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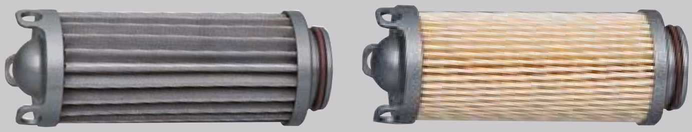

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One of Sebastian Vettel's tyres failed at the end of the Belgium Grand Prix after he stayed out on a single set for 29 laps. Pirelli responded to criticism by saying: 'In November 2013, Pirelli requested that there should be rules to govern the maximum number of laps that can be driven on the same set of tyres ... this request was not accepted'

Skirting the issue

F1's ground effect era was not without its problems, as our columnist remembers

Ground effects was the Pandora's box of motor racing, for the exploitation of depression under a racing car changed the paradigm of design forever. Despite all the King's horses and all the King's men, and all the regulations that the FIA and other sundry racing organisations have thrown at it, it embodies the cliche: once things have been seen, they cannot be unseen.

The Lotus 78 was the first ground effect car that really worked, and it was sealing the leak from the gap between bodywork and ground that was the *bingo* idea. The skirts used for this actually started as some brushes closing the gap between the sidepod and ground, massively increasing the depression caused by a nice application of Daniel Bernoulli's principle. Fluid dynamics states that for an inviscid flow an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in its potential energy.

Bernoulli's principle

It can be derived from the principle of conservation of energy. This states that, in a steady flow, the sum of all forms of energy in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy, potential energy and internal energy remains constant.

Thus an increase in the speed of the fluid – implying an increase in both its dynamic pressure and kinetic energy – occurs with a simultaneous decrease in (the sum of) its static pressure, potential energy and internal energy. If the fluid is flowing out of a reservoir, the sum of all forms of energy is the same on all streamlines because in a reservoir the energy per unit volume is the same everywhere.

Bernoulli's principle can also be derived directly from Newton's Second law. If a small volume of fluid is flowing horizontally from a region of high pressure to a region of low pressure, then there is more pressure behind than in front. This gives a net force on the volume, accelerating it along the streamline.

The first iterations of ground effects had to climb the steep mountain of getting the CP (centre of pressure) in the right place and making sidepods strong enough to take the loads. It was all a rather hit-or-miss affair, with a whole new paradigm being hammered out race by race as the new ideas were explored. One example of the conundrums we were facing was the inversion of known facts. Putting more rear wing on to counter high speed oversteer could actually increase the oversteer, as the underwing suction from the rear wing would increase the depression at the trailing edge of the underwing and, if your CP was slightly forward, would shift the aero balance even further forward. The eventual solution of suppressing front wings was one of the fixes if your CP was too far forwards, while drilling hole-saw cuts in the skirts to shift said CP backwards was another way.

The introduction of polypropylene skirts rubbing away at the ground evolved into different density sheets, flexi at the hinge-points, then stiffer near the ground. The next steps were more complex, and the introduction of sliding skirts morphed into quite complex spring-loaded slabs of honeycomb composites with ceramic skids to make them last longer than the easily worn poly skirts, plus the introduction of side rollers to keep stiction from jamming them in a leaky position, because the loads on skirts were rapidly increasing as the cars improved.

Many drivers did not like the cornering on rails behaviour this downforce gave, plus the fact that, counter-intuitively, the faster you went the car felt less on the edge, it being planted by the higher downforce provided by increased speed. It was also not too comforting to know that when that downforce was not there your intention of keeping it between the white lines was a forlorn hope.

Putting more rear wing on to counter high speed oversteer could actually increase oversteer

XPB

Formula 1 embraced ground effect after the Lotus 79 dominated in 1978. It was then banned in 1983

It got to the point that some cars had rods mounted on the front end of the skirts, protruding though the bodywork to give drivers fair warning that his skirt was up, thus avoiding the embarrassment of coming off the road due to lack of grip. Yet ground effect also made the cars look easy to drive. So much for showmanship.

Another side effect of the downforce was the dreaded porpoising. This describes the effect of vehicle dynamics, turbulent flow, near-sonic speeds at the venturi throat, all coupled with boundary layer detachment and suspension and tyre frequencies.

The sequence would go something like this: increased speed would compress the suspension and tyres, closing the venturi and accelerating the air passing underneath, which would increase the downforce, further closing the gap. Eventually the amount of downforce would be drastically reduced due to choking of the throat, it going sonic or detaching from the undersurface. This in turn would make the car rebound on tyres and springs, opening up the gap, and re-establishing the flow and thus the downforce.

Where your CP was would give either porpoising, with the entire car moving up and down, or the even more disconcerting, galloping, where it not only moved in the heave mode, but also in the pitch mode.

In its worst manifestations this would give drivers a rough ride as they bounced from bump-stop to droop-stop. As Keke Rosberg once complained to me when describing it: 'It's difficult aiming at the apex when the helmet is shuttling up and down and one only gets a stroboscopic view of the track.' The initial early attempts to control this by springing or damping did not get very far as the main culprit was the tyre, bouncing at its 4.5Hz characteristic frequency. The only way to get away from it was to work away on the venturi and associated aero gubbins to avoid the downforce loss, even to the extent of reducing total downforce, as a more controlled downforce was preferred to the 'ride 'em cowboy' mode.

Ground rules

The increase of cornering speeds brought on by all this pushed the powers-that-be to ban it all, bringing in the flat bottom that plagues all forms of racing now. The subsequent unintended consequences from the lift caused by big, flat slabs of surface area when in a wrong incidence is with us to this day. But ground effect know-how in the racing world has far outstripped anything the aviation industry has produced in that area. The complexity of modelling tyres for scale wind tunnels and the evolution of CFD for simulation derived from that need.

So why not commemorate Bernoulli's achievement by bringing back ground effects? It could rid F1 cars of their baroque wing arrays, they would be less affected by the leading car's wake, and provide more crush structure on the sides with bigger sidepods. Sounds good to me …


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Kerbing excess

Is it right that drivers can benefit from running wide on to run-off areas?

Scenario1. It's qualifying and I'm in sixth gear, pulling up to max revs. Ahead is a tricky uphill right-hander, blind apex over the top, off-camber afterwards and then falling away. *If I can come off the brakes a fraction earlier and get harder on the throttle a fraction sooner I know I can save a tenth of a second, or more, even though I've been very near the limit already, maybe on it. I've already worked out that if I'm carrying too much speed I'll run out of grip and go wide on the exit and spoil the lap, probably the following one also because I'll go over the half-acre of run-off and dirty the tyres, maybe damage the floor a bit and lose aero. But it's worth the risk, the penalty is not so great and it can put me up a whole row on the grid if I nail it just right. Here goes …*

Scenario 2. It's qualifying and I'm in sixth gear, pulling up to max revs. Ahead is a tricky uphill right-hander, blind apex over the top, off-camber afterwards and then falling away. *If I can come off the brakes a fraction earlier and get harder on the throttle a fraction sooner I know I can save a tenth of a second, or more, even though I've been very near the limit already, maybe on it. I've already worked out that if I'm carrying too much speed I'll run out of grip and go wide on the exit. If I do, the narrow run-off won't be enough and I'm going to hit the barrier – hard, maybe painfully. My car will be trashed expensively and it'll be a major struggle for the boys to repair it in time for the race. It's not worth the risk, even if it can put me up a whole row on the grid if I nail it just right. Best to try to find time elsewhere as qualifying still has five minutes to go. I'll come off the brakes where I have before, won't get on the gas any harder or sooner …*

Wide boys

Vive la difference! In this case the challenge between an artificially bland corner and an old-school one. Also, in the second scenario, between a driver without the confidence and willingness to take a big risk, and one who is. Sorting the men from the boys.

But there is another matter to be considered. In F1 recently there has been a move to tighten up on cars running wide. At Silverstone it was made clear that such a transgression at Copse corner, for instance, would result in that qualifying lap time being excluded, also that a penalty would be applied during the race. However, in Hungary it was deemed that, unlike at Copse, there was no advantage to be gained in exceeding the track limits at Turn 12, so it was open house for any driver who felt the need. Surely the real point was being missed? While there might have been no benefit to using the expansive Turn 12 run-off in itself, it meant that the entry to the corner could be taken faster, with a resulting potential reduction in lap time, without the risk of penalty if it proved to be an over-optimistic move. So it was an advantage, and the number of drivers that were using it rather proves the argument.

XPB

Running wide can gain a useful advantage for a driver yet in many cases very little is done about it

Jonathan Palmer's cracking down on those exceeding track limits at his MSV tracks has come in for criticism from disgruntled competitors. I recall one such saying how can it be possible to avoid using the grass when in a close-fought battle? Someone should whisper in his ear 'it's called skill.' No different at all from the restraint and concentration that a driver has to exercise on an Armco-lined street circuit, or on racetracks where no room exists for acres of run-off. Try going outside the limits on a concrete-lined oval, even with cars three-abreast fighting for position.

Of course, if one is pushed off by another, or makes a genuine mistake and momentarily goes wide, the circumstances must be taken into account and the stewards have to make a judgement call. However, the rule must be applied 100 per cent if any advantage has been gained. Unfortunately this emphasis on staying at all times on the racetrack has not so far been followed universally by circuits outside the UK. It should be.

Don't get me wrong; aggressive use of the kerbs themselves should be permissible and can add to the spectacle. Who can fail to draw a quick breath watching cars kerb-hopping at high speed through the Swimming Pool chicane at Monaco, or Touring Cars two-wheeling nose-to-tail while barnstorming their way around? However, the rule should be two wheels on the kerb at the most, but never beyond that.

Unfair advantage

Apart from constant damage to the circuits requiring expenditure that could otherwise be invested in better facilities, excess use of kerbs and the surface beyond them can cause punctures, plus damage to the racecars which consequently benefits those whose budgets can withstand this. Therefore it hands an unfair advantage to the competitor with more money; the poorer competitor is not competing on the so-called level playing-field regarded as being a basic right of anyone participating in any sport.

Drivers are frequently calling for consistency of applying penalties, so do the viewers and spectators who can get confused and consequently frustrated by such flip-flopping circuit-to-circuit. So let's give them what they want – mandate that all corners on every circuit be subject to penalties if a driver cuts corners and goes too wide, too often.

Let the discipline and concentration necessary in the make-up of a successful driver, together with skill and talent, dictate results, not willingness to deliberately ignore the confines of the track.

Aggressive use of the kerbs should be permissible, and can add to the spectacle

Born in the USA

Bringing a new team into Formula 1 is the toughest job in the sport, but Haas F1 believes its unique approach can help it succeed where others have failed

By SAM COLLINS

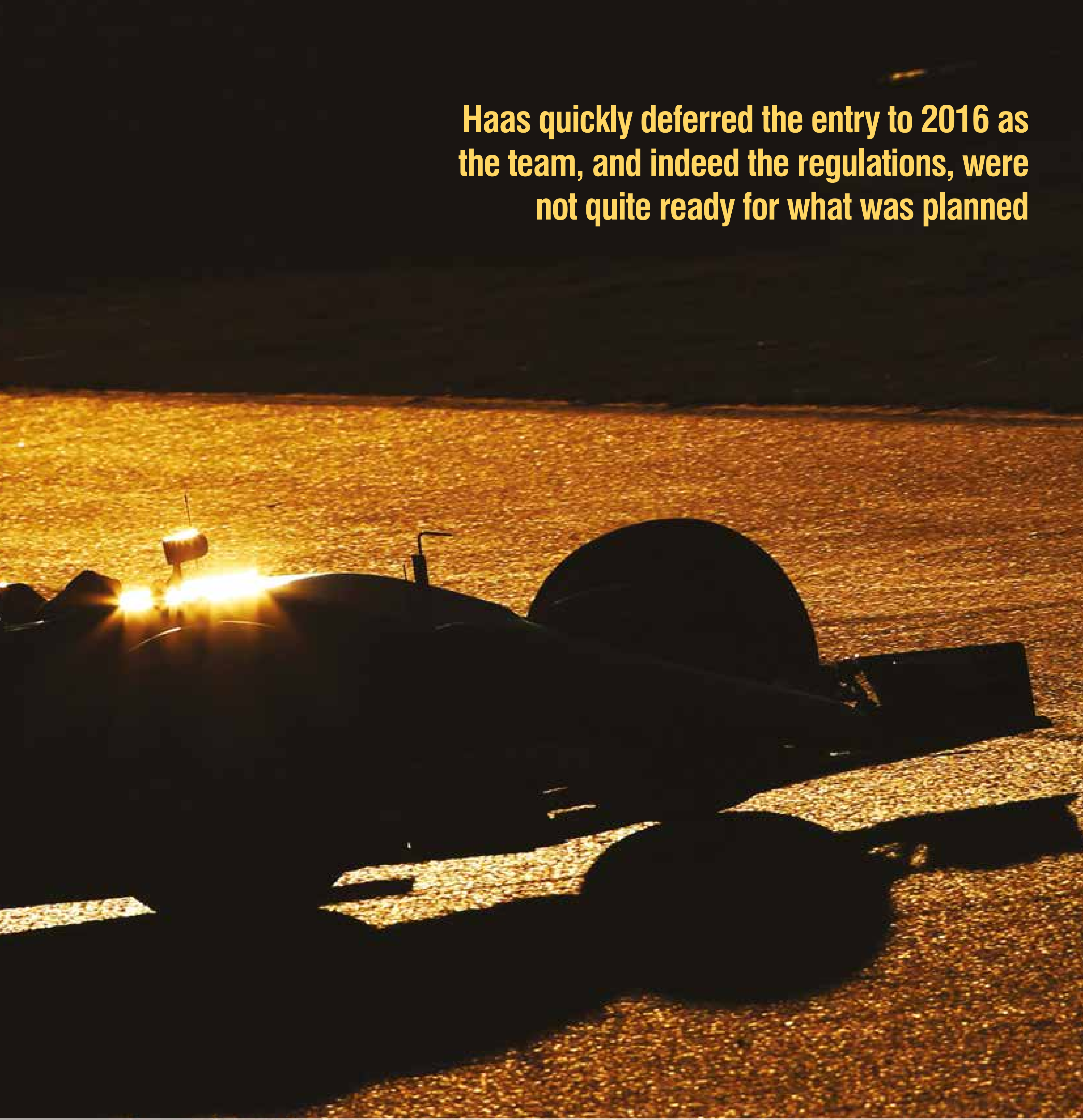
Gene Haas has always done things a little differently, rarely following a path just because it is the one most trodden. He built up his eponymous machine tool business exactly this way, looking at his competition and working out what not to do, and as a result he created a range of lower cost, easy to use designs.

Now Haas has decided to bring this ethos to grand prix racing, gaining an entry into the Formula 1 World Championship with an all-new American-based team. It is, of course, not the Californian's first foray into motor racing. His NASCAR team (co-owned with Tony Stewart) has won the Sprint Cup twice and is one of only four teams to have won all of the three major NASCAR championships.

In 2010 discussions started between Haas, Joe Custer (then the VP of Stewart Haas), and Gunther Steiner, the Italian former Red Bull Racing technical director who in recent years has run a composites business in North Carolina. The strategy they came up with was that Haas would launch his own Formula 1 team, but not in the same way as the likes of Caterham, Marussia and HRT.

'When we first started discussing this project four or five years ago I told Gene that you cannot do everything from scratch,' Steiner reveals. 'At the time the new teams were racing and all struggling and I told Gene "they will never catch up". F1 is such a high technological level it was always going to be impossible for them. Just to get where the others are will cost you billions and takes five to ten years, not one or two. An OEM maybe could do it but if an OEM came in they would buy a team and not start from scratc. Perhaps Porsche is the exception with its WEC programme, but even they would struggle as it's such a big step from LMP1 to F1. I don't think Audi could do it because it's not all in house, they use a lot of contractors.'

By 2014 the trio soon felt that they had a workable business model and lodged an official application for entry into the 2015 World



Haas quickly deferred the entry to 2016 as the team, and indeed the regulations, were not quite ready for what was planned

Championship season. This was accepted but Haas quickly deferred the entry to 2016 as the team, and indeed the regulations, were not quite ready for what was planned. Steiner by this point had been appointed team principal and Custer its COO.

Regulation changes

But it was some quiet changes to the F1 regulations that really got the ball rolling. 'We are not starting from nothing, our mechanical parts will come from Ferrari, our approach is completely different to everyone else,' Steiner says. This is because F1 teams *had* had to be full constructors and this meant that they had to use a bespoke chassis, front impact structure, suspension, suspension geometry, radiators, bodywork, steering system, brakes, floor and fuel tank. But a very quiet change to the F1 Sporting Regulations at the start of the 2014 season changed what it meant to be a F1 constructor. The 2014 definition allowed teams to buy everything but the chassis, front impact structure, suspension, suspension geometry, brake ducts and bodywork. In 2015 the rule changed again to remove the requirement for teams to design their own suspension, suspension geometry and brake ducts.

Haas is so far the only team which plans to fully exploit these stealthy rule changes via a partnership with Ferrari, which will see the Italian company supply the newcomers with not only power unit and gearbox, but much more.

'We have the front suspension, rear suspension, hydraulics, steering, electronics all from Ferrari. Radiators we have to do as that is classified as bodywork apparently,' Steiner says. 'We are using these things to focus on the overall car design, why make an effort to do our own damper or something when we can just get them from Ferrari? They are second in the championship and have won races, so we know that they are fine. We will have everything the same as Ferrari in 2016.'

Haas has succeeded in business by doing things his own way – now he's hoping that approach will pay dividends in Formula 1

The Haas factory is in the very heart of NASCAR country in North Carolina, next door to the Stewart-Haas team. It's located very close to the Charlotte Motor Speedway and the Haas-owned Windshear wind tunnel

Gene Haas has already tasted success on the race track with the crack NASCAR operation that he co-owns with Tony Stewart

As befits a Formula 1 race team owned by a successful businessman, the Kannapolis premises are plush. Haas will also have an in-season European race team base at the old Marussia factory at Banbury in the UK

All this means that the Haas team will focus its design efforts entirely on the bodywork and chassis, hugely streamlining the process of designing and constructing a modern grand prix car. Steiner continues: 'We are focussed on the wetted surfaces, cooling system and the chassis, and that is what we are completing the design of now. We were in the wind tunnel in December 2014 so we have done a lot already.'

The design and construction of the chassis became a joint project between the Haas engineers and the staff of Dallara, in Italy. 'Dallara was a good choice for us because we massively reduced the ramp up time, they were already 80 per cent there,' Steiner says. 'They have very good people there like Andrea Vecchi who are not only engineers but very good project managers.'

Italian connection

But to say the 2016 Haas is a Dallara would not be correct. This project is very definitely being run by the Haas engineers. 'We have blended our people with Dallara's because you cannot do everything from scratch,' Steiner says. 'It takes time to build things up. To do it from scratch you would have to put in IT infrastructure, HR, hire the right staff, but Dallara already has all of that. I have known Dallara for years and I know the strong points of the company as well as the weak points. Dallara's engineers have not been exposed to proper F1 for some time and they accept that. So we use their infrastructure, engineers and designers as well as putting our own highly experienced people in there, like Rob Taylor [who worked with Steiner at Red Bull in 2006]. Rob is the best lead designer you could ask for, he is calm, very intelligent and listens to everyone. He is sitting at Dallara directing the guys there and managing the car design.'

The aerodynamic design follows a similar philosophy, but the choice of wind tunnel was not a straightforward one for the new team. Haas already owns the vast 180mph full scale moving belt Windshear facility in Concord, North Carolina, once often utilised by F1 teams but deemed illegal some years ago to F1 teams. Now no team may conduct wind tunnel testing at more than 60 per cent scale. Steiner and his newly appointed chief aerodynamicist, Ben Agathangelou, had to find a suitable facility. One early idea was to adapt Windshear in order to accept 60 per cent models, but converting the huge working section designed primarily for stockcar racing to something that would meet the demands of F1 would be difficult.

'We knew you could adapt it,' says Steiner. 'You could put a sting in like a normal tunnel, but it would be very big, or change the scales under the belt, it was all doable, but would have to still be adaptable to NASCAR as that is the main business there. That switching was one of the concerns. It was possible but at what price, and what risk? We felt it was just easier to do a 60 per cent model and go somewhere designed for model testing. We are developing a racing car, not a wind tunnel, so we decided not to adapt Windshear for the time being. Maybe in a few years we will look at it again.'

Pristine race bays are awaiting the first 2016 Haas chassis, which will have a heavy Italian influence, with Dallara design input and plenty of parts supplied by the Ferrari F1 operation

Haas made fortune in CNC so it's no surprise there's a well-equipped machine shop. A big 5-axis machine specially designed for the team has been installed

While there is plenty of meeting space at the US headquarters Haas F1 has invested heavily in state of the art video conferencing kit so that it is able to keep in touch with its team in the UK

There are eight people currently working in the Kannapolis machine shop, mostly on parts for the F1 wind tunnel model. Stewart-Haas shop next door is also used

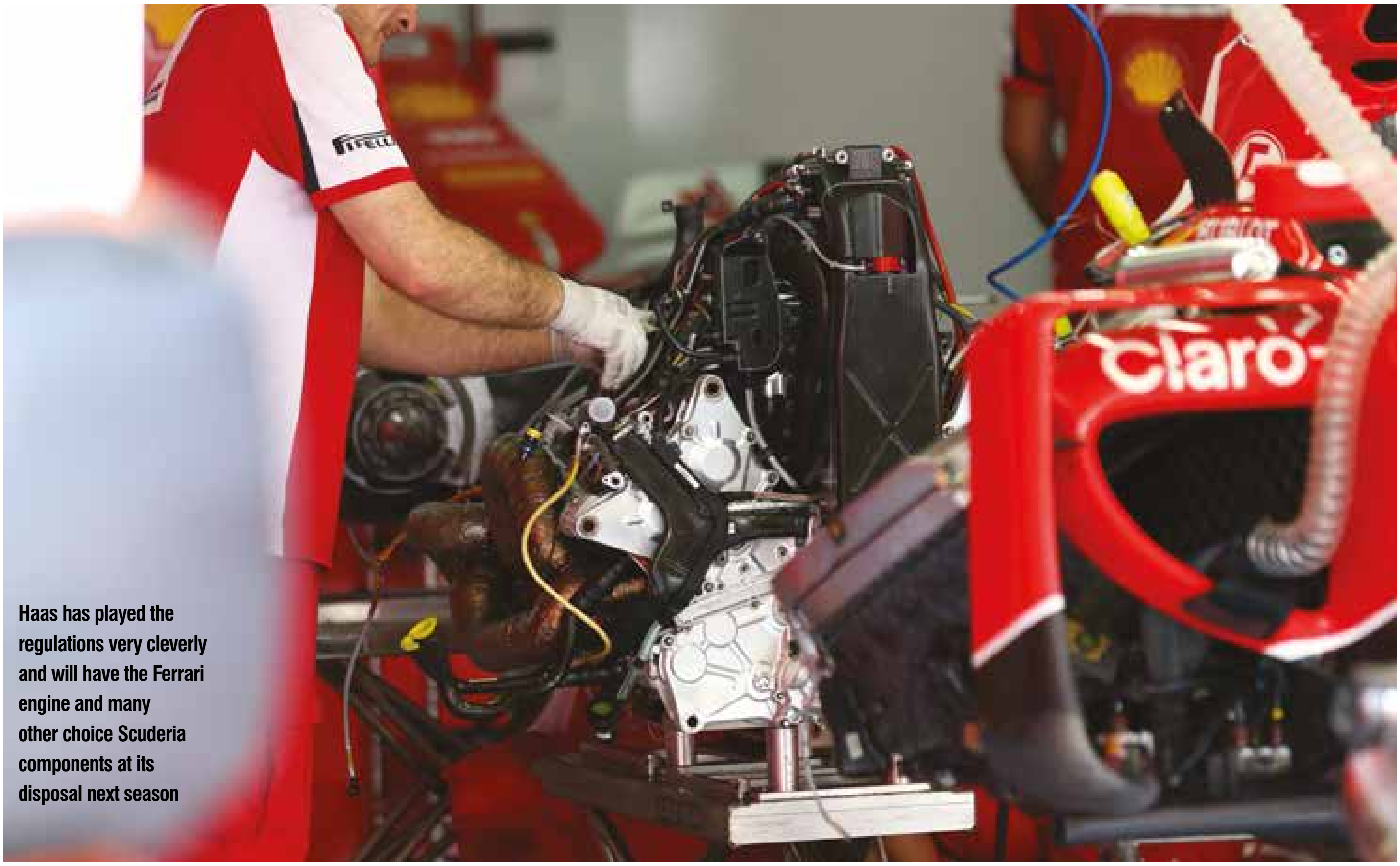
So the hunt was on for a suitable tunnel, and that meant looking beyond the USA. 'We could have rented Dallara's tunnel but it is only 50 per cent and we wanted to test at 60 per cent. Ferrari had capacity so we decided to use it. We plan to continue like this for the next two to three years.' One major factor in choosing to use the facility at Ferrari was that Agathangelou had recently overseen its modernisation. A few of the Italian based Haas staff are based at Ferrari but the main bulk are to be found at Dallara.

Home base

However, the entire team was not to be based in Italy. The organisation's main base would be in a large purpose built facility next door to the existing Stewart-Haas NASCAR team in Kannapolis, NC, and it is clear that the plan is for the entire design and manufacturing operation to move into the new factory. It has been deliberately designed with redundancy so that as the team expands its US staffing level and manufacturing capacity it already has the space waiting. This includes a space for a full composites facility including mountings for the autoclaves, and a clean room. However, for at least 2016 and probably 2017 the composites work will be done in Europe. 'We are prepared to do all the composites in-house, but it's difficult and you have to only take on what you can manage at first,' Steiner says. 'We already have the rooms set aside and laid out and we could put the machines in but you still need the people. It's very difficult to find good composites people in the USA. It took me years to build up my company, Fibreworks, and the last thing I want to do when setting up a new F1 team is set up another composites shop from scratch. Dallara are very good at things like wings and deflection because they have to do it on other projects all of the time. They own a composite manufacturer so they can produce what we need and they are very good at that. So we will have most of the composites done in Europe and focus on the bits we are good at like machining and fabrication.'

Gunther Steiner, pictured left in discussion with team owner Gene Haas, is the technical director at the Haas Formula 1 operation

Haas is so far the only team which plans to fully exploit these stealthy rule changes, via a partnership with Ferrari



Haas has played the regulations very cleverly and will have the Ferrari engine and many other choice Scuderia components at its disposal next season

Indeed, for Haas the machining and fabrication is an obvious point of focus. When *RE* visited the facility a large new 5-axis machine was being installed, a prototype specifically designed for the team. In another area a large machine shop kitted out with the latest Haas CNC equipment is already working on car parts and pit equipment. It is complemented by the equally well-equipped machine shop next door at Stewart-Haas.

'I think we have seven or eight people in the machine shop at the moment, and three more coming, and they are primarily working on parts for the wind tunnel model at the moment,' Steiner says. 'I think about 50 per cent of the parts on the model are made here, all the metal components, while all the SLA [3D printing] parts are done at Dallara. Next year we will make 100 per cent of the scale model parts here, but right now Dallara has eight SLA machines and we are waiting to install our first. We are making the pit equipment here and filling a shipping container with it all. We make all that kind of stuff here, USA is the home of fabrication.

'Making this stuff in the USA is much cheaper than in Europe. It takes about two days to ship the parts from here to Dallara so we know that if something you were doing in Europe would take four days, we would take five instead, as it takes two days rather than one to ship. But we know that and factor that into the production schedules.'

In the plush design offices on the first floor of the new factory much of the space is unoccupied, but will rapidly fill as the team grows. But one key group of engineers is already working long hours on the 2016 car 'We have about 10 people in the CFD group at the moment by next year that will be about 20, right now the main engineering work we are doing here in Kannapolis is the CFD. I think we have about four Phds in the CFD group at the moment,' Steiner says.

The group of CFD engineers are disarmingly young, many of them relatively recent graduates, but this is something Steiner sees as an advantage. 'We do have a lot of young guys in the team, but for CFD especially there are no old guys who know the cutting edge technology. These are scientists, really, and therefore it's a good thing to have the CFD here, they don't need the big F1 experience they just need to be clever people that know how to use computers and understand physics.'

Young talent

'We have bright people here from good universities,' Steiner adds. 'We think actually it's better to have them here so we keep them out of the mainstream of CFD in F1, and we are doing some very interesting and different things in that area. I expect we will reach the maximum allowed next season, we are doing some heavy stuff already. At the moment we can do what we like; the usage restrictions do not apply until next year so we are doing a lot of stuff.'

Here, the links with the NASCAR team start to become apparent. While the engineers do not work on both, an experienced engineer from Stewart Haas is playing a key role. 'That CFD group is run by Matt Borland, who was the technical director at the Stewart Haas NASCAR team for a long time,' Steiner explains. 'He is responsible for managing the knowledge transfer between the two. Technical approaches and methodologies, things like that.'

The CFD cluster used by Haas F1 is not located in the USA and this highlights how misfortune for some can be good fortune for others. The collapse of the Marussia team in late 2014 came just at the right time for Haas F1, which was not only looking for a cluster, but also a European base of operations for the racing team. The near-demise of the then Russian-branded operation gave Haas both of the things he was looking for. He acquired the former Marussia HQ in Banbury and some of the equipment within.

To say the 2016 Haas is a Dallara would not be correct. This project is very definitely being run by the Haas engineers

The show car is actually a 2013 Marussia bought at the auction at which Haas also acquired its UK team base

'The designers and the wind tunnel programme are in Italy and the race team will be in England,' Steiner says. 'We have the CFD engineers here in the USA but the cluster is at Banbury. Marussia had quite a good cluster, quite new as they had to replace it about nine months before the team collapsed. It was very difficult to take out the cluster and re-install it somewhere so we decided to leave it where it was. We have since put in MPLS lines between the sites we are using, and while it costs quite a bit, it means we have very fast data transfer. We have also invested in video conferencing between the facilities. It's much better to see people than just on the phone, especially when its new and you need to get to know the people.'

Beyond housing the cluster, the Banbury facility will be used primarily as a base for the racing team and it will not have any kind of manufacturing capabilities, although it will have some inspection areas and non-destructive testing equipment.

There is still a lot of growing for Haas to do, and for many it seems that little is happening, but this is perhaps because its operations are still rather spread out. 'There is a lot more happening here than people realise,' Steiner says. 'At first you don't get any credibility, but now people are realising this is serious. We have about 50 per cent of the mechanics employed already and we are interviewing more at the moment. If we had to race in two months' time we could do, though if we did have to do that we would not be as prepared as we should be.'

Yet while the team does not have to comply with the F1 testing ban until 1 January 2016, it has nothing to test on track. It will have to wait until Ferrari finishes the design of its 2016 car before it can finalise its own design. 'Right now the car is virtual, its design is not complete, but we have seven months before we have to run. The proof of all of this will be seen on March 1 in Barcelona. We may do a shakedown in Italy at Fiorano, or Vairano, first, but it depends on the production schedule,' Steiner says.

Some may believe that the new definition of a F1 constructor being used by Haas is the road to full customer cars, but Steiner argues that it is still a major piece of engineering, and it is an efficient way of going racing, in line with the philosophy of Haas himself. 'Our approach is different but could be copied and that could be good for F1,' Steiner says. 'We don't want to buy our way to success. We have a fair budget but we are trying to do things the most efficient way, not cheap, not low budget but efficient. Sometimes that means doing things outside of the box. Gene Haas has based his whole business on being efficient. It's not just throw money at it and if it does not work then we are bankrupt in three years as others have done before. It is about spending the money wisely.'

With Ferrari supplying much of the 2016 Haas car it perhaps could be expected that it might be rather more competitive than the cars of other new teams in recent years, and Steiner makes it clear just what the team's own performance expectations are. 'I don't want to make big claims because we will be judged on the race track not before. In the first year we are not out there to beat Ferrari or Mercedes, that's not our target. But it's important to say we do not want to be last. I'm not going racing just to be there, just to be in Formula 1, and nor is Gene. Our aim is not just to participate. For us, our aim is to get points, to be competitive. To win is difficult and will take time, but to get points, that is what we must do.'

The Haas F1 car is scheduled to make its track debut on 1 March 2016 at Barcelona and the team will stage a formal launch in Europe ahead of that. For the rest of the 2016 season those in the industry on both sides of the Atlantic will be looking on with interest. Ⓡ

'If we had to race in two months' time we could do, though if we did have to do that we would not be as prepared as we should be'

Fear of flying

IndyCar introduced new aero kits at the start of 2015 but since then there have been a number of high profile airborne accidents. *Racecar* investigates

By ANDREW COTTON

‘Once we had the first car flip over, it really got our attention, because we had not seen a car fly like that for a long time’

IndyCar has suffered from a spate of spectacular but worrying airborne accidents this year. This is Ryan Briscoe’s crash at Fontana; the cause was different to those at Indianapolis as one of his wheels rode up over the rear of another car, but the effect was that air flowed under the car, which then flipped it into a sickening series of somersaults

New aero kits introduced to give competing engine manufacturers Honda and Chevrolet greater identity at IndyCar circuits, have proven to be costly and controversial this season. Both manufacturers have invested a rumoured $25m in aero development, matching the estimated cost of engine development. There have also been some much-publicised flights for cars of both manufacturers at the Indianapolis 500 and at Fontana, and aero development for the remainder of the 2015 season, and into 2016, is concentrating on further increasing the speed at which the cars take-off, a study that may have a wider single-seat application.

The manufacturer-developed kits were limited to the amount of downforce generated compared to the standard Dallara aero kit, and car performance in 2015 has improved as expected – at Mid-Ohio in August Scott Dixon’s pole position lap broke a 15-year track record by seven tenths of a second. However, the cost of development also took IndyCar by surprise, and outgoing president of operations, Derrick Walker, says that the organisation should in hindsight have controlled that better. ‘The racing is better, we have more grip in some places and that has made it faster and more exciting,’ says Walker of the new aero kits. ‘We have areas of the car that we call volume boxes, an imaginary box in which you can design whatever you want. In hindsight we could have had more control there so that it didn’t become too expensive, with too many parts, but it is a balance between making it look sexy and technical without spending too much money. We exceeded our costs a bit too much and I wish we had controlled that more.’

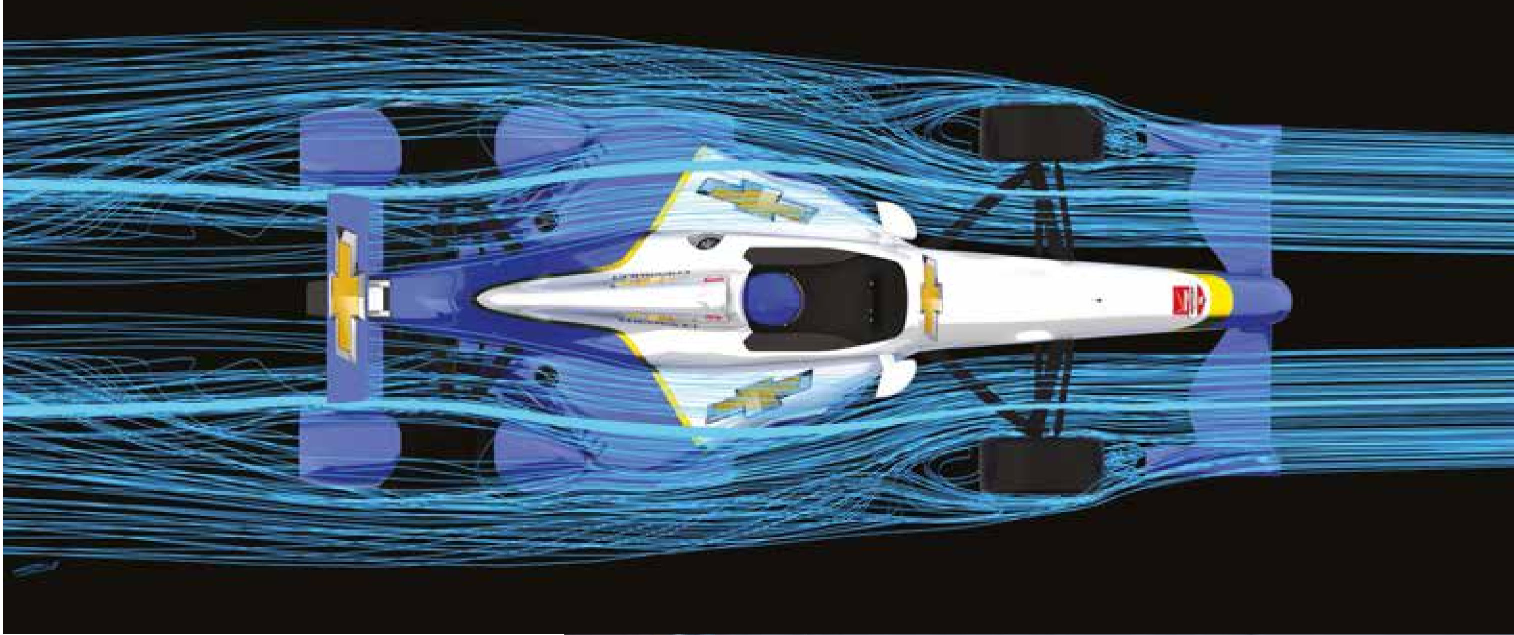
Walker won't be around to see in the changes for next year, having resigned his post mid-season (see p88), but there is controversy brewing for next season. Manufacturers are allowed to develop the aero in three volume boxes, but Honda believes that it has raced this season with a deficit to Chevrolet, and says it may need more than its rival in 2016.

