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Sebastien Ogier opened his WRC account in 2023 with victory on the Monte Carlo Rally for TGR, during the month that Toyota Company President Akio Toyoda confirmed he was stepping down

IMSA's debutante ball

Pre-race doubts were dashed as the new prototype era was ushered in

Many were predicting a reliability horror show at the Daytona 24 hours as the new GT Prototypes ran with a hybrid system that had, at best, been heavily criticised in the run up to the race.

However, come the 24-hour race, the opening round of the IMSA WeatherTech sportscar series, the new hybrid-equipped cars ran well, and the fight for the win came down to usual racing dramas: mistakes in the pit by teams; mechanical issues that could be expected of any new cars; and varying driver tactics in managing traffic.

From a supplier perspective – Bosch, which supplied the MGU, WAE that provided the battery and Xtrac that made the gearbox for the hybrid system that was used by all the GTPs – each of the components performed better than expected. There was an undiagnosed failure on one of the BMWs, the team electing to change the entire system for caution sake, and Porsche changed a battery, despite WAE noting there was no evidence of failure. Porsche also had a gearbox issse, but Xtrac preferred not to comment until full analysis had been completed.

Considering one motorsport boss said the chance of running to the end without a mechanical issue was 'zero' on Saturday morning before the race, he was delighted to be proven wrong.

Be prepared

Most of the prototype teams, including BMW, Porsche and Cadillac, had completed long run testing over the autumn and winter. These tests were regularly interrupted by failures of some description, but that's normal. You see what breaks and then you fix it.

The problems continued at the December test, where teams had sight for the first time of the new 2023 tyres from Michelin and new fuel blend from VP Racing. Cars still regularly broke down and consequently, in the paddock before the race, there was feverish activity as parts were prepared for the race. Complete rear ends were built up in case of an MGU failure, teams calculated lost time (40 minutes) for a battery change, and uprights were prepared for change, just in case of failure there, too. Yet during the race these items were not required as teams changed their philosophies from running what they wanted, to running what they needed.

The race was not perfect in terms of reliability of course, but it was better than expected. BMW had its first issue in the first hour, and subsequently had another stop to chase what turned out to be finger trouble on Saturday night. Porsche lost time changing the battery on one of its cars on Saturday evening, and then a hole appeared in the gearbox casing of the second car on Sunday afternoon. Cadillac lost time with accident damage to two of its cars but were otherwise reliable. Acura had a gearbox oil leak from 3am in the Meyer Shank car that won the race overall. The team managed to the end of the race, while a mistake in the pits while topping up with oil cost the Wayne Taylor Racing team three laps during the night. They recovered to second overall having broken the guiding pins to fit a low drag rear wing for the sprint to the flag which forced them to run the high downforce wing to the end.

Richard Dole

Teams expected reliability problems with the GTP cars, but there were four cars on the lead lap in the final hour, giving teams and fans plenty of reasons to be cheerful

Teams debuted Michelin's cold and medium temperature tyres. They had to use the cold temperature tyre between 7pm and 8am to help cope with the anticipated drop in ambient and track temperature. That didn't happen, so the medium tyre was deemed better all through the race. Teams used the cold temperature tyres when they had to, simply to stack the mediums for the final run to the flag.

That said, there was some off-track drama with the tyres. Michelin's new tyre will be used in the World Endurance Championship, where Porsche and Cadillac will race at Sebring in March against Peugeot, Toyota and Ferrari. The LMH teams were reported to be grumpy that they did not have the same opportunity to race on the tyre before facing these cars in Florida. However, there were not too many other options for Michelin as LMH cars did not enter the Daytona race and the GTP cars did.

Due to the reliability issues, IMSA had little relative data to work from, the BoP could not be adjusted ahead of the race, but even BMW, which was woefully off the pace, didn't say anything as the team was so early in its programme it was still finding chunks of time as it learned how to set the car up.

