at 100mph. So the engine cover added a bit of aerodynamic lift but the benefit of its drag reduction, which was somewhat greater than the gains made in other areas, outweighed the lift changes.

CONTACT

Simon McBeath offers aerodynamic advisory services under his own brand of SM Aerotechniques – www.sm-aerotechniques.co.uk.
In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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A new **ICE** age

Reports of the death of the internal combustion engine have been greatly exaggerated and, as *Racecar* discovered, ICE technology is now being developed at a staggering rate as motorsport responds to new challenges

By GEMMA HATTON

With governments all over the world continuing to encourage manufacturers to develop electric technology the question has to be asked – how much longer will internal combustion engines (ICE) be around? Short answer: for a very long time.

'Recent news headlines have been making claims such as; "No more IC engine vehicles allowed on the road after 2040", "Death of the IC engine", "Volvo are only making electric cars from 2019", and in most cases these announcements are all incorrect,' says Steve Sapsford, director of business strategy at Ricardo. 'What has actually been said is that vehicles won't have IC engines as the *sole* source of propulsion after 2040. Instead, the majority of vehicles will be some form of hybrid, whether it be full hybrid (HEV), plug-in (PHEV), mild hybrid (MHEV) or one of the many other variants.

'So really, there is no need for businesses to panic and have a knee-jerk reaction and suddenly convert everything to electric,' Sapsford adds. 'The IC engine is not dead yet. In fact, we believe that in addition to pure battery electric vehicles (EVs), between 70 to 80 per cent of vehicles will still have an IC engine as part of a hybrid powertrain in 2030.'

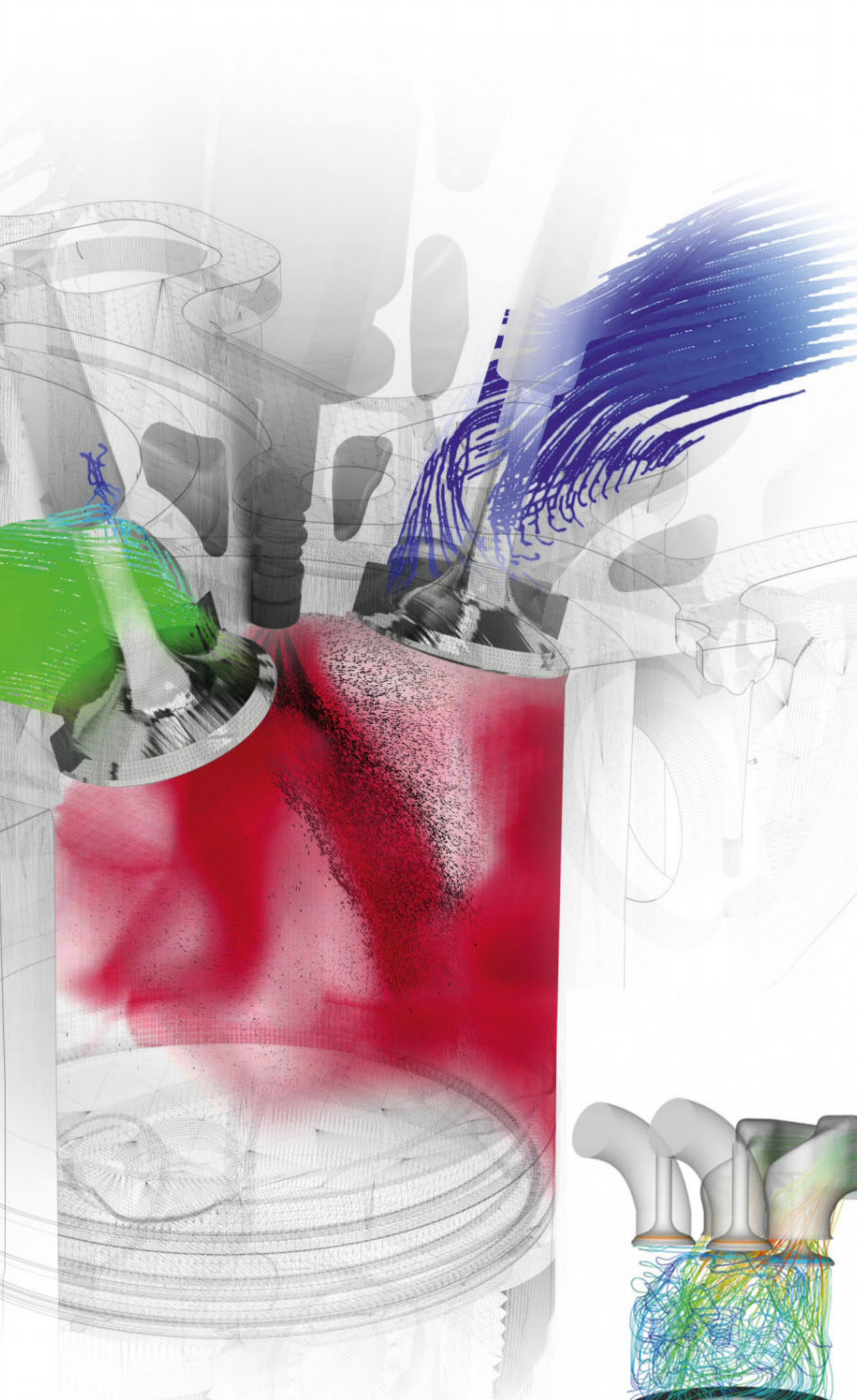
This is good news for motorsport too. If IC engines still have a role to play in the future, then improving their efficiencies will remain important enough to continue development. And what better test bed than the brutal environment of a race track?

Power shift

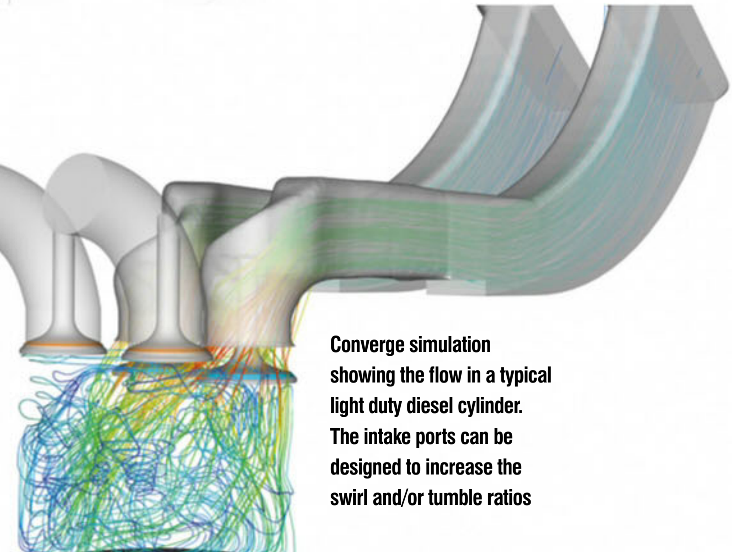
This drive for efficiency has already transformed motorsport from the power-hungry, fuel-guzzling endeavour it was, to the sophisticated testing platform it is today. 'Motorsport used to be about producing as much power as possible, and if that used more fuel then it didn't matter, and if it burnt inefficiently and ended up spewing out of the exhaust then that didn't matter either,' says Ken Pendlebury, director, gasoline engines, at Ricardo. 'The challenge was to get as much air through the engine as was possible in the time available and you just dealt with whatever combustion you could, which was usually running rich.

'That is why classic Formula 1 engines had ports that were two great holes and also why they ended up revving to 20,000rpm, because you could burn an awful lot of air if you ran the pump very quickly,' Pendlebury adds. 'To manage this, the governing bodies used air restrictors in the intake system to limit the amount of air available to the engine and this is still done in lots of Formulae today. But now in major categories such as Formula 1 and WEC, the regulations limit fuel, so you need to burn this as efficiently as possible to extract the most power. This means you end up in a slightly strange situation where these engines are running lean to achieve the best efficiency.'

Rather than simply reducing the total amount of fuel that could be used during a race, F1, for example, introduced a fuel flow limit. The fear was that teams would run high fuel rates at the start of the race, and by the end would be running so lean that they would have to slow down, damaging the spectacle. Introducing the fuel flow limit ensures that teams focus on fuel efficiency, whilst running at approximately the same pace throughout the race.



Converge flowbench simulation illustrating swirl, which is defined as the rotational air motion about the cylinder axis. Tumble is where it rotates about an axis perpendicular to the cylinder axis



Converge simulation showing the flow in a typical light duty diesel cylinder. The intake ports can be designed to increase the swirl and/or tumble ratios

'Between 70 to 80 per cent of vehicles will still have an IC engine as part of a hybrid powertrain in 2030'

Combustion Analysis Software is used on the test bench to tune the engine, for calibration, and for defining the knock limits

Bizarrely, despite the mass demand of the passenger car world encouraging racecars to become fuel efficient, a lot of the resulting technologies cannot be utilised in the road car industry. To maximise power, each droplet of fuel needs to be burned with as much air as possible, which means engines run very lean. This can, in turn, lead to the generation of hydrocarbons which are obviously undesirable, particularly with the current importance of emissions regulations. Therefore, just because a car is fuel efficient, it doesn't necessarily mean it is *clean* from an emissions standpoint.

Efficiency drive

Lean combustion does have further benefits in increasing efficiency, because it reduces heat and pumping losses. But what do we mean when we talk about efficiency? 'Usually we are discussing thermal efficiency, which is then broken down into the various losses we have: frictional losses, gas exchange losses as well as heat [thermodynamic] losses and then any fuel that doesn't get burnt as a result of the combustion efficiency,' says Dr Richard Osborne, global technical expert – gasoline combustion, at Ricardo. 'Where Spark Ignition [SI] engines typically fall down is in thermodynamic efficiency, so this is where a lot of development is focused on in both race and road cars. High compression ratios, different valve-train strategies and Miller cycle engines are all ways to increase the thermodynamic efficiency.'

There are not many levers to pull when trying to improve this thermodynamic efficiency. However, a fundamental method for improving the ability to run lean is to increase the turbulence of the air motion within the combustion chamber. This helps uniformly distribute the injected fuel throughout the air charge, but it also helps to mix the fuel and air mixture encouraging complete combustion. This air motion can be characterised in two ways: swirl or tumble.

Swirl and tumble

Swirl is the rotation of the charge about the cylinder axis and is a result of the intake port design initiating angular momentum as the air flows into the cylinder. Tumble, on the other hand, is the rotation of the charge around the axis perpendicular to the cylinder axis. You can also have a combination of both which is sometimes referred to as 'drumble' and is overall a more diagonal air motion.

'Swirl-based combustion systems for 4-valve gasoline engines are quite unusual, which is why we are primarily talking about tumble because it gives good mixing and velocities at the spark plug,' Osborne says. 'As well as mixing, the air motion also provides the energy and turbulence which drives the flame propagation across the combustion chamber. A 4-valve combustion chamber with two intake valves on one side is, by nature, well set up to generate tumble. As the valves lift from the seats the air will naturally flow over one side which starts this tumbling cylindrical air motion and as you reach higher valve lifts, the flow is increased, encouraging more tumble. You can also increase tumble ratios through the design of the intake ports by incorporating certain angles or features, such as ski ramps. The design of the combustion chamber also plays a role, so shrouding or masking the back of the intake valves can be used to assist tumble at lower valve lifts. Although high tumble ratios can reduce the efficiency of intake ports, so as ever with engineering there is always a balance.'

'Port design' and 'tumble ratios' are terms now more commonly used in today's race engine design than they might have been before, and this is all due to the requirement for lean combustion that has been driven by the regulations. A low tumble engine can run at around 1.1 or 1.2 lambda, but if high tumble ratios can be achieved then this air to fuel ratio can increase to 1.5 or 1.6, which is a big improvement in thermal efficiency.

Pre-chambers

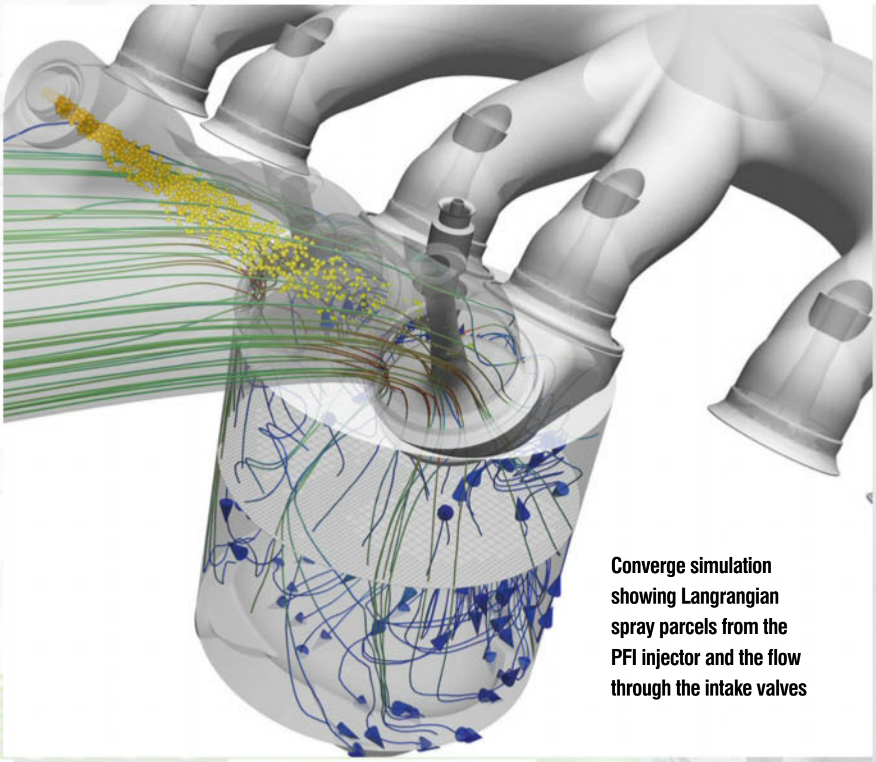
Using pre-chambers is another technique that helps to manage the demands of lean combustion. Whether it is a passive pre-chamber, which only has a spark plug, or an active pre-chamber, which has another fuel injector, both help to stabilise a leaner mixture.