Indy drama

Three separate accidents in the lead up to the Indianapolis 500 led to crisis meetings before the race, and an intense development programme was initiated between Honda, Chevrolet and IndyCar to find a way for them to race safely.

The compromise was to ban the teams from running in qualifying specification, aero and turbo boost, while the Chevrolet aero kits were changed; the centre-line 'wicker' from the nose to the cockpit was removed. It was rumoured that Walker had made the decision himself, a suggestion that the Scot hotly denies. In fact, IndyCar, Honda and Chevrolet worked their simulation packages hard in order to understand the accidents and try to eliminate them before the biggest race of the season.

'The exact process was, once we had the first car flip over it really got our attention, because we had not seen a car fly like that for a long time,' says Walker. 'Both manufacturers started doing some modelling to see at 135 [degrees] was a car starting to lift? We [IndyCar] didn't have the computing capability but they did, so every day and night they were running their super computers. They would come to us in the day, we would come together in one room, and we would review it. Honda and Chevrolet would talk openly about the results, and the lift that they did and didn't see, and then another



It's rumoured that Chevrolet and Honda have spent as much on their IndyCar aero kits as they have on their engine programmes

'In the end they were testing at 200mph, 3.5 degrees tail up, and going backwards!'

Honda (pictured) and Chevrolet have cooperated with IndyCar to find out what caused the Indianapolis accidents, simulating situations at ever greater speeds and degrees of lift, and making modifications

[crash] happened, and we started to see that we had to go to 180 degrees yaw. We never had a test that said you had to go 200mph backwards and not fly. Each day we were ramping up the criteria of what needed to be looked at. In the end they were testing at 200mph, 3.5 degrees tail up and going backwards!'

Although only Chevrolet cars were becoming airborne, the company says that it met the safety requirements set by the governing body. While Honda denied that it had an issue with its Super Speedway aero kit, IndyCar says that it had the potential to also fly given a similar set of circumstances. With no one able to agree, it boiled down to IndyCar to make a decision, and that was to slow the cars in qualifying.

'There were stability points that were part of the regulations, 135-degree backwards travelling, and we met them, and continue to meet them,' said Chris Berube, Chevrolet programme manager. 'There is more to be learned about cars going backwards at those speeds and this is nothing new. Open wheel cars have become airborne all through the different versions of them. The fact that we got three in a row got everyone's attention.

'We broke it down into what causes a car to spin, and they are all explainable. Cars will spin when things go wrong at those speeds. Then you take it to the next phase, which is how fast do they spin around? The major factor of the car becoming airborne is how fast they go. If you can reduce the speed of the car as it gets to that rearward facing position, your likelihood of a car flying will drop.'

Yaw moment

Berube continued: 'That is a phase of the incident that you can try to address. The centre-line wicker was taken off our car after we analysed it and determined that, because of our engine cover design, it caused more of a yaw moment. It adds downforce to the front of the car, unloads the rear, so you start to put your car in the position to spin faster. Honda has the large sail panel on the engine cover and they are more balanced with the wicker on the front of the chassis. There was nothing sinister about it.'

The move to effectively ban the qualifying kits and boost was controversial, and Honda in particular was unhappy with the solution chosen by the race organisers. 'At Indy, the changes that were done we didn't agree with necessarily,' says Honda's race team leader, Allen Miller. 'We [Honda] had one incidence of a car travelling backwards that didn't take off, although it was a different point of the track, corner exit rather than corner entry. It wasn't the same conditions so I cannot say that ours would have gone over in the same way, but we didn't have a problem. We felt that we were safe, we met all of the regulation requirements for stability in CFD, and we were very adamant with IndyCar that we should be allowed to run as the car is designed. Let us run what we felt was a good qualifying spec, and if Chevy had

The road course kits, also used on smaller ovals such as Iowa (pictured), have been criticised for looking over-complicated and have also suffered from their own problems with brittle components breaking when the cars tangled in early races

Chevrolet says that its original engine cover caused more of a yaw moment, adding front downforce, which in turn unloaded the tail and caused car to pivot into a faster spin, bringing the back around at very high speed

an issue, force change on them that would be able to take care of the problem that only appeared on their car. That was over-ruled. It was a requirement of everyone to qualify and race the same spec, but I think it hurt us more than Chevrolet.'

Walker felt that he had no other option. 'The only thing I could do that was constant for both cars was not to run higher boost and to run race downforce,' he says. 'The Honda guys went blue. They said "you have ruined our chances of getting on pole." Well, maybe, but I didn't see them anywhere in the race, so if they were screwed for qualifying with low downforce they should have knocked them dead in the race and they were as far off as in qualifying.

'To their credit, the manufacturers have continued to do more tests because we are trying to increase the take off speed even higher than it is now. We had a handle on where the standard Dallara was, and the conclusions were that a Honda had the potential to [fly], it didn't get all the way around and it wasn't going quick enough at the time. They could simulate it and see that the Honda would have done the same thing. What do you do in that scenario? I went for the easy solution, and people still would disagree, but I would do it again in a New York minute.'

One of the key elements to the design of the IndyCar in 2015 was a hole in the floor by the sidepods that was included with the purpose of reducing the chance of a car flying should the nose of the car become airborne. It worked, and also had the benefit of reducing downforce, but at Indianapolis the 'underwing' seemed to work in reverse, contributing to the lift.

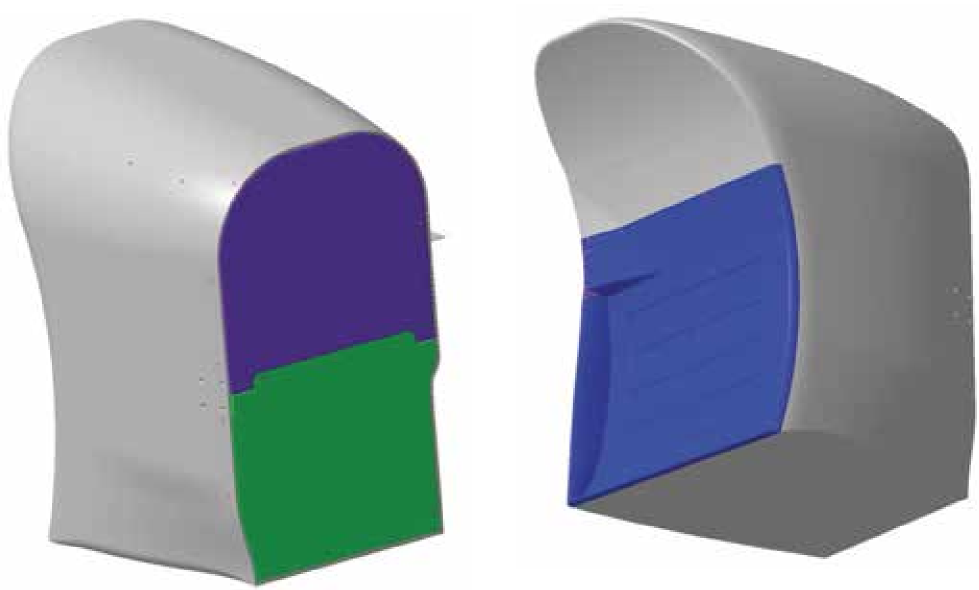
Did the hole in the floor contribute to the flips or not? Opinion is still divided. 'The hole in the floor was introduced for the nose-up situation where people run over someone else's wheel, or debris and it is well documented that we have had some back flips,' says Tino Belli, director, aerodynamic development at IndyCar. 'An unintended consequence was that, at 180 degrees and going backwards, the underwing works well as a wing and so it gives quite a lot of downforce at the lowest part, which is forward of the centre of gravity. It tends to pin the front of the car a bit too much when it is going backwards, and that surprised us.'

Berube adds: 'It was a safety initiative that made sense. We are confident that it did what it was intended to do, but the unintended consequence was that, when the rear of the car is in the air, the restorative moment, depending on where the centre of gravity of the car is, the floor surface area forward of that point will help to restore the car and we took away some of that floor, so it didn't help a backwards flying car.'

Seeking answers

With downforce producing a step change in performance, the series is in uncharted territory when it comes to its new aerodynamics package. Controlling cars in difficulty on the super speedways has proven to be more difficult than anyone expected. 'In all three cases [at Indianapolis], the left front suspension had broken when it hit the wall, so the extra stability that you get as the car climbed the wall, that extra stability from the leg was gone,' said Belli. 'The car was like a three-wheeler tipping about its left rear/right front axis and that didn't help at all. We have no way to investigate that. It is possible to investigate anything, but there are man-hours and resources, and it is a difficult situation. We have also looked at the effect of the wall before impact, because it gets a lot

High-speed running at Texas Motor Speedway: IndyCar has worked hard since the high-profile Indianapolis crashes to increase the speed at which a car takes off once it's pitched into a spin



Rear blanking panels were introduced for Super Speedway use only in time for the Texas race and were immediately effective, raising the take off speed of the cars by an estimated 20mph. Both Honda and Chevrolet welcomed the panels

> 'The target is to push the speeds as far as we can. Everything that we can do to make the tip-over speed as high as possible, we will do it'

more complicated once it has impacted the wall. The proximity of the wall funnels air under the back of the car and tries to make the rear of the car lift. That was a major aerodynamic problem for us this year and we have put a lot of work into it. It will be on-going work until we are as close to the 500 as we can take it. More complicated solutions have to be created earlier. All credit to Honda and Chevrolet, they are giving us tremendous resources to work on that.'

The target is to raise the take off speed far beyond the speed of the cars, to take into account any other contributing factors, such as a broken suspension, or a rear tyre rising up as it impacts a wall. For the Texas race, rear blanking panels were introduced for use on the Super Speedways only and immediately proved not only effective, but were readily accepted by both Honda and Chevrolet.

'It is not enough to say that the car can do 230mph and so 230mph is enough, because most of the cases we look at the car is flat on the ground,' says Belli. 'You get a situation where a wheel gets on top of another car, or you hit the wall, or you lose your front suspension and create an angle greater than zero degrees, and you are not sure how that angle contributes to starting the process.

'The target is to push the speeds as far as we can. Everything that we can do to make the tip over speed as high as possible, we will do it. If we can get it to 300mph we will do it. I have seen in some cases, we have got the speed to 500mph, but that is in one phase of the spin. We investigate at 180 degrees and flat, and 3.5 degrees tail up which is a complete car, pivoting around the front contact patch, and that's the angle at which the nose touches the ground. It is quite innovative, and it is new work. The FIA looked at this. We were investigating it not as a generic car, but in terms of both aero kits; the same things seem to work in both instances.'

One thing that did help was the introduction of 'blanking panels', adjusting airflow ahead of and behind the rear wheels. 'The blanking panels were a really big contributor, more than 20mph,' says Miller, referring to the minimum take-off speed of the cars. 'It was the right thing to do. We were happy to make it a permanent change, and apply it to all the events, but it was super speedways only and it was a scramble to make all the pieces in time.'

Missing performance

With Juan Pablo Montoya (Chevrolet) and Graham Rahal (Honda) battling for the title this year, it would appear that the kits are balanced,

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With downforce producing a step change in performance, the series is in uncharted territory when it comes to its new aerodynamics package

but Honda says that it is missing performance and might need to make extra changes for 2016. Manufacturers are allowed to select 'volume boxes', areas of the car in which design is free, to develop next year. IndyCar has taken measures to avoid the complicated winglets that both manufacturers homologated on the front wings, which proved to be too fragile, and Honda's rear, which was complicated and heavy. The front wing change, however, is the one that Honda believes has had the most impact, and it thinks that it might need more than the three mandated volume boxes to become competitive against Chevrolet.

Honda road kit minus the front wing endplates. Honda believes it has been at a disadvantage this year and is looking to make improvements in more than the three stipulated modification boxes, and is especially keen to develop the front wing

Rules Bulletin 2015-22

The following Rules have been added or modified. All other Rules remain the same.

14.8.5. Race Location Specific Configurations

Manufacturer Aero Kit Race Location Specific Configurations	Indianapolis 500	Texas	Pocono	Fontana	Milwaukee	Iowa*	Road & Street
Rear Mainplane IR1205B001	0° -> -10.5°	-6° -> -10.5°	0° -> -10.5°	0° -> -10.5°	M	M	M
Aero Kit Indy 500 Rear Mainplane	O	U	U	U	-	-	-
Rear Wing Wicker	O	U	O	U	O	O	O
Side Wall IR1203A007/08	O	U	O	O	U	U	U
Trimmed Side Wall IR1203A007/08	O	U	O	O	U	U	U
Underwing Strake IR1203A003/04	U	U	U	U	U	U	U
SWY Front Brake Backing Plate IR1210E001/02	O	O	O	O	M	M	U
Rear Wheel Backing Plate IR1210H001->011	O	O	O	O	U	U	U
Homologated Optional Components	O	O	O	O	O	O	O
Underwing Knob protector IR1203A039/40	O	O	O	O	O	O	O
Homologated rear wheel guard front and rear blocker panels	M	M	M	M	U	U	U

*Subject to additional restrictions
M= Mandatory
O= Optional
U= Unapproved

The rules bulletin issued at the Texas Motor Speedway round after IndyCar's initial investigation into aero kits

'We are looking at the whole car right now,' confirms Miller. 'The rule is that there are three boxes of around eight or nine that you can work in. We are looking at the whole car to decide which of those to apply, and then decide if we want to try to push further, or ask to push further. First we have to revisit the whole car, knowing where the two cars are. We have a good idea of what we need to hit, can we do it with three or not?'

It is not an easy task. IndyCar's technical team has no way of testing the various options within each aero kit, and so cannot say definitively why the Hondas are slower than the Chevrolets. 'We don't have instrumentation that we can look at,' says Belli. 'In the engine we have a torque sensor, which is an IndyCar owned torque sensor and Indycar only gets the data from that. We can compare engines reasonably well. Aerodynamically, we can download the team's data, but that is from their own load cells calibrated by the teams, which we can't verify the calibrations of. Comparing downforce for us is quite difficult. Right now we can honestly say that Honda has a deficit, but we can't say categorically whether or not that is an aerodynamic deficit, a team deficit, or a driver deficit, or a combination of all three which is a distinct possibility, and the engine could be in there too.'

The greater good

For Walker, the changes come down to money and resource. 'The manufacturer has to come to us and say that we need to change this, and we need to ask why?' he says. 'They have to prove their case and they have to provide the data.

'We then say that we will measure that component. The manufacturer pays for an independent wind tunnel, we measure the standard car, they put on their pieces and we see how much of an advantage that it is. We can also in that same wind tunnel put the Chevrolet model and measure the two. There is a process and we can do that, but when someone applies to do that they have to pay. At the beginning of the aero kit, we needed to have that process, to fund that, and have the data early on. We needed to develop that ourselves but we never had the capability so we were ill-prepared for the start of the aero kit, and we knew it,' Walker concludes.

The introduction of new aero kits proved to be far more complicated than anyone had predicted. They were so effective that they had to be scaled back, and at Indianapolis may have contributed to some spectacular accidents. IndyCar has opened a Pandora's Box, but its solutions could benefit future open-wheel racing around the world.


ARROW

Split time

As the 2015 World Rally Championship goes into its final stages *Racecar* examines the technical developments made by the top WRC teams this season

By MARTIN SHARP

There seems to have been little change in the WRC this year at first glance. Volkswagen has won eight of the nine rounds completed (of 12) at the time of writing with Citroen picking up the remaining win (Rally Argentina). So, on the surface it all seems much the same as last year, then – only substitute Hyundai's somewhat fortunate 2014 Rally Deutschland Win in place of Citroen's.

Yet while things might seem very familiar when it comes to who is spraying the champagne at the end of the rally (usually Sebastien Ogier), under the bonnets – and indeed throughout the cars – development has been constant. So we stopped the clock as the championship passed its half way stage to take a look at the state of the technical race this season, both in terms of in-season development and future trends.

Volkswagen Polo R WRC

Volkswagen Motorsport arrived at the 2015 Monte Carlo Rally with a new homologation of its car. The team took advantage of the rule change last year from minimum individual weights of engine components such as cylinder block, head and so on to a minimum dressed engine weight limitation. Under the 2013 rules the team wasn't able to get an engine assembly to the overall minimum weight because of the weight of other engine components.

VW Motorsport did not have a homologation available when the rule changed to a dressed engine weight minimum for 2014 and so introduced a new, lighter, engine for the 2015 Polo R WRC. This has a new cast and machined cylinder block and head, and VW Motorsport engineer Francois-Xavier 'FX' Demaison explained the modifications were: 'Not big changes; details. We are now down to the minimum weight we could have for the head and block. In some way before we had to artificially ballast [engine parts] but now we are to the minimum weight.'

The Polo engine has featured finger follower valve actuation from the outset. Perhaps a more complex solution than 'conventional' bucket tappets and therefore carrying more potential reliability issues, the system does have potential advantages and is well-developed these days. Demaison is a chassis engineer and fully admits he's not an expert engine specialist, but he knows his rally car: 'Finger followers are a well-known design now. I remember when I started to work in motorsport in the previous millennium and we tried to make it [finger followers work] for the Renault touring car engine and we were struggling with small design problems. We went from the normal tappet to cam follower and in a normally aspirated engine it's a bigger advantage than in a turbocharged engine.' Demaison also thinks the FIA's 8500rpm engine speed limit reduces the potentiality of reliability difficulties ensuing from the use of finger follower valve actuation: 'Potential reliability issues, yes; but we don't have high revs in our engine,' he says.

Following its failed Bosch fuel injector during the Rally Argentina this year the team took a joker to move to revised specification Bosch injectors. Demaison posits that the original failure could have been due to a batch problem and points out that the team also has Magneti-Marelli injectors available.

Detail improvements to the rest of the new car homologation also feature: 'It's a bit everywhere but nothing major. New drive train; new gearbox, new rear diff, new rear disconnect; just improvements – it's nothing major. We save a bit of weight everywhere to give a wider range of adjustment,' explains Demaison.

The first gearbox used in the Polo WRC was a standard Xtrac unit but with the need to integrate paddle shifts for this year the team took the opportunity to request specific detail changes from Xtrac, so the 2015 gearbox is a bespoke assembly.

'It's difficult to change a winning car; you don't know which way to go'

Like its rivals the VW team has integrated the rear drive disengage-controlling hydraulics into the operation of the paddle gear shift mechanism, which has a slightly revised design to increase its reaction speed. The rules stipulate that maximum hydraulic pressure in the system is 120bar, which is why all WRC1 teams employ an electric motor (front-mounted to serve the paddle shift and low down in the engine bay) to maintain pressure when it falls below the optimum figure in the hydraulic accumulator.

The Polo WRC's differentials have featured negative preload from the car's inception. Demaison speaks from experience: 'It goes against the positive preload [set in the differential] so that's why we call it negative but it's not really the right description. It works; but it's a dangerous tool; if you don't set it correctly it can be a big problem … because you just delay the effect of the [differential] ramps. It's a Belleville spring acting against the ramps. The Bellevilles are linear.'

The WRC rules allow current differentials to have their positive preload adjusted from outside the diff casing. While M-Sport, uniquely in WRC rallying, now uses nitrogen gas pressure to achieve this in the latest Fiesta RS WRC diffs, the convention used by all other WRC teams is to wind preload on or off via the Belleville

Lighter weight, with a flatter and wider torque and improved bhp at higher rpm, M-Sport's innovative power unit has immense potential

spring using spanner-activated clicks to a screw pressure-loader. Demaison explains that, during testing, the team will have a series of optional diff ramps available: 'But, especially with the negative preload, in some way it's sometimes like changing a ramp so you can fine-tune the ramp. With a sealed diff you can adjust your torque transfer a bit by winding up the spring one way or the other.'

The suspension geometry and specification of the Sachs dampers remain similar to last year with no big changes, although Demaison plans small internal changes and slightly lighter damper units for the rough rallies during the later stages of this season.

The latest car's rear wing is modified, using computational fluid dynamics [CFD] techniques and a wind tunnel, to improve aerodynamic efficiency. The result is less drag and more downforce but Demaison points out: 'Sometimes it's not easy; if you remove a bit of downforce the driver is crying; "Oh the car is difficult to drive, too edgy".'

So, the latest Polo R WRC is a new homologation with detail changes, which Demaison summarises thus: 'Just optimisation of most parts. Saving weight here and there, having heavier protection underneath the car. We have no ballast; we only have heavy protection because ballast is not allowed – just protection is allowed. It's good that the protection is very low in the car because it's just to protect against impact. The thing is it's difficult to change a winning car; you don't know which way to go.'

M-Sport Ford Fiesta RS WRC

M-Sport introduced a new homologation of the Ford Fiesta RS WRC at the 2015 Rally Portugal; the most significant change from the previous car being an in-house designed all-new engine.

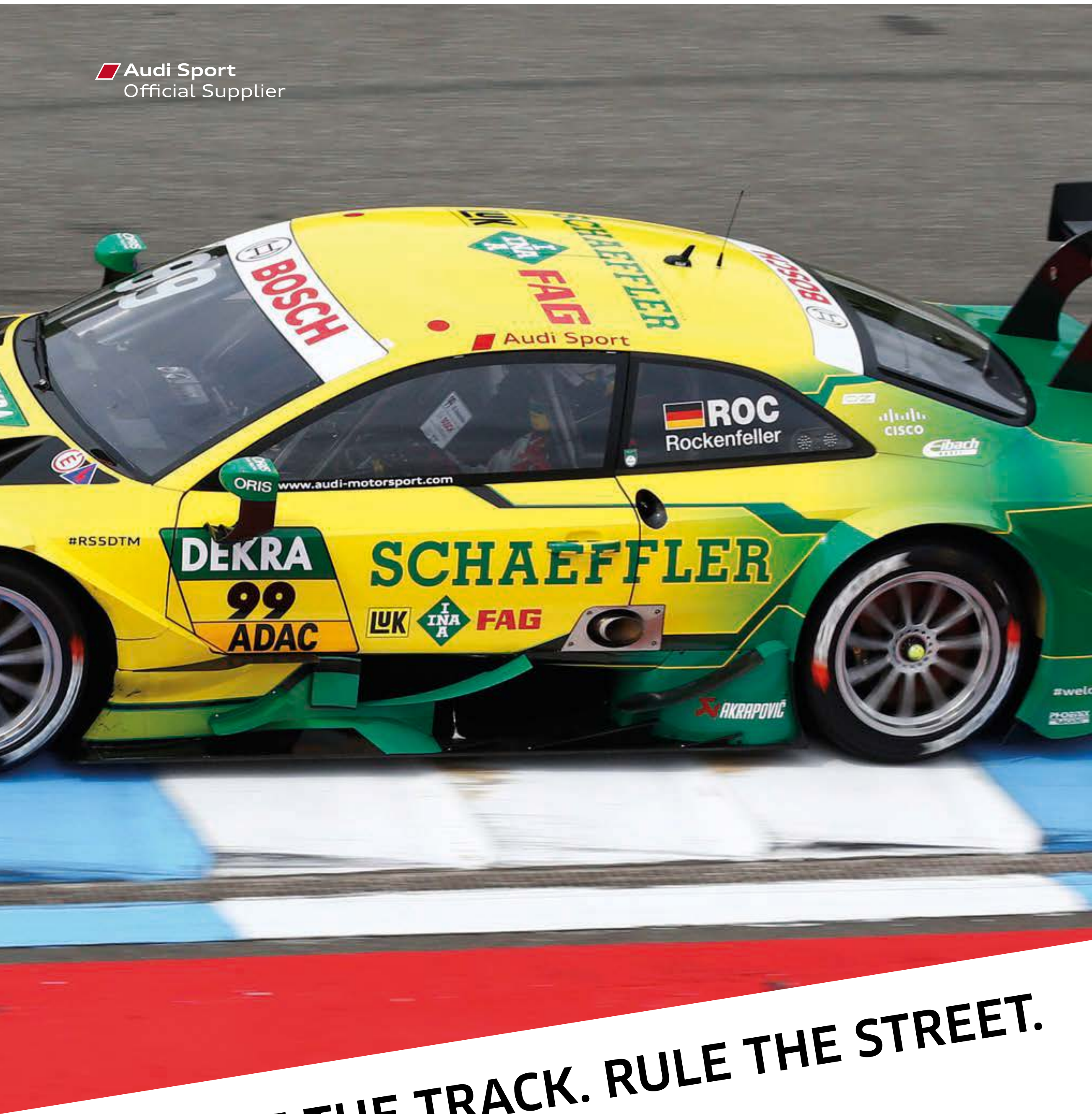
An interesting aspect of this power unit is that its cylinder block is not cast and machined as per convention, but machined directly from a solid billet of aluminium alloy. It is not the first time the British company has used such technology. In 2012/13, when M-Sport's works rally effort was funded by Ford, a similar engine with a machined-from-billet aluminium alloy cylinder block was developed for the Fiesta RS WRC.

This first engine was something of a compromise because it was not part of a new car homologation and changes had to be made under the joker system, so the M-Sport engine designers had limited development scope. It was intended that it should be homologated in 2013, but then Ford pulled its funding from the team and the first engine ran only in a test car. The lack of funds meant that the team did not have sufficient budget to update all its cars. This first engine was therefore put on ice.

The 2013 cylinder blocks were machined at M-Sport, but to keep the team's machine shop free and flexible the 2015 blocks are machined by a specialist supplier. The first engine was used as a base for the 2015 iteration but because the latest unit was being developed for a new homologation the designers had much more development freedom. M-Sport's chief engine engineer, Nigel Arnfield, got budget approval and sign-off for the project at the beginning of March 2014, but at that time M-Sport's engine engineers were flat out on the organisation's GT3 Bentley racing project, and so it wasn't until the middle of the year that the rally engine programme picked up speed.

For the 2013 engine, it was necessary to retain the skirt of the cylinder block, while the latest machined-from-billet cylinder block differs in being fitted with a full ladder frame at its base. Location of the connecting rod caps is no longer by dowel, which had caused problems with the old engine in the past, but is provided by a cross-toothed form; longitudinal and

M-Sport introduced a new homologation of its Ford Fiesta RS WRC part way into this season. It features an M-Sport designed new engine which is machined directly from a solid billet of aluminium alloy. The engine also makes use of finger follower valve actuation



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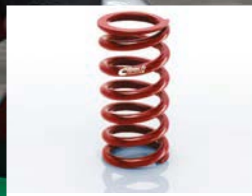

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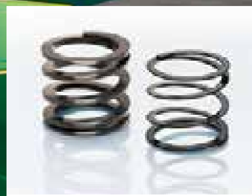

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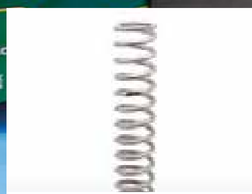

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‘It’s not easy; if you remove a bit of downforce the driver is crying: “oh, the car is too difficult to drive, too edgy”’

VW’s all-conquering Polo R WRC is a new homologation for 2015, yet while it features a new engine – built to take advantage of dressed engine weight limits introduced in 2014 – in most respects the changes from the previous Polo are matters of detail

transversal grooves on each face with which to locate the faces between the rod and cap and spread the side loads.

Up at the top end of the new engine the major change is a switch from bucket tappets to finger follower valve actuation, as also used on the VW Polo R WRC. Arnfield elected to use the original cylinder head from the old WRC engine, suitably modified to accept finger followers, for logical reasons. ‘What that meant was that, if I had a disaster with either the block or the head [during development], I always had the option to revert back one way or the other and to be perfectly honest there’s nothing wrong with that top deck that I have – never caused us a problem in the past so there was really no need to change it.’

The fuel injection hardware stays the same as before with a Bosch pump and Magneti-Marelli injectors with a new spray pattern developed by M-Sport with assistance from Ford. There’s a new carbon inlet manifold, equipped with a heat shield; which both brings the assembly to the minimum weight and avoids some of the effects of latent underbonnet heat.

The Fiesta RS WRC engine has always had dry sump lubrication since 2011, but the latest unit has a bigger oil pump with four scavenge stages thereby pulling depression into the crankcase. The flywheel is unchanged other than a reversed ring gear to cater for the starter motor, now located effectively under the bottom of the engine.

As discussed earlier, the latest rules regulate dressed engine weight and not weights of individual components as before. The new M-Sport engine is right on the minimum limit of 81kg, while the old one weighed 85kg. The new engine design has also enabled the intercooler and radiator packs to be moved rearwards, improving potential weight distribution and reducing overhanging masses.

Lighter weight, with a flatter and wider torque and improved bhp at higher rpm, this innovative power unit has immense potential. The WRC crankshaft speed limit is 8500rpm and Nigel Arnfield explains: ‘Generally speaking you operate through the gearbox with a maximum of 7000rpm/7200rpm to keep it around the peak and you only really start to use that area between 7200rpm and 8500rpm in top.’

The revised engine characteristics enable the use of higher gears more often, which means the need to go down a gear to maintain vehicle speed is reduced. Shifting down to a lower gear encourages wheelspin, which makes the car move and slide more; so the new wider power band and more torque also adds dynamic stability to the car.

With altered ratios to suit Arnfield’s in-gear rpm explanation, the gearbox is largely unchanged apart from having been adapted to package with the new engine and hydraulic paddle shift, which replaces the previous pneumatic arrangement.

Meanwhile, the differentials have adopted torque-activated negative preload to enable more control in tailoring their locking characteristics. Mechanically they are interesting in that Belleville washers are no longer used to provide positive preload: this is achieved by pressurised nitrogen gas within the units. So, externally adjusting preload settings is no longer done via spanner clicks; gas pressure changes now do the job.

The hydraulic pressure for the Fiesta’s paddle shift system comes by way of an electric pump. This system incorporates an accumulator and it also powers the rear drive disengagement arrangement.

The Reiger dampers and geometry have not changed for the new car nor has the roll cage – after mutual agreement with the FIA and other WRC manufacturers. M-Sport chief rally engineer Chris Williams summed up: ‘We know where we are with the bodyshell and suspension roughly;

The new Citroen rally engine features a raft of small detail changes aimed at reducing internal friction, improving efficiency, increasing maximum horsepower and driveability

Citroen has commonised the engine in its DS3 WRC with the unit in its WTCC C-Elysee car, as the engine regs in both championships are the same. A wide range of aerodynamic upgrades also feature

we want to develop the engine that we'd been working on in 2013; we want to go with the engine and transmission: we don't have the money for a whole car.'

Citroen DS3 WRC

Citroen Racing had a new homologation of the DS3 WRC ready for the 2015 Monte-Carlo Rally. WRC and WTCC engine regulations are the same and so the opportunity was taken to commonise the rally engine with that used in the team's WTCC racing C-Elysee models.

With modifications to fit the DS3 chassis and a 33mm diameter inlet restrictor instead of the 36mm racing restrictor the rally engine is about 95 per cent the same as the racing engine and produces some 50bhp less.

The old camshaft drive belts are replaced by drive gears and the all new aluminium alloy cylinder block and head are machined from castings, as were the units on the old rally power unit. The Bosch fuel injection system has not changed too much between the two engines. Bucket tappets are retained, and the new rally engine features a raft of small detail changes aimed at reducing internal friction, improving its efficiency, and increasing its maximum horsepower and driveability.

A hydraulic paddle shift system was introduced with this car; the hydraulic block and accumulator is mounted low in the front subframe and powers both the paddle shift and rear disengage systems, while the Belleville washer-equipped Xtrac differentials have had negative preload from the beginning with the DS3 WRC.

From the start of 2011, roller bearing dampers were outlawed for WRC cars and Citroen Racing switched from using EXE-TC units to in-house built own-design shock absorbers. Detail specification changes and revised damper diagrams have improved the efficiency of the dampers in the current car.

A new rear subframe was also approved in the new homologation. While not achieving any gains in wheel travel – which would require major driveshaft/damper architecture rearrangement – this change provided team engineers with more scope to achieve preferred suspension geometry settings.

The DS3 WRC appeared in Monte Carlo with a new fence on the rear aerodynamic device, while for the 2015 Rally Portugal there was a chassis joker homologation of a new front spoiler and a new front wheelarch extension design, developed using a scale model in the Paris Eiffel wind tunnel. Citroen engineer Didier Clement said that these 'improve aerodynamic efficiency a little bit; improve a little bit the front downforce and at the same time we reduce drag a little bit. It's not a massive advantage but of course we improve the car step-by-step and now we can say that the car is much more efficient than it was last year. As ever in Citroen, it's never completely the same but never completely different. Of course, we are not able to divide the drag by two! Just small changes but, in fact we have improved in both directions.'

Hyundai i20 WRC

Introduced to the WRC at the 2014 Monte Carlo Rally after a remarkably swift development programme, undertaken when the team was not fully formed, unlike its rivals the i20 WRC did not have the option of a new homologation for this year. The team therefore had to use jokers to make improvements to the car.

A joker was used for Rally GB in 2014, and one other was validated later that year. These were software changes to enhance the engine's torque output. Meanwhile, inlet manifold cracks had appeared in 2014, so a new aluminium alloy inlet manifold, reinforced with composites, was homologated for this year.

In March of this year a joker was used to homologate a new fuel injector. The car had a full Magneti-Marelli direct fuel injection system in 2014, then after a testing campaign of different types of injector the team adopted

Unlike its rivals the Hyundai i20 WRC did not have the option of a new homologation for this year

Hyundai had intended to introduce a new car half way through this season but problems with the homologation of its coupe meant this was shelved in favour of a five-door version of its new i20, now set to make its WRC debut next year. Current three-door i20 is pictured

new Bosch injectors from Rally Mexico this year. The original Marelli fuel pump is retained, while, in common with rival teams, lightweight lights were also introduced.

Hyundai introduced its paddle shift system in Argentina this year. This electro-hydraulic system also powers the rear drive disengage mechanism. The hydraulic pump looks similar to last year's rear disengage unit externally but the rear disengage/paddle shift pump has revised internal components. The rear disengage clutch and its electrovalve remain the same, while an additional hydraulic block and valve to serve the paddle shift is introduced. Apart from ongoing work on ECU maps there have been no other hardware changes to the current car this year.

The team intended to introduce its new car in the middle of 2015. This was to be based on the i20 coupe, which has the same platform as the new generation car, the same wheelbase, mostly similar dimensions and components as the five-door new generation car. However, there were glitches. The first was that the FIA decided that, because as a coupe the car is a different shape to the five-door saloon i20, it is not from the same family, which means 25,000 versions would have to be produced before the car could be homologated. Then the production of the i20 coupe in Korea was delayed until March 2015.

Hyundai Motorsport president Michel Nandan had to make a decision. 'It was close but not so because otherwise you compromise all the operation, so then we decided to shift back to the five-door because that's easy anyway – a big, big amount of cars,' Nandon said. 'So we said okay, better to postpone it to Monte Carlo [2016] at least we had no problem with everything and it gives us more time for development. So I think it was quite sensible to do it this way.'

Yet the previous decision had been to go with the coupe, and work had begun on that model, but fortunately the finally decided five-door version of the new generation i20 is sufficiently close in architecture for much of the early work on the 2016 rally car to carry over.