Rocket launcher

In GTD, however, it was a different story. Porsche and BMW both appeared to be heavily penalised by the BoP, as was Lamborghini, and the governing body, IMSA, made it clear it was not the fault of the BoP engineers. All cars need to show their true performance for the regulators to do their job, and IMSA fired a rocket at the teams for building vehicles overweight, leaving excess fuel on board after qualifying, running wing angles not representative of fast times and ride heights not in conformity. Such is the modern endurance racing world.

Finally, there was talk in the paddock of the future of LMP2. With a shrinking market as the class is dropped from the WEC, it is clear to the suppliers that there is not room for all four chassis manufacturers – Multimatic, Ligier, Dallara and ORECA – to maintain a business case. So, they are looking at reducing the number of manufacturers, either by opening it to tender, or having two drop out voluntarily. Each of the manufacturers want to continue to produce LMP2 cars, so this will keep the FIA and ACO busy in the first half of the year. An announcement is expected at Le Mans.

One motorsport boss said the chance of running to the end without a mechanical issue was 'zero' on Saturday morning… he was delighted to be proven wrong

Vetting process

General Motors has fulfilled its promise and produced a ground-up GT3 car for the global market. Racecar *spoke to the project's lead development engineers at its launch in Daytona*

By ANDREW COTTON

With the collapse of the GTE / GTLM regulations in top-flight American endurance racing at the end of the 2021 season, General Motors faced something of a challenge. The rules for GT racing in the US had switched to GT3 and the company did not have a suitable car to enter the competition. Instead, it reached an agreement with IMSA organisers to downgrade its existing car to meet the performance windows set by the series' technical team (see *RE* V32N4) and started work on a completely new racecar with which to enter global competition.

A full 12 months before the car will make its race debut, Corvette launched the Z06 GT3.R and outlined some of the main differences between it and its predecessor. Key among those is the chassis, which comes straight from the Corvette production line.

The technology within in the car is geared more towards the customer market this time as, while IMSA still has a class for all platinum-grade driver line ups, the regulations stipulate 20 cars must be built for competition within the first two years. When the World Endurance Championship takes GT3 cars in 2024, it too will stipulate customer drivers.

GM's team behind it has therefore worked particularly hard on serviceability, knowing the car will be run primarily by customer teams and driven by customer drivers.

Stable regulations

While Stephane Ratel developed the class, GT3 regulations are owned and governed by the FIA. As such it was up to the FIA to work with manufacturers to create a set of regulations that they were happy with.

With these in mind, each of the major manufacturers have created new cars, including Ferrari and Porsche, and each debuted their offerings in international competition at Daytona in 2023. Now, Corvette has produced an all-new challenger for the category but, unlike its rivals, there is no global customer racing department, so that needs to be built up in short order.

The plan is to enter four cars into IMSA in 2024, and a further two into the FIA World Endurance Championship the same year, before the car will be made available to teams competing in other racing series. This means GM will offer support to teams competing in IMSA and the WEC in both the GT class for Corvette, and the prototype class with Cadillac. During its initial fact-finding mission for what the teams would want, it was this on-track support that was key.

GM says it has yet to select teams, but has had advanced discussions with interested parties and, with such a limited programme in 2024, is in a position to select the teams that will represent it in global competition.

Production base

Corvette will continue to work with its long-time partner, Pratt Miller Engineering, to construct and develop the Z06 GT3.R. But, for the first time, the chassis frame comes from the same production line as the road going car, which has helped to keep costs down for what is essentially a customer-based car.

The rollcage is installed into the all-aluminium chassis frame at Pratt Miller, while the previous C8.R was disassembled and then rebuilt around its 'cage. The first Z06 GT3.R 'cage was CNC cut and hand assembled, with measurements on dimensions and angles individually checked to maximise safety and efficiency. With that structure signed off, future builds will be done more efficiently, and the process sped up by the use of highly repeatable fixturing.

Access to the cockpit has been improved compared to the C8.R, allowing for different sized drivers to make quick driver changes, but Corvette has retained its impressive side-impact honeycomb structure that also serves to minimise debris ingression into the cockpit in the event of an accident.