'Pre-chambers are gaining the most interest from a Formula 1 perspective,' says Pendlebury. 'Most of the leading Formula 1 engines use a passive pre-chamber now. This is primarily driven by regulation as the teams are only allowed one fuel injector and so cannot use another one in the pre-chamber as well.'

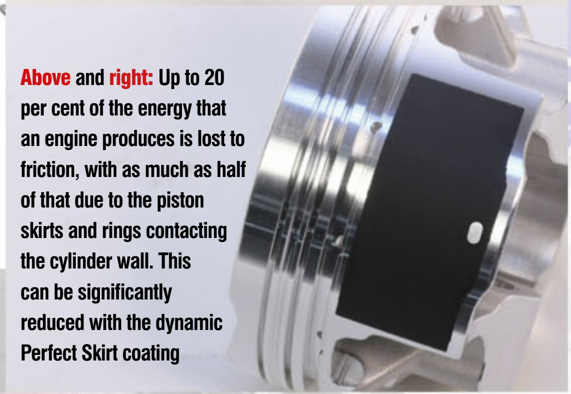
Another method to minimise heat losses from the chamber, therefore improving thermodynamic efficiency, is utilising thermal barrier coatings. These are usually ceramic or nickel based and as well as minimising heat losses in the more conventional areas, they can also be coated on the top of the piston head.

'The idea is that the coating reflects heat back into the combustion chamber, instead of being absorbed by the piston. It is essentially acting like a mirror, reflecting a ray of light, although in this case it is a ray of heat,' explains Eugene Salomon, application design engineer at JE Pistons. 'This helps to maintain the high pressure in the combustion chamber which ultimately generates more power to the rear wheels. Also, if your engine is turbocharged, it allows you to have some control of temperature and so you can spin up the turbocharger much faster.' However, if the combustion chamber remains too hot for too long this can increase the risk of knock.

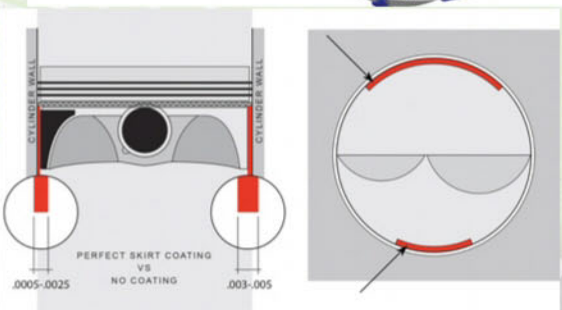
Just because a car has been shown to be fuel efficient, it doesn't necessarily mean it is *clean* from an emissions standpoint



Converge simulation showing Langrangian spray parcels from the PFI injector and the flow through the intake valves



Above and **right:** Up to 20 per cent of the energy that an engine produces is lost to friction, with as much as half of that due to the piston skirts and rings contacting the cylinder wall. This can be significantly reduced with the dynamic Perfect Skirt coating



A piston with the Perfect Skirt coating needs 0.0005-0.0025in of clearance (left), whereas a piston without the coating needs 0.003-0.005in clearance (right), increasing the rate of wear

One innovative type of coating is the Perfect Skirt from JE Pistons, which is essentially a solvent based solid-film lubricant coating that is permanently applied to the piston skirts through a three-stage bonding process. This patented technology dynamically changes shape automatically as the piston reciprocates and therefore reduces the piston-to-wall clearance almost entirely. Consequently, this ensures piston stability as well as achieving perfect sealing of the piston rings. However, as the coating's compressibility is temperature dependent, when the piston expands under high temperatures, the coating will compress, reducing its thickness and therefore minimising any form of scuffing on the cylinder wall.

'When an engine is first fired up, the piston coating in contact with the cylinder wall will quickly adjust to a precise form and provide minimum running clearance,' says Nick DiBlasi, the product manager at JE Pistons. 'At this point, the coating has settled into a uniform and equalised pattern, providing very low friction and quiet operation throughout its service life. By reducing clearances, the Perfect Skirt coating reduces cold-start wear and also, more importantly, the chance of false knock readings in late-model engines.'

However, with one stroke taking a matter of milliseconds, the coating needs to react instantly, which is an impossible material property. Yet despite this minute element of lag, the coating still provides levels of sealing that previously could not be achieved. An estimated 10 to 20 per cent of an engine's total energy output is lost through friction and up to half of that is purely down to the friction between the piston skirts and rings with the cylinder wall. Therefore, this technology offers huge performance advantages in minimising friction and wear around the piston.

Coating process

The coating is applied to the piston skirts by an advanced screen-printing process that can achieve accuracies to within several microns. First, the piston is thoroughly cleaned and its surface is then inspected to ensure an immaculate base for the coating to stick to. Once sprayed onto the skirt, an operation undertaken in a climate controlled room, the piston then undergoes two thermal treatments to help bond and cure the coating.

The shape and design of the pistons play a major role in determining the achievable efficiency of an engine. 'Small volumes heat up quickly, so in a naturally aspirated engine, usually you want a large dome piston to try and fill up as much of the volume as possible,' Salomon says. 'Whereas in large combustion chambers where you are running a turbocharger, then you want the largest volume possible, with the lowest compression ratio. Therefore, you incorporate a dish into the piston head, to increase the volume. Let's say I have a 1-litre engine, and add 1bar of overboost, I essentially make a 2-litre engine, and that's why you want a large combustion chamber.'

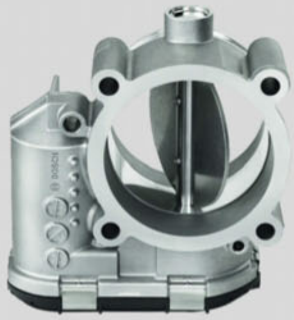
'The problem is you always need to find a good balance between achieving a high and low volume,' adds Martin Stelleman, JE Pistons VP and general manager EMEA/Asia. 'At low volumes when the turbo is not adding much pressure, the engine is extremely inefficient, so you need a small volume. But, as the turbo gets up to speed, the volume needs to be bigger, so it's always a compromise. In motorsport however, you are usually at the higher end of the rpm range with the turbo up to speed.'

Smooth finish

The surface finish of the piston head is also crucial. Sharp edges and corners need to be avoided at all costs to minimise the threat of pre-ignition and knock, and also to help encourage flame travel across the piston head for uniform combustion. Therefore, the surface

'Pre-chambers are gaining the most interest from a Formula 1 perspective'

ELECTRONIC THROTTLE BODIES



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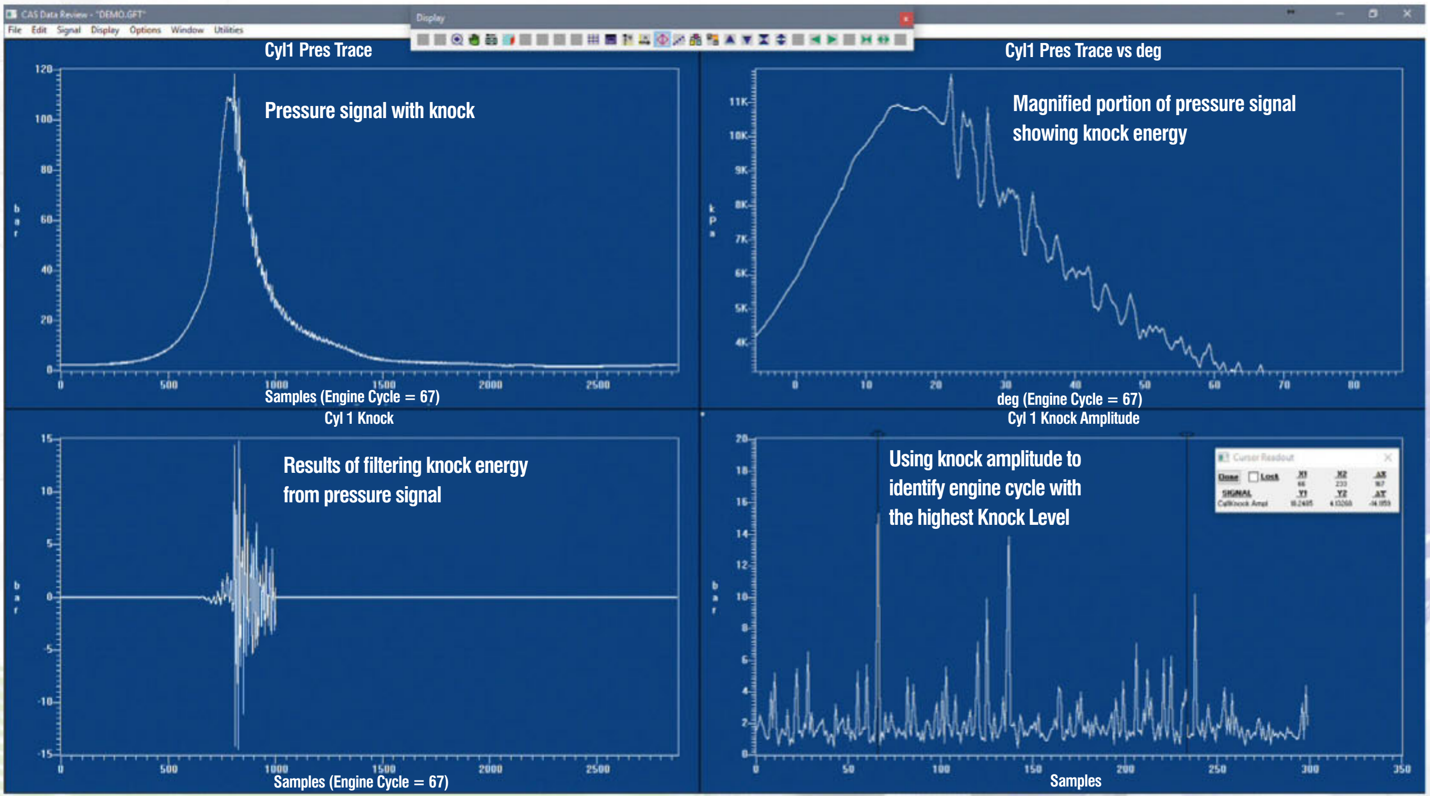
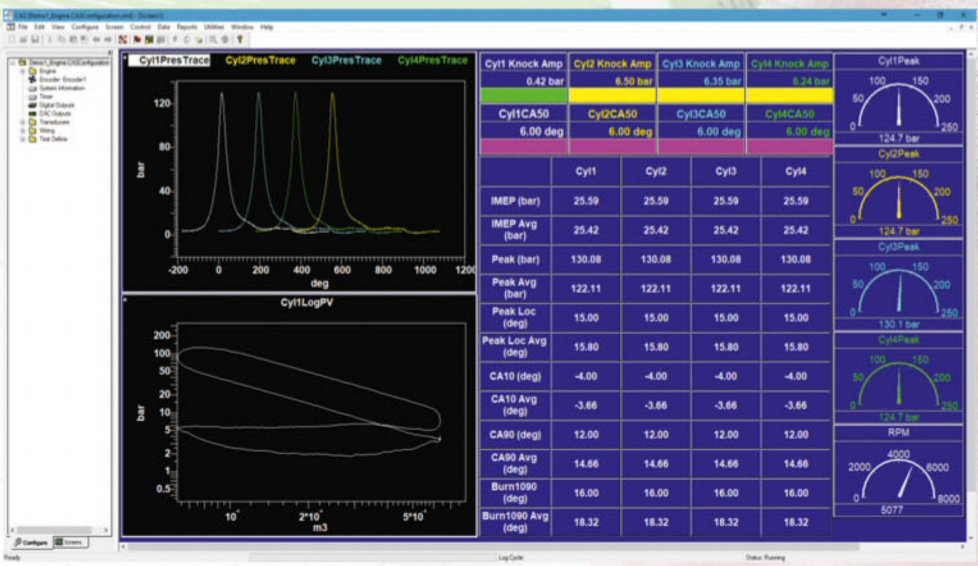


A&D's system measures pressure within the chamber which can then be used to determine the presence of knock. When knock is present the pressure signal oscillates about TDC (top left; with a zoomed-in view top right). The knock energy is subtracted from the signal (bottom left) for further analysis of the amplitude and maximum knock level (bottom right)



An example of the output from the Phoenix Combustion Analysis Software. Only a cylinder pressure signal and a crank angle reference signal is needed to perform approximately 75 per cent of the analysis required to calibrate and tune a race engine

is usually brushed by hand to ensure the smoothest finish possible.

'Combustion temperatures are usually around 650degF (342degC) and any sharp edges will heat up quickly and have no time to cool down before the next combustion event that is only milliseconds away,' says Salomon. 'As the new fuel and air mixture circulates around the combustion chamber, these hot spots of material can cause the mixture to ignite prematurely. If this occurs when the piston has not yet reached TDC, the gas will start to burn and expand, increasing the pressure which can in turn detonate the mixture at another spot, causing a second flame. If these flames travel in opposite directions, then you are talking about pressures up to 60 times more than average, and that will kill your engine.'

Pre-ignition can be a particular issue in direct injection turbocharged engines, which is why a lot of motorsport operations continuously monitor the risk of this phenomenon throughout the entire engine development process, particularly during dyno testing.

'A lot of racing teams use combustion analysis software on the test bench to define when their engines are getting too hot and are therefore likely to pre-ignite,' explains Craig Giraud, product manager at A&D Combustion Analysis Systems. 'The other primary goal of such software is to tune the engine to strike that delicate balance between producing more power, whilst remaining fuel efficient.'

Pressure measure

This tuning requires the measurement of pressure within the combustion chamber which can then be used to determine the presence of knock, abnormal combustion, the quality of the fuel mixture as well as the air to fuel ratio and characteristics such as wall wetting and piston load. The pressure is measured by a piezoelectric transducer which is installed in the cylinder head or in the spark plug (for SI engines). The pressure generated during the combustion, compression or expansion processes, deforms the crystal element within the transducer, this emits a small amount of capacitive charge which is proportional to the amount of pressure applied to the face of the crystal. This signal is then converted into a voltage and then

'The piston coating in contact with the cylinder wall will quickly adjust to a precise form and provide minimum running clearance'

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As manufacturers continue to develop hybrid technology they are investing far more in prototyping. Prototype engines can be extraordinarily expensive in development parts. Additive manufacturing can play a big part in the prototyping process

run through a high-speed digitiser which mathematically processes the signal to quantify parameters such as burn rate and how much torque each individual cylinder is contributing to the combustion process.