The five-door new generation i20 WRC will debut at Monte Carlo 2016. And it will be close to 99 per cent new compared to the outgoing WRC, with an entirely new bodyshell, transmission and engine. The work is being undertaken at the team's Alzenau, Germany, base by Bertrand Vallet for the chassis and Stephane Girard – who liaises with Pipo Moteurs – for the engine. Rarely have these engineers actually been seen on rallies, so hectic was the development on the current three-door car and now the development of the 2016 WRC car.

Compromise is reduced in the design of the 2016 i20 WRC, and particularly in the area of the transmission, which is packaged around the car rather than trying to fit an existing motorsport transmission into the car. The new transmission is built by a specialist, most likely French, supplier and Michel Nandan describes it as: 'More of a Hyundai design. It's much better integrated into the car, because when you take an existing component there are always [packaging] problems: crossmember, steering rack, the steering rack is always a nightmare. And in fact if you do your own layout it's possible to be adapted. So the integration in the new car is much, much better than in this [current] one.'

The new car is slightly bigger than the current one and 13kg/14kg heavier than the three-door new generation version, but Nandan considers this a small handicap, and actually an improvement over the current car. This concentration on the new car means that, according to Nandan, there is 'no big revolution' planned for the current car.

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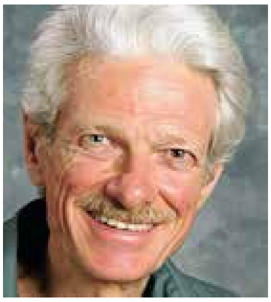

Tricky trikes and three-wheeled thrills

Camber gain and why converting a bike to a trike is a bad idea

Question

How critical is camber gain in suspension? I am considering converting a BMW motorcycle to a trike using the two front forks set wide apart, one on each side. The standard sliding system would be used for suspension, and the wheels would turn with the sliding pillar for steering. I could use a lower link to provide caster gain with the tube pivoting at the top. However, it would be far easier to fix the fork tube solid to the chassis and set the KPI and caster by location of the fork tube. Has this system ever been used, to your knowledge? There was an English Morgan sportscar that used sliding pillar suspension but I have not seen a schematic of it. I have not determined just what this would do to lead, though I can set caster, camber, scrub anywhere necessary.

The consultant says

I will offer some comments later about the general vehicle concept the questioner has in mind, but first I will address his actual question regarding importance of camber gain.

For those new to the term, camber gain is the rate of camber change with respect to suspension displacement, as measured with the sprung structure (frame) held stationary. Typically, the measurement is done in the shop, with the wheel replaced by a bump steer plate with inch or millimetre graduations on it, and a caster/camber gauge or an angle finder. To really be precise, however, displacement should be measured at the contact patch, or where the contact patch would be if the wheel were in place.

In English units, camber gain is expressed in degrees per inch. It is positive when camber goes toward negative (top of tyre inboard) as the suspension compresses and toward positive as the suspension extends.

In most suspensions, camber gain is not a constant. It has an instantaneous value at any given point in the range of suspension displacement, and this changes as the suspension moves. For short and long arm (SLA) suspensions, where the upper arm is the shorter one, camber gain increases (goes toward positive) as the suspension compresses and decreases (goes toward negative) as the suspension extends. If the arms are similar length, camber gain stays nearly constant as the suspension moves. With MacPherson strut suspension, camber gain changes the opposite way: decreases as the suspension compresses and increases as the suspension extends. With sliding pillar or pure trailing arm suspension, camber gain is zero throughout the suspension travel.

It isn't customary, but we could speak of 'camber gain gain', or perhaps camber acceleration: the rate of change of camber gain with respect to displacement – in other words, the second derivative of camber with respect to displacement, or the first derivative of camber gain with respect to displacement. This would be expressed in degrees per inch squared. It would be positive in most SLA suspension, zero for sliding pillar, and negative for MacPherson strut. For swing axle suspension, it would be slightly negative but close to zero, provided that we measure displacement at the contact patch as suggested above. Camber acceleration would also not be a constant for most systems, but would have an identifiable instantaneous value at any point in the travel.

Camber recovery in roll is related to camber gain. It is the reason we generally want some camber gain. With independent suspension, if camber gain is zero the wheels lean with the frame in cornering. This is undesirable; we would like the wheels to stay upright.

Camber recovery is expressed in per cent. If the wheels lean 75 per cent as much as the body, we have 25 per cent camber recovery. If the wheels don't lean at all, we have 100 per cent recovery. If the wheels lean the same as the body, we have zero camber recovery. If the wheels lean into the turn, we have more than 100 per cent camber recovery. If the wheels lean more than the body, we have negative camber recovery.

Camber gain is the rate of camber change with respect to suspension displacement

There are certain rules that govern the relationships among camber gain, camber recovery, front view swing arm length, and track width. (Note that these simple rules do not account for compliance effects or jacking).

Camber gain in degrees per inch equals 180/π (approximately 57.3) divided by front view swing arm length in inches. This also works with any other units of length, provided we use matching ones for suspension displacement and front view swing arm length. An FVSA of 57.3in gives one degree per inch of camber gain.

Camber recovery in per cent equals camber gain times track width divided by

Sidecar racing's wacky enough at the best of times; but just why are the passengers in this pic holding steering wheels?

Morgan made its name constructing 'tadpole' trikes, that's a three-wheeler with two wheels at the front. It still sells them too

The Morgan's track is wider than on most English cars of that time, while everything in the vehicle is situated as low possible

360/π (approximately 114.6, or twice 57.3), this quantity multiplied by 100 per cent. Camber gain of one degree per inch gives 50 per cent camber recovery with a track width of 57.3in. Camber gain of two degrees per inch gives 100 per cent camber recovery with that track. Any given amount of camber gain gives more camber recovery as we widen the track.

For a single wheel, track width is zero or undefined, and there is no way to get camber recovery in roll. This is the situation at the rear of a tadpole trike (one with two front wheels) or the front of a delta trike (one front wheel).

So, returning to the questioner's proposed vehicle, if there's no camber gain and hence no camber recovery at the front, it's no worse than the rear. In fact, the first Morgans to use sliding pillar suspension were trikes. For about the first decade of the company's existence, trikes were all it made. When it decided to build cars, it adapted the front suspension concept from the trikes. An image search for 'Morgan front suspension' will turn up lots of pictures, including exploded views.

However, I strongly advise against all attempts to convert a motorcycle into an upright-cornering trike, regardless of the suspension and steering geometry. All such vehicles are death traps. They cannot be made stable enough for the speeds they are capable of. They will all flip at half a *g* lateral acceleration or less. The c.g. is too high and too close to a line connecting either front contact patch centre and the rear one, or either rear contact patch centre and the front one. Both the tadpole and delta variations of trike have this problem.

The only way to make an upright-cornering trike that's reasonably safe is to spread out the wheels both laterally and longitudinally, get the c.g. very low, and put the c.g. well toward the two-wheeled end. The Morgan trike design illustrates this approach. The track is wider than most English cars of the time. Everything in the vehicle is as low as possible. They came with a variety of engines, but the best known versions had a big Matchless V-twin about at the front axle line or a little ahead. *Road & Track* tested one years ago. I was interested to see what they'd get when they measured the weight distribution. As I recall, it was around 60 per cent front. I don't recall any skid pad results being mentioned. I think this was before they adopted that as part of their road test procedure. The tyres are narrow and run at high pressures. I doubt that they'll generate a μy above .75. Yet on dry asphalt that vehicle will bicycle before it will slide, based on videos of these trikes competing in hillclimbs.

Tippy physics

So anything with the proportions of a motorcycle trike conversion is really tippy. That doesn't keep them from being fairly popular, unfortunately. I see such conversions on the road all the time, both with two rear wheels and two fronts. Some of them are based on really powerful motorcycles that will do well over 100mph. I've also seen some lately based on scooters. Evidently, there are a lot of people who know nothing of physics and who suppose that if other people do something it must be safe.

Some ostensibly forward-looking manufacturers in recent years have been equally oblivious to the requirements for stability in a three-wheeler. Designers of the Corbin Sparrow (now being marketed under the NMG moniker) and the Aptera both got it wrong. They failed to put the weight at the wide end. Yes, they incorporated rollover protection systems. But that's no substitute for building a vehicle that slides before it flips.

Somebody did get it right, though, about three decades ago. The vehicle was called the Trihawk. It used a boxer-4 engine from a front-whee-drive Panhard, hung out ahead of the front axle and driving the front wheels through the original car transaxle. *Car and Driver* tested one of those. They got around .85*g* on the skid pad on something like 185/60-14 street tyres, with no wheel lift. An image search will turn up pictures of this car, too.

I have been talking so far about trikes that corner upright. There is an alternative way of building a three-wheeler, especially if the operator sits astride it, as in a motorcycle conversion. You can make it lean like a two-wheeler. You either let it lean completely freely, or spring it very softly in roll. Optionally, you incorporate a roll brake or roll lock to hold the vehicle upright on slippery surfaces and when parked.

There will of course be some limit to how far the vehicle can tilt, but that can be upwards of 45 degrees to either side. We then have a vehicle that can corner about like a motorcycle, but if it loses traction when cornering hard it is caught by the inside wheel rather than falling on the ground. This would offer advantages over both two-wheelers and upright-cornering trikes. It could also be fairly narrow, preserving some of the cornering line advantages of a single-track vehicle.

Who's driving?

If I were to try something like that using motorcycle front forks and head tubes, I would connect these with a pair of beams pivoted in the middle at the original motorcycle head tube. I would keep the original two-wheeler's steering geometry at each of the two front wheels.

Leaner trikes (and also leaner four-wheelers) are an old idea, with potential still unrealised. There is a picture (p35) I recently got from Chris Beebe in Madison, Wisconsin. It shows dirt oval sidecar racing using leaner sidecar rigs. I don't know much about the history of these, and Chris doesn't either. Any readers with knowledge of this bizarre niche of motorsports history are invited to share what they know. The sidecar monkeys (passengers) are not climbing all over the rig to keep it right side up. They have a steering wheel that they are working. It doesn't appear to steer any wheels, though. It appears to work a rack and pinion mechanism that controls the tilt of the rig. The driver also appears to be controlling tilt with his right foot.

Again, anybody who knows anything about these rigs or the history of this class is invited to educate me.

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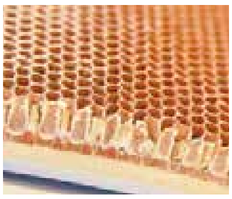

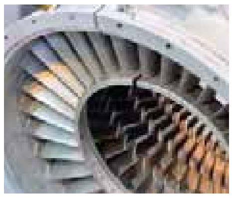

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- **One of the most useful features of an IPS is built-in logging functionality. Data recorded by the device during a session allows engineers to diagnose and resolve a fault by observing device behaviour recorded from the time the fault occurred.**

There are occasions where a trip could occur, even though a genuine fault does not exist. For example, in windy conditions, a trip can occur on the down-stroke of the windscreen wipers when the wiper meets increased resistance from the air flowing up over the bonnet of the car. This resistance means the wiper motor draws more current in order to complete the motion.

- **On a car equipped with fuses, a trip would result in loss of wiper function, impaired visibility and could mean the end of a driver's race in extreme circumstance. This is because the only way to restore functionality would be to stop the car and physically replace the fuse.**
- **An IPS can be configured to attempt to reset a trip and restore power a set number of times over a predefined time period, without requiring any input from the driver.**

Logic control

A number of race series, including VLN, make use of math and logic channels to control the state and flashing of the cars headlights under certain conditions whilst on track. It is not desirable for a car to enter the pits with high beams on. Just like on the public road, this can be disorientating and dangerous for those looking into the beam. This can be controlled by using a simple logic function whereby the high beams are forced into an off state whilst the pit limiter is activated. It is equally important that the high beams can be switched back on once the pit limiter has been deactivated.

VLN allow drivers to flash their headlights to signal an overtaking manoeuvre – this is especially important in race series which involves multiple classes being on track at the same time. In endurance racing, the speed difference between different classes of car is great, meaning in some cases, a driver may not otherwise be aware of an approaching car.

Normally, this would be done by momentarily manually switching between the headlights high beams and low beams at short intervals. To allow the driver to focus on racing, this entire process can be controlled using math and logic channels when a short press of the high beam button is received.

This sequence can be implemented using the following logic channel (**Figure 1**). In literal terms this means; when the 'Car is Moving' AND 'Pit Limiter is Inactive' AND 'Flash Headlights Button Clicked'

An Intelligent Power Supply can help control headlight beams on a racecar and ensure wiper blades keep working after a fuse has blown

XPB

A trip could occur, even though a genuine fault does not exist

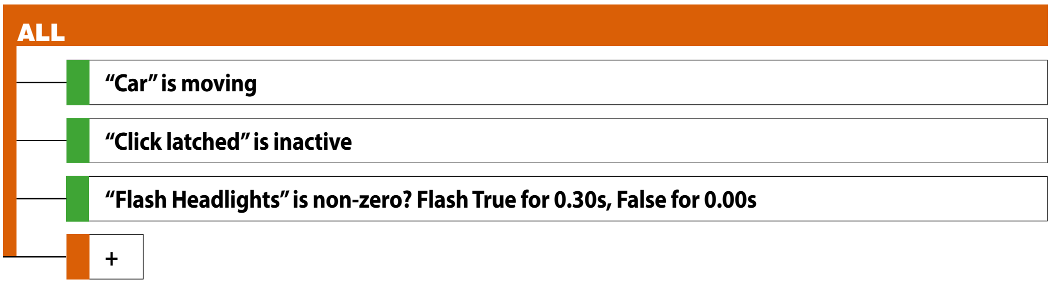

Figure 1: The above shows the logic channel of the sequence on the main beam flash for an IPS

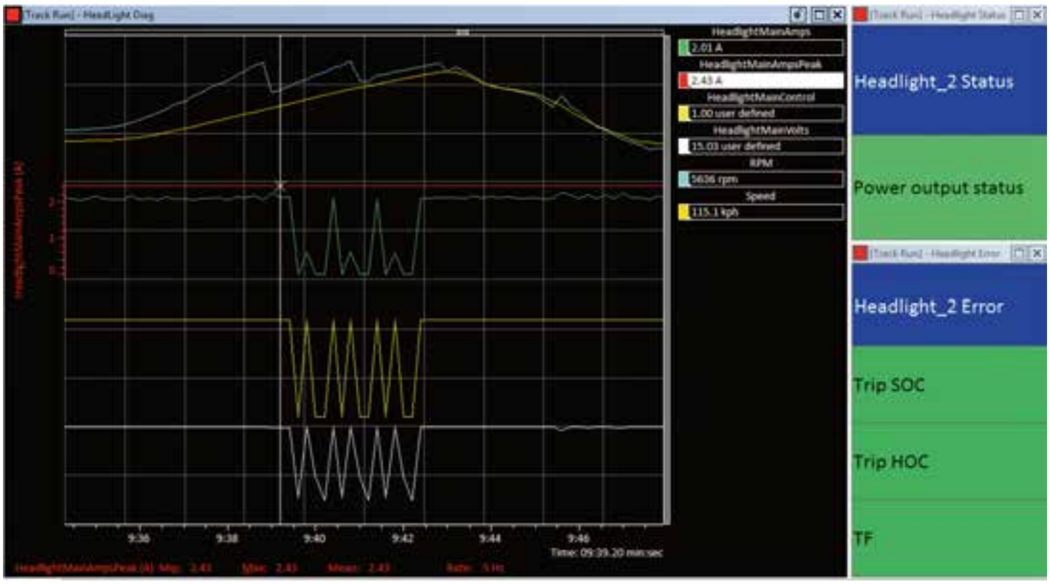

Figure 2: Status indicators are on the right while the graph depicts the current draw, voltage and output signal of the headlights

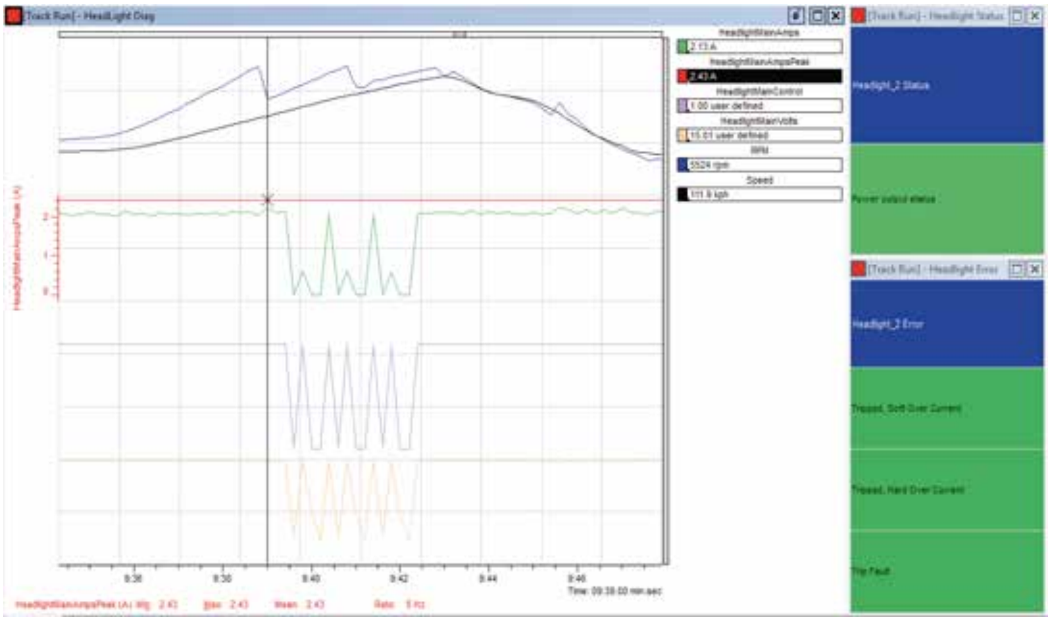

Figure 3: The maximum current drawn appears on the readout to show any spikes in the current to help diagnose a fault

It is clear that using an IPS can allow the user to implement a control set-up quickly and simply using math and logic channels

the Headlights will flash ON for 0.3 seconds and OFF for 0.7 seconds.

Analysis of the data logged from an IPS with a data analysis software package indicates how the state of the headlights changes throughout headlight flash sequence (**Figure 2 and 3**).

- **Status indicators to the right of the display clearly show the current state of the output channel to the headlights as well as any trip events; limits are specified in the IPS configuration to determine at what level a trip will occur. Often there are both high and low levels, sometimes referred to as hard and soft trips.**
- **The graph trends the current draw, voltage and output signal to the headlights over time. It shows normal operation during night racing. The driver has pressed the flash headlights button causing the control signal to toggle a total of five times which corresponds to the changing current draw as the headlights flash five times.**
- **The maximum current drawn appears on the trend to help identify any spikes in current to help diagnose a fault as well as monitoring the demand of a device.**

Further benefits of an IPS might be as simple as:

- **Placement within the car. The IPS box can be positioned lower in the car as the driver does not need access to it. Driver access to the IPS functions can be via a light weight switch panel that can be mounted within easy reach of the driver.**
- **Reduced loom design as each on car system can be connected directly rather than the extra wiring need to connect through the fuse box.**

It is clear that using an IPS can allow the user to implement a control set-up quickly and simply using math and logic channels which when combined result in some complex yet powerful control strategies.

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Classic club racers in the wind tunnel

Part three of our study into Mallock Clubman aerodynamics

To conclude our homage to 'Clubmans 50' we will round off with some comparisons between cars past and present. But first, a recap. Started in 1965, Clubmans remains a popular category for drivers and manufacturers alike to compete with front engine, rear wheel drive sports racers. One of the mainstays of the category from the outset has been Mallock, and we put three examples of the marque, run by Orex Competition, through their paces in the MIRA wind tunnel. The Mk18B first appeared in 1977; the Mk 28B was a 1990 car and a second Mk 28 wore bodywork based on the Mk 36 and therefore represented the current era.

In our two previous instalments we have looked at the Mk 18B and Mk 28B and at a number of aerodynamic devices frequently seen on the cars, such as high and low downforce noses, Gurneys on the nose and rear wing, and side skirts (seemingly allowed in Classic Clubmans because they were used in period). The Mk 18B needed its high downforce nose to obtain a reasonably well-balanced set up whereas the Mk 28B was fairly well balanced from the outset and generated roughly 12 per cent more downforce for very slightly less drag than the Mk 18B. It's important to note, though, that these comparisons were valid only for the configurations tested and should not be regarded as definitive statements of relative aerodynamic performance. **Table 1** summarises the data we obtained with comparable aerodynamic balance (per cent front) values.

Current concept

Moving on to the 'current' car then, this again was a Mk 28 chassis, but it had been clad in bodywork based on that used on the Mk 36. The major differences between this and the earlier cars tested here were the enveloping front end instead of the separate nose and 'mudguards', and a lower-mounted rear wing. With time running short at the end of our half-day session we had no opportunity to optimise this car but did squeeze in some quick balancing adjustments to give a per cent front value of just under 40 per cent. However, the results make for interesting reading, shown in **Table 2** along with the Mk 18B and Mk 28B in their best balanced states from **Table 1**.

The current car in this configuration, and in this approximately balanced state, generated around 11 per cent less drag than either of the two earlier cars, but also between 23 and 28 per cent less downforce. While a reduction in drag might have been expected, the downforce deficit was not. It's instructive, however, to look at how this particular balanced set-up was achieved in the wind tunnel. The car's baseline, first run data are shown in **Table 3.**

The front end was performing reasonably well at this point compared with the other cars, but clearly the rear end lacked downforce. Drag, of course, was very low at this point, but in this configuration the car would certainly have been 'aerodynamically loose', or an oversteerer

Mk 28/36 with current style all-enveloping front aerodynamics produced surprises

The classic Clubmans Mallock Mk 18B provided the answers to some old questions

1990s Mk 28B performed well and was generally well-balanced from the outset

Table 1 – data from the Mallock Mk 18B and Mk 28B at similar balance values

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Mk 18B	0.529	0.793	0.287	0.506	36.2%	1.499
Mk 28B	0.526	0.852	0.321	0.530	37.7%	1.620

Table 2 – comparison between the three Mallocks at roughly similar balance values

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Mk 18B	0.529	0.793	0.287	0.506	36.2%	1.499
Mk 28B	0.526	0.852	0.321	0.530	37.7%	1.620
Mk 28/36	0.467	0.614	0.242	0.372	39.4%	1.315

Table 3 – the Mk 28.36 baseline data at 80mph

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Mk 28/36	0.399	0.446	0.280	0.166	62.8%	1.118

Rapid adjustments to the rear wing of the Mk 28/36 and the fitting of a 20mm-high Gurney to the trailing edge of the body balanced the 'current' spec Clubmans racer

Lola T390 raced in the same period as the Mallock Mk 18B but had weak front end

Tiga B CN sports racer was, as expected, the stand-out performer in aero comparison

Table 4 – the results for Mk 28/36 with increased rear wing angle and adding a Gurney

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Mk 28/36	0.458	0.514	0.249	0.265	48.4%	1.122

Table 5 – effects of a 20mm rear body Gurney on Mk 28/36

	CD	-CL	-CLfront	-CLrear	%front	-L/D
No Gurney	0.458	0.514	0.249	0.265	48.8%	1.122
With Gurney	0.467	0.614	0.242	0.372	39.4%	1.315
Δ, counts	+9	+100	-7	+107	-9.0%	+193

Table 6 – Comparisons with other sports racing cars previously tested for Aerobytes

	CD.A	-CL.A	%front	-L/D
Lola T390	0.707	0.780	35.2%	1.103
Mallock Mk 18B	0.709	1.063	36.2%	1.499
Mallock Mk 28B	0.709	1.142	37.7%	1.610
Mallock Mk28/36	0.626	0.822	39.4%	1.314
Tiga A CN	0.738	1.319	35.2%	1.787
Tiga B CN	0.789	2.079	34.0%	2.635

in faster corners. The first remedy applied was to increase the rear wing's angle of attack from four degrees to seven degrees and, because time was short, a full width Gurney was simultaneously fitted. Results shown in **Table 4.**

So there was a significant balance shift to the rear, albeit this change was not particularly efficient with 99 counts of extra rear downforce for 59 counts of extra drag. Nevertheless drag was still lower than on either of the earlier cars. The very last configuration change of the session saw a 20mm high Gurney attached to the upper, rear body's trailing edge, the results shown in the bottom line of **Table 2**, reasonably well-balanced but at a lower downforce level than the earlier cars. The actual effect of the rear body Gurney is shown in **Table 5.**

This sequence of balance adjustments implied that the Mk 28/36 was intrinsically short of rear downforce. As mentioned, the rear wing was mounted lower on this car, which would certainly reduce rear downforce, with a greater proportion of the wing masked by the driver and roll hoop structure, as well as the rest of the span working in less energetic air. Furthermore, the shape of the rear bodywork was notably different in that the rear wheel arches and rear deck curved downwards to the rear to give a much lower tail height. This convexity of the rear wheel arches and rear deck could in itself be generating body lift, which in turn would result in lower downforce at the rear wheels. That the rear body Gurney produced such an efficient gain suggests that a more 'flicked up' spoiler-like body termination would have produced more rear downforce. A larger, more efficient rear wing, perhaps mounted even lower to help energise the underbody, may be another solution to explore, too.

Finally in this mini-series we'll make some quick comparisons with other sports racing cars we have previously tested, with **Table 6** putting these Clubmans cars into perspective. The main coefficients have been multiplied by the relevant frontal areas to enable direct comparisons to be made, CD.A and –CL.A being directly proportional to drag force and downforce. The best balanced setting found on each car is used.

The contemporaneous Lola and the Mallock Mk 18B make an interesting comparison. The Lola had a much bigger rear wing, but a weak front end meant the wing had to be run very flat to achieve a balance; hence it had quite low downforce relative to the Mallock. The mid-engine CN Tigas performed very differently to each other and the Mallock Mk 28B was not far short of Tiga A on downforce and efficiency and had lower drag, suggesting it could match Tiga A's downforce with more work. Tiga B clearly outperformed the other cars here, but then so it should have!

The sequence of balance adjustments implied that the Mk 28/36 was short on rear downforce

Next month we will start another new and exciting project.

Racecar Engineering's thanks to James Kmieciak, Orex Competition and owner/drivers Chris and Morris Hart and Chris Lake for providing the cars for this session.

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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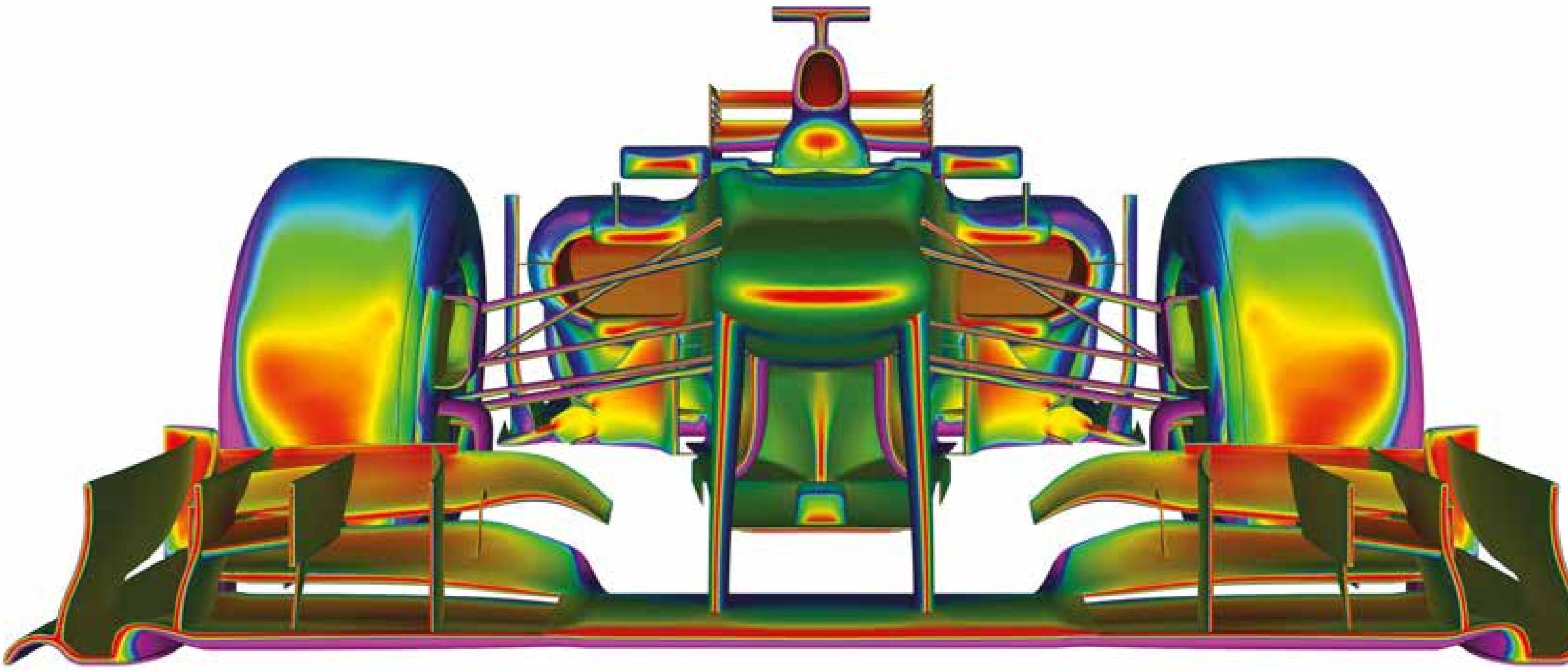
Dynamic flow fields

Racecar Engineering uncovers more Formula 1 aerodynamic secrets courtesy of the colourful world of CFD

By SIMON McBEATH



Continuing our foray into the details of Formula 1 aerodynamics, Dynamic Flow Solutions and its director Miqdad Ali have once again been running OpenFOAM CFD simulations on a highly realistic F1 model to provide *Racecar Engineering* readers with more unique and exclusive insights. In this instalment we look at major and minor modifications that have significant – and 'global' – effects, while we also visualise and quantify some of the side effects of deploying the Drag Reduction System (DRS).

In our first instalment of this exciting occasional series (RE V25N7) we examined our 2013 regulations baseline model to see where downforce and drag were generated, and looked at how the generation and management of vortices was (and still is) an important means of generating downforce with regulation-restricted underbodies. Then we examined how ride height changes affected the aerodynamic coefficients.

We also made some comparisons with public domain data on a 2009 Sauber F1 car, which highlighted some areas where 'our' model could be improved, as Miqdad Ali, ('MA') explains: 'We looked at body forces on individual component segments such as front wing, rear wing, body, floor and diffuser and so on, and compared those to a 2009 Sauber F1 car on the same segments. The data on the baseline model at representative ride heights showed that more downforce could be had from the underfloor region, which warranted modification of the diffuser to work the underfloor better. Also the extension of the wheelbase should be evaluated; gaining more floor area should improve the L/D of the car. We were targeting -3.5 as our L/D and hoping the changes we would make would help us get there.

'Furthermore, the rear tyres on the Sauber model generated a lot less lift because the flow around the contact patches close to the diffuser was accelerating faster, reducing the pressure on the tyres' lower surfaces and thus reducing lift as a result. This could only have happened if their diffuser was working better, another indicator that our diffuser needed improvement! We also wanted to make sure that we could get a reasonable balance since the baseline assessment showed forward-biased downforce generation that was not in line with the static weight distribution.'

For reference the basic CFD parameters are given in **Table 1** and the baseline aerodynamic coefficients found on the model at the start of this project are given in **Table 2**.

Although the downforce and drag coefficients were felt to be reasonable for a first iteration, balance (%front) was too far forwards with

The first configuration change made to the CAD model for this instalment was to lengthen the car's wheelbase by 200mm

Table 1 – Basic CFD parameters
OpenFOAM, steady state RANS solver
Hex and split-hex mesh, 38 million cells (half car)
Inlet speed 67m/s (150mph)
Moving ground and rotating wheels
SST k-omega turbulence model
Engine inlet and exhaust flows modelled at 17,000rpm equivalent

Table 2 – Baseline coefficients at representative ride height; '15f 72r' refers to 15mm front ride height and 72mm rear ride height (measured between the ground and the reference plane at the axle lines)

Configuration	CD	CL	L/D	%front
15f 72r	1.174	-3.476	-2.961	52.80%

Table 3 – Coefficients at representative ride height with 200mm longer wheelbase

Configuration	CD	CL	L/D	%front
15f 72r +200mm W/B	1.193	-3.640	-3.051	51.46%

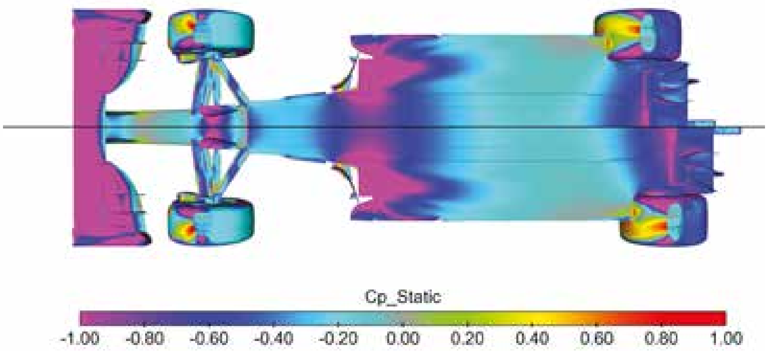


Figure 1: Underside surface pressures with original and 200mm extended wheelbase

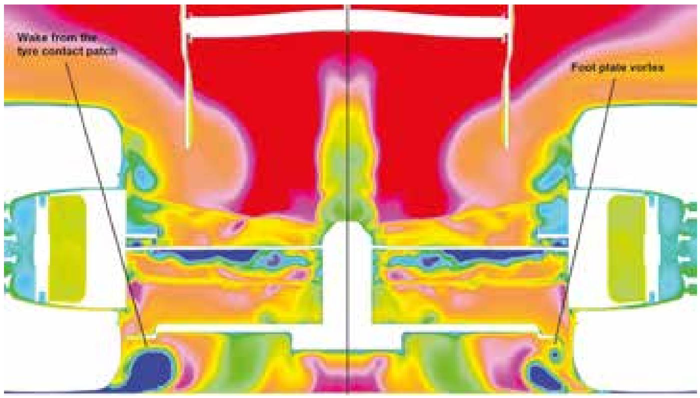


Figure 3: Transverse slice at the rear axle line (where the diffuser starts) showing total pressure (or energy) in the flow – footplate slot is in the right hand side image

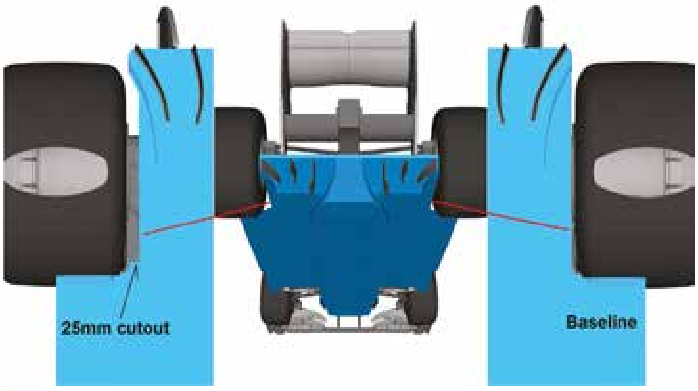


Figure 2: A slot in the diffuser footplate produced significant changes in coefficients

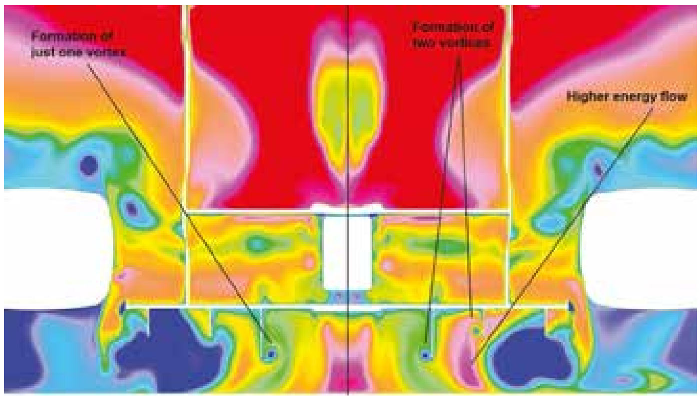


Figure 4: Total pressure slice part way along diffuser showing the higher energy flow

respect to the expected static weight distribution, and so improving that as well as overall aerodynamic performance were the priorities for this second phase of work.