In order to focus on the customers, all hardware on the body and chassis has been reviewed. Damper adjustment has been made more accessible, the bodywork is easier to take off, and the radiator is attached to the frame, rather than coming off with the nose, as was the case with the outgoing car.

'The serviceability of the car was something that we looked at, every part in every assembly when the car went together, and we understood that we had a lot of compromises in serviceability for the GTE [GTLM] car,' says Corvette Racing's technical director, Ben Johnson.

'We understood the GT3 car would be only run by a select group of teams, and it was very well controlled, so you could manage the complexities of the car. But when the GT3 car goes to a customer, we want them to be successful without necessary interaction from the factory. We want to be there for any questions or feedback from the teams, but they shouldn't need to reach back every time they service the car. That was a major focus.

'We have obviously done some very clever things with how the bodywork goes together, and a lot of that is dependent on how the base production car is constructed, and what freedoms that gives you. But the way we intend the car to be serviced has been re-thought for the GT3 car to make sure it makes sense from the customer perspective, also knowing that it's still an endurance car that can do 24-hour races around the world.'

Unlike its rivals [in GT3], there is no global customer racing department, so that needs to be built up in short order

A more powerful diffuser was part of the aero development as that then allows a cleaner over body design. A more complicated design was considered to be the cheaper solution for customers

‘The serviceability of the car was something that we looked at, every part in every assembly when the car went together’

Ben Johnson, technical director at Corvette Racing

The new cars will be constructed and developed by Corvette’s long-term racing partner, Pratt Miller Engineering, and homologation requires 20 units be built in the first two years

A swan neck support structure for the rear wing is now common in GT3 racing as it is more efficient than underside mounting

The car was developed on Michelin's confidential tyre, but suspension kinematics are designed to work on different tracks and rubber

Currently, there are six Corvette C8.R chassis in existence as the company moves into the second transition year, and two Z06 GT3.R chassis, but the move to the production base means the company will be able to scale up and intends to hit the target of two Z06 GT3.R cars every eight weeks. The utilisation of pre-built sub-assemblies and warehousing of these parts will also speed the process up, enabling concurrent rather than in sequence builds, as was the case with the C8.R.

Power unit

The car will be powered by a version of GM's flat-plane crank LT6 engine, a 5.5-litre V8 capable of producing around 525bhp, depending on Balance of Performance. The race engine will have a different sump and front cover castings, as well as fixed cams, oil and scavenge pumps, oil cooler and plumbing compared to the road car.

'Otherwise, it's really quite close to the Z06 engine, which is a big cost enabler,' says GM assistant sportscar racing programme manager, Christie Bagne. 'It is also good because that engine has gone through production level durability, so it's expected to last for thousands of miles in a high-performance road car. We know we've taken that and modified it to work in a racecar, but we have still maintained that durability from the production design process, which spun the engine up to 8600rpm, as opposed to 7400rpm on the race version.'

The engine was always designed and maintained in house, even in the GTLM programme, so the team is well used to working on race engines.

One of the key differences with the LT6 engine is that it is not governed by a sonic air restrictor, which has allowed the engine to breathe a little easier.

'Although the red line is still 7400rpm, the shift point is higher for the GT3, at 6800rpm rather than 6300rpm,' notes Bagne.

As usual, the engine is mounted lower and further forward in the chassis to help move the c of g forwards, but Corvette has not gone as far in the design process as some of its rivals. While others have mounted the engine so close to the floor that they need protection, Corvette's designers did not feel the same need to do so.

The team is using a bespoke Xtrac race gearbox and, says Johnson, the weight is similar to the one used in its predecessor. 'Relative to GTE, those components and their weight placement, and overall weight is generally pretty similar,' confirms Johnson. 'Specifically, they have not had a large impact on the c of g location.'

The gearbox has simplified internals, more in line with a customer racing programme than one of factory competition, but the casing is also new. Originally, it was designed to work optimally with Michelin's confidential tyre, but was then adapted to run on the commercial tyre from Michelin in the new GTD regulations.