'Almost every output of our Phoenix system is going to be a calculation based on cylinder pressure,' highlights Giraud. 'We only need a cylinder pressure signal and a crank angle reference signal and we can perform up to 75 per cent of the analysis that is required to calibrate, adjust and tune an engine for optimum performance.'

Spark sweep

One of the ways to determine if knock is present in an engine is through a simple spark sweep. Essentially, this is where the spark is advanced for each individual cylinder and the maximum limit of torque before knock occurs is defined. When knock is present, the top of the waveform of this high frequency transducer response will oscillate, so there will be positive and negative peaks around TDC. Once a digital filter has been applied, the knock energy is subtracted to allow for further analysis of the amplitude, maximum delta and knock intensity.

'A lot of the NASCAR Cup teams are not only using combustion analysis for calibration, but also for durability,' says Giraud. 'They will set them up according to their specified parameters and essentially tune the engine to gain that extra one or two horsepower per cylinder, which can make a big difference on a Sunday afternoon. The output of our analysis software can also be used to populate models to help with predictive combustion analysis.'

Real time analysis

The Phoenix system from A&D Technology is the only system on the market that can calculate all analysis results from one cycle, before acquiring the data from the next, enabling real-time analysis. This is particularly useful for teams who are using the data from this software to feed automated test beds so that decisions can be made before any unrecoverable situations are reached. Full real-time feedback from the combustion analysis software is how the top 20 per cent of well funded teams continue to find those all important extra horses.

Although internal combustion engines are set to be around for a long while yet, there is no point denying the growth of hybrid powertrains and the potential business opportunities this technology shift can offer. With some of the biggest powertrain manufacturers in the world focusing half their business on developing small 4-cylinder 1.2-litre engines that work in conjunction with electric motors, prototypes are becoming an increasingly important area for companies to invest in.

'The increasing rate of development of hybrid technologies is resulting in more and more prototypes,' explains Jonathan Warbrick, sales and marketing manager at Graphite. 'To keep up, the industry is moving away from traditional metal castings and those first few hundred prototype engines now have a whole variety of 3D printed parts such as water pipes, baffles, heat shields and radiators.'

Prototype stage

One prototype engine can be made of up to £100,000 worth of component parts before it even reaches the dyno. Naturally, when these powerplants go into mass production, then their prices drop, but during this prototype stage the target is proof of concept, so money usually isn't so much of an issue – although developing an innovative concept can often make manufacturing processes more cost effective further down the line.

'During this prototyping stage, there are a lot of one-off parts that are designed and need to be manufactured. However, tooling up and making moulds for such low volumes is simply not a cost effective solution,' highlights Warbrick. 'This is another opportunity for 3D printing – as soon as a customer needs to push on with a design, additive manufacturing plays a key role in helping them achieve that.'

In addition to the weight saving advantages of such a technology, 3D printing can also help to plug the gaps if the supply chain breaks down. This avoids any delays, which for the larger companies can result in astronomical costs. 'We had one manufacturer in China where some parts were taking too long to make and this was consequently delaying the whole production line. We quickly designed and printed the parts which then filled this void in the supply chain. We were delighted to be exporting parts to China rather than the other way around,' says Warbrick.

The demand for internal combustion engines and battery packs to produce power harmoniously is forcing manufacturers to develop smaller, more efficient and often turbocharged engines. Therefore, under-bonnet temperatures have been rising, and are continuing to rise. Designing components that can not only cope, but also perform under these higher temperatures, is becoming the daily challenge of both motorsport and automotive engineers. Innovative materials as well as the manufacturing procedures to process them need to be further developed, and fast.

'A lot of the NASCAR Cup teams are not only using combustion analysis for calibration purposes, but also to help with durability'


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Seal of approval

A race engine is only as good as the seals within it – which is why the very latest technology is now employed in their design and manufacture

By GEMMA HATTON

These days, in motorsport, most effort with regard to the engine is focussed on maximising efficient interaction between the fuel and air within the combustion chamber, as well as the tuning, mapping and monitoring of the unit.

But the same level of consideration is often not given to the actual sealing of the engine, which can lead to difficulties later on. Ancillary components such as seals can sometimes be undervalued, but are nevertheless extremely important. There is no point spending large sums of money developing a high performance dry sump engine, using high vacuum, if the crankshaft seals are not capable of sealing and maintaining that vacuum.

One company that takes a unique approach to the design and development of high performance seals is Race-Tec Seals. By using its in-house non-linear finite element analysis (FEA), it can simulate the operating conditions of the component and therefore optimise its designs. 'We have worked very closely with the software provider and spent many hours gathering the necessary performance data, utilising a wide range of operating temperatures for the materials used,' says Gary Williams, its technical sales manager. 'This data is then incorporated into a CAD model of the proposed component design and imported into FEA. The various performance related influencers such as pressure, vacuum and centrifugal forces are then applied to the model; representing the operating conditions of the component. These simulations are repeated over a number of iterations enabling us to optimise the design.'

'Until recently, using radial lip seals has had limited success'

Ancillary components like seals are often undervalued but without them and you could end up with some catastrophic engine failures

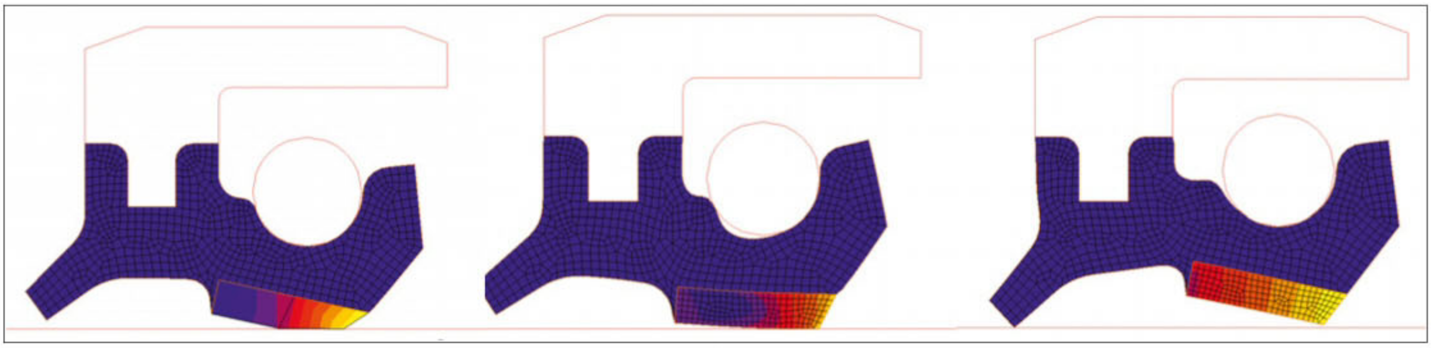
To enhance this non-linear FEA capability Race-Tec has also investigated the benefits of different high performance rubbers for seal manufacture, such as FKM, HNBR and a wide variety of different grades of PTFE. This has helped to provide the seal designer with a 'toolbox' of material options which can be used to improve the final seal design.

'One of the main areas where this non-linear FEA method can be used to great advantage is in the design of low friction PTFE lined crankshaft seals,' says Williams. 'For example, when subject to negative pressure [vacuum], 0.2bar absolute is a typical pressure requirement for a dry sump race engine. Being able to simulate the reaction of the sealing lip to a given level of engine pressure enables the seal to be designed with the minimum necessary interference and lip force to maintain that pressure. Therefore, the lowest possible frictional losses and temperature generation between the seal and shaft is sustained.'

Another challenging area for seal design is overcoming the lubrication and wear issues found when using radial lip seals in pressurised cooling systems and water pumps. Historically, mechanical face seals have been used in these types of application; however, whilst mechanical face seals generally offer good sealing capability, they do have their drawbacks; costs can be prohibitive for small bespoke batches, the seals tend to be very large and they have limited PV (pressure/velocity) capabilities.' The ability to use radial lip seals in these applications would offer significant advantages, particularly when it comes to the required space envelope. However, until recently, using radial lip seals in these applications has had limited success, suffering wear of both the shaft and the seal due to the lack of lubrication offered by water/Glycol mixes,' explains Williams.

'This condition is made worse by the formation of silicates, which then act as an abrasive, damaging the shaft and wearing out the sealing lip,' Williams adds. 'We have managed to overcome these problems with our latest pressure seal developments. Seals have been tested at 12,500rpm at 6bar absolute pressure for 150 hours without any leakage, offering engine designers an alternative seal of reduced size, friction and cost.'

By utilising its non-linear FEA, Race-Tec Seals can optimise its seal designs to match the performance demands required, while also reducing the overall amount of live testing that is needed to approve a seal.



Left: The FEA analysis of wear of the PTFE contact lip **Middle:** Seal under positive pressure and pressing down on the shaft **Right:** Seal under vacuum lifting away from the shaft

Made in Taiwan

Taiwanese firm Xing Mobility has not only come up with a clever way of supplying modular battery packs for low volume use such as motorsport, but with its Miss R it has also designed a rather neat EV to showcase this technology. *Racecar* took a closer look

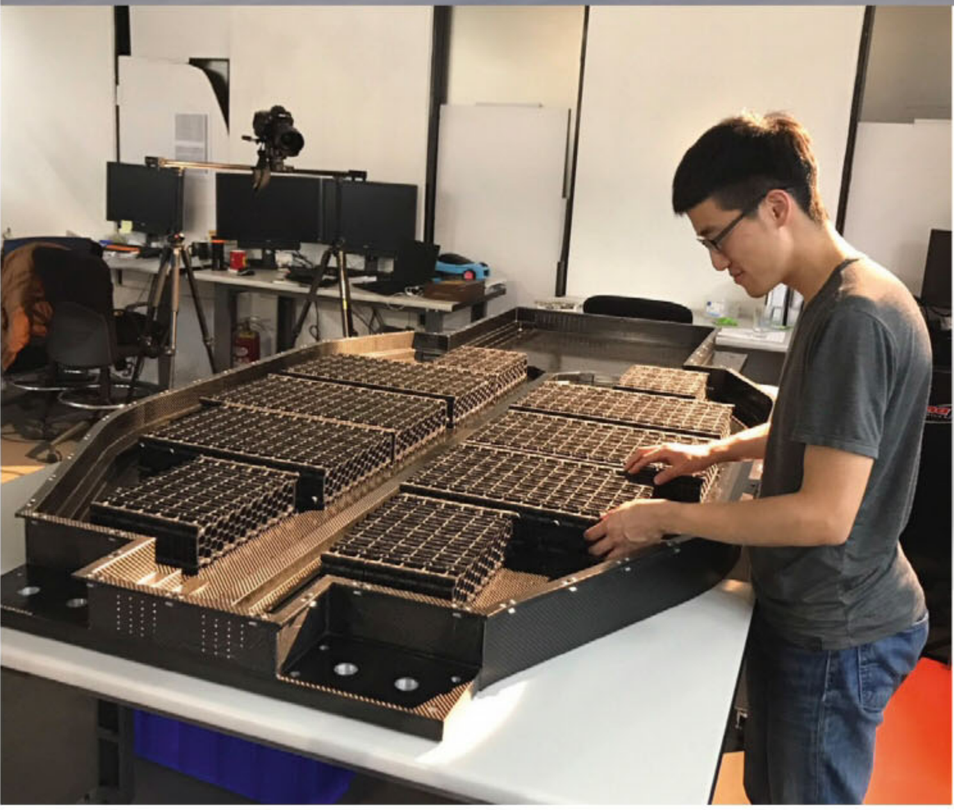
By SAM COLLINS

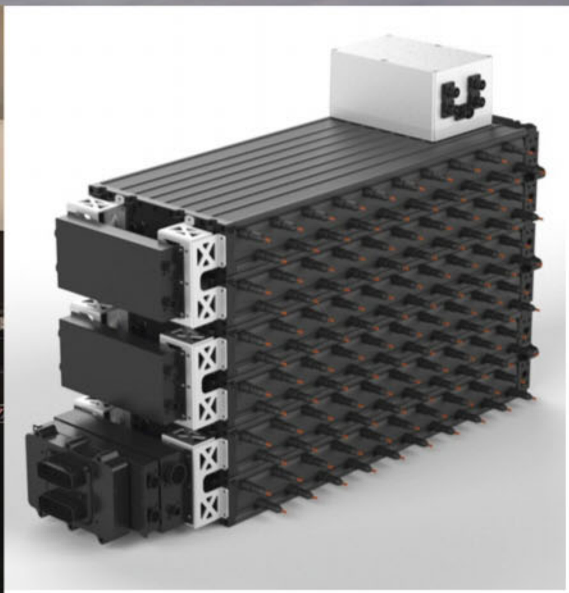
With the automotive industry shifting its focus from conventional internal combustion propulsion to varying levels of electrification, the motorsport industry is now also starting to shift, and this has seen a number of start-up enterprises enter the business for the first time.

Among these is Xing Mobility, a Taiwanese company who started with an initial goal of becoming a new competition car constructor for the growing Asian market. 'I had been working at Tesla Motors from 2006 to 2012, during that time I worked in Asia and came to realise the potential advantages of operating an engineering consultancy in the region,' Azizi Tucker, chief technical officer of Xing says. 'I moved to Taiwan, started a consultancy and joined with some local businesses who wanted to build an FIA CN spec car. Ultimately that car became the first Xing, which we call Miss E. There was a change in the business structure and that saw the [Xing] CEO Royce Hong become more involved and he is someone who is a real believer in electric cars, so when we did the car as an FIA CN I also worked on the design for an EV version in the background. Then, with the changes, we built that first car as an EV.'