Longer wheelbase

The first configuration change MA made to the CAD model for this instalment was to lengthen the car's wheelbase by 200mm. This was achieved by stretching the centre section just aft of the roll hoop so the whole rear end was moved back by 200mm, otherwise the front half and rear end were left unmodified. The data is shown in **Table 3**, and a comparative plot of the underside surface pressures is shown in **Figure 1**. MA commented: 'As expected the downforce went up because of the bigger floor area, and the balance shifted towards the rear.' Indeed, close inspection of **Figure 1** reveals that not only did the 'suction peak' at the diffuser transition move aft relative to the rest of the car, but also somewhat lower pressures were obtained in parts of the diffuser. Downforce increased by 4.7 per cent compared to the baseline model, and L/D went up by 3.0 per cent with a 1.5 per cent (absolute) rearwards shift in aerodynamic balance (%front).

MA remarked: 'I realised that the floor could generate more downforce so I investigated the diffuser area. A few transverse slices of total pressure coefficient close to the rear tyre contact patch area revealed that the flow from the tyre contact separation was spilling into the diffuser region and reducing its effective working area. If the effect of tyre contact 'spillage' could be reduced, the diffuser would work better and increase mass flow under the whole car, so increasing downforce as a result. One way to do this is by exhaust blowing.

'In 2012 the F1 teams used to blow exhaust gases into that area to seal the diffuser from tyre spillage, so improving floor performance. The FIA banned that so teams resorted to the Coanda exhaust approach where they aimed the exhaust gases so they would be roughly in that area and produce similar results. It worked, but not as well as the full blown concept. Either way, I decided to use a slightly different approach and look at the Coanda effect at a later date.'

MA's chosen modification was to cut a 25mm slot out of the footplate along the outer edges of the diffuser, just inboard of the rear tyres **(Figure 2)**. MA said: 'The idea of the slot was to allow some high energy air into the affected region. The pressure difference between the diffuser (low pressure) and above the footplate (high pressure) would create a vortex which would interact with the tyre contact separation and reduce its effect on the diffuser area.'

'As expected the downforce went up because of the bigger floor area, and the balance shifted towards the rear'

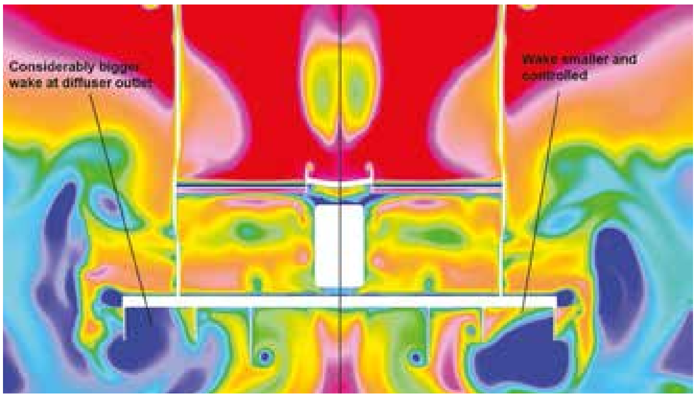


Figure 5: Total pressure slice at the diffuser exit

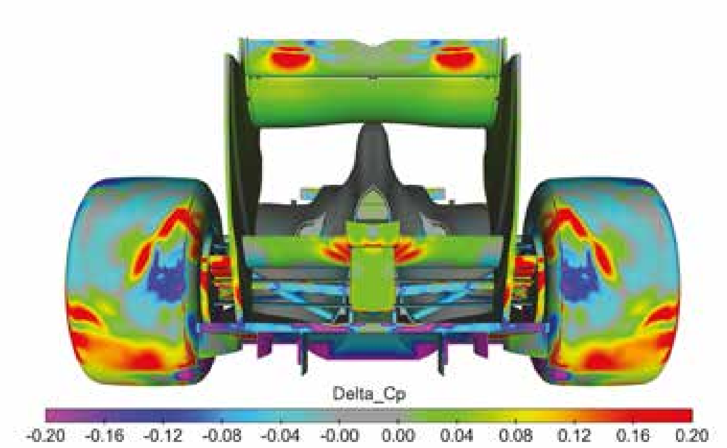


Figure 7: Rear delta_Cp view shows the changes on wing assembly and tyres which are caused by the footplate slot

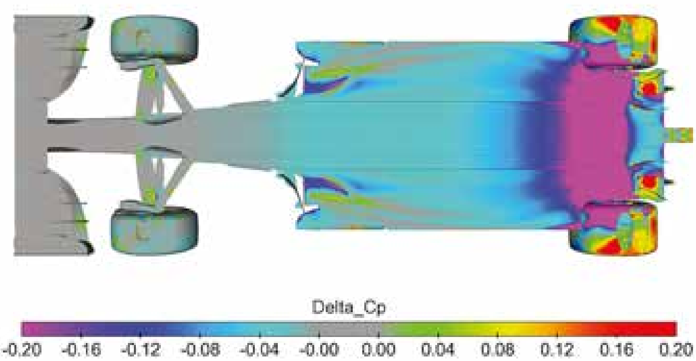


Figure 6: Delta_Cp plot shows how the underside pressures changed with the diffuser footplate slot – note just how far upstream the effects extended

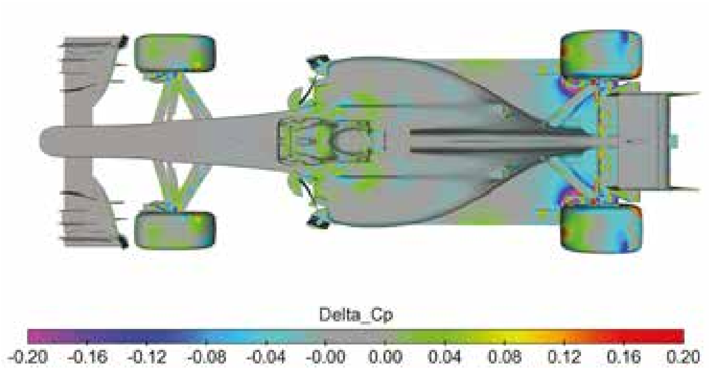


Figure 8: Upper surface delta_Cp plot shows the extent of the changes caused by the footplate slot modification. Both 7 and 8 show that what you change on front affects rear

Table 4 – Coefficients after the diffuser footplate modification, at two ride heights

Configuration	CD	CL	L/D	%front
15f 72r +200mm W/B + diffuser footplate mod	1.171	-3.940	-3.360	48.83%
10f 67r +200mm W/B + diffuser footplate mod	1.161	-4.046	-3.480	49.38%

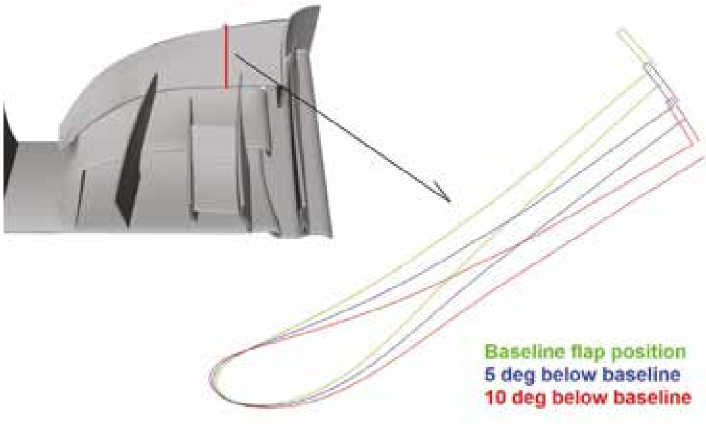


Figure 9: Front flap adjustments were in 5-degree increments

Figure 3 is a transverse slice at the rear axle line (where the diffuser starts) showing total pressure (or energy), and we can see this mechanism at work. A vortex has indeed rolled into the gap created by the slot (right hand side of the image) and has already reduced the size of the wake from the tyre contact patch. And just inboard of the reduced tyre contact patch wake the area of higher energy air (red and pink) has increased. Moving downstream to roughly in line with the back of the rear tyres, **Figure 4** shows that the area of higher energy air carries on into the diffuser. Furthermore, the energy in this region is now sufficient that a pair of vortices has formed from the diffuser turning vanes, which in turn will help reduce the pressure within the diffuser. And at the diffuser exit **(Figure 5)** we can see that the reduced tyre wake and increased higher energy region have persisted through the diffuser.

MA says: 'This shows that the energy in the diffuser is slightly higher and as a result downforce has gone up significantly. This small change increased downforce by around eight per cent from the previous run and by 13 per cent compared to the baseline, a massive gain by F1 standards. You can see from **Figure 6** that there is significant pressure reduction in the diffuser area as a result, meaning the vortex seal was working. More work can be done to improve that area but for now we know how the concept works! Also, the rest of the floor area also worked better after the footplate modification. This change moved the balance rearwards, which was still heading to the right direction. At this stage we were at around 48 per cent to 49 per cent front and we were aiming for 44 to 47 per cent."

MA continued: 'The footplate modification not only improved the floor significantly, the resulting changed flows have also interacted differently with the rear tyre contact patch area, reducing the pressure and rear tyre lift as a result, as also seen in **Figure 6**. Other changes can be seen on the rear wing, top surfaces of the car, etc. – illustrating the fact that the car works as a system and what you change in the rear really affects the front and vice versa **(Figures 7 and 8)**.'

Table 4 shows the coefficients and balance with the footplate modification. Compare this table with **Tables 2 and 3** to see the true extent of these changes. The CL exceeded -4.0 at the lower ride height and the L/D was almost -3.5.

'Energy in the diffuser is slightly higher and as a result downforce has gone up significantly. This small change increased it by eight per cent'

Table 5 – The effects of changing front flap angle					
Configuration	Front flap	CD	CL	L/D	%front
15f 72r	Baseline	1.171	-3.940	-3.360	48.83%
15f 72r	-5deg	1.166	-3.945	-3.380	47.48%
15f 72r	-10deg	1.173	-3.892	-3.320	44.63%
10f 67r	Baseline	1.161	-4.046	-3.480	49.38%
10f 67r	-5deg	1.165	-3.988	-3.420	47.89%
10f 67r	-10deg	1.159	-3.931	-3.390	45.00%

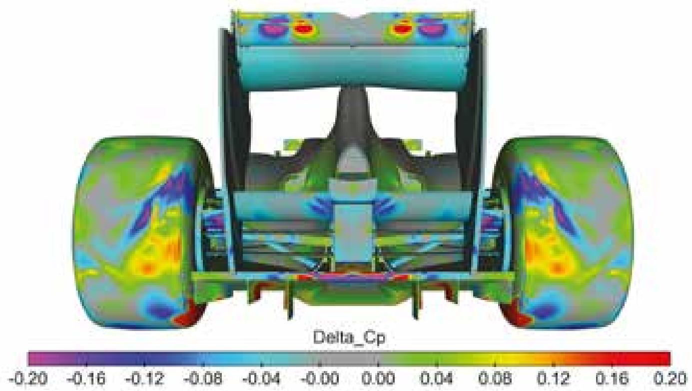


Figure 10: With a 5-degree front flap reduction the rear wing and beam wing worked slightly better, with more suction (pale blue) on the lower surfaces

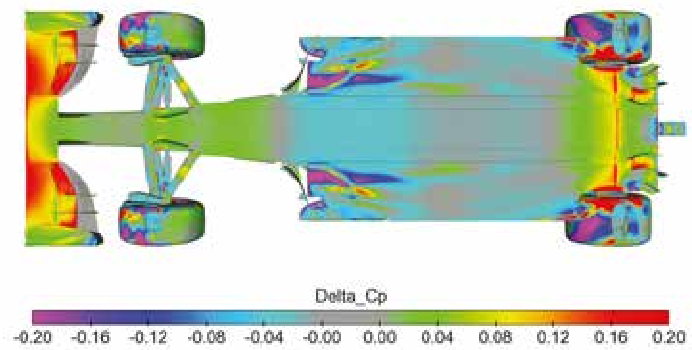


Figure 11: The changes to underside pressures with a 5-degree front flap reduction differed from …

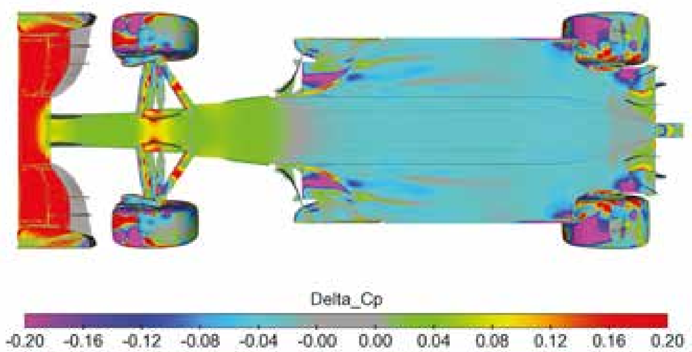


Figure 12: … the changes to underside pressures with 10-degree front flap reduction

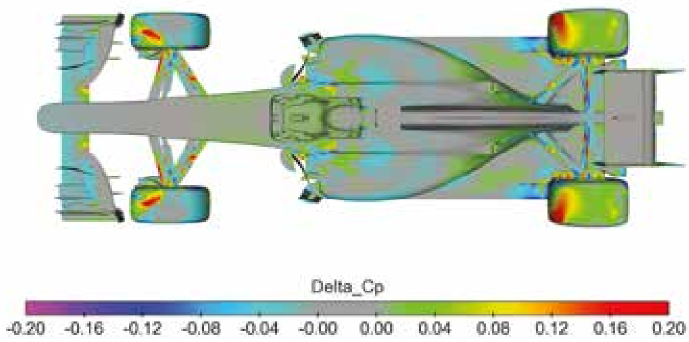


Figure 13: The tyres see different air too. Surface pressures from above show the extra drag from the rear tyres when the front flap angle was reduced

Table 6 – Downforce distribution at three flap angles, as a percentage of the total. Negative values represent positive lift contributions. The 2009 Sauber values are for comparison

Configuration	Downforce distribution			
15f 72r	Baseline	-50 front flap	-100 front flap	2009 Sauber
Front wing assembly	34.0%	32.2%	29.9%	29.0%
Front wheels, brake ducts, suspension,	-2.3%	-1.9%	-1.8%	-1.0%
Chassis, bodywork	-8.8%	-9.3%	-10.1%	-8.0%
Floor and diffuser	51.9%	52.9%	56.5%	52.0%
Rear wheels, brake ducts, suspension	1.1%	1.7%	0.9%	3.0%
Rear wing assembly	24.0%	24.4%	24.6%	25.0%
CL	-3.940	-3.945	-3.892	n/a

Table 7 – Drag distributions at three flap angles, as a percentage of the total. The 2009 Sauber values are for comparison

Configuration	Drag distribution			
15f 72r	Baseline	-50 front flap	-100 front flap	2009 Sauber
Front wing assembly	23.7%	21.9%	19.0%	20.0%
Front wheels, suspension, brake ducts	6.2%	6.8%	8.1%	10.0%
Chassis, bodywork	12.2%	13.2%	13.0%	10.0%
Floor and diffuser	6.0%	5.4%	6.3%	13.0%
Rear wheels, suspension, brake ducts	22.2%	22.2%	23.3%	17.0%
Rear wing assembly	29.7%	30.4%	30.3%	30.0%
CD	1.171	1.166	1.173	n/a

Balance changing

Probably the most obvious means of altering the balance would be to alter the front wing flap angle. Yet, we saw in our Aerobytes studies on the 2007 Honda F1 car back in 2012, adjusting the front flaps does more than alter the downforce generated by the front wing. It was clear from that wind tunnel exercise that other things changed as front flap angle was adjusted, but what we couldn't tell in the wind tunnel was just what those changes were or where they came from, other than the changes in forces at the tyre contacts. However, with CFD we can visualise pressure changes around the car, and the exercise here is very revealing.

MA: 'To get the balance close to 45 per cent front I tried two 5-degree increments **(Figure 9)** which gave around 44.7 and 47 per cent front.'

The results at two different ride heights are shown in **Table 5**. For comparison, according to the data in the Force India *vs* Lotus court case, the Lotus R30's 2010 launch target had L/D at 3.26 and balance at 42 per cent.

MA: 'Looking at the numbers in **Table 5** and correlating the changes with **Figures 10 to 13**, although 5-degree and 10-degree flap angle reductions may not seem much, they do allow more air to reach the rear of the car, and the global changes are interesting as well as how the balance change occurs. In the wind tunnel one would think that the balance just shifts to the rear because the front wing is working less hard, but there is more to it than that. Looking at the delta_Cp images makes things clearer. The rear wing is working better as a result of the 5-degree front flap angle change since more air is reaching the rear **(Figure 10)**. This carries on further at the 10-degree flap angle change.

'Another thing that is apparent,' MA continues, 'from the images and results, is that the 5-degree changes are slightly different to the 10-degree

It was clear that other things changed as front wing flap was adjusted

Table 8 – Coefficients with the under-chassis vanes removed, compared to the balanced set up from earlier

Configuration	Front flap	CD	CL	L/D	%front
15f 72r	-10deg	1.173	-3.892	-3.320	44.63%
Above minus vanes	-10deg	1.169	-3.636	-3.110	49.26%

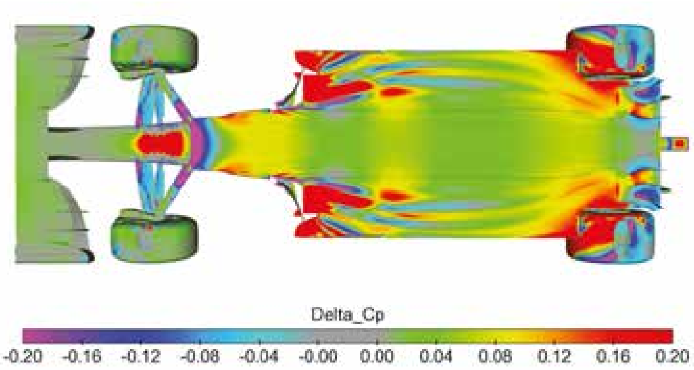


Figure 14: Removing the vanes from beneath the forward chassis had a pronounced effect on underbody pressures

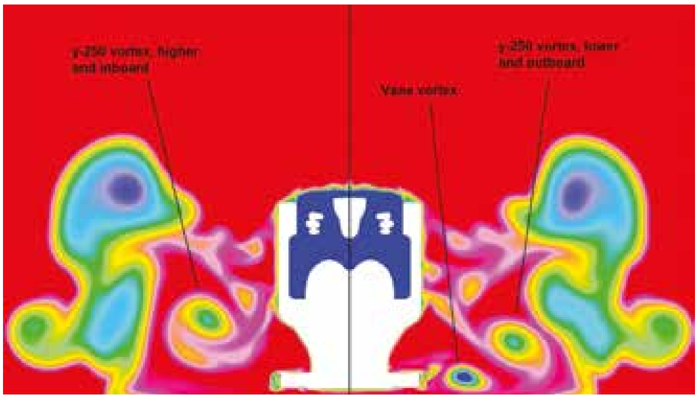


Figure 15: This transverse total pressure slice from just aft of the under-chassis vane location shows just how flow features were altered by the vane (right)

changes. The complex flow changes downstream of the car affect the diffuser and rear floor area negatively at 5 and positively at 10 **(Figures 11 and 12)** Also, the tyres see different air too **(Figure 13)**, increasing front and rear tyre drag and, as a result, hitting our efficiency target! Perhaps the front wing could see more development at a later stage to reduce this effect and gain back what was lost with flap angle changes. One could perhaps use a smaller chord wing and run it closer to the ground to get similar performance to the current wing but which allows more air to the rear of the car. These are all thoughts which can be looked into later on as to how all the interactions around the car help optimise it further.'

Table 6 shows the distribution of downforce contributions from the various component segments, this time at the three different flap angles, and the above trends can be picked out in the data. The front wing's contribution obviously reduces with decreasing front flap angle, the floor and diffuser contribution increases, especially at the shallowest flap angle, and the rear wing's contribution increases slightly with each front flap angle reduction. Interestingly, chassis and bodywork positive lift increases with each flap angle reduction, a downside of more mass flow over the upper surfaces.

Notice that although the change in force distribution and balance are quite marked, the change in overall downforce across this adjustment range is quite small. The trends at the lower ride height were similar.

Table 7 shows the distribution of drag contributions in the same way, and again the patterns seen in the images are reflected in the data. Here the overall trend is that total drag barely changes as the front flap angle is reduced, even though the front wing's contribution does reduce with each flap angle reduction. This is not really surprising because, simplistically speaking, the front flap angle reduction is allowing more air to encounter drag-inducing components downstream.

Under-nose vanes

Interactions are a crucial aspect of the aerodynamics on any racecar, and particularly on F1 cars, and in our introductory feature to this project in the July 2015 issue we briefly examined the role of the vanes under the forward chassis, located between the inboard front suspension pick up points. These vanes clearly generated a region of reduced pressure between them, under the chassis, and could also be seen to generate vortices which modified the downstream path of the front wing's 'y-250' vortex and induced some downwash ahead of the main underbody. This was expected to increase the underbody's downforce contribution.

MA: 'This is an opportunity to demonstrate the importance of using vortices to manage the flow. To illustrate how important that component is on this car, I ran a simulation without the vanes on our now balanced car and compared it with the one with the vanes in place. It showed, as expected, a significant loss of downforce when the vanes were removed, around seven per cent **(Table 8)**, and the delta_Cp image of the floor **(Figure 14)** shows the generally increased pressures on the floor's underside with the vanes removed. The vanes also affected the other components of the car too, as the total pressure slice taken just aft of the vane location in **Figure 15** shows. The y-250 vortex followed a different path, changing the flow to the rear of the car, affecting the rear tyre region and other areas as well as the floor.'

As **Table 8** shows, the under-chassis vanes were responsible for 256 counts of extra downforce for just four counts of extra drag, and the balance shift was very marked too, a clear demonstration of how

Interactions are a crucial aspect of the aerodynamics on any racecar, and this is particularly so on Formula 1 cars

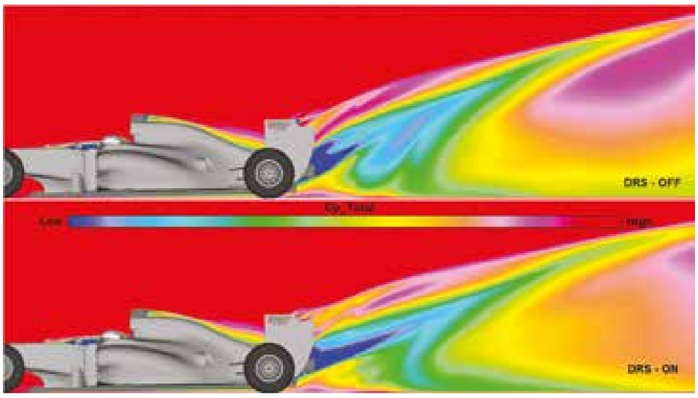


Figure 16: This longitudinal total pressure slice on the car's centreline compares upwash in the wake with the DRS opened (ON, bottom) and DRS closed (OFF, top)

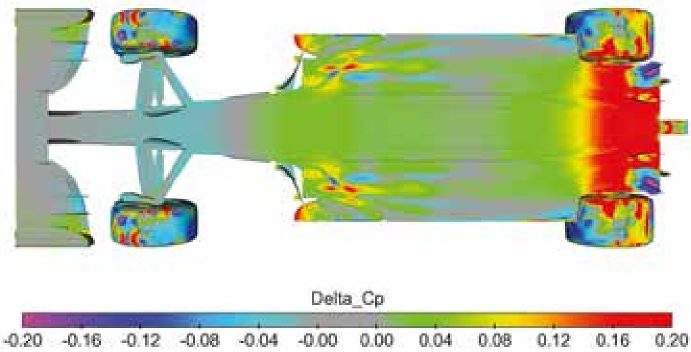
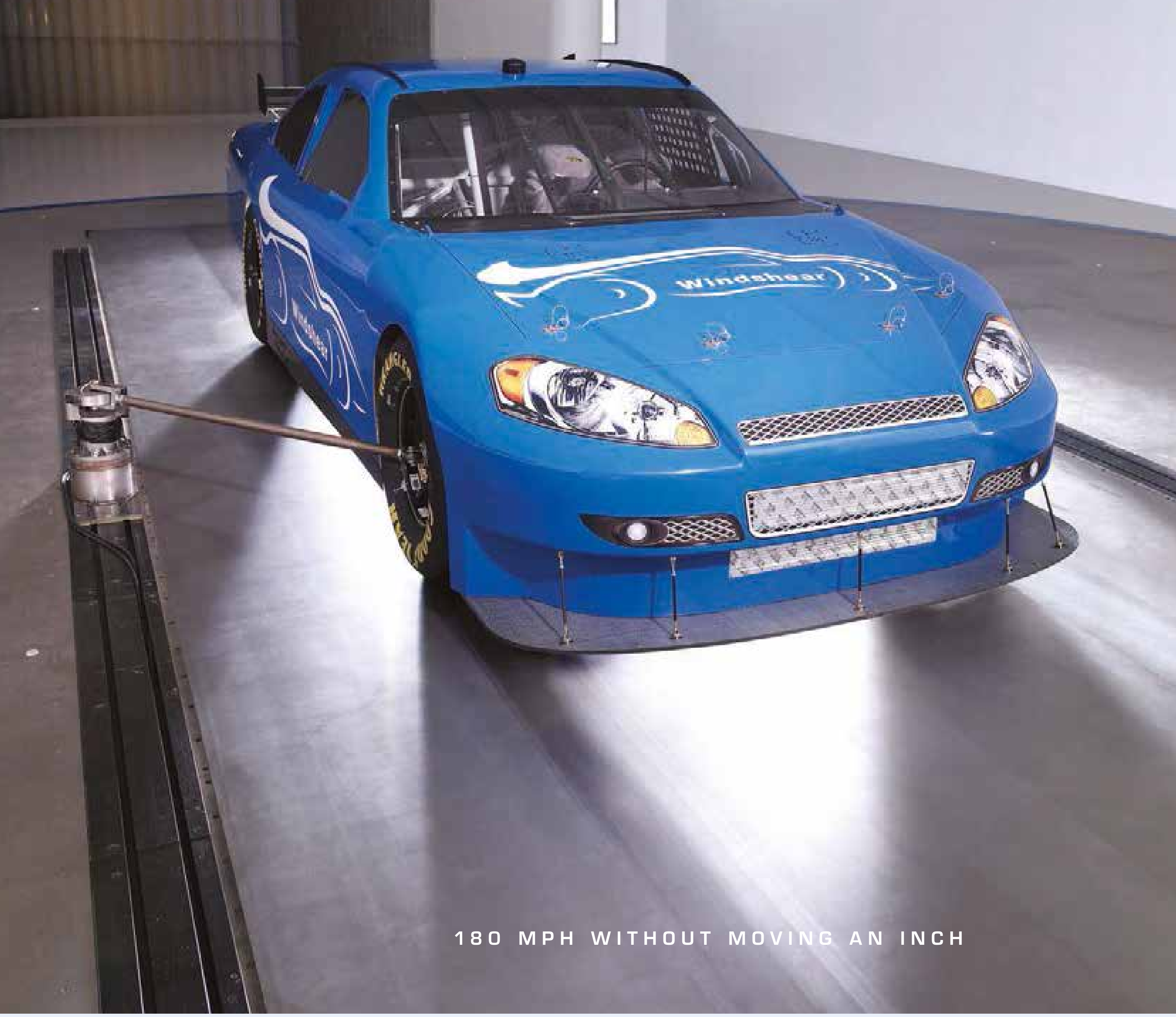


Figure 17: Activating the DRS also had a significant effect on underbody pressures


180 MPH WITHOUT MOVING AN INCH

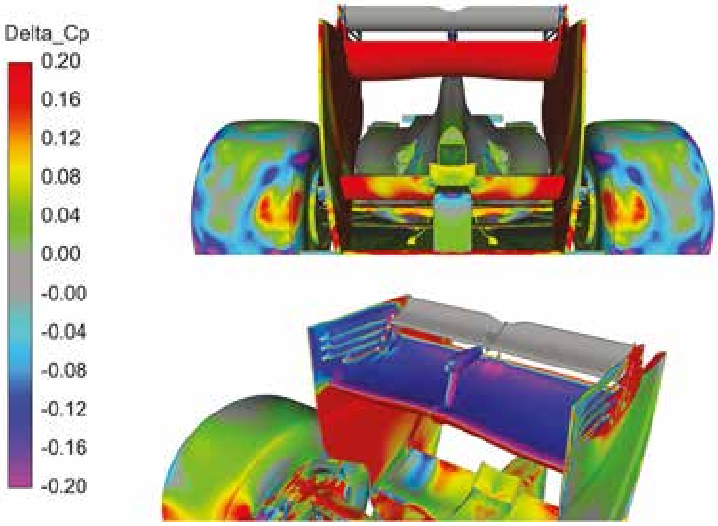


Figure 18: The opening of the DRS had the expected effects on the rear wing itself

Table 9 – Coefficients and balance with and without DRS

Configuration	Front flap	CD	CL	L/D	%front
15f 72r	-10deg	1.173	-3.892	-3.320	44.63%
Above with DRS deployed	-10deg	1.083	-3.610	-3.330	48.86%

Table 10 – Drag force distributions with and without DRS deployed

15f 72r, -100 front flap	Drag distribution with DRS closed (OFF)	Drag distribution with DRS open (ON)
Front wing assembly	19.0%	20.6%
Front wheels, suspension, brake ducts	8.1%	10.2%
Chassis, bodywork	13.0%	13.2%
Floor and Diffuser	6.3%	5.8%
Rear wheels, suspension and brake ducts	23.3%	26.2%
Rear wing assembly	30.3%	24.0%
CD	1.173	1.083

a seemingly modest component, designed and located correctly, can make a really significant difference.

DRS code

In 2009 the rules for rear wings in F1 changed so that they became much narrower (750mm instead of 1000mm) but with the same maximum chord, and were mounted significantly higher (maximum height became 950mm from the reference plane instead of 800mm). They were, therefore, located in slightly 'cleaner' air, but the loss of 25 per cent in plan area meant they were considerably less potent than previously. This was all part of a broad raft of changes made to enable the cars to run close together more easily, the aerodynamic changes focussed on reducing total downforce and cleaning up the cars' wakes. However, two years later the 'Drag Reduction System' or DRS became an integral part of the rear wing in order to further increase overtaking opportunities. DRS together with the 2009 dimensions and location of the rear wing were still in use in 2013, and indeed are currently.

MA: 'The rear wing on the pre-2009 cars had a strong interaction with the diffuser which in turn drove the underbody, working as a system. In 2009 wing height was increased to reduce that interaction. However, the interaction still exists and we can see that by looking at the DRS system. The wing produces a strong upwash that interacts with the diffuser and lower beam wing on our 2013 model, whereas a DRS activated wing changes things significantly.

'The DRS system is there to reduce drag on the straights. Simple explanations say that the flap opens up and the stagnation region (and associated high pressure) on the flap's forward facing surface reduces, and the suction on the other side of the flap diminishes, too, jointly reducing drag as a result. However, there is more to it than that. Once the DRS is activated, the strong up-wash component reduces, which can be seen in **Figure 16**, where slices of total pressure at the longitudinal centreline of the two set-ups are compared, one with DRS open (ON) and one closed (OFF). The resulting changes are apparent in the delta_Cp plot **Figure 17** where the under floor and diffuser region have clearly lost downforce.'

Figure 18 is a delta_Cp plot showing two views of the rear of the car, comparing with and without the DRS activated. It is evident that not only has the high pressure on the wing's upper surface reduced and the low pressure on the lower surface of the wing increased (both leading to less downforce from the wing), but the pressure on the underside of the lower beam wing has increased, also contributing to the reduction in downforce. So the downforce contributions of the wing, the lower beam wing and the diffuser and main floor all reduce when DRS is deployed, and this results in a fairly significant shift in balance too, as **Table 9** summarises.

The change in drag is, as stated earlier, what DRS is all about, and **Table 9** shows that drag reduced by 7.7 per cent with DRS open. By looking at the force distributions we can see that the dominant source of drag reduction is indeed the rear wing, as shown by **Table 10**. The proportions in the 'DRS open (ON)' column are obviously relative to a lower total drag value, which is why some of the smaller percentage changes arise, such as the barely changed actual drag contribution of the front wing, although other smaller changes are due to actual changes in forces. But it is evident that the biggest change was to the rear wing's drag contribution.

So in that respect this simulation bears out that the DRS fulfils its primary purpose; however, what we saw in the preceding paragraphs is that it also makes significant changes to downforce and its distribution.

Summary

We have seen how changing large components (wheelbase) and small details (e.g. diffuser slots or small front flap adjustments) can each have 'global' and sometimes surprising effects on aerodynamic coefficients and balance. In the next instalment we will examine how a switch to ground effect might change Formula 1.

Thanks to Dynamic Flow Solutions for its help with this piece.

Dynamic Flow Solutions

Dynamic Flow Solutions Ltd is an aerodynamics consultancy headed up by director Miqdad Ali, ex-MIRA aerodynamicist, who has performed design, development, simulation and test work at the highest levels of professional motorsport, from junior formula cars to World and British touring cars, Le Mans prototypes, up through to F1 and Land Speed Records.

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Ex-MIRA aero man Miqdad Ali is the boss of Dynamic Flow Solutions Ltd

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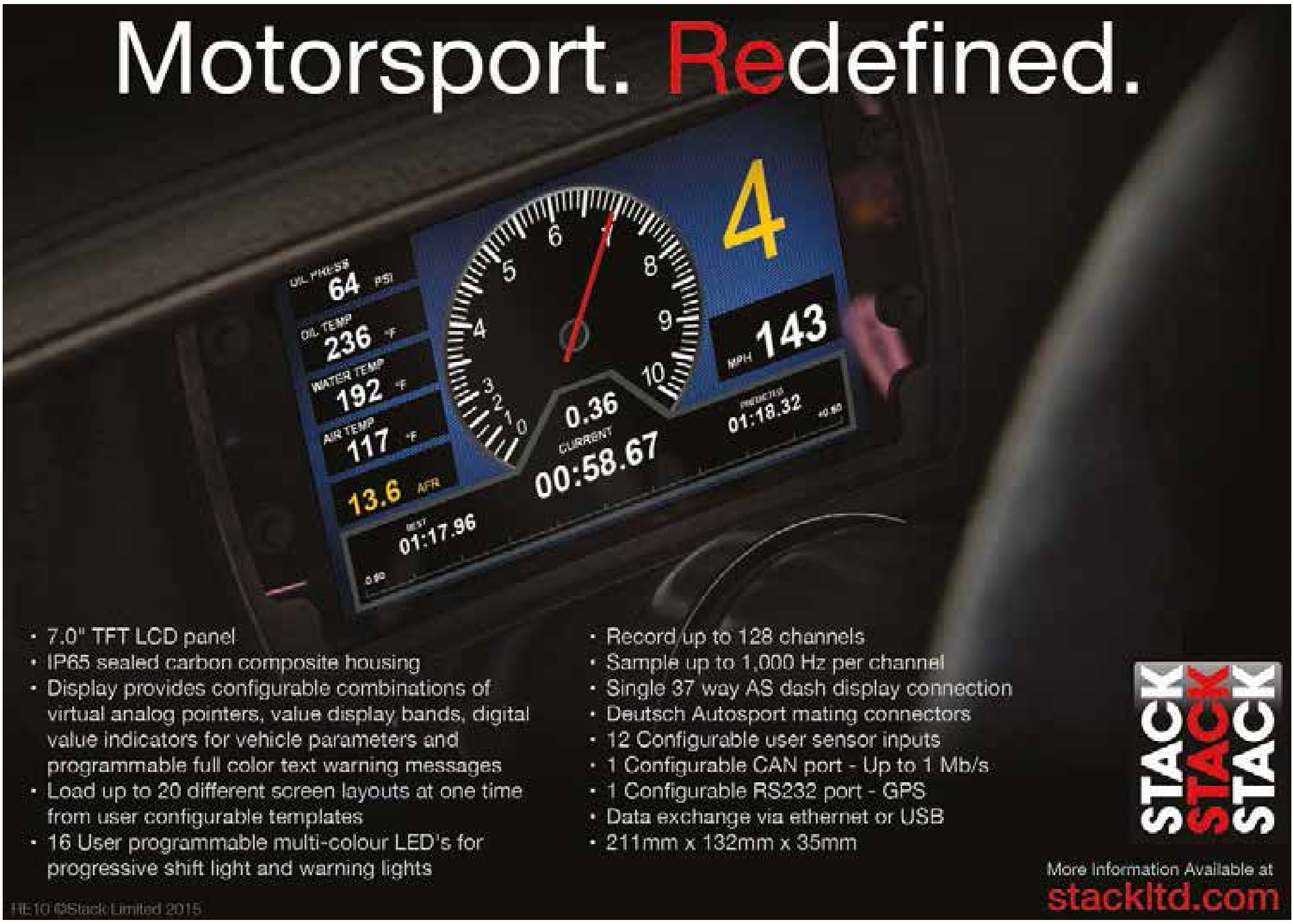
'The rear wing on the pre-2009 Formula 1 cars had a strong interaction with the diffuser, which in turn drove the underbody'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4
MPH 143
PREDICTED 01:18.32
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Air conditioned

A NASCAR aerodynamicist explains how the Sprint Cup is fighting back against race-ruining dirty air at some of its tracks with bespoke aero solutions

By ERIC JACUZZI

Aerodynamics have pushed the capabilities of modern racecars vastly beyond what might have ever been imagined before the science was understood and harnessed to the level it is today. Of course, whether that's a good thing for actual racing – for our sport as a spectacle – is another matter entirely.