Operating window

In competition, the Z06 GT3.R will race on many different makes of tyre, as well as on various different European surfaces, along with the US tracks, so the team has had to work hard on suspension kinematics to widen the car's operating window.

'The confidential tyres were a bit easier in terms of development because you have to develop your car based on the sensitivities and the targets that were available from this virtual development phase,' says Johnson. 'Then you are ready to work with Michelin, and customise the tyre specifically to the choices you have made.

'That was done concurrently with Michelin, and we have carried that process forward where we now know the performance level of the commercial tyre.'

The car's final aerodynamic configuration has not yet been set and homologation is not due to be signed off until October this year

View from the cockpit

Tommy Milner is one of GM's development drivers for the Z06 GT3.R and has been on the project from the start.

'We started on the simulator as early as 2021, and what that offered us is the opportunity for the engineers, both aero and chassis-wise, to drive a car that you normally wouldn't try in real life. You can run 30 different aero configurations in a day and have some direction, so that speeds up development and when the car hits the track for the first time it is in the performance window you are looking for.

'The Z06 GT3.R is designed to run on the customer tyre and it does certain things better than what we can achieve with the current GTD-spec car.

'It does feel different, but we are hyper critical of what we are feeling. It does certain things differently, so there is a bit more aero and putting power down is a bit better. Ultimately, the car has to be good for everyone, not just for us.'

The Z06 GT3.R will race on many different makes of tyre, as well as on various different European surfaces, along with the US tracks, so the team has had to work hard on suspension kinematics to widen the car's operating window

Working with a wider range of circuits, track surfaces and conditions is one thing, but the car also has to be driven by customer drivers of differing skill levels on the different manufacturers' rubber.

'As the car is saleable, we expect to have a wide range of driver experience, so we put a big focus on ensuring the car was stable and comfortable to drive, and that while a platinum-grade driver is able to extract the performance they would expect from the car, a bronze driver with less experience is also comfortable in the car and able to produce the lap time they would expect,' says Johnson.

With that customer driver in mind, the design team also worked on the cockpit ergonomics, but here they were more able to rely on the experience of the GTLM car.

'We put a large focus into that in the C7R, understanding the main points and making quite a large step forward in terms of ergonomics and the drivers' ability to adjust critical functions on the fly while still keeping their focus on track,' says Johnson. 'For the GT3, it's fair to say it's an evolution of that.'

Electronic systems

The GT3 regulations have very different demands from the electronic systems, with a ban on such items as stability control, though ABS and traction control are permitted. The current specification GTD car meets these criteria, but it's a very different prospect to start with a car that already had these systems integrated and then take them out, compared to designing and building a car without them in the first place.

Corvette's engineers therefore worked hard to retain what worked from the GTLM version of the car in the GT3 version.

'Similar to every other sub-system, such as the suspension, chassis, engine and gearbox, the electronics have also been updated to be appropriate and specific to a GT3 car,' says Johnson. 'There is less need to customise any of the background systems, algorithms and control strategies that were relatively open in GTE and a point of development. That's not the state of GT3, and IMSA must make sure the BoP is stable. Then the teams can focus on car operation vs background development. Again, we have retained everything we have learned from GTE and made that more fixed for GT3. So it's been a case of not removing capability, but removing complexity.'

One of the areas Corvette is most proud is the speed at which the new parts could be developed. The team worked in its DiL system to widen the operating window of the car as far as possible, but it also made use of 3D printing to accelerate the development of aero parts, including the front splitter.

'A big part of our goal is highlighting one of the capabilities GM is really proud of; our ability to print parts in house fairly efficiently to support our race programmes,' says Bagne. 'Being able to print four different iterations of the front splitter, for example, and go test each one of them, is a big technology enabler for racecar development.'

Aero development

The aero needed a lot of work to perfect in this new generation GT3 car, as the demands on cooling, and items such as the performance windows, are very different to those of the current generation car.