That first racecar was completed and conducted extensive testing at the Penbay Circuit in Taiwan. But it soon became clear that events in the wider racing world would mean that the company would need to shift its focus, using some of the lessons learned developing that first car. 'We found that building competition cars is not the easiest thing in terms of a business,' Tucker says. 'It was quite difficult to sustain and we got burned a bit, too, when LMP3 was announced. We knew it was coming but didn't have the draft regulations, and the local ASN didn't know anything about it. We wanted to make the car LMP3 legal, but by the

Miss E was conceived as a combustion engined CN racer for a one make championship but was later converted to electric power. The tubeframe prototype is shown here testing at Penbay in Taiwan





Left: Modular battery packs mounted in the floor of the Miss R car. Xing's approach allows for battery packs to be built up to suit the application and it is aimed at low volume electric vehicle projects
Above: The Xing battery system is fully sealed and cooled by Novec fluid – a non-conductive liquid that has long been used for solvent cleaning, fire suppression and supercomputer cooling

time we finally got the technical regulations other manufacturers had rolled out their first cars. We knew at that point that we were not in the best place to build racecars for the international market. We had wanted to have a one-make series with the car but I don't think we now have a huge value increase over LMP3.'

Volume control

But during the development of the car Tucker and Hong identified a gap in the market. 'Looking at low volume projects the standard of available battery packs was not great, when the budget was high or the volume was high you could get Williams or someone like that to do it, but a lot of people coming into this market come from other industries, everything from computers to palm oil growers,' Tucker says. 'That all means it is not possible to do the due diligence on every project but there are so many interesting ideas and projects out there. We wanted to democratise the technology and allow anybody who wants to have the parts they need to build an electric vehicle.

'Normally that would mean a development cost and a 16 week lead time, we have got that down to two weeks and no development costs,' Tucker adds. 'So while keeping very high quality

'Looking at low volume projects the standard of available battery packs was not great'

The battery packs can be built up like Lego bricks to suit the application

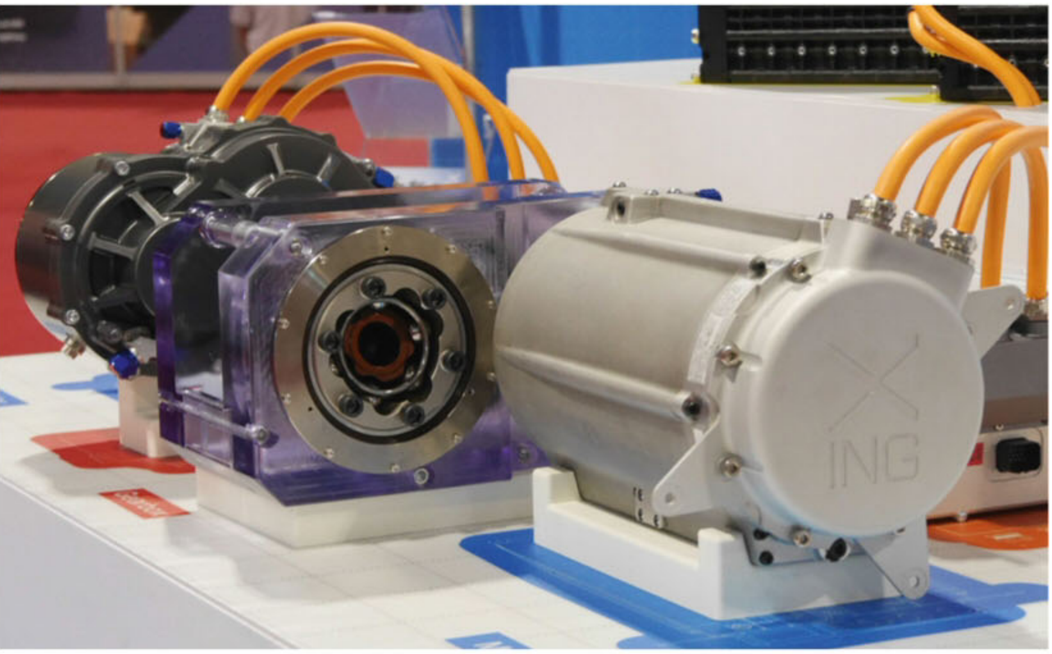
components we wanted to open up the market. We want to be the electric car equivalent of Cosworth or another tuner like that. We have a line up of powertrain components, from a battery to a complete system, and you can put them in whatever you want.'

Building blocks

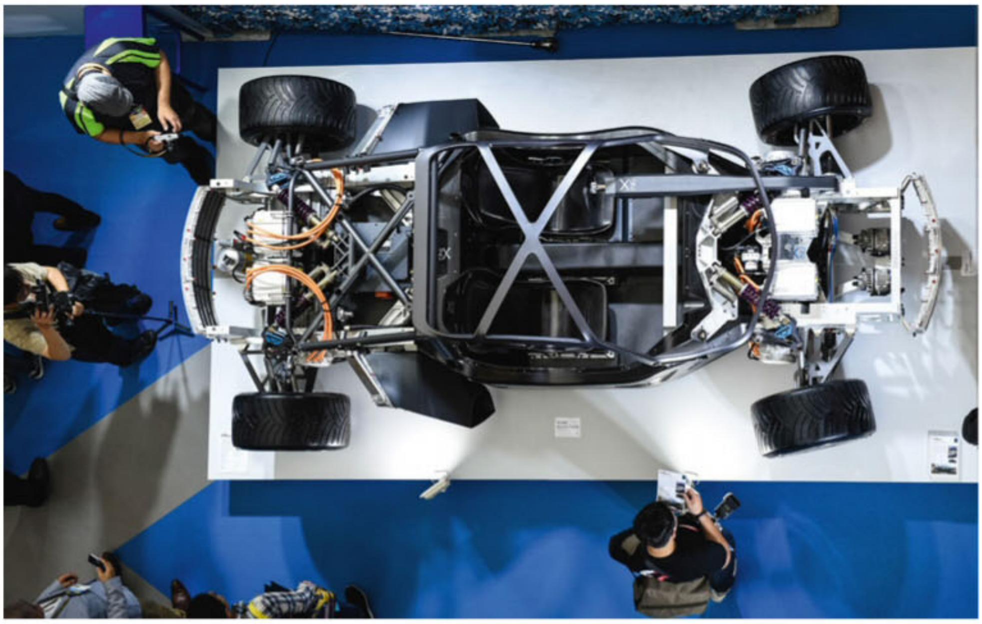
To achieve this goal Tucker and a team of engineers in Taiwan developed a brand new modular battery system. Consisting of stackable blocks of 42 lithium-ion cells, battery packs can literally be built up like Lego bricks to suit the application. 'Our modular concept gives a big advantage in terms of lead time, parts and scalability,' Tucker says. 'So while the overall shape and size of your pack is custom to your project it will not include any bespoke components. Ultimately we want to have it to the level where the more skilled users are able to modify the packs themselves, but that takes a fair amount of training, so right now all that work has to be done by us.

'We can extend a pack, if a car design change means it needs to be a different shape or split into two, then it's no big deal,' Tucker adds. 'Right now our packs are only up to 600V, mostly because of the supporting components, if you want to go over that level you end up having to use a lot of bespoke parts, even relays and things. Another benefit of the modular approach, the cost will fall with time, as we just make building blocks. We can make a system as easy as just three inputs; 12volt input, 0-5V for the throttle and direction, forward and reverse, and away you go.'

Xing has taken an unusual step with the design of the 'building blocks' in that they are fully sealed and liquid-cooled using 3M's Novec fluid. Its use in an EV powertrain is described at a 'breakthrough application' by the company which manufactures it. Novec is a family of non-conductive fluids that have long been used for solvent cleaning, heat transfer applications, fire suppression and supercomputer cooling. Tucker claims that the use of this fluid 'has unlocked the ability to achieve continuous high-discharge power output, increased stability and a high level of predictability due to the exceptional heat transfer, non-flammable and non-toxic properties of the fluids. It allows us to mount the cells closer together.'



Xing offers a complete powertrain with choices of motor. It hopes to become the go-to supplier for electric motorsport



The code name for Xing's car project was RS300, in homage to the Ford RS200 – an electric Group B car was the thinking

One-stop shop

The company hopes that it can be a one-stop shop for low volume vehicle producers and has plans to open up a supply and support facility in the EU in the near future. 'We can supply everything you need. We get motors and inverters from a company called Cleanwave Technologies, we have been technical partners with them for about five years now and we handle all the low volume and motorsport applications for them,' Tucker says.

In order to promote the Xing battery system the company has decided to create a new electric car to showcase its capabilities, and it will be sold in limited numbers to customers. 'When I was 12 years old I had an RS200 poster on my wall, and right after I left Tesla, I lost out on buying an RS200. I couldn't bring myself to spend that kind of money, but I regret not doing so now, not least because of how they have gone up in value. So when we started this project we needed an ethos and a code name for the chassis, that code name is RS300.'

Electric Group B

'The thought is, if we bring back Group B rallying and make it electric, then this is what we would build,' Tucker adds. 'At the end of 2018 you'll be able to buy the car, and it will be capable of running in hillclimb, autocross, gymkhana, and if you can find someone who will allow an EV to do it, maybe rallying. But it will be able to be used on the street too. We felt that most of the supercars were getting too fragile, in real world conditions you can't exactly exploit a LaFerrari on the road. We wanted to create something which is more viable on real world roads. In terms of cost it will be around $1m so it's not a low cost product, and it is quite niche, our plan will be to do 10 cars a year for just two years.'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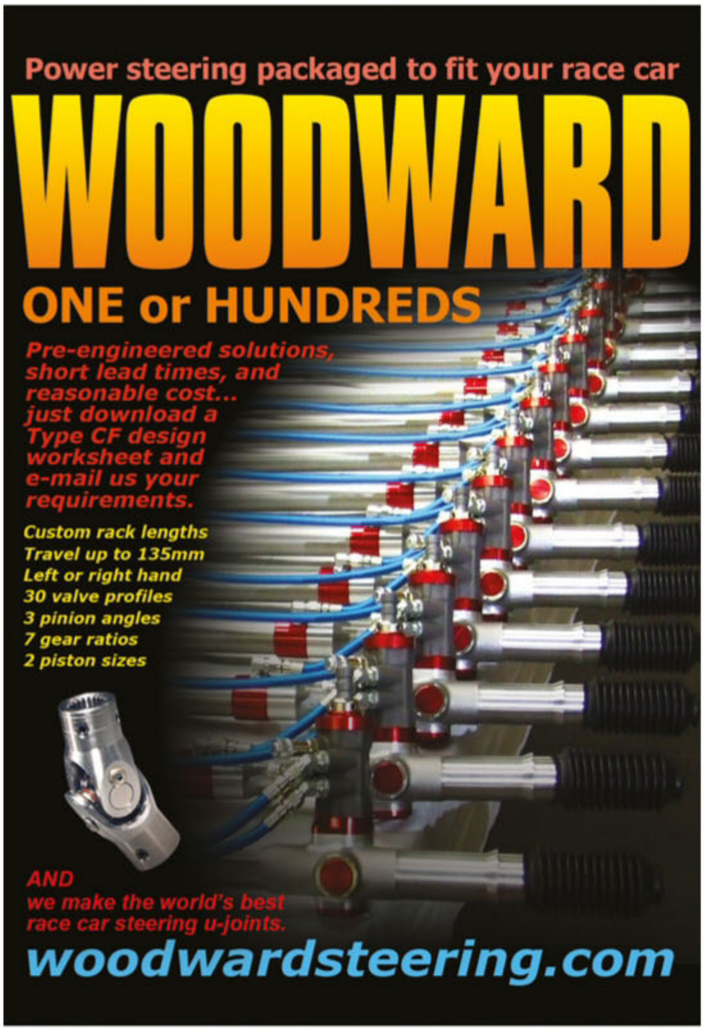
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Naked Miss R in testing. It has a projected performance of 0-100kmh in 1.8s, 0-200kmh in 5.1s, with a max speed of over 270kmh. Battery pack can produce one megawatt of power

Miss R is designed as a niche road car, though Xing hopes it will be used in competition. It uses the GT300 Mother Chassis

Called the Xing Miss R the car has already been testing without its bodywork (incomplete at the time of writing) but with its 1341bhp powertrain fully functional. Featuring four independent 350V motors, the prototype has projected performance of 0-100kmh in 1.8 seconds, 0-200kmh in 5.1 seconds and a maximum speed of over 270kmh. Its battery pack can produce one megawatt of power with 98 modules holding 4116 cells. Additionally, while car manufacturers race to tackle the challenge of range by adding batteries to their designs, Xing Mobility has taken an alternative approach by adopting a battery swap system that allows the entire battery enclosure to be exchanged within five minutes.

At the heart of the car is a familiar looking composite monocoque chassis, the Dome 'Mother Chassis' developed for use in GT300 cars raced in the Super GT Championship in Japan. The Xing is the first application for the MC outside of Super GT but its use is in line with the original concept laid out by Dome when the chassis was first announced some years ago.

Mother's day

'When we started the project about four years ago we had just finished designing the first competition car which had a tubeframe chassis, that was the first racing car I had designed,' Ticker says. 'I opted for a tubeframe chassis as it was for an arrive and drive series in Asia and we wanted it to be easy to maintain and repair. I felt that the damage assessment capability for composite chassis was not really all that good in this part of the world at the time, but it turned out I was wrong. There is actually some really good non-destructive testing capability in the area and so going forward we decided to build a composite chassis car.

'In the company we didn't have the skills or the capability to design our own monocoque, though we are changing that,' Tucker adds. 'We started looking at what monocoques were available to purchase, and really there are not a lot out there you can just get off the shelf. Through my business partner I found a connection with Dome in Japan. We got an introduction to them and visited the factory at Maibara, where we were shown the Mother Chassis. We proposed what we wanted to do, and the response was silence! After a few minutes the guy asked me a few very detailed technical questions and following those responses he indicated that maybe Dome would be willing to work with us. A month later we bought the chassis and did the rest from there. I had not realised until I read an article in *Racecar Engineering* that the Mother Chassis was originally designed to be a road car as well as a racecar chassis, so we are kind of bringing back the road car part of that.'

Xing in tune

While there are some who have wondered if the increased electrification of production cars would lead to the end of the tuner, companies and projects such as Xing demonstrate that the industry shift is creating opportunities for new operations from around the world. Perhaps in a decade or so the name Xing, or start-ups like it which until now have been unknown in the motorsport and performance tuning industry, will be heard as regularly as names such as Cosworth and Swindon are now.