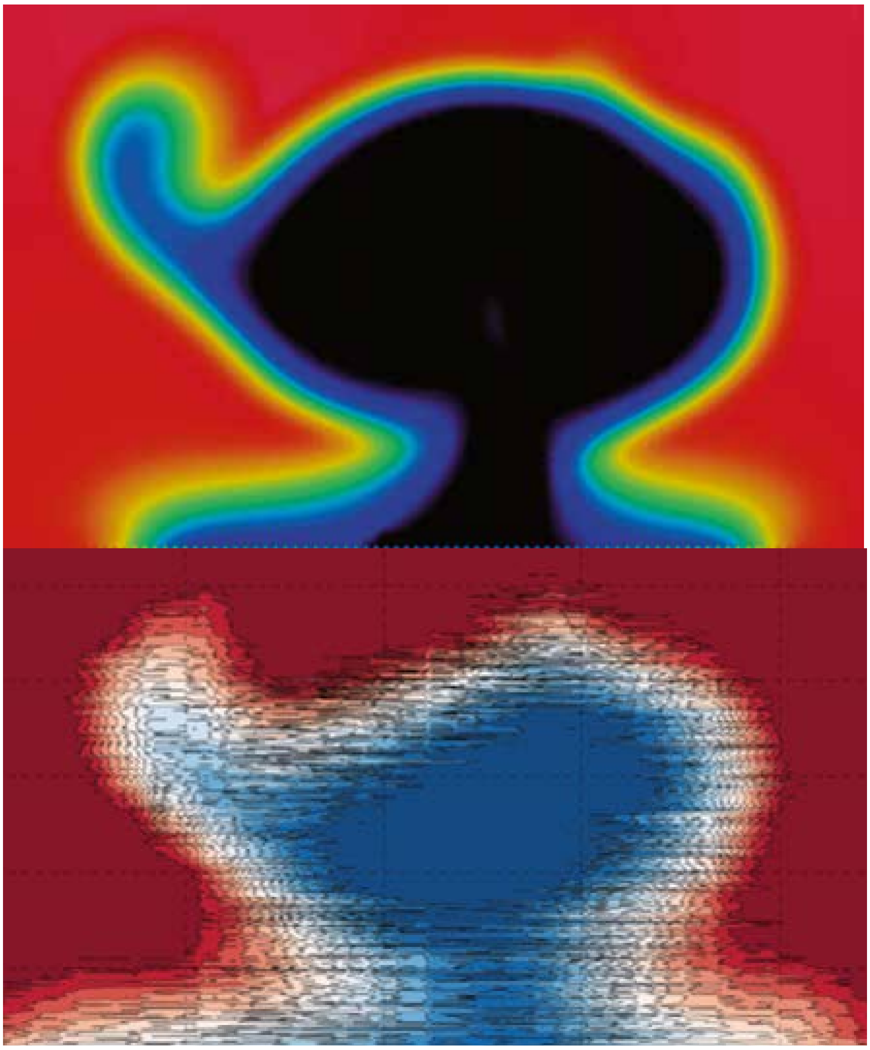
For most major motorsport series the world over, fans do not pay to simply see a single car lap a track as quickly as possible, for while many enjoy qualifying, the main event has always been multiple cars on track. Yet while the track surface itself is the same for every car, the air those cars move through is constantly influenced by the passage of the high speed objects going through it. A car behind needs to run in the wash of the car in front, and while that can be beneficial on a straight, it is not always easy through a corner, and this can have a detrimental impact on the quality of the racing. In an era when the show is always a talking point, it is very easy to see why this has become such a hot topic, particularly in the fan-friendly environment of the NASCAR Sprint Cup [the writer works as an aerodynamics/vehicle performance engineer at NASCAR].

Clean air

A leading car has everything going for it. It's probably the fastest car on the track. The driver has no traffic to contend with (except for lapped cars) and he or she can focus on driving perfect corners. Aerodynamically, the air passing over and under the car has the maximum energy possible to be converted into downforce, as well as sideforce in oval racing. Depending on the vehicle shape and downforce generating mechanisms, air is moved opposite to the direction of force. Generating downforce results in a wake that moves upward, while in NASCAR there is also a movement of air to the right of the tail of the car due to the sideforce generation. Plots of both the Computational Fluid Dynamics (CFD) calculated wake and the wake measured via Kiel probe rake are shown in **Figure 1**. In addition to the upward movement of air, there is entrainment of air – air that is pulled along with the car due to the movement of the car through the air.

For the trailing car this moving column of air behind the lead car is both a blessing and a curse. On a straight, the entrained air means less energy for the car to push through, resulting in

Sprint Cup cars are at their limit through the four corners, while an IndyCar can run very near to flat out around Indianapolis



Main Pic: Kentucky has low drag package. Figure 1(above): CFD Predicted NASCAR Sprint Cup car wake *vs* aero rake measurement at wind tunnel. Note the boundary layer development due to cessation of boundary layer suction/blowing toward the rear of car

drafting. But the curse occurs when that same reduced energy is needed to produce cornering forces. The result of this depends on how much aero performance is needed to get through the corner. For a corner that is at the limits of adhesion, any loss of aero performance will result in reduced lateral cornering capability and a time loss compared to the leading car. If the corner does not require maximum downforce for the car to navigate it at maximum speed, there will be little to no implications on the car's performance due to the 'dirty' air it is experiencing. An example of this is any car going down a straight, or highly banked ovals such as NASCAR's Daytona and Talladega tracks, where the car is easily able to navigate the large radii and high banked corners with no downforce.

There is a saying beloved by many motorsport fans and drivers that goes something like this: 'if there isn't any downforce to begin with, there won't be any to lose in traffic'. It's easy to accept that if we evacuated all of the air at a race track, and somehow could still make the engines work, there would be zero aerodynamics to contend with (and no drafting), and racing would be determined purely by mechanical grip and the driver. Since we can never achieve this, we have to accept the fact that aerodynamics will play a role in the car's performance no matter what. So, if we move the total downforce up and down, what is the effect?

In total magnitude, a reduced level of total downforce will fluctuate less in traffic. However, the percentage change is nearly the same. Sideforce fluctuations buck this trend, and change on a similar magnitude due to the fact that the body shape is responsible for the vast majority of sideforce generation. In NASCAR, lap simulation of vehicles in traffic yields a similar time loss between a low downforce package, and the 2015 intermediate rules package. The major drawback of low downforce is the resultant low drag of the vehicle. With drag being extremely low to begin with, the draft is nearly non-existent. Thus, there is no real advantage to be gained while behind another vehicle and only losses will be encountered.

Kentucky low drag

The characteristics of tracks on the NASCAR calendar vary wildly, from the 0.5-mile paperclip shaped Martinsville Speedway, to highly banked

The moving column of air behind the lead car is a both a blessing and a curse

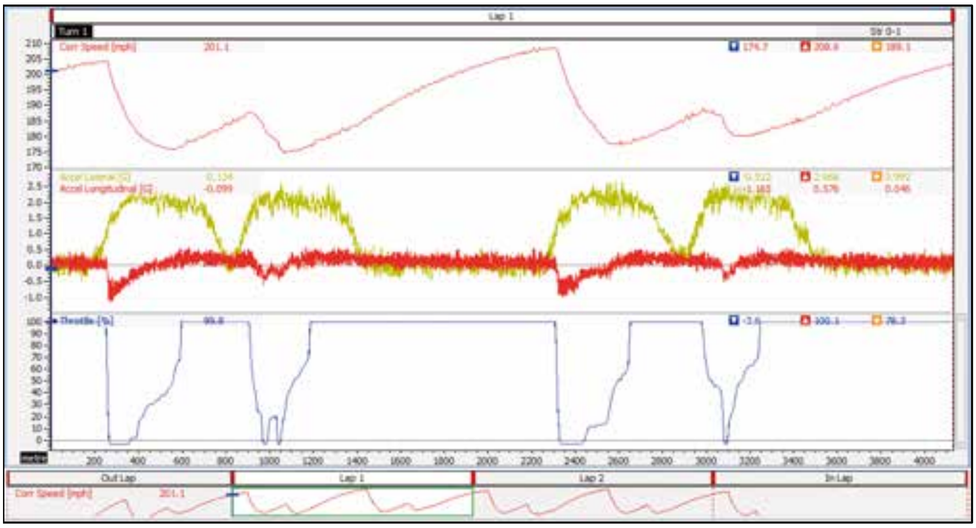


Figure 2. Indianapolis lap in 2014 configuration – blue trace shows the Sprint Cup car is on the limit in each of the four turns

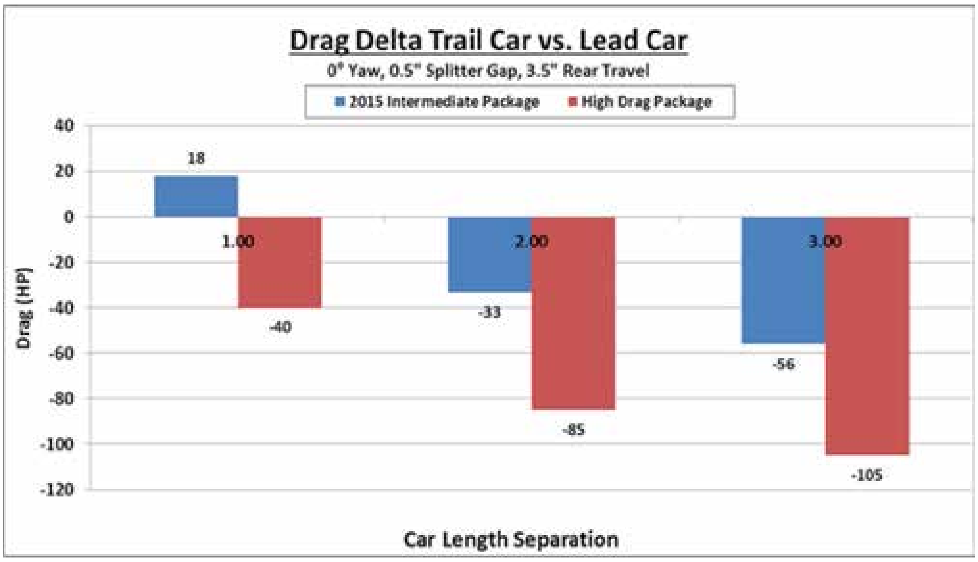


Figure 3. Drag deltas for both a leading and a trailing Sprint Cup car with current 2015 and Indianapolis high drag packages

1.5-mile ovals like Charlotte and Texas, to unique long and low banked tracks like the 2.5-mile Pocono and Indianapolis.

While these tracks are very different in their demands, there has historically only been two rules packages: the superspeedway package for Talladega and Daytona, and then one for everywhere else, for reasons of simplicity and costs. This leads to some tracks being more suitable to the car performance parameters, rather than varying the car to specific tracks.

At Kentucky Speedway, an extremely rough 1.5-mile oval that has not always generated the best racing, NASCAR made the decision to reduce downforce by approximately 1000lbf (lb-force). At 200mph, a Kentucky car made approximate 1700lbf of downforce with around 850lbf of drag. This was achieved by reducing the splitter overhang by 1.75in from the front of the car, and reducing the radiator pan size to 25in in width. The radiator pan forms the diffuser surface for the splitter, for those not familiar. Rear spoiler size was reduced to 3.5in.

The tyre compound was not altered to provide more grip, and practice lap times were in the order of 1.2 seconds slower than the lap times from tyre testing earlier in the year. The cars proved difficult to drive on the bumpy surface, leading to a record number of caution flags and a noted increase in overtaking throughout the field.

This race was much re-viewed by drivers and fans alike. Yet a wind tunnel impound test of three cars after the race showed that race performance was not directly linked to aerodynamic performance at this event. There was a complicating factor: a major reduction in practice time due to rain may have helped with the excitement, as many teams struggled with set-up early on in the race.

Indy aero

There are two main 'crown jewel' races in NASCAR: the Daytona 500 and the Brickyard 400 at Indianapolis. Yet while NASCAR has now been racing at Indianapolis for 21 years, it has struggled at times with the realities of the track, especially in comparison to IndyCar and its iconic Indianapolis 500.

Why is this? Let's take a look at what makes a lap at Indianapolis. The track is 2.5 miles in total length, with four identical turns, banked at 9 degrees, 12 minutes, with two long straights at 5/8 of a mile, and two short chutes of 1/8 mile between Turns 1-2 and 3-4. In 2014, this meant a 200mph-plus entry at the end of the straights, followed by heavy braking, and cornering at around 175mph. The track is approximately 50ft wide, so there is only a single racing line for Sprint Cup cars through the corners. The only way to successfully execute a pass is on the long straights, with the passing car getting back into position to take the optimum line through the corners.

Sprint Cup cars are at their limit through the four corners, as evidenced by the blue throttle trace in **Figure 2**. While an IndyCar can run close to flat out around Indianapolis, every ounce of mechanical and aerodynamic grip is required to run as fast as possible for a NASCAR Sprint Cup car. Even if the leader is only the slightest fraction of a per cent better, over the course of 400 miles this translates into a considerable gap. The only recourse is to offer some sort of advantage to the trailing car. Without gimmicks like increasing engine power or reducing aero drag, drafting is the only way to achieve this goal. But how strong does the draft need to be to counteract cornering losses?

High drag package

After the decision was made to attempt to improve the racing at Indianapolis – and at Michigan – CFD studies were initiated to determine how much drag could be added to the car and how effective it could be expected to perform. **Figure 3** shows the drag difference between a trail and lead car. Currently, at three car lengths back, there is a 50-60 drag horsepower advantage for the trail car. However, as the car approaches the leader, this advantage is gradually reduced and by one car length it actually inverts and the trailing car has more drag than the leader.

Since the goal was to add as much drag as possible to the cars and make the largest wake for drafting, a 9in spoiler with a 1in wicker were used. The wicker is mounted perpendicular to the spoiler, and is an incredibly inefficient device, adding on the order of a pound of drag for a pound of downforce. The wicker also provided an opportunity to reinforce the polycarbonate spoiler extension with a composite band. The total drag ended up in the order of 720 drag horsepower, substantially reducing the top speed of the car.

Controlling the downforce was the next challenge. Lowering the tail of the car

The Penske No.2 NASCAR Sprint Cup entry sporting the Indianapolis spec high drag package in the Aerodyn wind tunnel

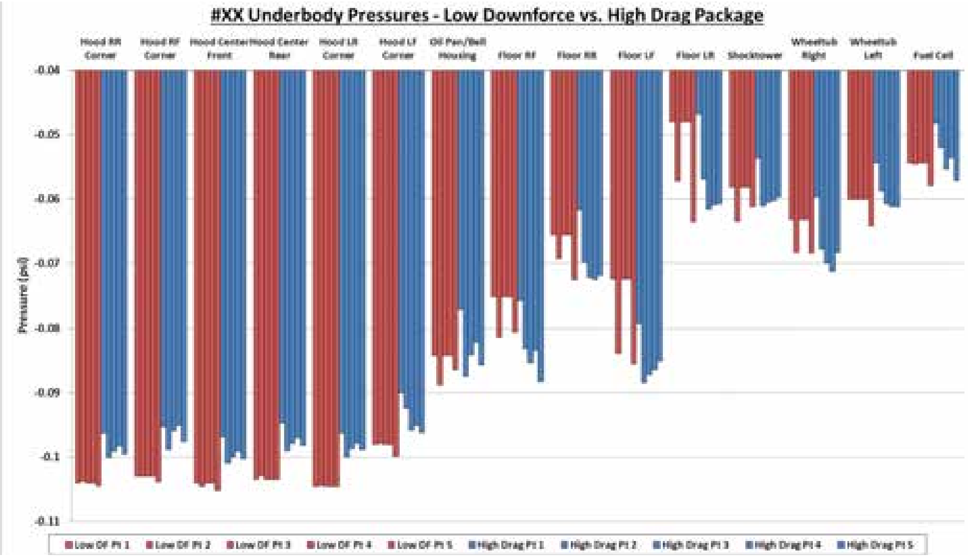


Figure 4: Underbody pressure comparison of low downforce Kentucky car compared with Indianapolis high drag package

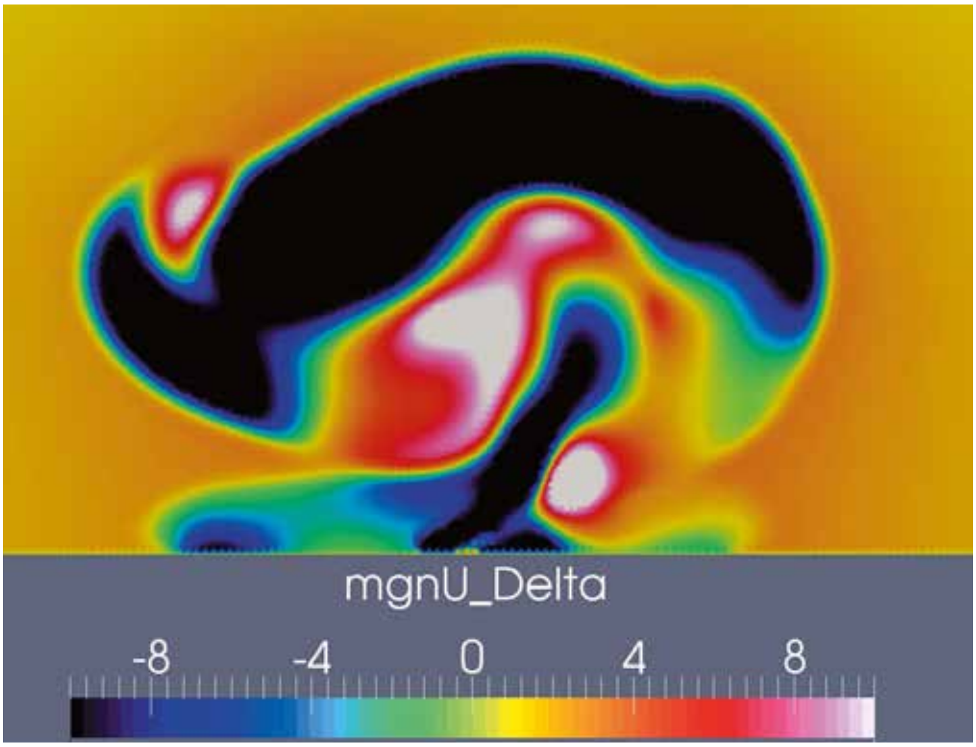


Figure 5: Wake delta between current 2015 Sprint Cup intermediate rules and the Indianapolis high drag package – latter has less total downforce variation on trailing car. Black regions indicate lower energy areas and a more favourable draft

with NASCAR's existing superspeedway tail extension not only helped make a larger wake, but also cut the downforce potential of the large spoiler by over 1000lbf. This resulted in around 2500lbf of total downforce at 200mph. The package is shown in the picture (left) on Brad Keselowski's No.2 Penske Ford Fusion at Aerodyn Wind Tunnel, where we tested the Indy package on the three race cars impounded from Kentucky, to verify performance estimates.

An interesting characteristic of this package is that by extending the tail to counteract the large spoiler, downforce was redistributed from under the car to the outer body. This was predicted in CFD and verified with undercar pressure taps to compare the low downforce Kentucky package to the same car fitted with the Indianapolis high drag package, as plotted in **Figure 4**.

This raised an interesting in-race learning experience on whether more downforce on the body is better than relying on the underbody. The general industry consensus is undercar aerodynamics are better in traffic, but this has been contradicted by CFD and wake measurements which indicate a NASCAR Sprint Cup car leaves a large wake on the ground behind the car. Coupled with the fact that the sedan body generates positive lift, any time it is in the wake of the car in front the greenhouse actually gains downforce. This is reflected in the CFD results that show the high drag package actually has less total downforce variation on the trailing car than the current rules package. Wake variation between the two packages is shown in **Figure 5**.

Moving to lap simulation, the predicted effect of the draft from the high drag package is shown in **Figure 6**. The green trace represents track test data from a 2014 specification car. The red trace represents a single car with the high drag package, lapping approximately 1.4 seconds slower and reaching a top speed of 192mph *vs* a 2014 peak speed of 208mph. The black trace represents a car in the draft three car lengths back, with the ChassisSim model activating the drag delta using the DRS option on the long straights only. The drafting car would come to the end of the straight going 5.6mph faster than the isolated car, covering five to six car lengths at 200mph. The total time advantage is 0.6 seconds per lap. The hope was that the increased draft advantage would outweigh cornering losses.

Indianapolis race

While there was an observable gain in drafting performance by the Sprint Cup cars at Indianapolis, overall the effect was not as pronounced as hoped. Post-race analysis showed there were two major factors at play: cornering losses resulting in reduced corner exit momentum, and difficulty in obtaining the optimum lateral positioning to capture maximum draft advantage.

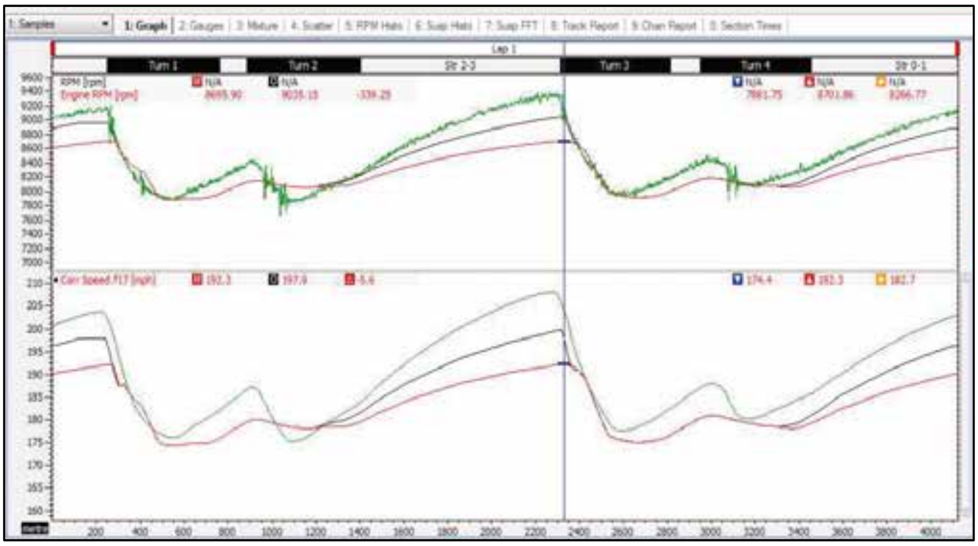


Figure 6: ChassisSim Indianapolis lap simulation for a Sprint Cup car – green trace is 2014 car, red is high drag package

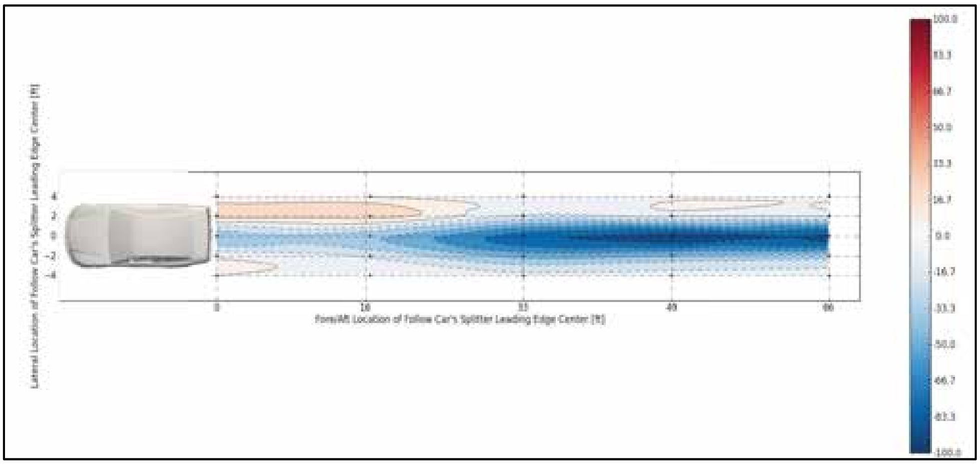


Figure 7: Drafting position sensitivity – scale is in drag horsepower. A narrow wake limited the ability to produce drafting

The momentum problem was created by Turn 2 and Turn 4 at Indianapolis. Since the cars could not take the corner flat out due to mechanical grip and downforce limitations, the second place car was at a cornering disadvantage. This resulted in a cornering speed loss and thus, distance loss on the lead car, which played into a reduced draft due to separation distance. Drivers described a 'loose' handling condition, also known as oversteer.

While an increase in spoiler size contributes to dramatic increases in downforce, the spoiler itself contributes something in the order of 150lbf to the total downforce of the car. The majority of the downforce increase is due to increasing separation on the lift-generating greenhouse, which by nature is centred on the car. Overall downforce levels were lower than the 2015 intermediate track rules package due to a lower tail height, which does not allow the underbody to work as effectively. Downforce does not appear to be contributing to the handling evils.

The large spoiler does not escape blame, though. The spoiler itself contributes nearly all of the drag increase, and thus exerts an approximate 500lbf contribution to the drag of the vehicle. Since the tail of the car is offset 4in to the right to generate sideforce, the spoiler is also 4in to the right of vehicle centre-line. The centre of pressure of the spoiler is thus offset to the right of vehicle center-line, causing a dramatic rise in rear sideforce. In comparison to the Kentucky low downforce package, the yaw moment of the vehicle increased by over 200 per cent.

This is perfect for driver stability, a car with great rear cushion. However, in traffic, when the spoiler met the wake of a car in front, it reduced the yaw moment of a car that was already set in the corner and utilising maximum downforce and rear sideforce. The effect of the wake was thus a dramatic snap oversteer condition, causing a lack of driver confidence and inability to carry sufficient momentum through the turns before the long straight.

The second major contributor was the narrowness of the wake. Even with the very large spoiler, the wake of a Sprint Cup car is mostly confined to the vehicle width. This is in contrast to the relatively wide wake of an open wheel car, caused by the exposed tyres. The effect means that even a 2ft lateral offset from centre-line meant a 50-85 per cent less effective draft, visible in **Figure 7**. This was particularly pronounced in race conditions with a lead car moving with the intent to shake the draft and the trail car having to react and attempt to maintain the best position.

The next steps

At the time of writing, both low downforce and high drag packages were still to have another opportunity on track at Darlington and Michigan respectively. One variation was that the Southern 500 at Darlington was to have a Goodyear tyre specifically designed for the track and downforce level, with hopes high that varying tyre falloff will lead to more variation and passing throughout the field. The tyre features an increase in grip when compared to the tyre last raced at the circuit.

The ultimate goal is not to find one perfect rules package for all of the tracks, but use track characteristics to craft the best solutions for the many challenging tracks on which NASCAR races. Furthermore, work continues to make the cars race as competitively as possible at every venue.

On some tracks, this may mean low downforce, while on other tracks drag will play more of a factor. This not only gives the drivers more unique challenges on the demanding NASCAR calendar, but gives fans the opportunity to see the best stock car racers deal with varied tracks and vehicle characteristics week in and week out.

Meanwhile, work continues with an experimental low downforce, low sideforce racecar to make its testing debut at Kansas Speedway in mid-September. It is hoped this experimental vehicle will further our understanding of the relationship between aerodynamic forces and their ability to influence racing quality.

The real point is that, unless we can convince the racing industry to collectively forget all it has learned about harnessing the air to make speed, we must accept that aerodynamics will be both our friend and enemy for a long, long time into the future. Management of this powerful force will continue to be of paramount importance for all parties in the motorsport community.

The high drag package actually has less total downforce variation on the trailing car than the current rules package

L'Ouest inquest

The numbers for the GT-R LM appeared to add up before Le Mans, but the cars failed to perform and were not at the Nurburgring for the WEC event. So what went wrong for Nissan?

By DANNY NOWLAN

Nissan's GT-R LM was way off the pace at Le Mans but our numbers man argues that at heart this is still a worthwhile concept if the problems can be fixed

One of the ingredients that spiced up anticipation for the 2015 Le Mans 24 Hours was the participation of Nissan's GT-R LMP1 car. Much was written about this car going into the event, and some of it was optimistic. Some believed the car would do well and I for one was very enthused by the potential of its design. But the results did not live up to the promise. With a qualifying time of 3:36.995s Nissan was trounced by the other LMP1 cars. The race results where no better, either, with just one car making it to the end of the race, finishing last in LMP1.

What we'll be discussing in this article is my take on what went wrong and, perhaps more importantly, how it can be fixed.

Before we begin let me state that I do not intend to rewrite history. One of my pet peeves is that when things go wrong, often everyone goes into a defensive mode, refusing to take responsibility. It is a cancer that has infected western society and I have no interest in jumping on that bandwagon. For the record I stand by every word I stated in my original feature on the GT-R LM (May, V25N5). There are some strokes of genius in this car and it is a project that deserves to be continued.

However, ultimately the two factors that let this car down was the front weight distribution of 66 per cent and no rear wheel drive KERS. The first factor was actually an oversight in my first article and I should have been more on the ball with that. In my defence I was focusing more on the potential of the design, but I should have taken this into account. The second aspect of no rear wheel drive KERS was the equivalent of going into a gunfight with a laptop. When I arrived at Le Mans and the Nissan boys told me this I just shook my head and I figured 'you boys are going to have a rough week'. We'll be exploring both of these elements in detail.

First things first, before we do any simulation lets look at some basic numbers at a weight distribution of 66 per cent. To illustrate this let's consider some basic car parameters. For effect I'm going to trim the weight from 1000kg to 900kg. This is no accident and you'll see why I've done this shortly. Parameters shown in **Table 1**.

Where things get really interesting is when you take into account load transfer

Just for the record, the peak lateral and longitudinal *g* has been taken from customer LMP1 data. Let's now have a look at how the corner weights vary from static conditions to a speed of 120kmh and 220kmh, which are typical cornering speeds at Le Mans. These where calculated using the **Equation 1.**

Here *wd* is the relevant weight distribution and *V* is in m/s. I'm also assuming the aero distribution is the same as the weight distribution. The corner weight results are presented in **Table 2**

Load transfer

Before we have done anything you can see the front tyres are going to get a workout. Where things get really interesting is when you take into account load transfer. Working this out for each corner weight we have, **Equation 2.**

Here *prr* is the lateral load transfer distribution at the front, *LTax* is the load transfer due to longitudinal acceleration and *LTAYF* and *LTAYR* are the load transfers due to lateral acceleration for the front and rear. Crunching the results the numbers are shown in **Table 3.**

This analysis shows very clearly that the central problem is the front tyres are taking far too much load. This is as clear as a bell looking at **Tables 2 and 3.** Firstly, in a high speed corner we could potentially be looking at a front load of 900kg. In practice you would run less front lateral load transfer. Most likely this will be in the order of 50 per cent. However, this raises another problem. As we shift the lateral load transfer to the rear we'll start unloading the inside rear tyre. Do really want to be doing that in the middle of the Porsche curves? The other case to consider is braking into a low speed corner. If we look at the 120kmh case the rear tyres are very light loaded. They would be carrying a load of 70kgf (kg-force). You don't have to be a rocket scientist to see you're painting yourself into a few corners here. A graphic illustration of this is shown in the picture (right). Note the inside rear wheel lifting clean off in the mid corner. This is the situation you are dealing with. Also the very sobering thing is we haven't taken into accounts bumps yet, and we underestimated the weight.

To put things in perspective, re-do these numbers for a rear wheel drive car with a 45 per cent weight distribution at the front. We'll return to this theme very shortly. Some might counter this by saying that in a rear wheel drive car the front unloads as well. However, there is one fundamental difference here. With a mid engined Rwd car the front provides the steering input and the rear provides traction. As the load shifts to the rear we get stability and the ability to put the power down. In a front wheel drive car in addition to taking the steering input we are also asking the front tyres to provide traction. In addition, typically we unload the inside rear as well. At extreme weight distribution this is not a good situation.

The simulation results reflect the situation that we viewed in our hand calculations. For a front weight distribution of 66 per cent and front wheel drive with the KERS turned off the lap time was 3:37.8s. Our baseline Rwd LMP1 car with no KERS ran a 3:33.7s lap. The reason we have lost so much time is illustrated in **Figure 1.**

The simulation

The Rwd baseline is coloured and the Fwd 66 per cent front weight distribution is black. While the steering hasn't massively increased (since ChassisSim is driving to the grip) the damage is done at mid corner to turn exit. The standard LMP1 car was 142kmh. The 66 per cent Fwd car was 135kmh and this was reflected with turn exit condition as well, where the speed was down by 10kmh. Having engineered a high powered and high downforce front wheel drive car, I've also seen this in actual data. To be honest I was expecting the simulation results to be a lot worse than this.

Table 1 - Base Nissan GT-R LM Parameters

Paramater	Value
Car mass	900 kg
Front weight distribution	66 per cent
CLA	4
Cg height	300mm
Aero distribution at the front	66 per cent
Peak longitudinal *g*	3*g*
Peak lateral *g*	3*g*
Wheel base	3m
Mean track	1.6m

Table 2 - Corner weights for the Nissan GT-R LM

Condition	Front corner weight (kg)	Rear corner weight (kg)
Static	297	153
120 kmh	388	200.2
220 kmh	605	311.7

Table 3 - Load transfer loads as corner weights

Load transfer case	Magnitude (kg)
Longitudinally	135
Front lateral load transfer case	334
Rear lateral load transfer case	167

EQUATIONS 1 and 2

EQUATION 1

$$cw = wd \cdot \left(m_t + \tfrac{1}{2} \cdot \rho \cdot V^2 \cdot C_L A\right) / 2$$

EQUATION 2

$$LT_{ax} = 0.5 \cdot \frac{m_t \cdot a_x \cdot h}{wb}$$

$$LT_{ayf} = prr \cdot \frac{m_t \cdot a_y \cdot h}{tm}$$

$$LT_{ayr} = (1 - prr) \cdot \frac{m_t \cdot a_y \cdot h}{tm}$$

One of Nissan's GT-R LMs in mid-corner at this year's Le Mans 24 Hour race – the inside rear wheel is clearly off the deck

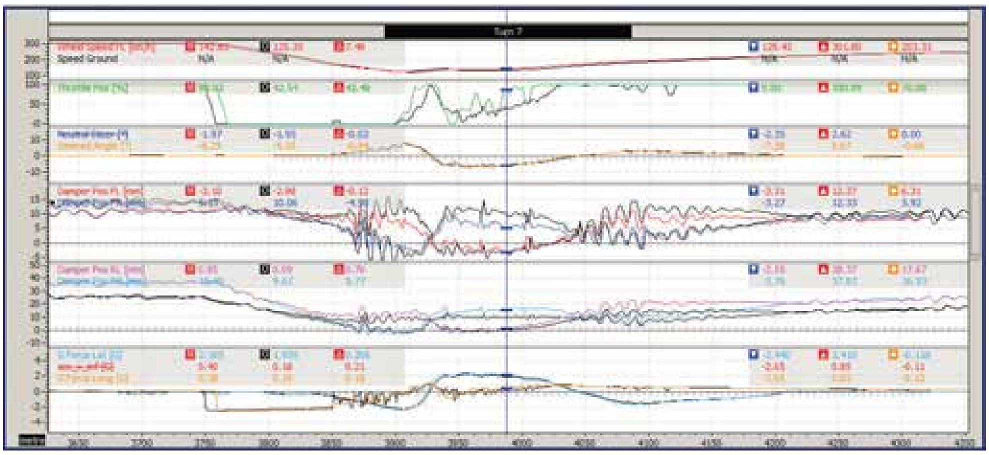


Figure 1: Comparison between standard rear wheel drive and the front wheel drive with 66 per cent front weight distribution

Figure 2: Graphic charts the maximum available longitudinal force at the rear – bottom trace is available force at corner exit

EQUATIONS 3

EQUATION 3

$$P_A = (157/3.6)\cdot(710+710)\cdot 9.8 = 606kW$$

Ultimately, two factors that let this car down was the front weight distribution of 66 per cent and that there was no rear wheel drive KERS

The Nissan personnel will counter this by saying 'we have tyres custom made for us', but there are two pitfalls here. Firstly Michelin have a lot of experience in building tyres that can carry 55 per cent of the load distribution of an existing LMP1. However you have just asked Michelin to up this to 66 per cent. You're asking the tyres to put up with at least another 100kgf of load at least and produce the same co-efficient of friction. I'm no tyre expert, but is this a bridge too far? Michelin would probably be the only tyre company that I know of which could attempt this, but even assuming they succeed (and this is a big if) if I was Porsche and Audi I would be raising holy hell.