'Aside from what has to be production surfaces by the regulations, the aero windows are different, and the aero regulations are far more open in GT3 so every manufacturer, regardless of the base car, can get into those aero windows,' says Johnson. 'We have taken that opportunity to learn from what worked well in C8.R, while also acknowledging the car needs to be very stable and driver friendly.

'The targets for the aero system are different, your pitch sensitivity is different, your aero balance migration through the corner is a different target that makes the car more stable and easier to operate across a range of driver experience.'

One of the main targets of the aero development were making sure the car was adequately cooled in all temperatures, and all elevations for the circuits it will visit. The IMSA schedule is already challenging in that it runs in hot temperatures in the summer, close to freezing temperatures in the 24-hour race at Daytona in January, and often in the rain in the 1000-mile race at Road Atlanta.

For the GT3 design team, that meant sizing everything properly to ensure that no matter the conditions, or altitude, they would not lose performance cooling the car.

'In GTE, you are operating on the ragged edge of the engine and gearbox durability to try to gain performance back into the car,' says Johnson. 'Certainly, we are within the GT3 aero windows, and making sure the car is competitive, but the last thing we want is the customer teams to be overly concerned with operating temperatures, so opening up and extracting as much cooling as necessary for the car [was a priority].'

Tidy airflow

To facilitate this, the team was able to change the airflow under the front bodywork. The GTE car had air exiting the bodywork out of the front and the wheel arches, while the Z06 GT3.R will have almost all of it exiting out of the front bodywork, tidying the airflow around the front wheels.

With more efficient airflow at the front, all the downstream components are positively affected, including the rear wing, cooling and the downforce generated by the rear diffuser.

The team also had to bear in mind the cost of the individual component parts, so a lot of effort was put into making the car more efficient on the wallet, too.

'Extracting as much performance from the bottom of the car as possible was one of the targets, because you can then make the top side of the car less complex, less expensive and less prone to race damage than the bottom of the car,' says Johnson. 'A simple diffuser or a more complex diffuser, the difference in cost is relatively small, so you want to extract as much performance from that as you can.'

Starting ahead

Clearly, that led to a discussion with the suspension design team, and then the gearbox design team, but that's all part of a normal development process.

One major point in the team's favour was that the Corvette came from a base design of a successful factory GT car, so they had to take out complexity, whereas others may have only ever had a GT3 car, and have had to introduce improvements. It's an interesting point, highlighted by Johnson:

'Relative to our benchmark, the car is less complex and therefore easier to service and less expensive as a result.

'The systems, engine placement, gearbox and how its placed, how that advantages axle angles, the architecture of the suspension and how that is integrated into the chassis, I think it's all still very cutting edge and making full use of the regulations.

'Extracting as much performance from the bottom of the car as possible was one of the targets, because you can then make the top side of the car less complex, less expensive and less prone to race damage'

Ben Johnson

'When people see under the body they will see more and there will be similar revelations to those shown by Ferrari and Porsche. We see them and say that's clever. But realistically, we have pulled back on the complexity relative to the baseline we have today, though that's just looking at the situation through a different lens.'

Homologation of the car is expected to take place in October this year, and the car will not run in competition until the Daytona 24 hours in January 2024. Before that, however, there is an immense testing programme to complete, and then a build schedule to put in place and implement to meet what is expected to be high demand for this exciting new racecar.

Acknowledging its customer focus, aero development has concentrated on making a car that is stable and easy to operate over a wide range of conditions for drivers of differing abilities

It's not the first time a NASCAR has competed at Le Mans, though admittedly the last time was in 1976

Richard Prince

NASCAR's gamble

The idea of a NASCAR racing at Le Mans has proved controversial on many levels. Racecar *spoke to Chad Knaus, vice president of competition at Hendrick Motorsports, to find out what the thinking is behind the programme*

By ANDREW COTTON

Many were sceptical about the announcement in March 2022 that NASCAR would take one of its Gen 7 Cup cars to Le Mans to compete as the Garage 56 entry for the 2023 centenary race. It seemed to be an unlikely pairing for the race, but GM's Hendrick Motorsport, NASCAR and IMSA are working to get the car prepared and ready for the Centenary race in June.