The entire battery enclosure can be exchanged within five minutes


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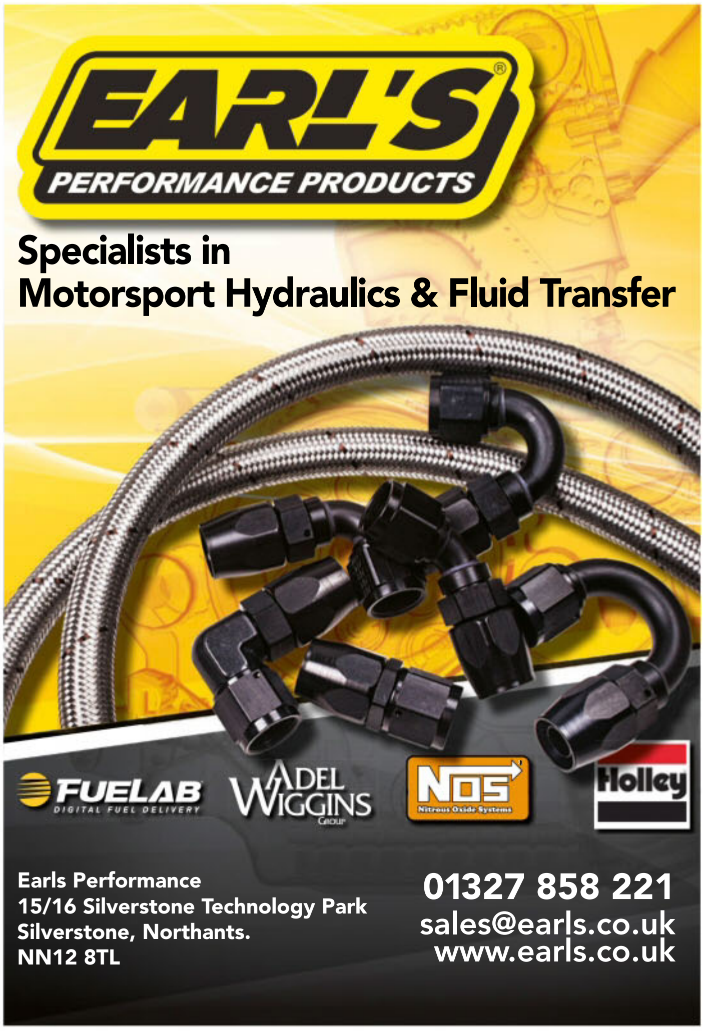
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The hard cell

Racecar's maths guru crunches the numbers for some of the most important elements of a race-bred electric powertrain – the cells

By DANNY NOWLAN

In December I was at a trade show in the US catching up with my colleagues from *Racecar Engineering.* It was suggested that given ChassisSim's presence in Formula E and other electric powertrain projects, I should write an article spilling the beans. I'm actually not going to do this, since our customers would get rather grumpy. But this is a great opportunity to talk about, and put some numbers to, the most important yet fragile link in electric powertrains – the electric cells.

The big difference between an internal combustion drivetrain and its electric counterpart is the lithium ion/polymer cells (LIPos) you use. With an internal combustion engine, while the quality and grade of the fuel is certainly very important, within reason you can work around it. With an electric powertrain if you don't have the right cells you are sunk before you even start. Consequently, we need the language to describe what the cells are doing, and to have a detailed exploration of what really counts.

C worthy

The very first thing you need to understand with a lithium ion/polymer cell is it's C rating. The C rating is a direct measure of how hard you can discharge/charge a cell. For example, most cells that are used in road cars and motorsport are 3300mAh or 3.3Ah cells. If the rating of that cell is 20C discharge and 5C charge, it means the cell can be discharged at a current of 66A and charged at 16.5A. We'll discuss the implications of this shortly, but it is critical for what you can do since energy density for an electric cell for motorsport use is so marginal. However, there is one critical analogy to draw here. With an internal combustion engine it is often said there is no replacement for displacement. Its electrical equivalent is there is no replacement for C rating. There are no exceptions to this rule.

The other critical element to understand is the cell voltage *vs* cell discharge capacity and current draw plot. With electric powertrains it is no exaggeration to say that your performance lives and dies by this curve, an example of which is shown in **Figure 1**

Figure 1 is pretty self explanatory. As the cell uses up its capacity the voltage drops. Also, as we subject the cell to greater current the available cell voltage drops.

Electric cell nirvana is when the plot in **Figure1** is as flat as possible. If I was the magic genie and you asked me to provide you with the

With an ICE it is often said there's no replacement for displacement. The electrical equivalent to this is there is no replacement for C rating

Formula E is very much the standard bearer for electric motorsport, yet the development of batteries within the series is constrained thanks to the use of a spec item

Figure 1: A sample of a cell discharge *vs* capacity and current for a high capacity cell

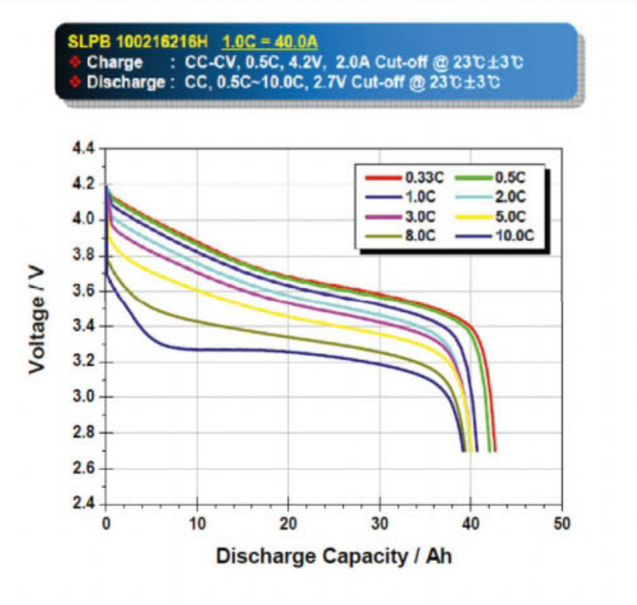
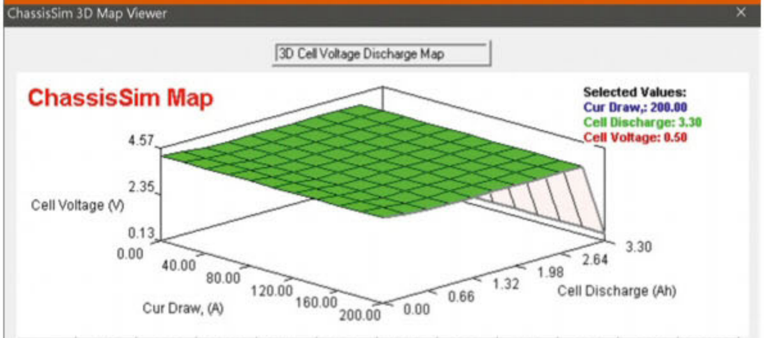


Figure 2: The perfect cell discharge curve



	0.00	0.33	0.66	0.99	1.32	1.65	1.98	2.31	2.64	2.97	3.30
0.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
20.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
40.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
60.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
80.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
100.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
120.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
140.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
160.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
180.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.50
200.00	4.20	4.10	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.500

perfect electric cell discharge curve it would look something like that shown in **Figure 2**.

The thing to note about **Figure 2** is that regardless of the used cell capacity or the current draw the cell voltage remains perfectly flat. Then as we get to the end it falls of a cliff. The reason that this is electric powertrain nirvana is that, regardless of the load on the cell, the cell voltage is perfectly flat which means the performance of the cell is perfectly consistent.

On rcgroups.com, one of the key discussion forums for people involved in radio control flying, in the electric section you will see endless discussions on this. This is particularly apparent on the high performance/racing section where these cell discharge curves are discussed at length. This is not that surprising since with the F5D pylon class you are dealing with one metre span carbon fibre planes running at least 6C battery packs drawing at least 200 amps that are capable of 380 km/h plus. Cell performance in this category is absolutely critical.

The next step in understanding the cells is to know the language of battery packs. When specifying a battery pack using LiPos the convention to use is shown in **Equation 1**.

As a rough rule of thumb put the cell voltage at 3.5V. This is a number I use for my calculations that seems to work pretty well.

Battery pack

It is now time for the rubber to meet the road; to calculate what we need to do to specify a battery pack and what we need in terms of regeneration. This is where what we have discussed about cells come into its own.

The first thing you need to specify is the engine power that you will need. To do this correctly you will have to know how to read an electric torque engine curve and to

Equations

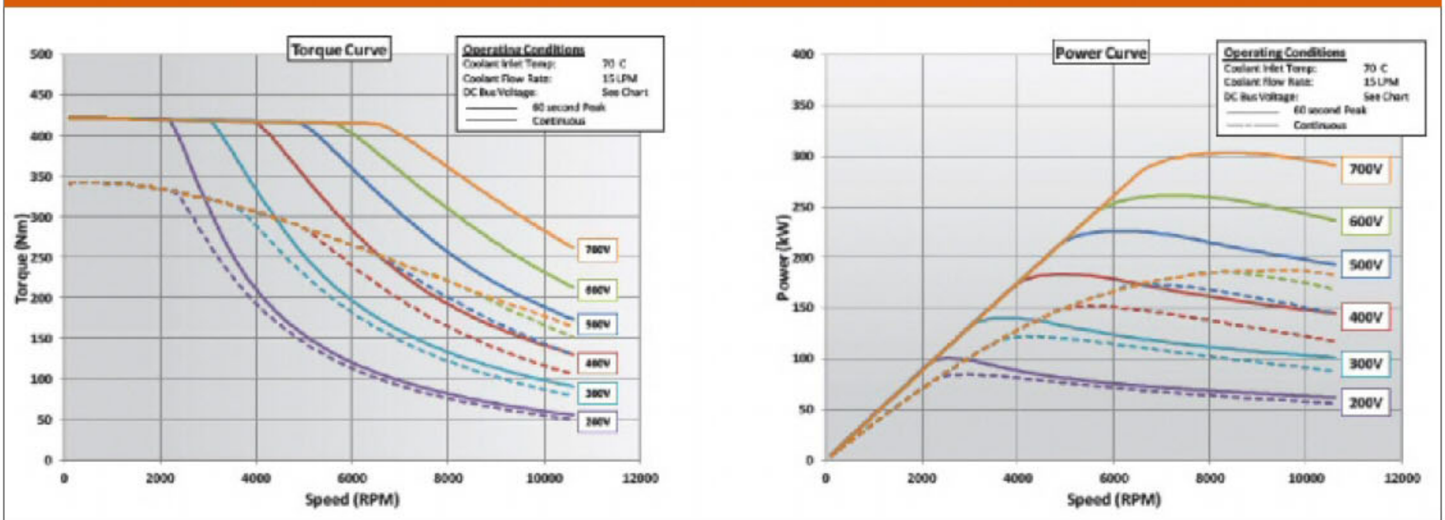
EQUATION 1

$$No\_Series \cdot S - No\_Parrallel \cdot P$$
$$V_P = No\_of\_Series \cdot V_{CELL}$$
$$Ah_P = No\_of\_Parrallel \cdot Ah_{CELL}$$

Here we have:

No_Series = Number of cells in series
No_Parrallel = Number of cells in parallel
V_P = Voltage of the pack (V)
Ah_P = Capacity or C rating of the pack (Ah)
V_{CELL} = Voltage of the cell (V)
Ah_{CELL} = Capacity or C rating of the cell (Ah)

Figure 3: Electric torque curve for RPM and Voltage (*courtesy of EV Systems Australia*)



Depending on the power you need and the rev range required, you can determine the required pack voltage from the associated power curve

understand its implication on the power that is needed. This is illustrated in **Figure 3**.

The first thing that jumps out here is the flat nature of the torque curve. The bigger the voltage the more this is maintained throughout the rev range. Depending on the power you need and the rev range that is required, you can determine the required pack voltage from the associated power curve. The power curve is the money shot, because that will tell you the number of cells you need in series.

For example, if we were looking at doing a Formula 3 conversion from ICE to electric we simply look at the power curve on the left hand side. An F3 engine runs in the order of 150 to 200kW. So all we need to do is read off the voltage on the left hand side of **Figure 3** to determine the required pack voltage. So for the engine in **Figure 3** to run between 150 to 200kW and be able to rev at 6000 to 6500rpm then we would have to run a pack voltage in the order of 400 to 500V. This determines the number of cells you need in series. So given that we have a working voltage of 3.5V/cell the number of cells we need in series is 500/3.5 –143.

But how do you determine the number of cells you need in parallel? The first step is to deduce the total current draw on the pack. Continuing our discussion on the Formula 3 car, a typical F3 racecar has an engine power of 220bhp or about 160kW. For the sake of argument, let's target 166kW. From **Figure 3** this means we need to be targeting a pack voltage between 400 to 500V. To make things easier let's target 500V. From the power equation the current we need is shown in **Equation 2** (where *P* = Power and *V* = Voltage).

In terms of the C rating of the battery, let's just park this for the time being. However, we will return to this very shortly.

Figure 4: Plot of speed, throttle and RPM for a lap with a conventional car

Current affairs

Now that we have the current draw we can figure out the current consumed. This is actually not as onerous as you might think. The first stage of this task is to bring up a plot of a conventional car, which is shown in **Figure 4**. Note that I have plotted this against time. To get us into the ball park we are going to add all the time we are on full throttle. For this particular lap this happened to be 52s. So the amount of current we will discharge for this lap is shown in **Equation 3**.

Let's presume we have energy recovery fitted to the car so we can harvest the energy under brakes. For the sake of argument let's say we can harvest 100kW of brake energy. So the charge current will be given by **Equation 4**.

Looking at the lap, the racecar spends 8.8s on the brakes. So as an approximation the amount of charge we can put back into the pack is **Equation 5**. So, over the course of a lap we'll discharge 4.8Ah but we can recharge 0.5Ah, so we'll be losing 4.3Ah for this one minute lap.

Cell capacity

Now that we have all this we can figure out what we need from the battery pack. Let's say our goal is to last 15 laps, or 15 minutes. Thus our cell capacity will be **Equation 6**.

So, given we are dealing with 3.3Ah packs we need 64.5/3.3 or 19.5 cells in parallel. To give ourselves some wiggle room here we will use 20 cells in parallel. Consequently, the spec of our battery pack will be 143S-20P.

Now that we have all this to hand here is where things get interesting. Firstly, a 3300mAh cell will weigh about 80g, give or take. So the pack weight will be **Equation 7**.