The other thing that played against Nissan was the limit on the KERS and not having it rear wheel drive. Just before Le Mans the energy recovery of the Nissan GT-R LM was downgraded from 8MJ to 2MJ. Despite the weight you incur with a KERS system this is going to hurt. This is because you've just cut your effective push to pass potential by a factor of four. To put this in perspective, even with a KERS discharge limit of 80kW it effectively works out in the order of 80Nm of extra engine torque. To have that limited is devastating.

However, the real killer here was not having the KERS discharging at the rear. This meant you lost the effective all wheel drive capability this design has to offer. To remind everyone of what you've just walked away from, let me present the potential of what we had available. Looking at the sim results of the weight distribution at 60 per cent that we performed in our previous article, one of the channels that ChassisSim returns is the maximum available longitudinal force available from all four wheels. Looking at the rear tyres we see the results in **Figure 2.**

Discarded boost

I would draw the readers attention to the bottom traces which shows the available longitudinal force at turn exit. At a speed of 157kmh we have an available longitudinal force of 710kgf per rear tyre. In terms of available power take a look at **Equation 3.**

What this means is we have a potential of 606kW on tap at the rear. In reality it will be much less than this because the rear tyres have to corner as well. Let's just say for the sake of the argument it is 300kW of power you can use from the rear tyres. What this means is KERS used the right way means we effectively get a turbo boost. When you're competing against well sorted and well founded opposition from Audi and Porsche you just can't afford to give away this sort of an advantage.

However, the good news is all this is eminently fixable …

Playing the percentages

First things first, don't be too surprised to see the weight distribution move back to 60 per cent. This will be for three reasons. Firstly the tyre loads we discussed in **Tables 1 – 3**. At 66 per cent front weight distribution we had painted ourselves into a corner. However, I invite the reader to work the numbers at 60 per cent and you'll see the situation is a lot healthier. Also our sim results showed from the May issue article that the performance at a 60 per cent was comparable to the rear wheel drive LMP1 car.

The second reason is that at 60 per cent front weight distribution you've just given the tyre manufacturer a more straightforward job. Now you are only asking Michelin to come up with tyres working at maybe 50 to 100kgf extra. This should not be a bridge too far and Audi and Porsche can't complain too much, since it will have knock on effects for them, too.

The third and final reason is energy recovery. KERS works by taking the available tyre force at the rear of the car and using that to store the Hybrid energy. It's why modern F1 cars and Formula E cars run very far forward brake bias. The excess rear tyre force is charging the KERS and contributing to the braking. With more weight at the rear of the car two things are going to happen. You'll be able to charge more since you'll have more tyre load and you can also discharge more energy since you have more load at the rear to put the power down. As we saw in the analysis in **Figure 2**


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Table - 4 Limit calculation numbers

Paramater	Mass	xlocation
Car without battery	850kg	1.2m
Battery pack	150kg	3m

EQUATION 4

EQUATION 4

$$x_{cg} = \frac{\sum m_i \cdot x_i}{\sum m_i}$$

$$= \frac{850 \cdot 1.2 + 150 \cdot 3}{850 + 150}$$

$$= 1.47m$$

$$\therefore wdf = \frac{3 - 1.47}{3} = 0.51 = 51\%$$

you have effectively opened up the potential of transmitting 300kW at the rear for a front weight distribution of 60 per cent. This is effectively all wheel drive for free, and 4wd is one of the key reasons the original Nissan Skyline R32 GT-R made the opposition at Bathurst look totally ridiculous in the early '90s.

Also, the other change I would make is to shift the car to an electric energy recovery system as opposed to a mechanical one. This is nothing against Flybrid. Just for the record if you were running a rear wheel drive LMP1 you'd have rocks in your head not to talk to Flybrid. It's a great system and the guys know what they are doing. However, for the GT-R I would go electrical as opposed to mechanical.

The primary reason for going electrical is that you can use the batteries as ballast for a chassis tuning device. To recall some calculations from my previous article, let's calculate a limit c.g based on the assumptions outlined in **Table 4.**

The xlocation is measured from the front axle. We are assuming a weight distribution of 60 per cent on the front axle without a battery pack. Calculating the c.g location longitudinally we see the result in **Equation 4.**

As can be seen the c.g limit is 51 per cent. What I have presented here is an extreme case, but it shows you have plenty of flexibility in fine tuning where you want the c.g. This is manna from heaven for a race engineer.

In closing, the two things that were the undoing of the Nissan GT-R LM was its far forward c.g distribution and the lack of rear wheel drive KERS.

As we saw from our hand calculations and simulation results with the 66 per cent front weight distribution. we had painted ourselves into a corner. Also, the lack of rear wheel drive KERS really hurt.

However, the brilliant news about this is that not only is all of it fixable, but when it is fixed this thing will go like a bullet. Having seen this car up close and personal there are some strokes of genius. I have no doubt that with the c.g shifted further back (the analysis we did in the last article showed 60 per cent was very good) and the rear wheel drive KERS back on, the GT-R LM could be giving Audi and Porsche a genuine run for their money. It will be interesting to see how this plays out.

The brilliant news about all this is that not only is all of it fixable, but when it is fixed the Nissan GT-R LM will go like a bullet


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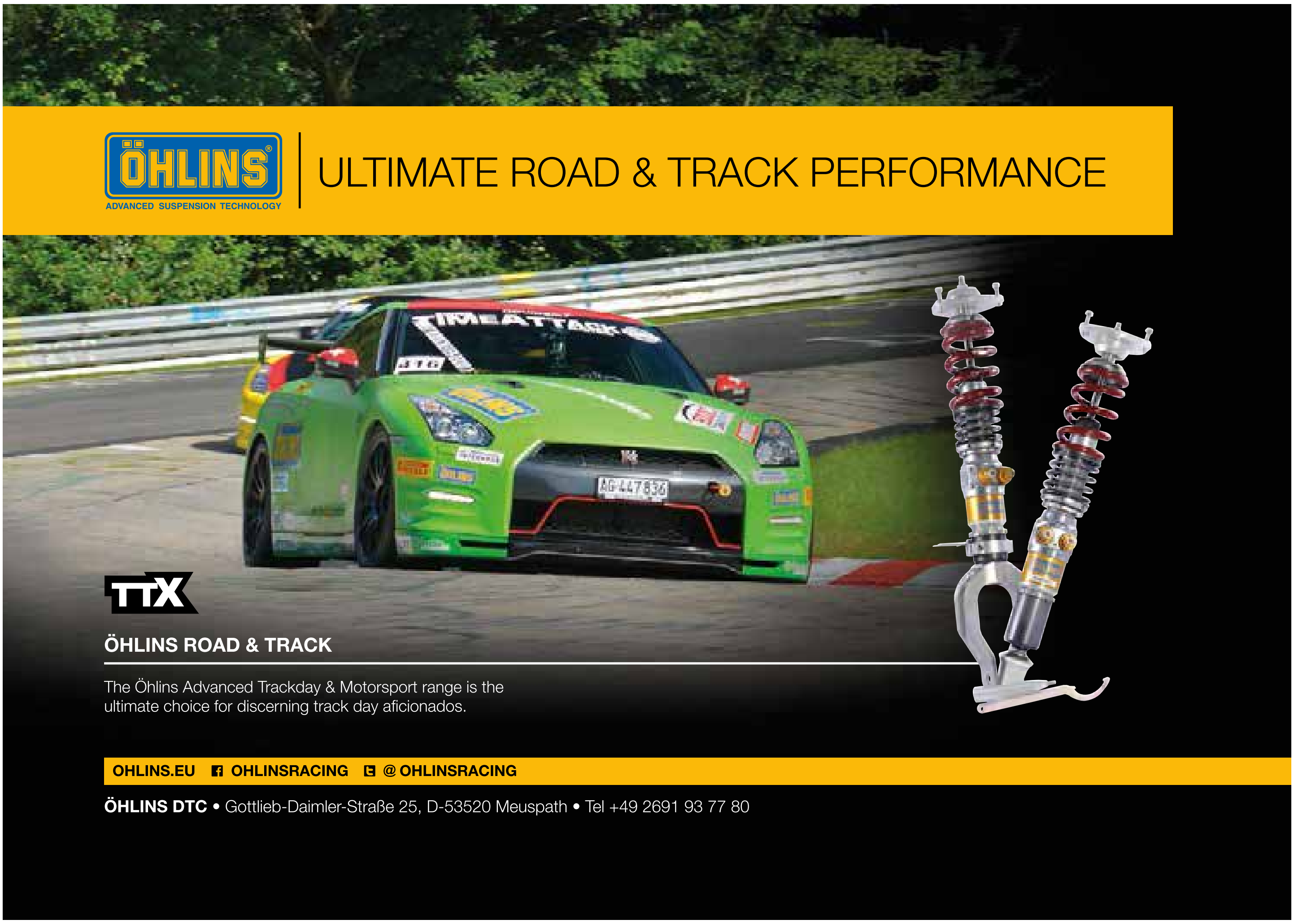
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Slick and tyred

Pirelli introduced a new GT endurance tyre for 2015 – but at Spa the lack of preparation by some teams with the new rubber was exposed

By ANDREW COTTON

This year's Spa 24 Hours was the perfect test for Pirelli's endurance tyre with the usual four seasons in one day adding to the fun in Belgium

Pirelli's new endurance GT tyre was developed with the aim of giving the teams more reliability as the loads are spread better across the tyre, yet not all of the teams got to grips with the new construction immediately, as was shown at Spa in the summer.

This year's Spa 24 Hour race started wet, then dried out slightly in the mid-afternoon, was wet again in the evening and only stopped raining as darkness fell, leaving a wet track and a dry line.

On Sunday morning the track dried out properly, by which time BMW was pretty much established at the front of the field with its Z4 and it increased with well-timed pit stops during safety car periods. However, many expected that Audi's new R8 LMS would challenge strongly on Sunday. Yet although its cars filled the remainder of the podium, BMW held the upper hand at the flag.

The fastest lap of the No.46 BMW was a 2m18.751s, and the average fastest 15 per cent of laps were clocked at 2m20.750s. This compares to a 2m19.348s fastest lap and an average of 2m21.331s for the No.2 Audi, while Mercedes, which was also in the hunt come Sunday morning, had a fastest lap that was more than a second slower than the Z4, but its average was 2m21.144s.

The BMW was given a larger air restrictor for the race, but still felt that the Audi had an overall advantage on balance of performance. One theory for Audi's relative lack of pace in dry conditions was that the manufacturer, having tested extensively on Michelin tyres, then decided to select the largest front tyre available, to its own detriment.

Changed process

While Pirelli's sprint tyre is the same as in 2014, for the long-distance races the cars had to be set up very differently. 'The material and geometry are similar, but we changed the process of constructing the tyre,' says Pirelli's Matteo Braga. 'The energy is better distributed over the carcass but the compound is the same. It is just stressed less and therefore lasts longer.

'The cars are optimised more on our rubber because the teams have more knowledge of it. At Monza, the cars were about one second faster and at Ricard it was something like six tenths of a second.

'Because we use the endurance series as a proving ground for the GT tyres, we decided to move forward with the product in terms of reliability and consistency. We kept for the sprint the same product as last year. It is less important for reliability and the mileage, they have half an hour maximum. The set-up of the cars are very different because they push the tyres to the limit in 30 minutes and last year they could run the same tyres in one hour and a half. This year, we use the same compound, but the construction in terms of pure performance is not a huge difference.'

One of the key elements to success at Spa is coping with the changes in weather. Unlike a sprint race, where the car can be optimised at the start, in endurance racing the set-up must last for 24 hours, and often compromises need to be made.

The winning BMW really started to show its pace during the night but it was fast in all conditions and used the Pirelli tyres to its advantage

Audi lacked pace at Spa. Some said this was because it had tested extensively with Michelins rather than the Pirelli race tyres

In the race, Pirelli and the teams particularly learned from the transition from wet weather at the start, that seemed to suit McLaren, to the dry weather suiting Audi, before BMW started to exert its strength during the night, when the track had a dry line, but was wet off-line.

'In dry conditions it is something that we have already seen in past years, but the wet conditions were interesting for us,' says Braga. 'Particularly the transition from wet to dry. It stayed mostly damp and teams were able to use the slick tyre in not proper dry conditions, and they had confidence in the tyre. That is a good experience for us and for the teams.

'It stayed wet, it stopped raining when the sun was gone, and it only dried up because of the cars, so off-line it stayed wet. The temperature was going down and without the sun out it was not possible to dry out the track. Some of the mistakes of the drivers were due to the fact that the track was not dry. In the dark it is difficult to distinguish what is dry.'

The transition from wet to dry has a dramatic impact on tyre pressures. This was exacerbated by the extensive use of the safety car – a team that predicted dry conditions and sent its car out on to a damp track behind the safety car could safely assume a significant drop in position.

'Some cars were starting, getting some temperatures in the tyres, and then it was difficult to get back to the temperatures,' said Braga of the safety car decisions in the changing conditions. 'When the rain was worse they were too low on the pressures. Some of the teams were happy with the higher pressures, such as the Ferraris and the Audis and McLaren, and some liked to run very low pressures very far from our recommended limit. If it was drying the pressures go up quickly, but if it is wet they stay, or they drop!'

With tyre pressures so critical, it was the cars fitted with tyre pressure sensors that were better able to cope, having identified the pressure problem. Some teams were trying to run with temperatures of around 45 degrees when the optimal operating temperature was above 80degC, but car set-up was also critical.

With BMW producing its new M6 next season, Mercedes the new SLS, Ferrari the new 488, Audi with its R8 LMS for the remainder of 2015, and with all learning more about Pirelli's new tyre, next year could see a startling improvement in the pace of GT3 cars.

The transition from wet to dry has a dramatic impact on tyre pressures. This was exacerbated by the extensive use of the safety car


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New age thinking

An FIA test at Michelin's Ladoux test track in France signals a bright future for GT racing

The new generation of GT cars will be presented to the FIA at Michelin's Ladoux test facility in France in September. Ferrari's 488 featuring a turbocharged engine, Ford's GT, also fitted with a turbo and Corvette's C7R will all undergo analysis in preparation for the Balance of Performance testing based on aero efficiency and power.

The biggest change to the regulations for 2016 is to the aero (see REV25 N8), but teams that have adapted their cars to the new rules have also had to change the roll cages to accommodate an area in the roof for a hatch to help with driver extraction after an accident.

'The changes fall into two categories, one is mandatory changes, the other is voluntary,' says Corvette's programme manager, Doug Fehan. 'The mandatory changes that were the most significant was the development of the roll cage. We had to develop the roll cage to accommodate the ingress and egress of the back board which is something that all the manufacturers agreed to.'

Lighter and stronger

Fehan continued: 'The hatch required a complete redesign of the roll cage from a racing standpoint and a performance standpoint. We developed the cage to be a little bit lighter, and a little bit stronger than before, so it was a three-pronged attack; make it lighter, stronger and allow the hatch. That was probably the biggest change. The rest of the car is essentially the same; we will have a few aero tweaks that we have incorporated into the free area of the bodywork. To the naked eye, you would not ascertain any difference at all.'

The roll cage was already the lightest, most efficient cage that the team could design, and taking out tubing around the driver will change the way that the cage deals with a big impact. 'We tried to create the same load paths, without any change in the load, so we didn't want to overload one particular area,' says Fehan. 'The biggest challenge was developing the system on top that would equally distribute the load as before. It is pretty much all in the roof. The mounting points and fixing points are all identical, the tube sizes and diameters are all the same, it is simply the geometry of that top hoop that changed. It didn't change the loads that were transmitted to the key loading points.'

The redesign of the tub is in stark contrast to the challenges faced by Ford, which has designed a car to the new regulations, rather than adapting an existing car. Getting the measurements right at the Ladoux test is critical to ensuring the survival of GT racing and Fehan says that he has complete faith in the process. 'The fact that they have a new product, it is a huge challenge for them to do what they are doing in a compressed time frame,' says Fehan. 'They have the luxury of doing a racecar and essentially converting it into a road car, which would be a huge advantage, but we have worked for a successful balance of performance, and if you have confidence in that, which we do, then it is not an over bearing concern that because the product is so exotic and specific built that it is going to just walk away and win every race. We watched Maserati bring the MC12, and they were able to balance that. We believe that will be the case with the Ford so we are not wringing our hands and worrying that Ford will totally dominate. We have to believe in the system, and trust the BoP, and we do.

'Forty years ago, no one was able to successfully balance naturally aspirated and turbo motors. We went through it in the IMSA GTP days. It was impossible to do because no one achieved it. In today's world, with the sciences that are available looking at engine performance and what we are attempting to do, variable boost based on engine rpm, you can fine tune the thing to build a curve that virtually overlays an n/a engine. Literally, everyday someone has a new twist and turn, the adjustability, the controllability and we are fairly confident that it will work out. We could be naive and be walking into the slaughter, but we have a level of trust.'

The Ferrari will be the most interesting car as it will share its common components with the GT3 version, bumping the price of the GT3 up above the €500,000 barrier, the only GT3 car to do so. Builder Michelotto is following a path down which most manufacturers are expected to go under updated regulations for 2017, in which GT3 and GTE cars will share components.

GT racing will be entering its new era at an FIA test at Ladoux, where Corvette, Ferrari and Ford will be assessed for BoP

'You can do some common sense things that help people to race,' Fehan continues. 'That is looking at some of the most basic elements, constructing a common tub, so an SRO, GT3 or GT LM would take a common tub, and taking whatever powerplant you wanted; brakes, splitter, and so on, you can create your series … That is where we are headed, and it is ultimately what we will end up with.'

'We are not wringing our hands and worrying that Ford will totally dominate. We have to believe in the system, and trust the BoP'

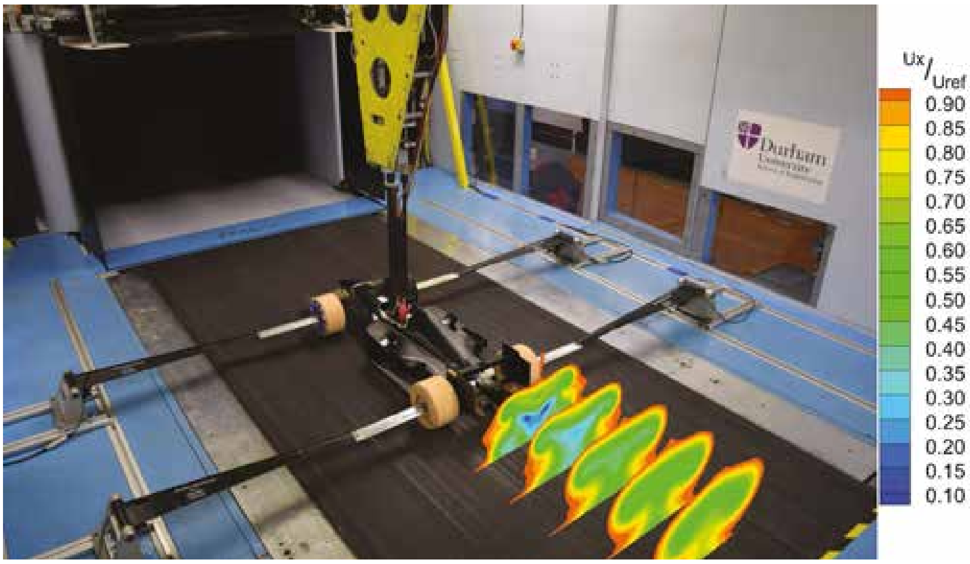
Wake up to wake

Formula 1 is now thinking of returning to ground effect cars – here's one academic's take on that and other aero issues …

By JOSHUA NEWBON

How many articles in the past have been penned bemoaning the F1 aerodynamicist? It must be increasingly frustrating for them to do the best job they can within an increasingly restrictive set of regulations, yet be blamed for most of Formula 1's ills.

I am an F1 fan and I have been since the early 1990s. I am also an engineer, and my experience as a fan has led me to undertake a PhD at Durham University, investigating the effect of wakes on F1 cars – so it's safe to say I spend more time than most thinking about the effect of wakes on racecars. As a scientist I am required to base my opinions on evidence, either from published data, or my own.



For his research the writer uses a generic scale Formula 1 model, both in the wind tunnel and for CFD. His brief at Durham is not so much to find aero gains but to investigate effects of wake on the performance of an F1 car

Bursting bubbles

In this piece I want to explore a few commonly held poisitions. Such as: *Turbulence in the wake is responsible for downforce loss for the car behind*.

Turbulence has become a generic term amongst the media and fans for the wake of an F1 car, and while it's true there is high intensity turbulence in the wake of an F1 car, it is neither the most dominant feature nor responsible for performance loss. In fact, turbulence has been shown to improve aerofoil performance in certain conditions. Instead, the wake should be characterised by a velocity and pressure drop, mainly caused by the vehicle drag, and a large pair of vortices which start at the rear wing. You've probably seen pictures of the rear wing vortices where in cool conditions the water vapour in the air condenses (contrails); this is only the low pressure core at the centre of the vortex. The rotational flow actually extends from the ground to above the full height of the car.

Cars are designed in wind tunnels and CFD, where airflow is aligned to the direction of travel (this can be straight ahead or yawed). The wake flow locally converges and diverges in places which will obviously reduce the efficiency of components. However, the front wing loses most performance on the centreline, where since 2009 teams are forced to run a neutral aerofoil to mitigate the loss. This is where the velocity and pressure deficit is greatest as the wake at front wing height is swept to the centreline by the rear wing vortices. This velocity deficit is the result of the vehicle having mass and being relatively bluff, and would be difficult to reduce within the constraints of an open-wheel formula. Interestingly the proposed return to 2m wide cars (last seen in F1 in 1997) could well increase the velocity deficit behind the car and make it more difficult to follow another car, though slipstreaming on straights would be improved.

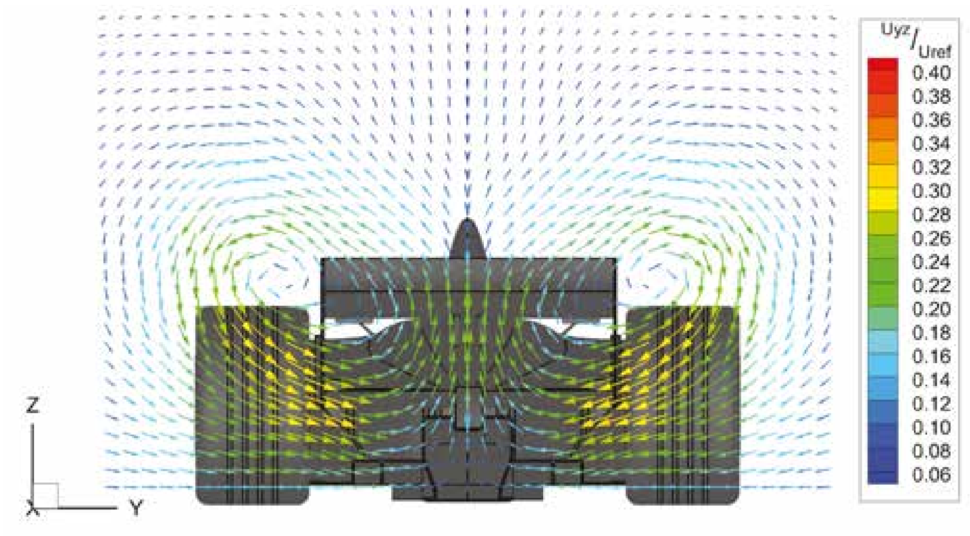
Next issue: *The front wing of the following car loses the most performance*.

My research has shown this not to be the case. While it is true the front wing downforce is almost halved with a one-car length separation between cars, so too is the rear wing and underbody downforce. I think this misconception is the result of the shift of aerodynamic balance to the rear axle, which results in increased understeer – force is only exerted to the ground though the tyres, so on-track downforce measurements are made using the suspension loads. So why the balance shift if all components lose downforce at the same rate? In free air the underbody balance is split roughly 50:50 between the front and rear axles, with an upstream vehicle wake more performance is lost at the front of the floor than the rear, so the understeer is mostly the result of the underfloor as the front and rear wing act on the front and rear axles respectively. While it's true the wing on my model is simplified and does not work the air to the same extent of a modern F1 wing, the cars today are so dependent on the front wing conditioning the air that I believe this holds true.

Ground-effect downforce is less susceptible to performance loss following a car.

I see this stated a lot and have to question where it comes from. I have yet to see any published data to support this – a thorough review of available literature is the first part of undertaking a PhD. My research appears to disprove this as the sub-atmospheric pressure (relative vacuum) at the front of the floor and diffuser throat increase (i.e. suction is reduced) in the presence of an upstream car. While the absolute suction pressure loss compared to 'clean' air is slightly lower than seen for the front wing, the surface area of the underfloor is

Turbulence has become a generic term for the wake of an F1 car



This shows the result of a wake survey in the wind tunnel. The velocity deficit begins locally, confined to the geometry that created it; behind the rear wheels, rear wing and base of the car. As the wake progresses the velocity deficit is swept upwards by the rear wing

significantly larger than a front wing. As force is equal to pressure multiplied by area, the resulting downforce loss from the underfloor is actually greater than the front wing.

The underfloor of a modern F1 car is also very sensitive to flow not aligned to the direction of travel, as is seen in the wake of another car. In fact part of the reason for the 1998 shift from 2m cars to 1.8m was to reduce performance by increasing wheel wake effects on the underfloor. Much aerodynamic effort at the front of the car is spent diverting the messy flow from the exposed front wheels and front wing outboard of the floor.

Getting closer

Bring back ground effect and cars will be able to follow each other more closely.

This is another simplification, as F1 cars already generate a large percentage of their downforce from ground effect. If we assume the approximate breakdown of downforce is 35 per cent each from the front and rear wings, 40 per cent from the body (combined upper and underbody), the exposed wheels (which also operate in ground effect) produce lift which slightly reduces the total downforce.

We all know what is actually meant is to increase the downforce contribution from the underbody while reducing reliance on wings. In fact F1 cars already generate as much downforce through ground-effect as they generate other downforce. That last statement is perhaps a bit confusing considering the rear wing is responsible for 35 per cent of the downforce, so allow me to explain.

Formula 1 cars already generate a large percentage of their downforce from ground effect

The front wing is in ground effect and so too is the body, but that's only 75 per cent, right? Well the upper bodywork of the car generates a not insignificant quantity of lift which cancels out some of the underfloor downforce generated.

There is a fantastic series of videos on YouTube by the Sauber F1 team explaining the running of its wind tunnel that I encourage anyone with an interest in F1 aerodynamics to watch. In the videos Willem Toet explains that the belt used to simulate the ground has to be physically sucked down to prevent lifting, which stalls the underfloor and corrupts measurements. This is because the car's ground effect downforce exerts a force on the ground. We can calculate the force exerted on the ground by integrating the pressure in the area under the car, which as it turns out is of a similar magnitude to the car downforce.

Wake effect

So what effect does this have on the wake? Well, very simply put, the wake of a downforce producing wing out of ground-effect will be in up-wash as the wing only exerts a force on the air around it. So, according to Newton's third law, as the wing is forced down the air is forced up. In ground effect the lift generated by the pressure on the ground, as mentioned this is a similar magnitude to the total downforce of the car, summed with the up-wash from the car will reduce the net up-wash to almost zero. So rather than continuing upwards and over the following car the ground-effect forces the wake to hang around at car height – affecting the front and rear wings and underbody of the following car.

This is a similar finding to the overtaking working group before the 2009 regulation change and has resulted in the size of the wings and rear diffuser we have on the cars now. However, the brief for 2009 was also to reduce downforce by up to 50 per cent – which was achieved by decreasing the rear wing span and ironically also reducing the up-wash in the wake.

Regulations 2017

As the goal for 2017 is to increase downforce while making it easier to follow another car, this could potentially be achieved by increasing the span of rear wings to pre-2009 size and introducing more elements, similar to the huge 'Venetian blind' designs of the 1990s, whilst maybe also limiting the surface area of the underfloor. This could be argued to not fulfil the secondary brief of making the car's aesthetic more 'aggressive', but the result should be increased up-wash in the wake, forcing the majority of the pressure deficit in the wake over the car behind.

Increasing the rear wing downforce would increase the vorticity in the wake and car drag (as aerodynamic drag is proportional to frontal area) but this may not be such an issue with Mercedes already predicting over 1000bhp from the new power units in the near future, which would help to overcome the extra drag penalty. This is where underbody ground effect is advantageous, as it allows a large quantity of downforce to be generated with a lower drag penalty than a rear wing and less vorticity in the wake. However, ground effect downforce is also 'peaky' and susceptible to losses with small variations in ride height or ground surface roughness. This could mean cars are less forgiving if the drivers run off circuit, and driver safety should always be of primary concern.

Ground effect tunnels do seem to allow for close racing in single make series, such as GP2 or IndyCar, though downforce in these series is generally lower than Formula 1 and teams are not in a race to optimise every surface on the car. They are also not on the same scale as seems to be being proposed for 2017. If it is to be increased ground effect, a simple way to limit performance could to be for the FIA and teams to design a predominately spec floor used by all cars, this is a similar concept used by the ACO with the Le Mans Prototypes where the shape of the underfloor and rear diffuser is defined, with teams only free to add strakes as required. Personally I am not keen on spec components in Formula 1, and I don't think I am alone in that view, but if it allows the cars to follow each other perhaps it's an acceptable compromise.

I'm not pretending to have all the answers, and my research is likely to conclude after the rules for 2017 have already been defined. Just be prepared for the inevitable headlines that overtaking is no easier in the new Formula 1, fans are switching off, and those aerodynamicists are to blame yet again.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FIA turns away two new teams with ambitions to join the F1 grid in 2016

The FIA has said that there will be no other new teams to join F1 newcomer Haas on the Formula 1 grid next year after bids to become a part the championship by two organisations were unsuccessful.

Motorsport's governing body called for teams to join Formula 1 back in May, with a deadline of June – later extended until the end of July – for applications. It has now said that two companies expressed an interest, but neither of them could meet the FIA's criteria.

American outfit Haas F1 will now be the only new team to join F1 in 2016, becoming Formula 1's 11th team.

Who the F1 hopefuls were has not been revealed by the FIA, although there was conjecture that crack French GP2 outfit Art Grand Prix was interested. However, Art has denied that it was one of the two applicants.

An FIA spokesman said: 'We can confirm that the FIA received two candidate Formula 1 team applications for vacant grid slots. We subsequently put these through our comprehensive diligence processes.

'Neither of the applications was able to meet the FIA's criteria for new teams, despite being given every opportunity to present their case. We consider this round of applications is now closed.'

When the FIA announced that it was looking for new teams to join F1 it said that it would make its decision based on the long-term interests of the championship. It also said that it would simply not choose a team if it failed to find a suitable organisation.

According to the original announcement the FIA said it would assess the technical ability of the team; its ability to raise the necessary funding; its experience and human resources; and the value the team would bring to the F1 World Championship as a whole.

The FIA called for the new teams after worries were expressed over thin grids this year. At the Australian Grand Prix season-opener just 15 cars made the start, after Manor's non-qualification and technical problems with others. This was the smallest field since the 2005 US GP, in which the Michelin shod runners did not start due to safety concerns, leaving just six cars to contest the race.

XPB

Just 15 cars started this year's Australian Grand Prix – there should be 22 in 2016 but no more than that as bids by two teams to join F1 have failed. The grid for this year's Australian race was the smallest since the US Grand Prix in 2005

New US single seater chassis construction deal out to tender

Andersen Promotions, the company behind the three series on the US single seater ladder leading to IndyCar, has issued a request for proposals from racecar constructors wishing to build replacement chassis for its ageing USF2000 and Pro Mazda championship cars.

The company requires a common chassis for both championships, though there will be differences in power and aerodynamics to separate the two in terms of looks and performance – USF2000 is the lower rung of the two in terms of the ladder.

The new car will come into use in USF2000 in 2017 and in Pro Mazda in 2018. Andersen's other formula, Indy Lights, introduced a well-received new car – the Dallara IL15 – for this year.

USF2000 is currently running a spaceframe chassis originally built by Van Diemen almost 15 years ago, while Pro Mazda runs a carbon tub, also originally built by Van Diemen in the 2000s.

The new common chassis will be carbon and is to be designed to the latest FIA specifications with added safety enhancements to suit US road, street and oval circuits, plus a more modern appearance. It will share many of the current FIA Formula 4 specifications, but with improved performance and increased horsepower.

It will be powered by a 2.0-litre Mazda MZR engine producing approximately 170bhp in USF2000 and 270bhp in Pro Mazda. All chassis will run on Cooper tyres and other applicable 'partner components' will be used, while there will also be tightly controlled car and spare parts costs. Current USF2000 cars will still be eligible for a recently announced 'B Class' in 2017.

Andersen Promotions founder and boss Dan Andersen said: 'The current USF2000 racecar has served us very well for a long time and is still a terrific training vehicle, but the time has come to provide our teams and drivers with more current technology and upgraded safety.'

An announcement regarding the new USF2000/Pro Mazda chassis constructor will be made in October and the new USF2000 chassis will be unveiled at the Indianapolis 500 next May, with prototype testing expected to begin in June. Car deliveries will take place in the autumn and a similar schedule will follow for Pro Mazda, a year later.

USF2000 (pictured) is to get a new car for 2017 while Pro Mazda will use that same new chassis from 2018

Ferrari shares to go up for sale on New York Exchange

Ferrari's parent company has filed an initial public offering (IPO) to list shares of the fabled sportscar brand on the New York Stock Exchange.

Fiat Chrysler (FCA) said in a statement that the proposed offering was not expected to exceed 10 per cent of Ferrari's shares.

According to the company's required filing with the US Securities and Exchange Commission (SEC, submitted at the end of July this year) Fiat Chrysler itself expects to retain about 80 per cent of Ferrari stock, while the remaining 10 per cent will be kept by Piero Ferrari, son of Enzo Ferrari, the company's founder.

The sale is expected to begin in the fourth quarter of this year and the shares will be sold under the title of 'Ferrari NV.'

Fiat, which took full control of Chrysler last year, purchased 50 per cent of Ferrari in 1969. In its SEC filing Fiat Chrysler Automobiles said that it intends to distribute its remaining shares in Ferrari to Fiat Chrysler's shareholders after the offered shares are listed on the New York Stock Exchange.

Ferrari shares will soon be up for grabs on the NYSE

Formula E powertrains homologated by the FIA

The FIA has homologated the eight Formula E powertrains to be used in the championship's second season.

From the start of the 2015/16 season, which kicks off in China on October 17, the series will allow manufacturers to pursue some of their own in-house innovations, beginning with the development of bespoke powertrains.

Of the 10 teams, eight will utilise their own powertrains, while Dragon Racing will partner with Venturi to run the French manufacturer's unit. The re-named Team Aguri will remain with season one's spec SRT_01E package.