The announcement was made at Sebring, and was immediately controversial. GM's Hendrick Motorsport was confirmed to run a Chevrolet Camaro ZL1, which could have disadvantaged both Ford and Toyota, both of which compete in the US Touring Car series.

Some claimed it was just a marketing gimmick, one that would take up a space on the grid instead of a more deserving competitor, likely from the LMP2 grid. It was, said the detractors, simply a move to strengthen the tie between the ACO and IMSA, which is part of the NASCAR family, and it did not showcase future technologies in the way Garage 56 was designed for.

Yet to put the project down on these bases alone would be to underestimate the effort being put into the project even to make it happen, never mind to be successful.

NASCAR introduced the Gen 7 cars in 2022. The new cars were closer aligned with the manufacturers' street cars than the previous Gen 6, with a smaller greenhouse, longer rear deck and changed underfloor aerodynamics aimed at enhancing the racing. The series also moved to 18-inch centre lock wheels, while tyre supplier, Goodyear, mounted softer compounds onto the bigger diameter rims to change the characteristics of the car throughout the race.

The [Gen 7] car is better suited to running further afield than just the traditional NASCAR courses, and there is a desire for the racing series to be promoted to a wider audience

The huge technological advances brought in for Gen 7, including IRS, five-way adjustable dampers, rack and pinion steering and 18in wheels and tyres opened up opportunities to show the car off that were never appropriate before

IMSA President John Doonan chats with test driver Mike Rockenfeller during testing at Virginia International Raceway.

More use was made of carbon in body panels, replacing the steel of the Gen 6 cars, and for the first time the racecars have independent rear suspension, replacing the solid rear axle that has been a feature of NASCAR from day one. On top of this, five-way adjustable dampers and rack and pinion steering were also introduced on the Gen 7 cars, giving teams more opportunity to set the cars up for ovals and road courses.

The new car is therefore better suited to running further afield than just the traditional NASCAR courses, and there is a desire for the racing series to be promoted to a wider audience. Think Kimi Raikkonen taking part in a race at Watkins Glen, for example.

Using NASCAR's influence on IMSA, the tie-in to run a car at Le Mans therefore makes sense. It is also not the first time a NASCAR has competed at Le Mans, though admittedly the last time was in 1976.

Competitive advantage?

However, even taking the suitability of the car into consideration, GM's programme has been developed to an extraordinary level. With such intense competition in NASCAR, rival teams and manufacturers were concerned that the Hendrick team would gain some advantage in terms of testing the car, and being able to transfer any learnings back into its Cup series activities.

The reality is different. While the car bears an outer resemblance to the Cup car, under the skin, and even the skin itself, is different.

'It's a completely unique vehicle,' says Hendrick Motorsports' vice president of competition, Chad Knaus. 'The overall architecture of the car is very similar to what we run in the NASCAR Cup series with the Gen 7; it will look very similar; but it has aerodynamic enhancements, so a more dynamic and powerful front splitter, a little bit more efficient rear diffuser and wider tyres that have been provided by Goodyear.

'The outer body is very similar, but it has dive planes and some quarter panel canards on it to increase performance. It also has headlights, tail lights, traction control and paddle shift, so there are lots of things to make the car appropriate to go racing over there. Even the engine is different compared to what we have raced in the Cup series.

'Le Mans is a unique venue, it is challenging, there is no way of knowing what is happening in the week and a half that we will be there from a weather perspective.

'So it has different dampers, the motion ratios are different, the aerodynamic forces are so different and the mass of the car is different, so there is not a tremendous amount that can carry over because we are able to reduce a lot of things that are ruled and governed by NASCAR that we don't necessarily need to have going over there.

'The cars here are designed to go 200mph in a circle and be able to hit the wall really hard. That is not what we are going to be doing over there! The risk is always there, but the car is a far departure from the Cup series.'