By the time you throw in some ancillaries to ensure the safety of the cells, this will then push the battery pack's weight up to somewhere in the order of 250kg or so.

Equations

EQUATION 2

$$I = \frac{P}{V} = \frac{166000}{500} = 332A$$

EQUATION 3

$$Amp\_h = I \cdot {}^{t}\!/_{3600} = 332 \cdot {}^{52}\!/_{3600} = 4.8Ah$$

EQUATION 4

$$I_{CHARGE} = \frac{P}{V} = \frac{100000}{500} = 200A$$

EQUATION 5

$$Amp\_h\_c = I_{CHARGE} \cdot {}^{t}\!/_{3600} = 200 \cdot {}^{8.8}\!/_{3600} = 0.5Ah$$

EQUATION 6

$$Ah_p = Ah_{LAP} \cdot No\_laps = 4.3 \times 15 = 64.5Ah$$

EQUATION 7

$$Pack\_mass = No\_S \cdot No\_P \cdot Cell\_mass = 143 \times 20 \times 0.08kg = 228.8kg$$


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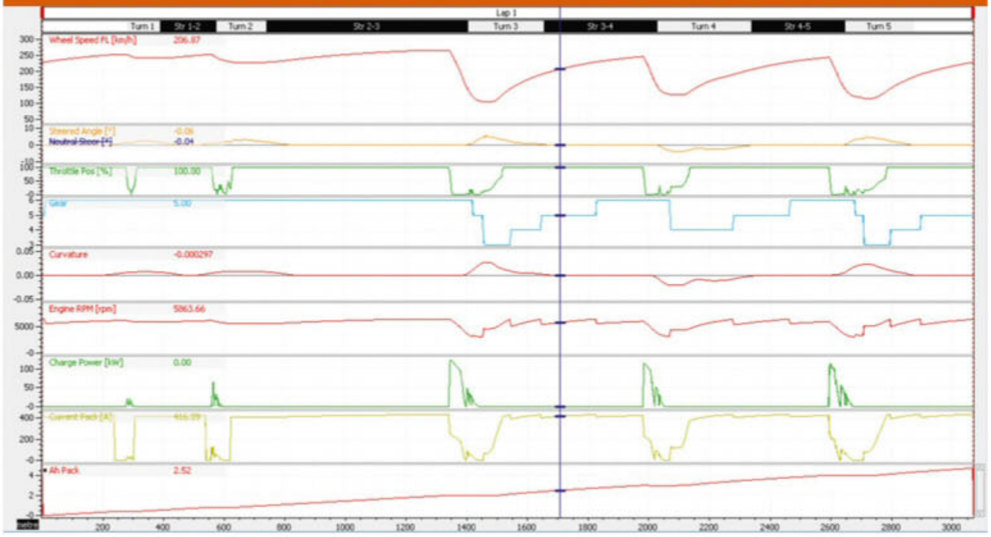
Figure 5: Charge power over the lap



Equations

EQUATION 8

$$P_{REGEN\_MAX} = V_P \cdot No\_P \cdot I_{charge}$$
$$= 500V \times 20 \times 39.6A$$
$$= 396kW$$

Here we have:

P_{REGEN_MAX} = Max regen power available
V_p = Pack voltage (V)
No_P = No cells in parallel
I_{charge} = Max cell charge limit (A)

But what is of much greater interest is what the cells have to put up with in terms of their C ratings. Given that we have 20 cells in parallel the individual cell load is 332/20A or 16.6A in discharge/power and 10A in charge/regen. The former is a C rating of 5C in discharge. Most high quality cells will do this easily.

Taking charge

Where things get really interesting is in charge mode. In our example here each cell was putting in 10A in charge or 3C. For most common or garden variety cells that is right up to the limit of what they can put up with. As a case in point, five years ago charging a LIPo pack at more than 1C was considered an extreme sport. That is, if you charged at more than 1C you had better have a fire extinguisher right next to you. Fortunately this has come on a long way; the cell manufacturer, Thunder Power, with its Rampage 70C cells, claims a maximum charge current of 39.6A on a 3.3Ah cell. But the crux of all this is that one of your fundamentally limiting factors is your C rating in charge/regen. Consequently the maximum you can harvest in terms of power will be given by **Equation 8**.

To flesh this out I did this based on the Thunder Power Rampage cell max charge limit. This worked out at 396kW. On paper that looks great, but realistically you would have to halve this to protect the cells. Consequently a more realistic limit would be 200kW in regen.

Regen maps

The great news is that software packages like ChassisSim can help you really nail down what you need from a regen map. An example of this is shown in **Figure 5**. By playing with the regen map specification and torque settings you can help dial this in. This and fine tuning with throttle lift and paddle maps is what ChassisSim customers involved in electric motorsport play around considerably with. However, the key thing to remember here is the limits in regen that are imposed by the cells.

There are a number of takeaways to note here. Firstly, if we review our numbers the hard limit on the battery pack will actually be the regen limits of the battery pack. As we saw from our F3 example the discharge case was 5C. A good quality battery pack will handle this without breaking a sweat. However, the real limit is the regen case which is at 3C.

Due to the nature of electric motorsport the ability to recharge is absolutely critical. This is a direct consequence of the current usage over the lap and anything you can get back in regen will pay for itself in reduced pack weight. As an example, in the above case, if you can get the Ah pack usage down from 4.3Ah to 4.0Ah, this means in cells alone the pack weight drops from 228.8kg to 217.4kg. And this clearly explains why the Formula E teams in particular are fanatical about their energy regeneration.

Another matter to review here is what a critical role regen strategies play with an electric powertrain. As we saw, for a modest one minute lap, in order to get 15 minutes of run time required a battery pack with a mass of 228.8kg in cells alone. It goes without saying that anything you can do to either get that weight down or extend endurance will be worth its weight in gold. This is why Formula E teams spend a lot of time and effort figuring out where to lift and how to employ both brake and paddle regen.

The need for aggressive regen strategies shows that energy densities of the lithium-ion/polymer cells are still marginal for motorsport use. Over the last 10 or so years, great progress has been made in the energy density of lithium-ion/polymer packs. Having flown radio-controlled electric planes for the last 20 years, I have had a front row seat to this. That said, there is considerable room for development here and we in motorsport have an important role to play in driving this.

Cell by date

Lastly, given the challenges still remaining with lithium-ion/polymer cells, I think it is now time to let cell technology off the leash. When Formula E started, engines and cells where tightly controlled. In order to get things running there was a fair bit of validity in that approach. However if electric motorsport (Formula E in particular) is going to stay relevant then there needs to be a genuine reason for people to get involved. While the current cells have proven fit for purpose in the early stages of launching the championship, if we are going to move the technology forward other suppliers should be given the opportunity to get involved. As we all know, in motor racing a bit of healthy competition never hurt anyone, and this is a golden opportunity to move cell technology forward. In that regards there is a lot of knowledge to be gained from the radio-controlled electric car and aircraft racing communities.

In closing, in order to understand electric powertrains you must understand the cells. Once you understand this everything will slot into place. Also, bear in mind that the regen case of the cell represents a key limit that you ignore at your peril. This and the mass of the cells and energy density is where the key focus of development for electric powertrains needs to be. On top of this, now is the time to let the cell technology off the leash. This will open up exciting possibilities as electric motorsport grows in the next decades.

The need for aggressive regen strategies shows that the energy densities of the lithium-ion/polymer cells are still marginal for motorsport use

Cadillac (front of queue) has slashed its engine's capacity down from the 6.2 litres it ran in 2017 to 5.5 litres for this season

Postcard from Florida

***Racecar* was on hand to check out the new tech – and a few surprises – when the IMSA DPi cars rolled out for new-season testing at Daytona in January**

By ANDREW COTTON

> 'We have reduced the torque, that's just simple engine maths – when you reduce the displacement you reduce the torque'

With a year of development under their belts, LMP2 and DPi teams contesting the IMSA United Sportscar Series introduced their updates for the 2018 season at the 'ROAR before the 24' test at Daytona in January.

Apart from the new GTLM car from BMW (page 8) and the heavily updated Mazda from Multimatic (page 16), there was also the new tyre from Continental, designed to address the problems seen in the 2017 Daytona 24 hours, while Cadillac turned up with a smaller capacity engine, down from 6.2 litres to 5.5 litres.

The prototypes were to 2018 specification, with the 'joker' packages that were allowed by the FIA and ACO to the base LMP2 car, which competes in Europe and forms the basis of the DPi. Working in collaboration with the French bodies, IMSA pared down the proposed wind tunnel schedule needed to test these joker packages in the short time that it had available at the Windshear testing facility, and unofficially confirmed that it had run through 90 per cent of its own planned programme.

IMSA itself had made tweaks to the balance of performance, introducing a rev limit for the engines, based on manufacturer recommendations and dyno testing of the power units. Cars were also running for the first time with the Sentronics fuel flow meter, which allows IMSA to better understand the fuel consumption for each engine, and that in turn will further help its BoP system in the future.

Caddy lack

The biggest talking point at the test session, however, was the smaller capacity Cadillac engine, and the subsequent performance changes made to the cars. During the 2017

Continental introduced new tyres for 2018, which were designed to get onto the grip spiral faster. This was in response to problems with its rubber in the cold temperatures at last year's Daytona 24 hours

season, Cadillac had many restrictions added to it, including aero changes, gear ratios and air restrictors, to the point that it was forced to consider changing engine concept.

Re-evaluation

'At the end of each season we evaluate our situation across the board,' says Laura Wontrop-Klausen, Cadillac programme manager. 'We look at where we started, where did we end, what do we look like relative to our competitors? When we looked at the entire package we saw a disconnect between our competitors through design choices and what the series had to do to equalise us, and we felt that what we gave up was not worth the discrepancy on the engine side, so we went down the path of reducing the size of the engine to gain back the aspects that were taken away and to allow for a better balance of performance going forwards.

'The wins that happened for us were all earned, but we started the season with a ready to race car, and so in a way, we were able to climb to the top quickly and hold that for a while. Towards the end of the season, you [saw] where there is a lot more opportunities for [other] people to take wins.'

Rivals pointed out that by changing the engine size and characteristics, Cadillac has created a grey area in which IMSA has to start with its balancing process again. No official figures were available from Cadillac regarding how much torque or power it had lost, and it wasn't willing to speculate either.

Balancing point

Scott Meesters, of Cadillac's engine builder ECR, said: 'We run on the dyno for a day, recording plus or minus five per cent, and they [IMSA] record what it took to get that five per cent. They get a good feel for what the engine makes for power, and they have a good correlation on what that means for a race track. This was our best foot forward for this event.'

The engine is not brand new; it is based on the title-winning powerplant from 2017, but ECR has reduced the stroke, which means the rotating and reciprocating assembly has had to change, as has the crankshaft. The engine was validated in a 33-hour test ahead of Daytona.

Torque talk

Rivals commented that the torque of the engine seemed hardly changed, but ECR's Matthew Wiles says: 'This is when we look at the vehicle system not just the engine, and we need to talk about dynamic range of the engine. Really what matters is the rear wheel torque, not the engine torque. If you look at the dynamic range of our engine, and other engines, parity can be achieved through gearing as well, and we have worked with IMSA on what our exact performance levels are.

'We have reduced the torque, that's just simple engine maths – when you reduce the displacement you reduce the torque – and we have worked with IMSA on restrictor size to put us more on parity in terms of power target and power level,' Wiles adds.

The biggest talking point was the smaller capacity Cadillac engine

The Ligier (seen here in Nissan guise) has lost a little weight, while the aero at the front of the car has been updated

Daytona scrutineering. IMSA has made tweaks to its balance of performance, including introducing a new rev limit for the racecars that was based on manufacturer recommendations and dyno testing of the power units

In 2017, with near freezing conditions and rain on the banking, drivers were highly critical of the Continental tyre that was designed exclusively for the Daytona race. In the cool temperatures, the tyres took up to three laps to get up to temperature, and the company has worked hard to change that for 2018.

'The fact that it was 30degF [1degC] last year and wet, you have to think that it is probably going to be cold and wet again,' says Continental's Product Manager Kevin Fandozzi. 'The problem is that it also has to go to COTA and places with 140degF [60degC] track temps. We have spent most of last year developing a compound that can handle those temperatures, and handle the temperatures here.'

Cold and tyred

'The test that we did was in October, up north, and we did it to get the cold temperatures,' Fandozzi adds. 'It was 42degF [5.5degC] when we tested with Joao Barbosa. Action Express were not happy with the tyre last year, and they could evaluate the two. He got out of the car and said that last year's tyre was okay, and this year's tyre, the confidence is 10 times better.'

The issue was that once the tyres didn't get up to temperature and started to slide, it became even more difficult to get the tyres to warm up. Continental has instead changed the tyre so that it is easier to get onto the upward spiral, where grip earlier in a lap leads to higher temperatures, and therefore more grip.

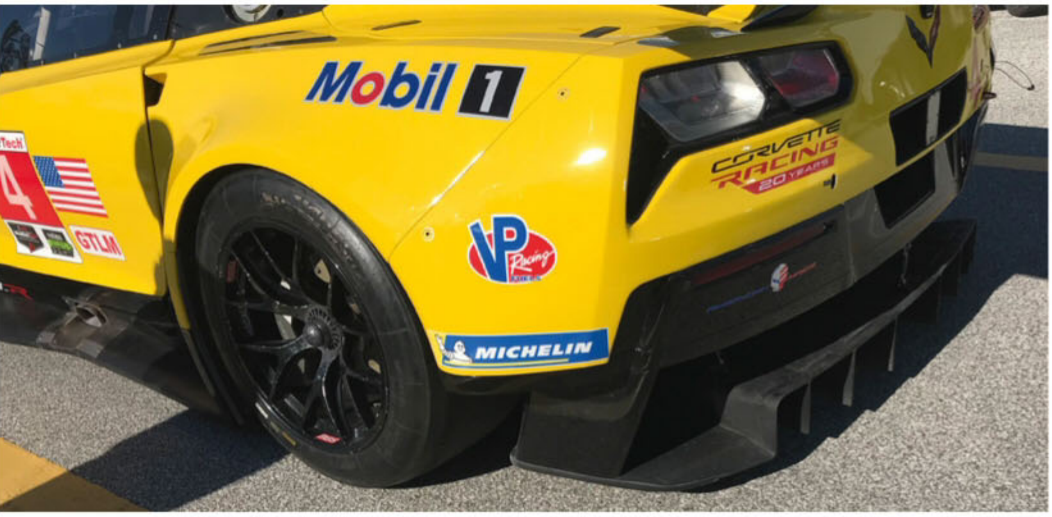
'It is a grip spiral – if we have enough grip to generate heat, then the compound starts to work, and you get grip, and that generates heat,' says Fandozzi. 'And it goes the other way – if you don't get onto that spiral, if you start sliding, the compound doesn't get heat, and you lose grip. We made sure that it didn't take much to get onto the upward spiral. Even if we go full course yellow, when you lose all the heat from the tyre, it took them three laps to get the heat back into the tyre, but now it is two turns. The key was how to get the tyre onto the grip spiral.'