The manufacturers' scope for innovation is initially limited to the powertrain – specifically the e-motor, the inverter, the gearbox and the cooling system. All other parts on the cars will remain as they are.

Meanwhile, mainstream manufacturer involvement has now been attracted to FE, which is crucial if it is to be successful in fulfilling its stated ambition of becoming a world championship – a condition of which is the involvement of car makers.

Renault has escalated its collaboration with reigning teams' champion e.Dams to enter what will be known as the Renault Z.E.15, while Citroen's DS brand is also joining FE in partnership with Virgin Racing, whose 2015/16 entry will be named the Virgin DSV-01.

Patrice Ratti, Renault Sport Technologies CEO, said of its involvement: 'We are doing Formula E to be consistent with our strategy in electric vehicles, and because we think it's the future to help grow the technology, and also show to the people that EVs are not only good for the environment, but they can be exciting and fun.'

The full list of teams and powertrains is: ABT Schaeffler Audi Sport (ABT Schaeffler FE01); Andretti Formula E Team (Andretti ATEC-01); Dragon Racing (Venturi VM200-FE-01); DS Virgin Racing Formula E Team (Virgin DSV-01); Mahindra Racing Formula E Team (Mahindra M2ELECTRO); NEXTEV TCR Formula E Team (NEXTEV TCR FormulaE 001); Renault e.Dams (Renault Z.E.15); Team Aguri (SRT_01E); Trulli Formula E Team (Motomatica JT-01); and Venturi Formula E Team (Venturi VM200-FE-01).

Renault is strengthening its ties with Formula E and is now an official powertrain manufacturer along with seven other organisations. FE's second season kicks off in China on October 17

SEEN: Opel Astra TCR

Opel is the latest manufacturer to commit to TCR, which has taken the customer racing approach proven in GT3 with sportscars into the touring car arena. Opel Motorsport has announced its new Astra OPC is being developed in line with the TCR technical regulations and the racecar, based on the new Astra K, was set to be debuted at the Frankfurt Motor Show in September. The Astra TCR is powered by a 2-litre turbocharged engine with an output of 330bhp and a maximum torque of 410Nm.

Opel Group chief marketing officer Tina Muller said: 'Touring car racing has always been an important part of Opel. The philosophy of the new TCR series corresponds to our idea of customer racing. We want to give ambitious privately owned teams a platform for exciting sport at reasonable costs.'

TCR International Series promoter Marcello Lotti said: 'We are very pleased with Opel's decision. We knew they were seriously evaluating the TCR concept … and now the announcement that the new Astra is being developed in TCR-spec makes us very proud and adds another premier automobile brand to the TCR world.'

Testing of the Opel Astra TCR is set to begin in October.

CAUGHT

Scott Eggleston, the crew chief on the No.98 Ford in the NASCAR Sprint Cup, has been fined $25,000 and suspended for one race after the Premium Motorsports-run car he tends shed a weight during practice for the Brickyard 400 at the Indianapolis Motor Speedway. Car chief Kevin Eagle was also suspended for one race for the infraction, while the car's owner, Mike Curb, was penalised 15 points in the owners' championship.

FINE: $25,000
PENALTY: 15 points

Name and sponsor change for United SportsCar

US sportscar series the UnitedSportscar Championship (USC) is to go into its third season with a brand new sponsor and a new name.

USC, which came into being at the start of last year with the amalgamation of GrandAm and the American Le Mans Series (ALMS), will from 2016 include the name of its sanctioning body, IMSA, in its title, while watchmaker Tudor will be replaced as naming sponsor by WeatherTech, an automotive accessory company.

The renamed series will be known as the IMSA WeatherTech SportsCar Championship from the end of the current season.

WeatherTech already has a presence in USC, its founder and CEO David MacNeil sponsors the Porsche of his son Cooper. MacNeil senior said of the deal: 'This is an exciting time for sportscar racing in America and I hope to broaden the appeal of this compelling sport.'

Cooper MacNeil, along with Jeroen Bleekemolen, won the ALMS GTC title in 2013, while his father finished on the podium in class in the inaugural event of the ALMS at Sebring back in 1999.

IMSA CEO Ed Bennett said: 'WeatherTech is the perfect choice to serve as our new entitlement partner as we further expand the marketing activation and exposure of what now will be known as the IMSA WeatherTech SportsCar Championship.

'David MacNeil's enthusiasm and personal passion for our sport, along with his proven success at growing the WeatherTech brand through brilliant, high-quality manufacturing and aggressive product marketing, will pay dividends for all involved.'

Outgoing backer Tudor, which is a subsidiary of Rolex, used its sponsorship of the USC to help relaunch the brand in the USA. It will not abandon USC completely, and will now be the official watch supplier to the series.

Rolex will continue its sponsorship of the Daytona 24 Hours – a deal which stretches back to 1992 – while it will also back the Sebring 12 Hours from next year.

WeatherTech has already been seen on the USC car of Cooper MacNeil, son of company boss and founder David MacNeil

Two BTCC teams have licences revoked

Two British Touring Car Championship (BTCC) teams have each had one of their TOCA BTCC Licences (TBL) taken away from them for failing to enter one of their cars in rounds of the championship.

The TBL was introduced at the start of last year in an effort to make sure that cars contested each and every round, and that teams enter consistent driver line-ups with only one change allowed per season – except in cases of *force majeure*.

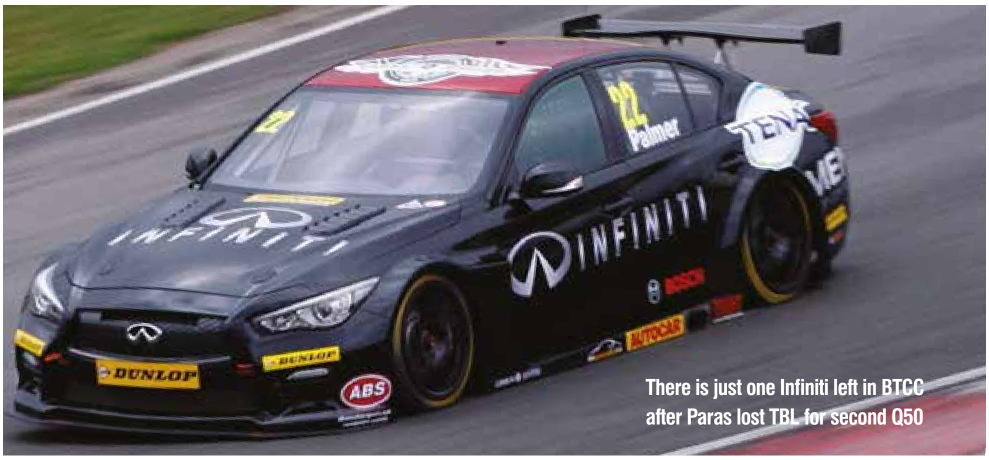
The teams concerned are Welch Motorsport and the Support Our Paras outfit, the latter of which also recently lost its works support from Infiniti.

One of the two Welch Protons missed the Snetterton and Knockhill events, while Support Our Paras was unable to field one of its pair of entries at Snetterton.

A statement from the BTCC on the no show of the Para entry at Snetterton said: 'The administrator has accepted the withdrawal from the Snetterton championship meeting of car No.71 (Max Coates, Support Our Paras Racing) and has subsequently cancelled the TBL associated with that entry for the remainder of the 2015 season.'

Derek Palmer Sr, team principal at Support Our Paras, said: 'We fully accept the decision made by TOCA. It's a major disappointment for the team that Max failed to deliver the sponsorship package he had pledged.

'For the remaining five rounds of this season's BTCC we will concentrate on ensuring we maximise the performance of the No.22 Infiniti Q50, which will continue to be driven by Derek Palmer [Jr].'



There is just one Infiniti left in BTCC after Paras lost TBL for second Q50

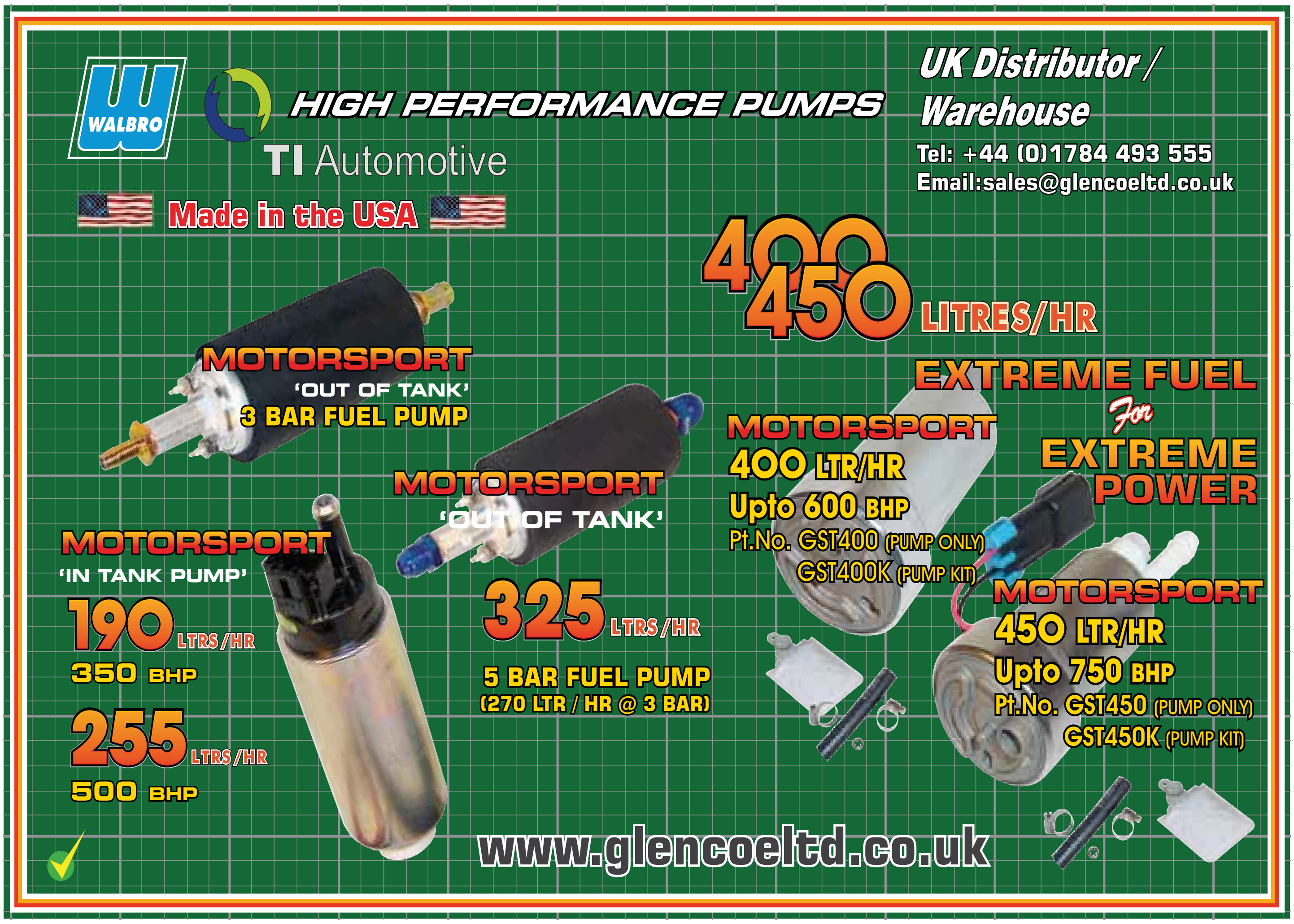
IN BRIEF

Bathurst Supercars

Australian company Supercars Events (which is part of the V8 Supercars business) has acquired the rights to run the Bathurst 12 Hour GT race from 2016, in partnership with Bathurst Regional Council. Supercars Events, which already runs Australia's most famous race, the Bathurst 1000, at the same track, takes over the promotion and running of the GT race from Yeehah Events, which has run the race since the event's revival in 2007. V8 Supercars boss James Warburton said the 2016 Bathurst 12 Hours, set for early February, will remain an International GT race and will retain its current format.

Back on the Road

Road America – also often known as Elkhart Lake – is to return to the IndyCar schedule for 2016, eight years after the premier US single seater category previously raced at the fabled road course. The circuit was once a regular fixture on the CART/ChampCar calendar. The return of IndyCar to Road America will take place on the weekend of June 24 to 26 next year. Mark Miles, IndyCar's CEO, said of the series' return to Elkhart Lake: 'We know how revered Road America is by our drivers, teams and fans and we're confident it will be a great event on the 2016 IndyCar Series calendar.'



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MWR to become part time operation for 2016 Sprint Cup

NASCAR outfit Michael Waltrip Racing (MWR) will not race the full Sprint Cup schedule next season, a decision that's been made in the wake of co-owner Rob Kauffman's acquisition of a stake in rival team Chip Ganassi Racing with Felix Sabates (CGR).

Kauffman originally said that the two teams would be integrated, though he had not been clear about the extent of this tie-up, but now Kauffmann and MWR founder Michael Waltrip have announced that the team is to go part time with one car in 2016, but will see out this season: 'MWR will race hard and compete with its two entries for the remainder of the 2015 season,' said Kauffman. 'This decision was made after weighing several different options and scenarios.'

Waltrip said: 'From where MWR started behind my house in Sherrill's Ford to winning Sprint Cup races, poles and earning Chase berths, I am proud of what we accomplished. My family has been a part of NASCAR for almost five decades and I plan on being a part of it for years to come.'

MWR will now sell its race shop in Cornelius, North Carolina. Waltrip said: 'It's a sad day for MWR obviously. I love the culture we've built there. Our sponsors – they're not sponsors; they're partners. And our employees are our teammates. We just have the perfect workplace, and unfortunately in 2016, we're not going to be racing there. My hope is somebody wants to have a really nice shop full of really cool people that work together well and want to have a race team and we can provide that for them.'

Waltrip added that Kauffman will no longer be involved with MWR from next season, though he has left on good terms: 'Rob is going to be a part of Chip Ganassi Racing going forward. Rob and I are best buddies,' he said.

MWR has been affiliated with Toyota since the Japanese car maker made the move into the Cup in 2007. That same year Kauffman came onboard to provide financial stability.

Recent years have seen the organisation struggle and it downsized from three teams to two after the 2013 season. Its one-time primary sponsor NAPA pulled out last year.

XPB

MWR's No.15 Toyota will run a part time programme in the Sprint Cup next year as the team scales down

Motorsport engineering firm invests in extra 3D printing

High performance engineering and additive manufacturing specialist, KW Special Projects (KWSP), has invested over £100,000 in new state-of-the-art 3D printing equipment.

The investment is part of KWSP's five-year growth strategy and has also been driven by the increasing demand for additive manufacturing technology.

KWSP's new equipment includes a Stratasys Fortus 400 MC FDM, an advanced 3D printing machine that will allow the company to rapidly manufacture soluble mandrels, low volume end user parts, prototypes, jigs or fixtures and one-off tools.

In addition to the 3D printing technology KWSP – which is located close to the Mercedes F1 team in Brackley, UK – has also invested in a HandySCAN 300 scanner and Geomagic Control 3D Software. It says this will allow it to provide additional inspection and quality control of manufactured parts as well as providing the ability to digitally scan, measure and re-engineer products. The scanner also enables KWSP to reverse engineer either components or complete products which can then be used for simulation.

Stuart Banyard, head of advanced manufacturing at KWSP, said: 'The opportunities and benefits this increase in capability will offer our customers are substantial. With a background in motorsport and high performance engineering, we have extensive relevant experience, which enables our clients to gain the optimum benefits of all aspects of digital fabrication, including additive manufacturing and scanning.'

Government cash secures future of Wales Rally GB

The future of the British round of the World Rally Championship has been secured thanks to a new deal with the Welsh government.

Questions had been raised about the long-term prospects for Wales Rally GB but now the Welsh Government has announced that it will continue to back the event until 2018. The UK's round of the FIA World Rally Championship (WRC) has been branded Wales Rally GB since the Welsh Government became its main sponsor in 2003.

Ben Taylor, managing director of IMS (international Motor Sport, the commercial arm of the MSA which runs the event), said: 'We are delighted to have agreed a new deal with the Welsh Government whose support has been critical to the long standing success of Wales Rally GB. Their forward thinking strategy allows our event to deliver around £10m of economic value to the Welsh economy in addition to a world-class event that brings business, tourism and many other commercial benefits to the country.'

Malcolm Wilson, team principal, M-Sport World Rally Team, also welcomed the news: 'It's great news to see this level of investment and the length of the investment which is important, particularly after the rally has now developed and has such a good base in north Wales. This will let the organising team continue to build on what has been such a success in recent years. This is a great stepping-stone for the event to go from strength-to-strength as I do believe now it has the right platform to build on.'

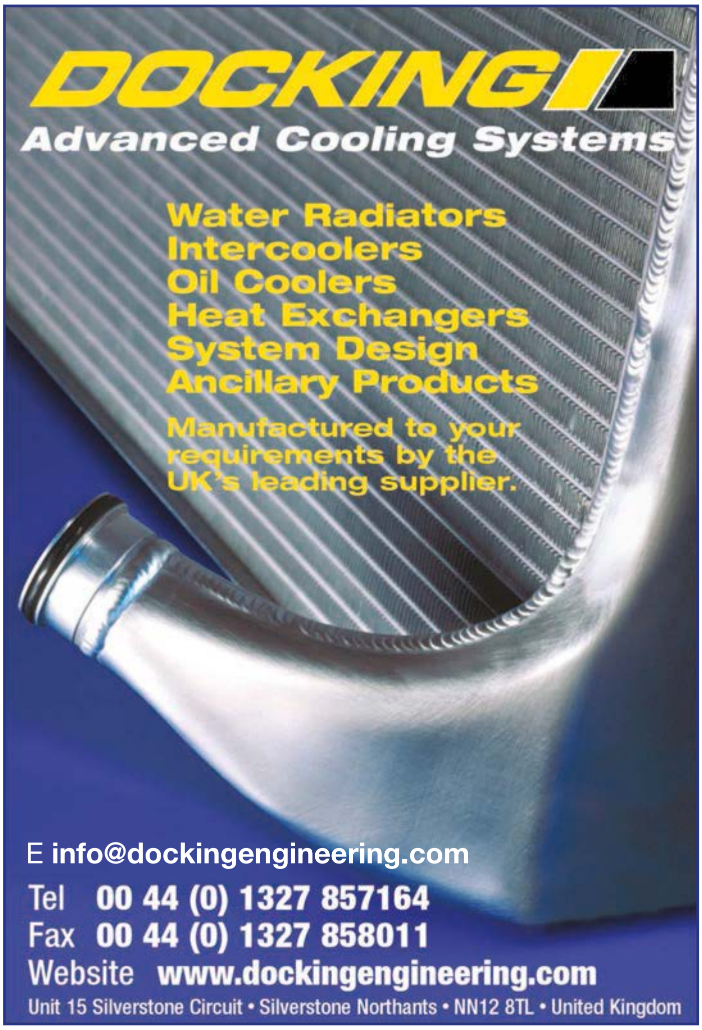
Meanwhile, Network Q has been named as an additional title sponsor. The company, Vauxhall's used car arm, previously sponsored the event for 10 years between 1993 and 2002.

UK round of the WRC is secure until at least 2018 thanks to the extension of its sponsorship deal with the Welsh Government

IN BRIEF

ORECA F3 debut

ORECA's F3 engine has finally made its race debut, powering a Dallara to second place in a round of the Austrian F3 Cup at the Most Circuit in the Czech Republic. The powerplant was originally badged as a Renault and the plan had been to run it in European F3 with crack French outfit Signature in 2014, but the team withdrew from the series before the first race. The engine powered a car run by German team Ma-Con Motorsport, though it was entered by Austrian F3 stalwart Franz Woss Racing.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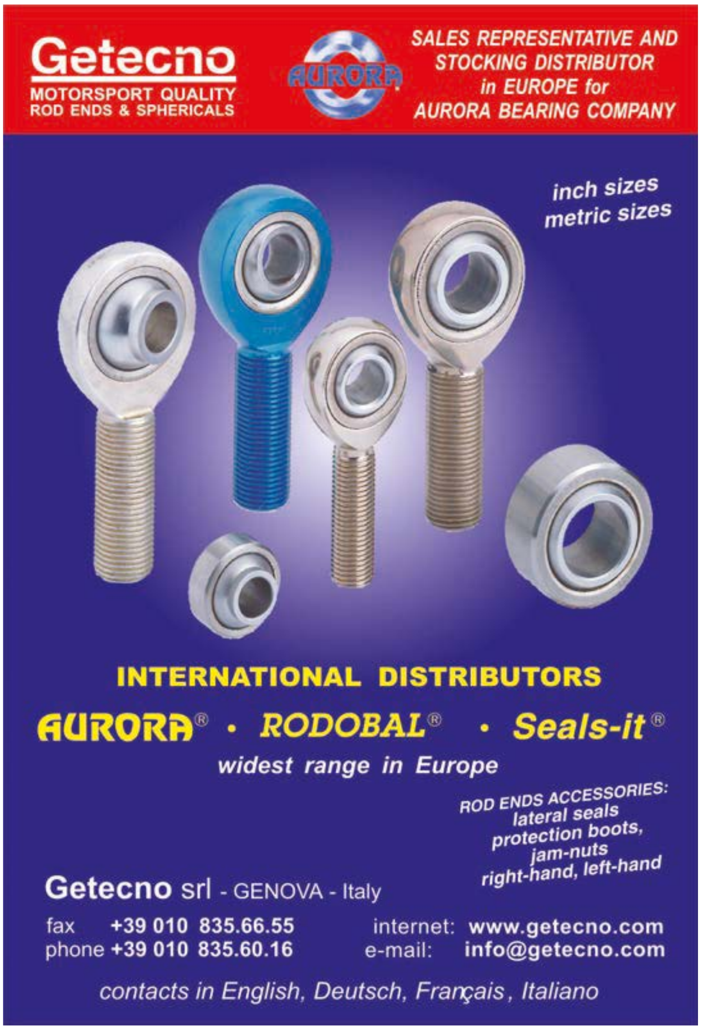
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$60m indoor tyre testing facility to be built in the US

A US company has raised the funds to build an innovative tyre testing facility, which is to include a half-mile oval indoor track for single tyre running, deep in the heart of NASCAR country.

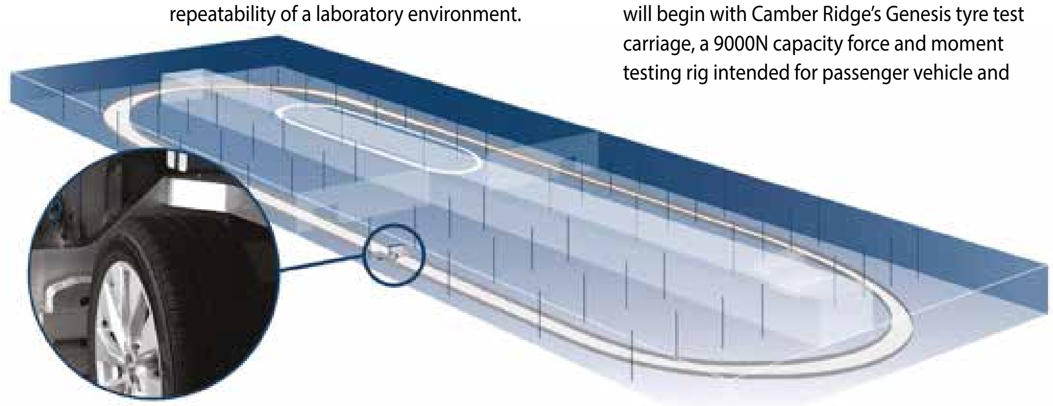
The new test centre, which is to be called Camber Ridge and built with the help of $60m of backing from Teton Capital, is being constructed with the aim of offering all the advantages of testing real tyres on real surfaces, but with the precision, environmental control and repeatability of a laboratory environment.

It is to be located in Charlotte, North Carolina, in the midst of the region's growing automotive research and manufacturing cluster, and also the heartland of the US motorsport industry. It will be opened in 2016.

Camber Ridge tells us: 'Unlike traditional tyre testing laboratories that use stationary test equipment, Camber Ridge will test tyres on a unique indoor test track, a paved 0.5-mile oval, using specially developed test carriages that are propelled along a guide rail system. Operations will begin with Camber Ridge's Genesis tyre test carriage, a 9000N capacity force and moment testing rig intended for passenger vehicle and light commercial tyres up to 34in diameter and at speeds up to 65mph. Initial running will be on dry reference surfaces at a controlled ambient temperature but the facility is being designed for phased introductions of additional paved surfaces, water testing and other controlled conditions.'

While it is not directed specifically at motorsport users – its top speed is just 65mph – Dr James F Cuttino, CEO of Camber Ridge, told *Racecar*: 'In some of the current motorsports tests, whether they're running or braking, using a belt machine, they're still doing 30mph, and getting decent data out if it. So I would be shocked if they didn't get useful information that they can't currently get, but obviously none of it at 200mph.'

Cuttino added that a 200mph-capable version would have to be one and a quarter miles long, and that it would not be able to be built indoors, which is a vital aspect of the test facility: 'Our approach is to combine the best features of traditional laboratory testing with the best features of proving ground testing, such that tyre measurements are both repeatable and accurate,' he said.



Camber Ridge has secured millions of dollars to set up its indoor tyre testing centre in North Carolina

Nissan GT-R race programme put on hold

Nissan's LMP1 World Endurance Championship campaign has been put on hold as the company has decided to focus on testing as it works to resolve issues with its recalcitrant GT-R LM.

The Japanese manufacturer has said that it will delay the return of the car to the World Endurance Championship and will now instead focus on sorting out the problems with the car (for more on which turn to page 62).

Nissan stated that: 'The bespoke Nissan V6 3-litre twin turbo petrol engine and the unique aerodynamics of the GT-R LM NISMO proved to be the main strengths of the car at Le Mans but without a fully working ERS, many of the car's other systems were compromised.'

Shoichi Miyatani, president of NISMO, said: 'We know people will be disappointed but be assured that nobody is more disappointed than us. We are racers and we want to compete but we also want to be competitive.

'That is why we have chosen to continue our test programme and prepare the GT-R LM NISMO for the strong competition we face in the World Endurance Championship. When you innovate you don't give up at the first hurdle. We are committed to overcoming this challenge.'

Darren Cox, global head of Brand, Marketing and Sales, NISMO, said: 'We've said it before but innovation hurts. We've built an LMP1 car that is very different to other racing cars as we continue to drive motorsport innovation. The beauty of this programme is that people have got behind us and they are willing us to succeed. This has shown us once again that people want something different in motorsport and that gives us increased motivation to make our LMP1 car competitive.'

Nissan will continue the test programme for the GT-R LM NISMO, predominantly – but not exclusively – in the United States.

A decision on the date for Nissan's return to the World Endurance Championship will be made in due course, depending on the progress of the test programme, Nissan tells us.

This news only affects Nissan's LMP1 WEC campaign. The manufacturer's other global motorsport programmes will carry on as normal.

Nissan's innovative, but so far less than successful, LMP1 is to skip WEC races to concentrate on a testing programme to resolve its issues

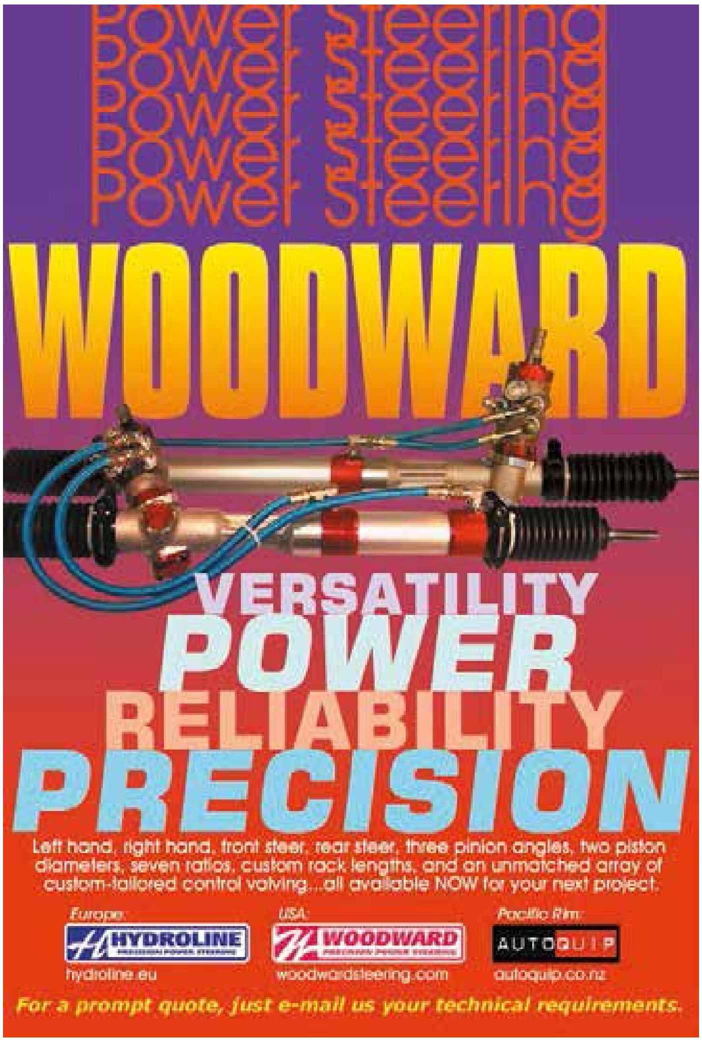
IN BRIEF

A1 Middle East

The Formula Acceleration 1 (FA1) Series, which used some of the first generation A1GP cars for a single season last year, is now looking to reinvent itself as a winter series called the Middle East Trophy. ISRA, the Dutch organisation behind FA1, is planning a three-round series to run in January and February 2016 on three Middle Eastern circuits, as yet these have not been chosen but they are to be selected from the leading quartet of top-level tracks in the region: Bahrain, Abu Dhabi, Dubai and Qatar. The cars used will continue to be the ageing Lola-Zytek B05/52 (first raced in 2005), versions of which are also used in the now stalled Auto GP series. Plans to merge Auto GP and Formula Acceleration earlier this year fell through.

Mygale Ford for US F4

Mygale and Ford, the chassis and engine suppliers to the MSA Formula (FIA Formula 4 in the UK, where the F4 title is owned by MSV and its BRDC F4 Championship) are to supply an all-new US Formula 4 Championship from next year. The US will therefore become the third country to use the Mygale and Ford combination for F4 – the other is Australia. The US Championship is to be over seven rounds, each of three races, and it will share the bill with the Formula Atlantic, F2000 and F1600 championships that are run by the Race Promotions organisation.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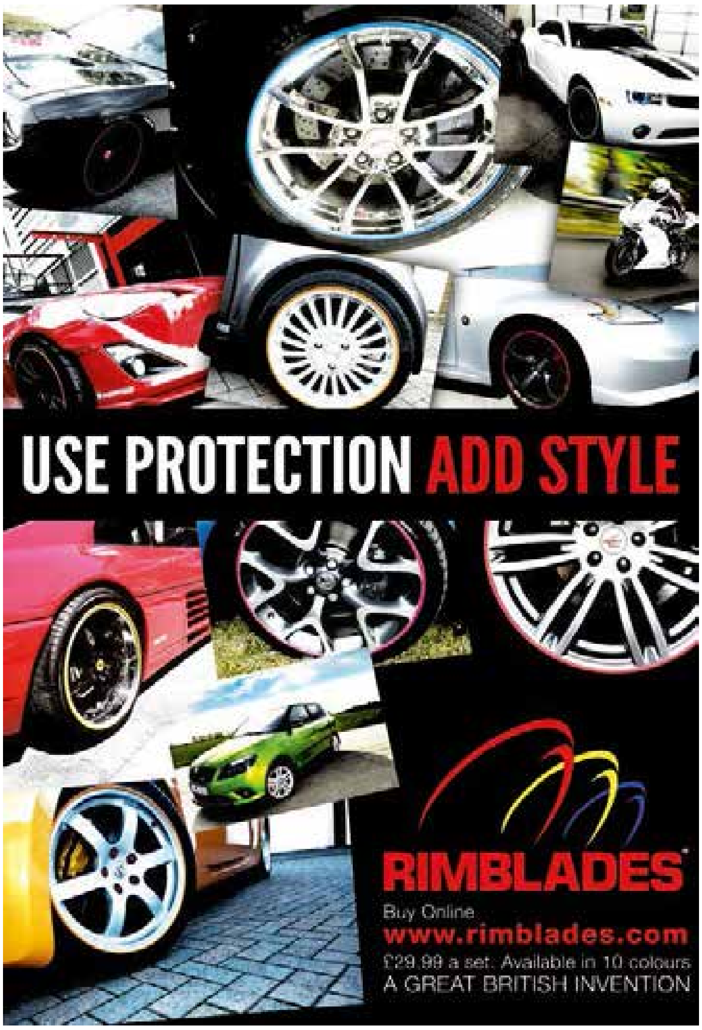
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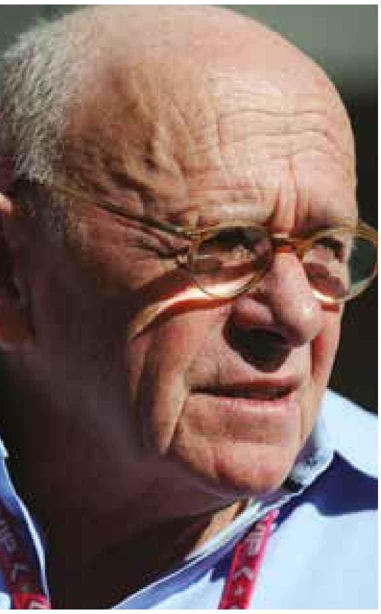
INTERVIEW – Derrick Walker

Oval and out

IndyCar's outgoing president of competition and operations tells *Racecar* why he thinks the time is now right for him to walk away from the role

Interview by ANDREW COTTON



'I'm looking for an opportunity to find some sponsorship to come back as a team owner'

Derrick Walker is a racer. He lives and breathes racing, and it has been a part of his life for over 40 years. So the opportunity to have a say in the way IndyCar progressed, the chance to help the series he had been involved in for so long, seemed like the ideal job for the Scot. But now it's all gone sour. Walker is walking away from IndyCar, at least as far as its governance is concerned although he says that he wants to come back as a team owner and remain involved in the category. So what went wrong with his spell at the top?

Before we get in to the whys and wherefores of Walker's departure, here's a brief resume of his career in motorsport up until he became involved with IndyCar management. He started out in racing in the UK, both with his own car and preparing cars for others, and then became a mechanic for Brabham in Formula 1, when Bernie Ecclestone ran the team in the '70s, before moving on to begin a 13-year association with Penske in 1976 – first in F1 and then heading up the IndyCar (CART) operation. Following a spell as co-owner and general manager at Al Holbert's IndyCar team Walker founded his own CART team, Walker Motorsports, in late 1990.

Throughout Walker's 19 years as a team owner, he fielded multi-car teams in 414 races in IndyCar, earning six victories and 16 poles. Or, in other words, when it comes to IndyCar, this man knows his stuff.

Oval office

Which is why IndyCar came to Walker when it wanted a president of competition and operations in 2013. One of the responsibilities of the role was introducing the aero kits into the sport, which have been brought in largely to inject an element of variety into IndyCar, so it is seen as a bit more than just another spec series. The problems with the aero kits have been widely reported (see p16 for a full investigation), but suffice to say the most alarming issue was a number of high speed aerial accidents, particularly in the lead up to the Indianapolis 500.

Walker now says of his part in the development of the aero kits: 'It's somewhat of a personal story. I came here because I wanted the opportunity to make a difference. I know I am not the brightest bulb in the room, and I have spent the last two and a half years learning a lot, and there is much more to learn. In those two and a half years I have made a lot of mistakes, but I don't think that any of the problems that I have created have been insurmountable and cannot be fixed.'

However, the writing was on the wall when Walker learnt that both IndyCar CEO Mark Miles and, perhaps more importantly, the team bosses, no longer had confidence in the job he was doing. 'It has become apparent that the guy that I work for [Miles], didn't feel I was doing a good enough job and some of the owners voiced an opinion about everything that was wrong, and blamed me for it. My boss said to me that he didn't think that the team owners were supporting me, and when I heard him say that, I thought sooner or later [I would be gone] … because I know this paddock really well and we eat our own in this business, we consume each other. I have seen many people in that position before and [I knew] my days would be numbered, so I offered my resignation.'