The slick tyre was unique for Daytona, to help with the higher loads put on to the outside tyres on the banking, but the wets are standard issue for the rest of the IMSA season. Tyre management for all teams has been a challenge in all classes, and there have been the usual tricks played to get tyres to work. 'In GTE to get grip, a lot of teams took pressure out of the tyres, GTD especially, and the tyres cannot survive without pressure on the banking,' Fandozzi says. 'A lot of teams that didn't know how to engineer the cars took pressure out, because that was an artificial way of making the cars work. No tyre is perfect, but if you take air out then it simply won't work.'

Camber changes

One of the issues faced, particularly by Pirelli, in Europe is that the Audi and Lamborghinis are designed to work best with very aggressive cambers. But in the States, Continental was able to convince the manufacturers to change the racecars to better suit the tyres.

'Audi released their GT4 car with aggressive cambers, and with the McLaren the minimum camber at the front is 4.5-degree, so you put that on the banking and it will be difficult,' says



Michelin is set to take over the tyre supply for the full series from Continental in 2019 after signing a 10-year deal with IMSA

Above: A rare glimpse of the engine and gearbox of the Porsche GTE out of the car **Right:** Ferrari's update kit includes a new front bumper shape with recesses to allow for the dive-planes to be better located. It also has a new front splitter profile

Ferrari kit also includes a reworked diffuser and newly shaped exhaust pipes; the latter to maintain the gap between the two

Fandozzi. 'The Pirelli tyre likes a lot of camber when the track has a lot of grip, but does not like it for durability. Here the Ferrari Challenge guys had to design a kit to allow them to run one degree of camber to make them work. It likes it for performance so long as there is no load. You can put 5-degree on them, but when you have load they are going to fail tyres. Our recommendations are 2.5-degree at the rear, three to 3.5 at the front, so it is in the window of homologation, but it is on the safer side.'

Rev limit

For IMSA, the rev limit was a further lid to place onto the box of engine development. 'IMSA manages the rpm limits across all IMSA WeatherTech SportsCar Championship classes based upon the results of the engine dyno testing and/or the manufacturer-submitted information contained within the FIA vehicle data sheets,' says technical chief Geoff Carter. 'Adding information to the BoP tables is a further example of IMSA's continued transparency with our stakeholders.'

The unofficial line regarding the joker packages for LMP2 was that there was a 0.2 per cent improvement in the performance permitted, although teams were baffled as to how that could be implemented. It is also clear that no car was capable of improving ahead of the ORECA chassis, which formed the baseline.

Manufacturers submitted their recommendations to the ACO and the FIA, and were told what they could and could not do. The changes permitted were surprisingly limited, with Dallara introducing a slightly different profile to the rear of its nose section, and Ligier coming to the party with a new front aerodynamic package and concentrating on weight loss throughout the racecar.

A new diff, new electronics (now all-Motec rather than a combination of Motec and Cosworth) have also made a difference in the Ligier DPi racecar. Also updated was the Acura DPi, which featured a tuned version of its title-winning engine built by HPD – which had previously run in the old LMP2 racecar.

Ferrari update

Meanwhile, in GTLM Ferrari introduced its update kit, including a newly profiled front splitter, with new fences on the outer edge, plus new sculpting in the rear diffuser, and different shaped exhaust pipes to maintain the gap between the diffuser and the bottom of the pipe. There's also a new front bumper profile with recesses to allow for the dive-planes to be better located. It may not have looked much of an upgrade, but the target is to keep the car within the performance window.

Continental's new slick tyre was unique for Daytona, to help with the higher loads on the outside tyres when the cars are on the banking

Interview – Oliver Ciesla

Stage managed

The commercial boss of the WRC explains its recent growth in popularity and tells us why he thinks it's a better fit for manufacturers than Formula E

By MIKE BRESLIN

'I don't understand Formula E's story, it's a kind of political correctness that has morphed into a sport'

While the BTCC has its Alan Gow, TCR its Marcello Lotti and GT3 its Stephane Ratel, you might be forgiven for not having heard of Oliver Ciesla. And yet this man, as the managing director of WRC Promoter – a company which does just that – has helped to bring new life into a major global motorsport championship that was, in his words, 'stuck in a ditch.'

But Ciesla is no former rally driver – or co-driver as is usually the way – turned promoter. He's a hard-nosed sports businessman, with 20 years' experience in the worldwide commercialisation of sports rights, including spells working for the English Premier League and Euro 2008 in football. And that just might be to his, and the WRC's, advantage.

'My job is not to drive the car, or build the car, or to do the detailed itinerary for a rally,' Ciesla say. 'It is the commercialisation and the knowledge of how a sport should be set up for the purpose of being attractive to fans.'

The German's hiring five years ago was the outcome of a change in strategy for the WRC. 'The change of strategy was getting someone on-board who has an outside view on things,' Ciesla says. 'And then what did we do? It's not that we only looked at the media and the marketing, we also started to redesign the sport carefully, to make it more attractive.'

The results are clear to see. The 2017 season was a huge success with seven different winners and those numbers promoters like to see, in the places they like to see them. 'Social media channels were growing from nothing, to 2.3 million followers. This is half of what the Olympics has,' Ciesla claims. 'This is a tremendous community that we feed here, but the even stronger figure is, we receive from these guys 138 million responses. So this is extremely interactive.'

Show business

While the social media stuff is impressive so is the more traditional live spectator numbers, which topped four million last year. Part of the reason for both is surely the new sexier and faster World Rally Cars, but there's a little more to it than just that. 'We have a new specification of cars, yes. And that hit the spot, it is what the fans loved,' Ciesla says. 'Then we also changed the sport; we changed the start order, and that was very important. We changed the fact that the shakedown is not qualifying anymore, that is very important, too. We gave more value to the Power Stage; there's five points to it now, to win it. We changed the rules so the teams could not communicate with the drivers anymore during the competition, cutting out the strategic element, not allowing them to go slowly when they don't need to go fast; so it's always flat out, always exciting. We gave the Power Stage a regular length and a regular time to start – we need the fans and the broadcasters to create habits.'

On the back of its 2017 success the WRC has now started its 2018 season in a similar shape to last year, with four manufacturers on-board (including M-Sport with increased backing from Ford). But for a championship that has always been about manufacturer competition, how can it compete with new kid on the block, Formula E, and also rallying's own offspring, in many ways, the World Rallycross Championship?

As far as the former is concerned, Ciesla is bemused. 'What are you selling on the Monday after a Formula E weekend? It's not a road car; it's a formula car that you cannot buy, and it has an electric engine that the car manufacturers are not even producing, it's a third party that they acquire it from. I don't understand the story, it's a kind of political correctness that has morphed into a sport. It is a serious car in rally, we go on normal roads, and the guys are very accessible; this is very authentic.'

Current thinking

But what of Rallycross? Peugeot has recently said that it's this discipline's drive to embrace electric that convinced it to tie its colours to the World Rallycross mast, isn't there a risk that other major car manufacturers will also ignore the WRC in favour of a an electric future in rallycross?

'Most of the cars today that are sold are fuel-driven cars,' Ciesla says. 'So even if the electric car market share is growing, if at some stage on a global scale about five per cent, still you need to do some promotion to sell the other 95 per cent. Nobody in deepest South America would buy a truck with an electric engine; and the United States and all these countries where they have big distances to cover. [Electric] is mostly in the big cities, and even if it's five or so per cent, this still means most of the turnover comes from fuel-driven cars.

The WRC's new formula proved a great success in 2017. Hyundai is one of four manufacturers involved; its i20 WRC is pictured here in action in Australia

'And the margin that they have is not on the 50bhp Polo,' Ciesla adds. 'The margin is on the cars the people are prepared to pay more for; that's a tuned car with the bigger engine, and the spoiler, this is where they make their money; with the GTi, with the R, with the RS, and the consequence is, they need to have the marketing budget to promote these cars, and to position them to make them look good, to make them look exciting, to emotionalise them.'

While the WRC remains a very good place to 'emotionalise' cars, as an FIA World Championship it also has a global stage on which to do this. However, a glance at the calendar shows that this is still a little Euro-centric.

'There is an agreed objective with [FIA president] Jean Todt to [expand outside Europe],' Ciesla says. 'In the medium term planning the calendar should be 50 per cent in and 50 per cent out of Europe, and this is exactly what our calendar strategy and my job is at the moment. All the prospects that we are talking to about new events are predominantly in Asia, or South America, even in Kenya. Bringing the Safari back? Yes.'

Reactive approach

Mention of the Safari Rally is a reminder of rallying of old, when the sport was far different to what it is today. And that begs an almost existential question; what is WRC, racing or adventure?

'Let the USP of the Cross Country championship be that [adventure]. Our USP is a different one,' Ciesla says. '[But we] are still telling a much more dramatic, exciting adventure story than this clinical formula competition where you are driving always on the same circuit, with surgeons sat in the garage waiting for you with their gloves on. Even so, it is not the same rallying anymore, as it was in the '70s and the '80s. No one today would follow a linear rally weekend, a 600km rally from the south to the north of England. There is zero media product in this context; the span of attention of a young man today, or a young woman, is between eight and 14 minutes and no one cares about a competition that lasts non-stop so long. So what we need is to be reactive on what the fans want today; and here again I come with my outside analysis, not being the guy who is sitting on the WRC commission for 20 years and says this is how we did it forever. But [forgetting that] in 10 years it didn't get out of a ditch.' The challenge now then is similar to that faced by the drivers – staying out of that ditch.

RACE MOVES

Former French presidential hopeful **Francois Fillon** has been appointed president of the FIA's Manufacturers' Committee. Fillon, whose brother Pierre is the president of the ACO, is a very keen motorsport fan and in this role he will be involved in renegotiating the Concorde Agreement, which will underpin all Formula 1 business from 2021 onwards. He has previously served on the FIA senate.

Transmission specialist Xtrac has announced that **Joe Greenwell** is to be appointed non-executive chairman with effect from July. Having recently joined the main board as one of three new non-executive directors, Greenwell will take over the role from **Peter Digby**, who becomes company president. Xtrac's chief executive, **Adrian Moore**, will continue to head up the executive team responsible for day-to-day operations.

Kyle Novak is now IndyCar's race director, replacing **Brian Barnhart**, who recently left to become president of Harding Racing. Novak comes from IMSA, where he has served as race director for its IMSA Continental Tire SportsCar Challenge, Porsche GT3 Cup Challenge USA, and the Ultra 94 Porsche GT3 Cup Challenge Canada series.

Michael-Julius Renz is to be the new CEO of Audi Sport – which focuses on development and sales of the Audi R and RS models and customer racing. He will take up the post in March and replaces **Stephan Winkelmann**, who is now the president of Bugatti.

Josh Smith has joined Mazda Motorsports in the US, where he will work across all of its programmes but will focus on grassroots competition, helping club racers with their technical queries and spare parts requests both over the phone and at race meetings.

Doug Duchardt has joined **Chip Ganassi** Racing as its chief operating officer. He comes to CGR from the Hendrick Motorsports NASCAR operation, where he spent 12 years, most latterly as executive vice president and general manager, a post he relinquished in the summer of 2017. Duchardt will be involved in CGR's IndyCar and sportscar programmes, as well as NASCAR.

Chip Ganassi Racing has established a new corporate office structure to oversee its various racing and commercial activities. It will include team owner and CEO Chip Ganassi, president **Steve Lauletta**, its new COO **Doug Duchardt** (see above), its CFO **Chuck Gottschalk** and vice president of human resources **Rob Wilder**.

Chip Ganassi Racing (see above) has also announced that **Max Jones** has been promoted to managing director of the team's NASCAR business. He joins **Mike Hull**, the managing director of CGR's IndyCar and IMSA operations, in the management team.

US race organising body the SCCA has taken on **Chris Robbins** as its new director of Region Development. In his new post Robbins will focus on helping the SCCA regions to grow.

Former NASCAR and IMSA team owner **Robby Benton** is now the team manager for Penske's NASCAR operation, reporting to competition director **Travis Geisler**. From 2008 until 2015 Benton co-owned RAB Racing in the NASCAR Xfinity Series, while he has also run a team in the Camping World Truck Series. This year Penske is fielding three cars in the Cup and one in Xfinity.

Australian Supercars engineer **Alistair McVean** has signed a multi-year contract extension with the Erebus Motorsport Supercars outfit, with which he helped to scoop Bathurst 1000 honours last season. McVean joined the Erebus team in October 2016 after more than 10 years working at Walkinshaw Racing.

Brian Corradi has joined **Daniel Hood** as a co-crew chief at crack US drag racing operation John Force Racing, and they will now both work on the **Courtney Force**-driven Chevrolet Camaro for the 2018 NHRA Mello Yello Drag Racing Series. Corradi was previously a crew chief at Don Schumacher Racing.

OBITUARY – Dan Gurney

If Dan Gurney had only ever been a driver he would be remembered as a great – he was after all the only rival Jim Clark was said to have truly feared – but as an engineer, car constructor and team boss he was also very special indeed.

As a driver he could turn his hand to anything and was one of only three to win races in F1, top level sportscars, NASCAR and Indy cars, a royal flush the American shared with Mario Andretti and Juan Pablo Montoya, while he is also remembered for being the first – along with AJ Foyt – to spray champagne on the podium to celebrate a race victory; at Le Mans in 1967. He was also the first driver to wear a full face helmet in Formula 1, in 1968.