So, with everything that has happened, does he now think the move to introduce the kits was misguided? 'I will go to my grave believing that we made the right step. Could we have made it more cost effective, could we have slowed down some of the costs, could we have managed it better? Sure! We know a lot more now than we did then and we were naive in some areas, and did a good job in other areas. If we are not going to do a new car, and I think the owners don't want a new car, we have at least three years of aero kits. The manufacturers wanted them to happen, they are spending millions on them and subsidising them to the teams.'

Other issues

While the aero kits seems to be the main reason for his departure, Walker says that that may not have been the only problem. 'I am sure aero kits will be high on the list, but I don't know what else. I don't know what their [team owners'] issue is with me, but I am not that singularly minded that the teams' owners come to me and say that it was all screwed up [and] that I would tell them to get on with it. I am not that way. I recognise their input and knowledge. They have to find the

XPB

money, they have the tough job. I have been one of them so I know what they are going through. I have helped many of them, people don't know that.

'There are many issues for IndyCar to solve. I think if the team owners get on board with the series, I don't think there are any problems that we can't solve. I don't think that my personal view, or attitude or personality cannot be part of that process. [But] I volunteered to walk away because I clearly don't have a mandate, but I am not bitter about it.'

Incidentally, IndyCar itself has acknowledged the good work Walker did in his time in the role, such as helping to secure Boston as a new event on the 2016 schedule; successfully introducing the Grand Prix of Indianapolis in 2014; and spearheading additional investment to improve technology in race control. It also said that his focus on continuous safety advancement resulted in changes to the IndyCar underwing, making the cars more stable, and the strengthening of the sidepods, further protecting the drivers.

Passing the stress test

You might think that in some ways Walker, now 70, will at least be glad to see the back of all the stress involved in the role, but that's not the kind of man he is – remember, he's a racer. 'I am not stressed out. I love the business and if I could have found a way to stay and work, I would love to have done so but it seems that I am singular in that view, so I have to acknowledge that.'

One thing is sure, racing has not seen the back of Derrick Walker: 'I want an opportunity to find some sponsorship and come back as a team owner. I am not bitter about this place. I love IndyCar racing. I think it is sad that it struggles to find itself in a way, but I still believe in it. I am not ready to retire. If you can go through the month of May and throw a few guys on their roof and still stop shaking when you know that there is some catastrophic stuff going on, you can stand anything. I am not gone. I will be hanging around, not in the role I am in now, but I have learned a lot and enjoyed the challenge.'

And just maybe, he jokes, he could go back to working for Ecclestone in Formula 1. 'I am hoping for a call from Bernie to come and help. I am looking for work. I want to be Herbie's [Blash, F1's deputy race director] briefcase carrier.'

Problems with IndyCar's new aero kits may have been the main reason for Walker's departure from his high profile position

RACE MOVES

XPB

Ferrari technical director **James Allison** has confirmed that former Mercedes performance engineer **Jock Clear** (pictured) will be joining the Italian team, although he will need to complete a period of gardening leave before he can take up his position. It's believed that Ferrari is currently in negotiations with Mercedes GP to allow Clear to start earlier. Clear left Mercedes at the end of last year.

Wayne Estes is now president and general manager of Sebring International Raceway, replacing **Tres Stephenson** in the role. Estes previously worked at Bristol Motor Speedway for 17 years in various posts, which included communications director and vice president of events. Before Bristol he handled the Ford Motorsport PR account at Campbell & Co.

Former Ferrari PR man **Luca Colajanni** has stepped down from his position as head of communications at Formula E. At the time of writing FE was working on a new structure for its PR department in the wake of his departure.

The Roush Fenway Racing NASCAR Xfinity team has swapped the crew chiefs on its No.6 and No.16 Fords. **Seth Barbour** has moved from the No.16 to serve as crew chief for the No.6, while **Chad Norris** moves in the opposite direction.

Allan Dean-Lewis has retired from the Motor Sport Association (MSA) after 20 years with the UK's governing body for the sport. He became a consultant to the MSA in 1995 and has been full-time since 1998, most recently as its director of training and education.

Richard Harris is now the race engineer for **Ash Walsh** at the Mercedes-running Erebus Motorsport team in the Australian V8 Supercars championship, replacing **Wes McDougall** in the post (see below). Harris has been promoted from data engineer. He has been at Erebus for a year and a half.

Wes McDougall, race engineer and technical director at Erebus Motorsport, has now left the Mercedes-running V8S team due to health reasons. McDougall had spent a decade at Stone Brothers/Erebus, joining the team in 2005 as a data engineer, and has also worked outside Australia, including engineering a car at the Le Mans 24 Hours.

Oscar Ramos Jassen, a Mexican lawyer from Tijuana who worked with SCORE International, the desert racing organisation which organises the Baja events, has died at the age of 52 after succumbing to cancer. He worked with SCORE for over 20 years.

Delena Johnson, who has worked in various roles for IMSA, NASCAR, International Speedway Corporation and Grand-Am in a 20-year career in motorsport, has died after losing her battle with cancer.

NASCAR, IndyCar and V8 Supercars team owner **Roger Penske** has been inducted into the Automotive Hall of Fame in Detroit. The 78-year-old former racecar constructor, both in IndyCar and also F1 back in the '70s, has an impressive 15 Indianapolis 500 victories to his name as a team boss. Former Ferrari chairman **Luca di Montezemolo** has also been inducted into Detroit's Hall of Fame.

South African **Peter de Klerk**, who raced a self-built Alfa Romeo special entered by **Jack Nucci** in two home grands prix ('63 and '65), has died at the age of 80 after a long illness. He also raced Brabham machinery at the South African Grand Prix in 1969 and 1970.

Tom Steward, a DTM engineer with Mercedes-AMG HWA, who looks after the car driven by Mercedes GP test driver **Pascal Wehrlein** in the German touring car series, made his race driving debut in Formula Ford 1600 at Castle Combe in July, finishing 22nd from 33 after qualifying 17th.

Andretti Sports Marketing lawsuit now resolved

Michael Andretti has settled a legal challenge from within his own organisation, filed by the co-owners of his race promotion arm Andretti Sports Marketing (ASM).

John Lopes, who has worked with Andretti for many years and was recently removed from his position as president of ASM, teamed up with Starke Taylor to file the suit. Both are co-owners in ASM; Lopes and Taylor each own 20 per cent while Andretti holds 60 per cent. The suit was filed at the Marion County Supreme Court against Andretti Autosport Holding Company.

The lawsuit made the claim that Andretti's IndyCar team is $7m in debt and has just $2m of assets to its name, while more pertinently it stated that Andretti himself had mismanaged ASM.

However, the dispute has now been resolved, though the terms of the settlement have not been disclosed. An Andretti Autosport statement said that the parties have reached a preliminary settlement agreement through the assistance of mediator John R Van Winkle.

According to the statement Van Winkle said that 'all parties…went to extraordinary lengths to keep their employees, fans and the racing community in mind.'

The statement added that there will be no further legal action, and that the matter has been dismissed.

As part of the settlement ASM will be sold to Lopes and Taylor, and will now be renamed.

ASM has been through a tough time of late, with some of its races falling off calendars while there is uncertainty over the future of others. The IndyCar race it promoted at Baltimore is no longer on the schedule and NOLA (New Orleans) is expected to be dropped next season, while there are doubts about the future of Milwaukee. Also, the ASM-promoted Miami Formula E race is not on the schedule for the second season of the series.

XPB

Michael Andretti has now resolved the legal issues he had with his partners in Andretti Sports Marketing

New chairman appointed for the Australian Grand Prix

John Harnden is the new chairman of the Australian Grand Prix Corporation (AGPC), the company responsible for both the F1 and MotoGP races in Australia. He replaces Ron Walker, who had held the position for 23 years.

Harnden has been on the AGPC board since 2006, becoming its deputy chairman a year later, while he has also held a number of high profile sports management roles in the past, including CEO of the 2006 Melbourne Commonwealth Games Corporation. He has also filled the position of CEO of the South Australian Cricket Association and CEO of the 2015 ICC Cricket World Cup Organising Committee.

On taking up the post, Harnden said: 'This appointment is a great honour and I am excited by the opportunity to be able to build upon the success Ron and the team have achieved. I wish to congratulate Ron for his vision and leadership over 23 years to make the Formula 1 Australian Grand Prix and the Australian Motorcycle Grand Prix two of the most iconic sporting events in Australia.'

Both the F1 grand prix and the MotoGP race are held in the state of Victoria, the former at Melbourne, the latter at Phillip Island, and Harnden said he was committed to building on Walker's success with these events: 'I look forward to working with everyone to ensure these great events continue to not only showcase and benefit the state of Victoria, but also provide unforgettable experiences for the fans,' he said.

RACE MOVES – continued

XPB

The family of **Kevin Ward Jr**, who was killed in an accident involving NASCAR driver and team boss **Tony Stewart** (pictured) last year, has filed a wrongful death action against the three-time Sprint Cup champion. Ward was killed when he was hit by Stewart's car after Ward walked on to the track to remonstrate with him following a crash between the two.

UK motorsport journalist **Paul Boothroyd** has passed away at the age of 69 after a battle with cancer. Boothroyd was especially well-known in the north of England, where he reported from events at Oulton Park, Croft and hillclimb venue Harewood, amongst others.

Dorsey Schroeder is the new race director for the Pirelli World Challenge. Schroeder is a former driver and has also worked as a television racing analyst.

Greg Hewgill has joined Lucas Oil as its technical director. Hewgill, who was born in Canada but brought up in the US, has had a long career in the oil industry, having previously worked at Union Oil (Unocal) and Wynn Oil. He will be based at Lucas Oil's global HQ in Corona, California.

NASCAR driver and broadcaster **Buddy Baker** has died at the age of 74 after losing his fight with cancer. Baker raced at the top level in NASCAR for 33 years, the high points of his career being 19 wins including his 1980 Daytona victory, which still holds the record for the track's fastest average race speed at 177mph. In 1970 Baker became the first driver to eclipse the 200mph mark on a closed course while testing at Talladega Superspeedway. He retired from driving in 1992 and went on to become a popular NASCAR commentator and broadcaster.

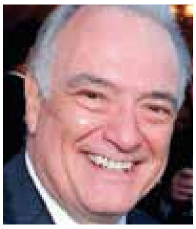
V8 Supercars has enlisted **Rainer Buchmann** to help it secure more events outside its core market of Australia and New Zealand. Singapore-based Buchmann played a key role in setting up Formula 1's Singapore Grand Prix and has also been a ChampCar team owner in the past. He also has experience of V8S, having raced at its Gold Coast event.

NASCAR has reinstated Sprint Cup crew member **Ernest F Pierce**, who has successfully completed its Substance Abuse Road to Recovery Program. Pierce was found to have violated NASCAR's strict substance abuse code back in June of this year.

Motorsport photographer **Jesse Alexander** has won the 2015 International Automotive Media Competition Lifetime Achievement Award, an award which is decided on by peers working in a variety of disciplines in the world of motoring media.

Veteran Sportscar team boss **David Stone,** a stalwart of IMSA-run racing in the US, has died after a long battle with cancer. Stone led Kelly Moss Motorsports with his brother Jeff, and was also in charge at Level 5 Motorsports.

◆ 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**



The Valley of Death

Motorsport is well placed to bridge the gap between innovation and production

Motorsport Valley UK has become known throughout the world as the centre for motorsport technology, and rightly so. Ironically, the engineering world recognises that within the process of the journey of innovation there is a 'Valley of Death'. This describes the period in product development when significant investment is required right at the time when the risk of failure is at its peak, and a reasonable return on investment seems most unlikely.

Products and processes, often innovated initially in the academic world, need to find companies to take the gamble of crossing the Valley of Death and turn these into prototypes, which may or may not succeed, and then move forward into production.

Based on the maxim that 'we race prototypes', followed by a close study of Technology Readiness Levels (TRLs), an extremely popular way of describing the journey of technology development, there lies a truly unique capability of motorsport companies. Not only do motorsport companies regularly bridge the infamous Valley of Death, but they gain financial success from doing so.

Mind the gap

This has caught the attention of many engineering institutions and central government. The latter has poured resources and funding into schemes which encourage UK companies to increase innovation. These include R&D Tax Credits, Catapult Centres, the Advanced Propulsion Centre and Innovate UK, to name just a few. All aim to help bridge this difficult gap and so de-risk investment in innovation.

A quick check on TRLs shows that TRL 4-7 is the section which best covers the work of motorsport companies, yet this is precisely where engineering communities are aware that the highest risk is taken and where courageous investment is most needed.

The motorsport supply chain continually enters the Valley of Death and emerges unscathed – and returns to do the journey again and again. Companies are commissioned to rapidly respond to a change in legislation, or competitive pressures, to innovate solutions and deliver prototypes. This journey, within TRL 4-7, is funded by sponsorship secured by the entertainment of motorsport. It is this cycle which has created the unique business model of motorsport.

It is the value gained by the sponsor, from motorsport entertainment and 'winning the race', that finances our innovative engineering companies to enter the Valley of Death and to travel comfortably, and regularly, across the bridge. No other engineering community has the benefit of this business cycle.

Motorsport suppliers never really emerge from the Valley of Death, their end product is a prototype (TRL 7) which upon delivery delivers immediate financial reward, both to the buyer and the seller, then the process starts all over again, sometimes just a weekend later.

It is this rapid and continuous vortex of innovation and the delivery of prototypes, well-funded by eager commercial sponsors, that is a valuable asset just waiting to be exploited by our UK industry.

Make no mistake, the wider engineering community is eager to source this capability to deliver innovative engineering solutions fast. The agility, courage and light-footedness of the motorsport supply chain is very attractive to large organisations who simply cannot commit the funds and resources needed to support a specific department to handle such variable outputs which are, by their nature, difficult to identify and cost.

No other engineering community has the benefit of this cycle

XPB

Entertainment drives sponsorship which then drives innovation in motorsport

Once our business community fully recognises the asset of their capability, I am confident they will attract investment from many sources. Skills, developed in the cauldron of motorsport, have less fear of failure than others. Motorsport recognises that failure is often a necessary rite of passage for innovation and can bring unexpected rewards. Their engineering teams are constantly driven to compete, intellectually and practically, and their rewards are seen on track and on TV by millions.

The automotive, aerospace and defence industries are now positively encouraging the creation of rapid response innovative supply chains. Motorsport companies are already in the position to fill this gap and should move to do so. They can, immediately, offer their innovative capability to provide engineering solutions and charge a fair price for doing so.

Anyone who is interested in the Valley of Death in engineering should download the House of Commons Science and Technology Select Committee Report published in March 2013. Although lengthy, it really highlights the outstanding opportunity waiting for the motorsport community.

Horizontal innovation

Some suggest that by encouraging companies to look in this direction, I will weaken the hard-core motorsport industry but in my view, they are wrong. The very essence of motorsport engineering is that regulations and competition constantly challenge suppliers to deliver innovative solutions. This demand is relentless, and has, over many years, bred core skills in competitive engineers who will always seek to find a winning solution. They live for that challenge and it is motorsport which provides it.

I want MIA members and others in motorsport to grab the chance and use their latent capability to earn greater return on investment from a more secure environment than that of motorsport, where 'only winners survive'.

Some have kindly said that the work of the MIA in this area is an exemplar of what is needed for the future in the UK as we encourage our members to exploit their capabilities in other sectors.

The largest engineering institution in Europe – the IET – will be launching in November a partnership with the MIA, based on 'Horizontal Innovation', which aims to increase exploitation across sectors to benefit the entire technology community in the UK, Europe and beyond. MIA member companies are central to that programme and news of this will be released in early November.

One executive who understands this opportunity summarised it succinctly. 'I now realise that my company lives and prospers in the Valley of Death, we fear no evil but reap substantial rewards!'

I would be interested to hear your views, so please contact me at www.the-mia.com, as your opinion really matters.

Cool runnings

Keeping your car cool in the desert becomes even more vital when you're hitting 1000mph

The race to 1000mph, Britain's engineering feat that is the Bloodhound project, is ramping up nicely with the first tests of the car scheduled to take place in Newquay in the UK early in the new year, 2016. As those first, crucial tests are underway, engineers are increasingly looking at the detail design challenges. These include the issues of cooling the tightly-packaged rocket engine together with ensuring the volatile HTP (High Test Peroxide) doesn't decompose before it reaches the rocket chamber and, in effect, becomes a bomb.

'We've got approximately 1000 litres of HTP that has the equivalent explosive force of one stick of dynamite per litre if it reaches 40degC, and starts to decompose,' says Tony Parraman of Bloodhound's sponsorship liaison team. 'Packaging dictates that our supercharged Jaguar engine, that we use to pump 900 litres in just 20 seconds, is sat next to the tank, so preventing heat transfer is on our essential list.'

As a prime source of heat in proximity to the tank, the Bloodhound SSC team specified Zircotec's ThermoHold ceramic coating for the Jaguar exhaust. Plasma-sprayed at twice the speed of sound itself, the coating can reduce surface temperatures by at least 30 per cent, ensuring even as heat builds up during the two runs needed for the record to be validated, the tank remains stable.

Temperature resistance

Unlike previous record challenging cars, a large proportion of the Bloodhound front structure is composite. Chosen for its excellent strength/weight ratio, the drawback of composites is its poor resistance to temperature compared to metallic options. 'We turned to Zircotec again,' says Parraman. 'We know that they have supplied heat resistant coatings to Formula 1 teams for years, literally preventing the delamination of carbon fibre in high temperature environments, enabling the material to be used above its traditional melting point.'

Zircotec proposed ThermoHold for Composites, a zirconia-based coating that is applied at temperatures exceeding 10,000degC but in such a way that the substrate is unaffected. 'Zircotec's patented technology for protecting composites offers a huge benefit, allowing the use of lightweight materials in places where they are exposed to significant heat. Our engineers are not experts in thermal management and having Zircotec's technical support is helping to ensure we only use the coating where it is needed, saving weight where we can,' adds Parraman. 'We have used the coating on the composite upper chassis hoop, offering lightweight resistance that lowers surface temperatures by 100degC.'

Digging deeper into the Zircotec parts bin has seen Bloodhound pick ZircoFlex. The proven hybrid aluminium/ceramic heatshield, just 0.3mm thick, is being applied around any areas of the vehicle where heat is expected. 'With ZircoFlex we can bend and mould it to shape, it's lightweight and with self-adhesive backing, good for up to 500°C. We can use it in lots of areas,' Parraman says. 'For example, after a two minute run, the internal temp of the jet or rocket might be 3000degC but the externals are 200degC. We can manage that heat with ZircoFlex.'

Desert heat

With ambient temperatures of 40degC expected in the South African desert, Zircotec is also being relied upon to keep temperatures down during the critical time slot of one hour between the two runs. 'We want to prevent heat soak during this time. It will help us work faster without the risk of getting burnt,' says Parraman.

The team will trial the car in South Africa, providing a real test of the thermal protection. 'We plan to thermocouple the car and see where the heat issues are,' Parraman says. 'It's a one-off and we are pushing the boundaries so we don't know all the answers. Once we do, we'll be working with Zircotec to ensure that when we do get to Hakseen Pan we are fully prepared for the heat.'

Zircotec will be at the Autosport Engineering Show, held in association with Racecar Engineering, in January 2016.

AUTOSPORT INTERNATIONAL Engineering Show
14 - 17 JANUARY 2016 NEC BIRMINGHAM
In association with Racecar Engineering

Useful information

Ticket prices:
- **Trade tickets – £28**
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- **BRSCC members – free (available later in the year). Members will need to contact the BRSCC for tickets**
- **Live Action Arena – £11**

How to book –
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or call 0844 335 1109

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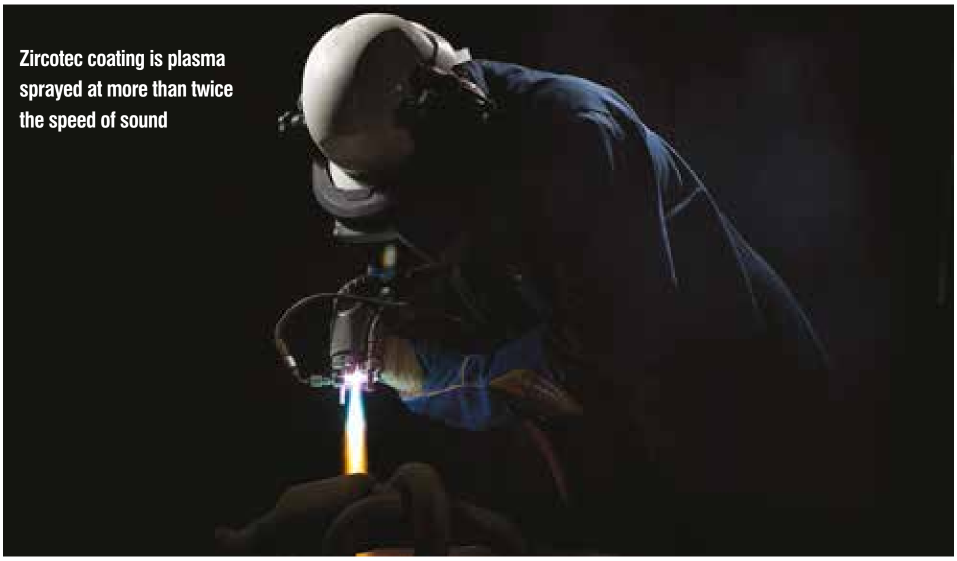
The shell scheme price includes a modern attractive shell scheme system with fascia board. All stands include carpet, cleaning, free stand listing in the official show guide and a hotlink on the Autosport International website.


Zircotec coating is plasma sprayed at more than twice the speed of sound

High speed hose

Fuel flow is vital for Land Speed record attempts – which is why it's vital to make sure you have top spec silicone hose

A good hose is vital when you're pumping 800 litres of HTP fuel in just 20 seconds

UK manufacturing brand SamcoSport has now joined the Bloodhound Land Speed Record project as the official silicone hose supplier.

SamcoSport supplies silicone hose to the world's top race teams including F1, BTCC and World Rally, and was approached by Bloodhound to help with its custom hose requirements, making use of SamcoSport's in-house fabrication and laboratory facilities at its headquaters in south Wales.

The Bloodhound Supersonic Car, with a weight of 7.5 tonnes fully fuelled, comprises of a 5-litre 550bhp supercharged V8 Jaguar engine (for the fuel pump), complete with custom designed SamcoSport hoses, making the heart of the car a formidable force, driving the rocket's oxidiser pump, which supplies 800 litres of high test peroxide (HTP) to the rocket in just 20 seconds.

A Eurofighter jet engine and three Nammo hybrid rockets will also be used, generating about 212kN (47,700lbs, equivalent to 135,000bhp), powering the car to reach its target of 1000mph across a South African desert in the summer of 2017.

Silicone hose

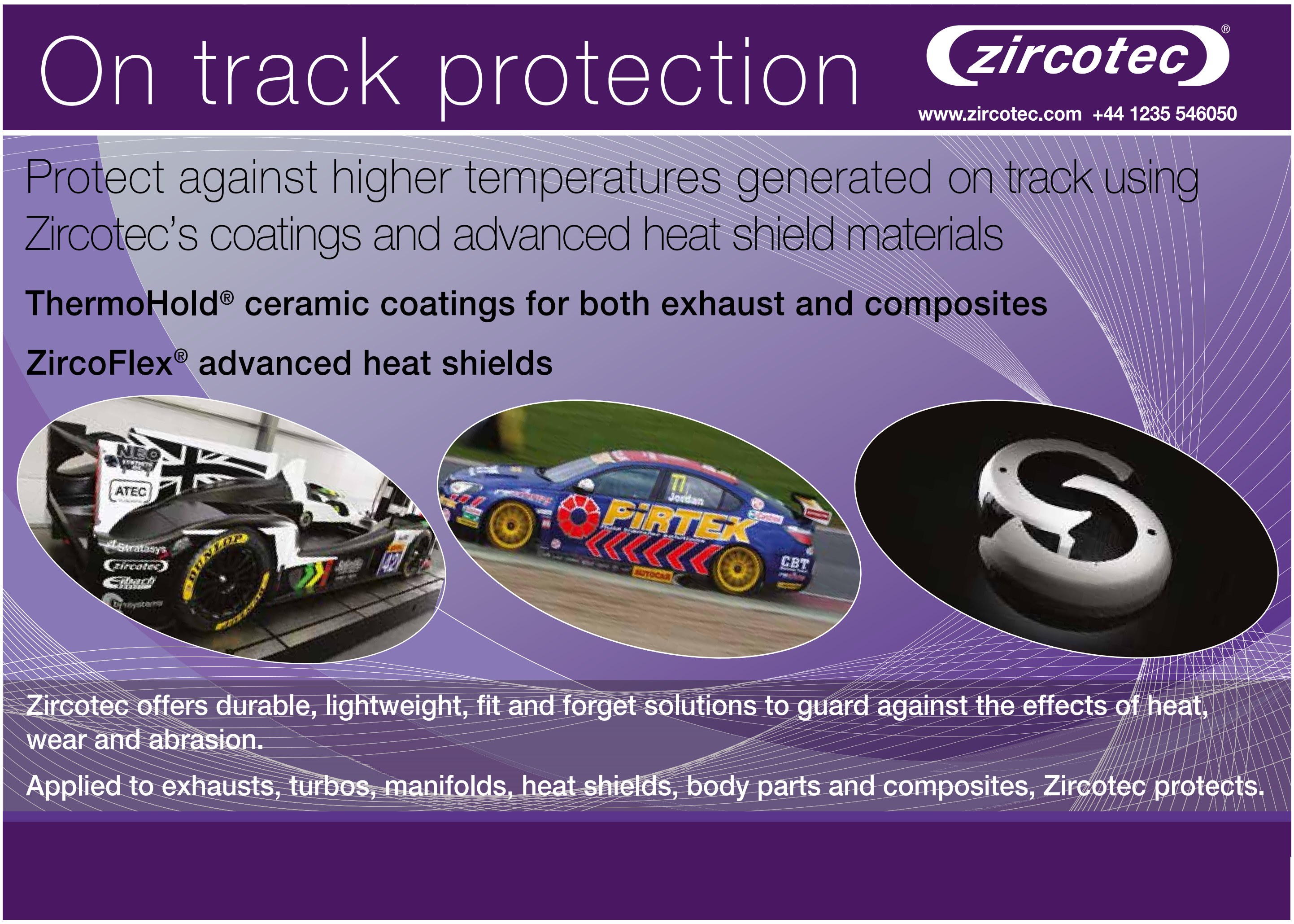
Besides the V8, many other parts of the build require high performance silicone hose, a product that SamcoSport is world-renowned for having pioneered in the market some 20 years ago. The system that pumps fuel into the jet itself requires a custom-made hose, and the development team at SamcoSport has had to work closely with those at the Bloodhound Technical Centre in Bristol to ensure that the hose will handle the extreme temperatures and pressures that the car will be under, during testing and its final run.

To prepare for this SamcoSport's product engineer, Daniel McDonnell, has headed up a series of tests on the required hose. 'The tests consisted of both working and burst pressure testing up to 10bar. We have to ensure the hose we provide are constructed to meet these specific requirements set by Bloodhound to ensure they can withstand the pressures and temperatures that will be put upon them when the car is being run.'

Lee Giles, Bloodhound's build technician, responsible for the Jaguar V8 and hybrid rocket system said: 'The support from SamcoSport has been fantastic. We give them complex hose requirements and they always deliver first class products on time.'

SamcoSport says it's thrilled to be helping a British manufacturer working with a UK-built supersonic vehicle trying to achieve the new world record and make history.

SamcoSport has had to work closely with those at the Bloodhound Technical Centre to ensure the hoses will handle extreme pressures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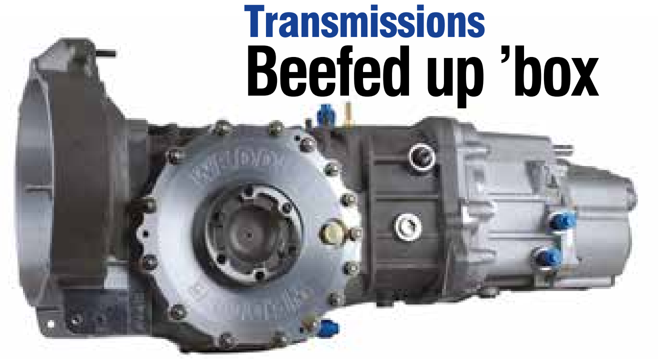
Transmissions
Beefed up ’box



Californian company Weddle has launched a new range of competition transaxles. The firm took the lessons of its well proven HV1 and ‘beefed it up’ to meet the demands of bigger tyres, bigger engines, and better suspension.

In addition to wider gears and larger bearings, the new HV2 gearboxes feature a completely redesigned shift mechanism, extra bearing supports, and a larger input shaft/mainshaft combination.

The HV2s come in both 4- and 5-speed versions. Both feature 27mm wide forward gears, a heavy duty synchronised reverse gear, Weddle Racing 10in Klingelnberg palloid ring and pinion, torsional 300M input shaft, tapered roller bearings on mainshaft to handle end thrust, heat treated and precision ground shift rails and shift shaft, billet shift forks, a shift shaft more centrally located for ease of installation, and mid-plate bearing support between second and third gears.

www.weddleindustries.com

Brakes
Tough brakes

Caparo has launched a range of five calipers for NASCAR, able to cover short track, intermediate and speedway set-ups.

Four of the five calipers have a monobloc design. Some of them feature ceramic coated caps to improve thermal performance.

www.caparovehicletechnologies.com

Components
External assistance

AP Racing has introduced a new pneumatic emergency clutch release system.

The CP9810 family of actuators fulfils the FIA’s requirements for external clutch disengagement, providing race marshals with a simple and efficient process when moving stricken cars – as the system enables clutches to be released from outside the car.

The new system is fully compatible with AP Racing’s CP4623 type master cylinders without the need for modifications. However, master cylinder bore sizes need to be calculated from clutch release load and travel.

The unit requires an air source of 8bar to 10bar, along with a 9-volt power source and an externally mounted activation switch. These are not supplied with the units but

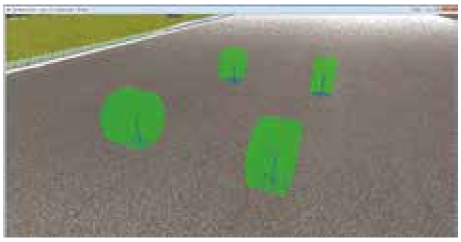
an air source can be provided by AP Racing. Appropriate AV mounts should be used if the unit is to be attached directly on to a gearbox or engine.

Clutch opening times are controlled by the amount of air pressure and the type of master cylinder and clutch specification, with an electrical response time of 10ms. The clutch is released once the power is removed using a push to break switch.

The CP9810 family comes in four variants. For more details go to: **www.apracing.com.**

Software
Tread softly with SISTer

Cruden has launched a new software application for tyre and vehicle models to help improve the accuracy of simulations. It works out of the box with any vehicle simulation that has Simulink connectivity.



The new software , SISTer, is programmed to determine how the contact patch is deformed, replacing the single point with multiple points. It provides highly improved input to the tyre model, resulting in far more detailed and precise forces and moments. The software works with any combination of vehicle and tyre model in real time, and is a separate process which frees the vehicle model from the computational load associated with evaluating 3D scanned surfaces.

Developed by Cruden in-house, it is a flexible package, working with many forms of surface data: LIDAR data represented by a triangular mesh or as a point cloud, OpenCRG files, or smooth splines enhanced with spatial properties. Based on the current wheel-position, orientation and road surface irregularities, SISTer evaluates contact path deformation for every tyre simulation time-step and returns road normal and dynamic application point to the tyre model within 2ms.

The software is not limited to tyre-road interaction; it can also be used to detect collision between the vehicle chassis or race car plank with the road surface, or as a ride height estimator for aero models.

www.cruden.com

Video
Vroom with a view

Race-Keeper has introduced the HDX2: a multi-camera, dual-stream, 1080p HD video-data logger.

The HDX2 captures broadcast quality images from two 1080p HD cameras and automatically synchronises this video with data from 20Hz GPS, built-in tri-axial accelerometer and ECU/CAN/OBDII connections.

It has already been used in high end motorsport including WRC and GT3. It has also seen action at both the Le Mans and Spa 24 hour races, Pikes Peak hillclimb and the Isle of Man TT.

www.race-keeper.com

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recycle

www.racecar-engineering.com

Bump daft in the USA

The rise of technology is an interesting topic, be it in road or racing cars. On a trip to the US recently I decided that there are two uses for it. One is to make life safer, preserve the breath in our bodies, and technology can certainly help to achieve this goal. The other is simply to get in the way of enjoyable driving.

Cadillac was kind enough to offer me an AST-VR, which boasts a 3.6-litre V6 twin turbo that could power the car to 189mph. When Doug Fehan, programme manager at Corvette Racing sat in the Recaro seats, he made the same 'ooh' noise as I did. He is impressed by GM products and, in this case, I agreed with him. The seats are pretty cool. The performance is pretty cool too – a drop in gear from sixth to fourth and a short stab of the throttle and plod might have taken an interest, particularly with the noise that it made.

This was lovely, but there was a problem with the car. It was fitted with an electronic glitch that meant changing lanes without using the indicator required some effort. The lane assist function warned when you were running off the road. This can only be good in limited circumstance; when falling asleep at the wheel, using the phone or generally not paying attention. None of these is good in practice, so to the irritation of someone who has no one behind to inform that they are changing lane, an indicator must be used at all times.

It was, in short, catering to the lowest common denominator, so I decided to see how low I could get the denominator. Setting cruise control at 55mph on an empty road, I loosened my grip on the steering wheel to see how far I would go before any input was required. 'Bumping' off the painted lines to the left and to the right was a gentle experience at first, and amusingly the car seemed to get increasingly frustrated. The first two 'bumps' were modest changes in direction, not even enough to take me to the other side of the lane. The third was more severe, the car assuming I had fallen asleep, I suppose, and tried to wake me up by firing me across the lane where I would bounce back again. I really was interested to see how severe this bouncing would be, but realised that, if a law enforcement officer had seen me, I couldn't really explain to him what I was doing.

So, here we have a 464bhp, 189mph car that requires no steering or throttle input from the driver on an open highway. The adaptive cruise control would cope with any traffic had I let it go that far. All that was missing was voice control to increase or decrease speed at will.

Is this safe? Many in the paddock at Mid-Ohio decided that all such safety features were a *good thing*, and this was disappointing. In fact, I struggled to find anyone who said this was a bad idea. If it saved you once, it must be good, was the thought process. People had more of a problem with the $3500 carbon fibre lip on the front spoiler that could easily and expensively catch a kerb. I was supremely relieved that I handed the car back with that, and everything else, intact.

So, this in my opinion was technology for technology's sake, and I was concerned at the lack of questions as to why this stuff is on the car. If you don't want to pay attention to your driving and you subsequently crash, you should not be prevented from doing so, particularly in a performance car. You should be paying attention much more often than just when you are parking. I had the same problem with the Lamborghini Huracan last year. For a car that was designed for speed, was noisy even at low speeds and had the fuel economy of a tanker, where on earth would you go that required an Audi A6-inspired sat-nav?

There are manufacturers that have introduced the technology in the right cars. A people carrier, for example, is designed for one purpose – to carry people and that should be as safe for passengers and difficult to crash as possible. A car full of screaming children is a distraction, as is a film in the head rest-mounted television sets that is designed to shut them up on a long journey, so all driver aids are welcome. Head-up displays are also interesting as they help to focus the eye on the road ahead (the ATS-VR had this too and it was great until the sun shone on it).

In the right environment, technology can work. In endurance racing, a long distance event can show off better fuel economy, hybrid technology, and tyre technology as well as non-road relevant information such as strategy. In Formula 1, a flat out sprint from lights to flag in unruly cars should be part of the fun. Much as the Cadillac was a performance car that had enough safety functions to save an average driver from acts of stupidity, I have said it before; each racing category should serve one function as best as possible. Trying to achieve more doesn't increase attraction, it dilutes the message. I was more worried that I seemed to be alone on this train of thought in a racing paddock.

It was, in short, catering to the lowest common denominator, so I decided to see how low I could get that denominator

ANDREW COTTON Editor