Dan Gurney, a legend of the sport as a driver and engineer, has died aged 86

Always an engineering-minded racer it was natural that he should set up as a constructor, especially having previously driven for owner-driver Jack Brabham, and in 1966 All American Racers (AAR) – also called Anglo American Racers when the cars were powered by British engines – was born.

Entering patriotically-named Eagles the cars struggled in 1966 but were on the pace in 1967, and he won the Belgium Grand Prix at Spa in his own Eagle-Weslake V12 that year. AAR left F1 at the end of 1968 but its cars were also successful in Indy style racing in the US, scoring victories at the Indianapolis 500 (1968 and 1975, while in 1973 a privately run Eagle also won), as well as claiming titles (1968 and 1974). It went on to build sports prototypes such as the Toyota-powered MkIII GTP car while more latterly AAR built the DeltaWing that raced at Le Mans in 2012.

Gurney was always known for his innovation and was, it will be no surprise to hear, the inventor of the Gurney flap.

Dan Gurney died in mid-January at the age of 86.

Dan Gurney 1931-2018

Former Citroen WRC team boss takes up top FIA rallies position

Citroen World Rally Championship boss Yves Matton has now left the team to fill the role of rally director at the FIA.

Matton replaces Jarmo Mahonen in the FIA's top rally job, the latter having retired, while Pierre Budar, who previously run PSA Motorsport's customer racing department, has replaced Matton at Citroen.

Belgian Matton will be responsible for the strategic vision of rallying and cross country at all levels, from grassroots through to the regions and the pinnacles of the disciplines, the FIA World Rally Championship and World Cup for Cross Country Rallies.

Matton had been responsible for Citroen's World Rally Championship and its now-defunct World Touring Car Championship programmes, having replaced Olivier Quesnel in the role in 2011.

Yves Matton is the new rally director for the FIA, replacing Jarmo Mahonen

He said of his new role: 'I must admit that I feel very honoured to take on this position at the FIA, the governing body of world motorsport. I have worked at various levels of the sport, including for one of the most successful manufacturers in history, but this is for me a real achievement in itself.'

FIA President Jean Todt said: 'Yves has a wealth of experience across many facets of rallying, which is important for its continued growth. He has great passion for the sport and his understanding of competition and management at independent and manufacturer levels will be a great asset to further securing the future development of our sport.

'I would also like to thank PSA Motorsport for making Yves' transition to the FIA so seamless,' Todt added.

RACE MOVES – continued

Alba Colon in now director of competition systems at the Hendrick Motorsports NASCAR operation, replacing **Darian Grubb** in the post, the latter having moved back to crew chief duties within the Hendrick team. Colon has been involved in NASCAR since 2001, as the programme manager for Chevrolet, while she had been a part of General Motors' motorsport efforts since 1994.

Former Tekno Autosports manager **Steve Greer** has been recruited by Matt Stone Racing ahead of its step up from Supercars feeder series Super2 – a championship it won in 2017 – to the premier Australian motorsport series. Greer has also worked with Stone Brothers Racing.

Nick Syrett, well-known for his work at Brands Hatch and the BRSCC, has died at the age of 84. Alongside Brands boss **John Webb** Syrett played a part in the founding of Formula Ford, the Clubmans sportscar formula, and Formula 5000. He went on to become president of the Grand Prix Drivers' Association in 1972.

Bob King, the founder of racecar constructor Royale, has died at the age of 79. Although it was perhaps best known for its Formula Fords, Royale – which King set up in 1968 – built a wide range of chassis including F2 and sports prototypes. Both **Rory Byrne** and **Pat Symonds** worked for Royale early in their careers.

Dorsey Schroeder has been appointed chief steward for the Trans Am Series. A former driver, Schroeder was a Trans Am stalwart from 1989 until 1999, and was champion in his first season. Schroeder joins Trans Am after a spell as race director for the Pirelli World Challenge, a post he held from late 2015 until the end of the 2017 season.

Former NASCAR crew chief **Barry Dodson** has died at the age of 64. Dodson worked with several of the sport's top drivers, including **Rusty Wallace, Tim Richmond** and **Darrell Waltrip**, winning the Cup Series with Wallace in 1989 and chalking up 19 top level NASCAR victories.

Billy Scott, formerly the crew chief for **Danica Patrick** at the Stewart-Haas Racing NASCAR Cup operation, will now fill the same position on the **Kurt Busch**-driven car, following Patrick's retirement from full-time racing. Busch's former crew chief **Tony Gibson** has now moved to a new, as yet undisclosed, role within the SHR organisation.

Also at Stewart-Haas Racing (see above), **John Klausmeier** is now the crew chief on the Aric Almirola-driven No.10 car. He has served as a race engineer at SHR since 2009 but he does have some experience as a crew chief, taking on the role on an interim basis for **Kurt Busch** at Pocono in 2016 – a partnership that resulted in victory on that day.

Chris Stuckey has been recruited by Nissan Motorsport to be the race engineer for **Simona De Silvestro** in the Australian Supercars series, replacing **Blake Smith** in the position – the latter having now taken on a job outside of motorsport. Stuckey has a decade of Supercars experience, most recently as a race engineer at Preston Hire Racing.

◆ Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect? Then email with your information to **Mike Breslin** at **mike@bresmedia.co.uk**

AUTOSPORT INTERNATIONAL
THE RACING CAR SHOW

The fast show

Racecar's **deputy editor reflects on this year's Autosport International Show and recalls some of its highlights**

From motorsport fan, to student, to graduate to Formula 1 engineer, and then to deputy editor of *Racecar Engineering*. My career so far has been one rich in variety, throughout which I have gained experience and contacts across a wide spectrum of the motorsport industry. Yet, regardless of the team, project or article I may be working on, the Autosport International show remains a key date in my diary.

This is simply because whoever I have needed to speak to at the time has always been at the show. Autosport International is not only an annual celebration of all things motorsport but is also a centralised hub, where all corners of the racing industry come together under one roof to catch up, network and do business.

As my years of experience in this industry continue to stack up, so does the ever growing list of those I know who also share my passion for racecars. But only this year did I recognise and realise the impressive calibre of people

Greaves 3D Engineering won the Technical Innovation Award at the Autosport Engineering show

At the ASI show all corners of the racing industry come together under one roof

Prodrive wins top MIA motorsport business award

Well-known motorsport engineering and technology company Prodrive scooped the top award at the annual Motorsport Industry Association's (MIA) Business Excellence Awards, which were held at Autosport International.

Prodrive won the The Business of the Year Award (with annual sales over £5m). The company has created innovative solutions in automotive, aerospace, marine and other sectors as well as making championship-winning race and rally cars.

In September Prodrive celebrated its 300th win of a race or rally since its formation in 1984, when its Aston Martin team took a class victory in the Austin, Texas round of the WEC. Prodrive employs more than 500 staff in Banbury and Milton Keynes. While it is perhaps best known for its many successes in global motorsport – rallying with Subaru, Mini, Volkswagen; Le Mans and GT with Aston Martin; and F1 with Benetton – over the past decade Prodrive has also diversified to become a high-performance technology business serving many sectors including space, automotive, defence and marine with design, manufacturing and consultation solutions.

MIA CEO Chris Aylett said: 'The Prodrive brand continues to be synonymous with British global motorsport success but, in recent years, it has come to mean so much more. For many years, the MIA has worked tirelessly to promote the benefits and opportunities that lie in diversification and technology transfer from motorsport. Prodrive personifies the success that such a strategy can deliver.'

The other category winners were: National College for Motorsport (Service to the Industry Award); RML (New Markets); Goodridge (Export Achievement); McLaren Applied Technologies (Technology and Innovation); M-Sport (Teamwork Award); Titan Motorsport and Automotive Engineering (Business of the Year with annual sales under £5m).

The MIA Business Excellence Awards for 2017 were presented in Birmingham in January. Seven companies were recognised, with Prodrive winning the headline award for a business with annual sales over £5m

who attend the Autosport show. Team bosses, chief engineers and race drivers can be found hovering around their stands and you can quite easily end up bumping shoulders with motorsport's movers and shakers.

But while the show is a great place to meet people, it's mostly about the hardware; the racecars and technology that the 600-plus exhibitors are showcasing, and the launches that are an integral part of the event.

For instance, this year saw the first ever launch of a top tier FIA world championship at the show in the form of the 2018 World Rally Championship. Meanwhile, Ginetta revealed its all-new LMP1 racer for the new WEC 'Super Season' (see page 30).

In terms of technology, there were several innovative designs showcased at the Autosport Engineering Show that caught the eye, too. The all-new Smart Fuel Management System from Greaves 3D Engineering scooped the Autosport Technical Innovation Award for its digital and wifi capabilities, for example. This allows the engineers on the pitwall to send fuel loads to the rig and once this amount has filled the racecar, it automatically shuts off, reducing those crucial seconds in the pitbox.

JE Pistons also revealed its new coating technology, which is applied to the piston skirts and dynamically changes shape as the piston reciprocates, minimising piston to wall clearance and therefore frictional losses (see page 62).

Show time?

There is no doubt that the Autosport Show has its place, as shown by the 95,000 fans and professionals that entered its doors across the four days. However, as far as show season goes, it is the last to cross the finish line. The PMW show in Cologne caters for the Continental European markets in November, with PRI in Indianapolis taking care of the American markets in December. Therefore, by the time it's Autosport's turn, most of the technology has already been unveiled and the exhibitors haven't got much left to say. However, the UK does need its own show to support all the teams and suppliers in the famed Motorsport Valley, but the question is, when?

January is a no man's land for the majority of motorsport. All the teams from Formula 1 to Formula 4 have their heads down for that final push to design their new cars, and all their suppliers are running around to help them. Then you have the new categories such as Formula E which races during the winter – with this year's round at Marrakesh actually clashing with the show. Meanwhile, WEC is moving to a winter schedule in the near future, too, so there may even be more than one race clashing. So how do you secure pole position on the show season grid whilst co-ordinating a free weekend between all the championships and suppliers when the off season is quickly becoming more like a 12 month 'on' season? A good question, and one I don't know the answer to.

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Global power games

The idea of a global race engine, which FIA president Jean Todt floated in Abu Dhabi last year, is nothing new. But the fact that the concept has re-emerged is something of a blessing for motor racing. Featured in 2009 on the cover of *Racecar*, it was a concept that could have formulated this past decade of racing, and encouraged new manufacturers to come into the sport with relatively little engine development cost.

In our November 2017 edition (V27N11), I wrote that the FIA was considering a joining up of the dots between Formula 1 and sportscar racing, with common engines between the two. This has been possible since 2014, but no one has taken that option, be it on the grounds of cost, complexity of installation, or fuels and lubricant demands. With F1 going to three engines this year, down from four in 2017, the mileages from the existing power units (including practice and qualifying) are approaching a race distance at Le Mans. For a global race engine concept to really work, there are clear problems to solve; F1 has fuel developed for an engine, while sportscar racing uses a standard fuel across engine concepts from a single fuel supplier, for example. However, the basic concept has already been explored and should only require some fettling to get it ready to be voted in.

Could the Global Race Engine concept really be resurrected?

The 4-cylinder engine concept is typical throughout most manufacturer ranges, as is small capacity configuration with turbocharging. Granted, today's world of electric and hybrid has changed that concept slightly, but the base idea is still a good one. So good, in fact, that it was swiftly voted through by BMW and Audi as the new DTM engine for the 2019 season. The concept of common architecture means that manufacturers could build an engine and spread that development cost across multiple disciplines. It also opens the door to smaller engine manufacturers such as Cosworth, Ilmor and Mecachrome who can amortise the costs.

The original idea, published almost 10 years ago now (RCE V19N11), was to have an engine that could service junior and senior formulae. In 2-litre form, it could happily power IndyCar and F1, while in 1.6-litre format, it could be used in feeder single seater formulae, such as F3. With the fuel flow meter concept that was introduced in 2014 that was intended to replace air restrictors, the two ideas could have gone hand in hand. As it happened, the Global Race Engine concept did not take off. Rumour has it that a fall out between Bernie Ecclestone and Ferdinand Piech over the VW Group's participation in Formula 1 meant that the idea, heavily promoted by Audi's Ulrich Baretzky, went out of the window as F1 adopted a 1.6-litre V6 hybrid policy. No one produces a 1.6 V6 hybrid; outside F1 the engine configuration does not exist, but it prevented Porsche, or Audi, from going to F1. Both chose to go endurance racing instead.

However, both have now withdrawn from endurance racing, Piech and Ecclestone are gone, while Porsche is back at the table, looking at the new F1 regulations and few believe that its Formula E plan, due to start in the 2019/2020 season, is a long-term solution as its flagship race series. Dieter Rencken, on the website *F1fantatic*, says that it was Ferrari and Mercedes that objected to the in-line 4-cylinder layout, with Renault the only manufacturer pushing for it.

Personally, I don't think that it is a coincidence that the Global Race Engine format has been rekindled after manufacturers pretty much rejected the idea of maintaining the current architecture. It was a good idea back then, it is a good idea now. Porsche wanted it then, and with the 2-litre, turbocharged 4-cylinder engine that powered its LMP1 car to three world titles and Le Mans wins, I would say it would be pretty keen to have it in Formula 1 in the future, too.

It is clear that something needs to be done. Engine costs for F1 teams are high, while LMP1 is suffering a lack of manufacturer entries, IndyCar has survived (and actually done well) with just two manufacturers, while F3 could also do with some more manufacturer involvement in its engine supply chain. Formula 1 is now at a point where it needs to make a decision and it could drip down. Any dramatic change in the regulations, such as we are looking at now, will require heavy investment and the abandonment of the technology in which they have heavily invested in already. However, this is an opportunity to make a change for the better.

Would there be such an impact on the hybrid systems that have been developed? In theory the hybrid systems that are now pretty much compulsory in top level racing in Europe could be carried over and introduced to the new engine. Plans to increase the power from the hybrid system would also fit with a reduction in power from the ICE, and reduce the fuel consumption allowing manufacturers to maintain their 'green' racing credentials.

So, could this concept really be resurrected? Certainly the idea will be shot down in flames during the discussion period, but if it were to be introduced into touring car racing, rallying, single seater and endurance racing, it could provide a firm foundation for the next decade of racing.

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