Mass factor

The first thing the team had to work out, then, was what the car needed to race at Le Mans. The Gen 7 car's base weight by regulation is nearly 1500kg, and so it needed to be put on a strict diet to bring it down to the GTE weight closer to 1200kg. For that, the development team approached each of its suppliers, asking them to take weight out of their individual components. That included the body panels, chassis, wheels and running gear. Everything has been spec'd to run at Le Mans for 24 hours, while also being considerably lighter. 'Everyone contributed to knocking mass out of the car,' confirms Knaus. 'We are still working on it and losing big chunks of weight, but everyone is working hard to get mass from the car because that is a good way to get performance.'

The team then looked at the aero loads for the car, and particularly at the high-speed changes of direction that would be needed to accommodate the Porsche Curves, and Indianapolis, while also dealing with lower-speed corners such as Tertre Rouge, and then balancing that with the long straights where the car will reach its maximum velocity.

'If you reference the Porsche Curves, that series and combination is not duplicated anywhere here in the States, but if you look at COTA, the esses going down the hill there gives us an idea what we have to prepare for,' says Knaus. 'We will have a fast car, but our intention is not to go 230mph or anything ridiculous like that. Instead, we are focused on making the car handle but, as you increase the downforce on the car, inevitably you increase drag too, so that will begin to reduce the top speed factor.'

One concern is that the heavy car, coupled with high straight-line speed, will be a recipe for disaster in the braking zones, particularly around the LMP2 cars. The fear is that the NASCAR will have high top speed, but its braking distance will be far longer, increasing the chance of rear-end impact should the Camaro overtake shortly before its braking.

'The LMP2 cars are significantly lighter and produce a tremendous amount of downforce but they don't have the horsepower, so we will have to see how that all equates once we get there,' admits Knaus. 'We are still in the preliminary stage of testing; we are going to Sebring [editor's note: that has now happened] and will get an idea of where we will stack up against the competitors because that is a track the others have been on.'

Drag act

Drag will be increased as, with a nod to NASCAR's heritage, the drivers will still be required to climb in and out of the car through the side window. That means it will run with side netting in place of a window, and that should slow the car in a straight line. Another drag-inducing device is the rear wing. The development team has opted not to use a bespoke rear wing, preferring to rely on a NASCAR-style spoiler on the boot lid.

'The basic architecture of the car is very much as we would race in the Cup series,' says Knaus. 'We have just been able to lighten it and do things we can't do legally in the NASCAR Cup series to race weekly in a controlled environment. We are running a conventional spoiler at the rear of the car, for example, not a rear wing, because we feel we can gain the efficiency we need through the appropriate measures to get the performance and keep that looking like the NASCAR Gen 7.'

One thing that will be different is the switch to a paddle shift, replacing the sequential stick normally used. The decision was made for reliability purposes as the pneumatic shift is less stressful on the Xtrac gearbox. The 'box itself is standard NASCAR spec, save for a slight adaptation for the new shift mechanism. The gear ratios, unsurprisingly, will be completely different, but the team has not yet finalised those. The pre-Christmas test at Sebring was primarily to work through such details.

'Just to be able to control the revs through the ECU made sense from a durability point of view,' says Knaus. 'Our goal is to try to go for the 24 hours, and NASCAR is looking at different things it can implement in the future. Who is to say that we don't need

'The cars here are designed to go 200mph in a circle and be able to hit the wall really hard. That is not what we are going to be doing over there!'

Chad Knaus, vice president of competition at Hendrick Motorsports

Richard Prince

Development has focused on handling and aerodynamics, with a more dynamic splitter, rear diffuser, dive planes, canards and wider wheels and tyres ensuring the car is capable of outright speed on the straights and also high speed changes of direction through the turns


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paddle shift in years to come? It is a good way for them to explore technologies that they might use in the future.'

Hybrid consideration

At the announcement, made at Sebring ahead of the 12-hour race, it came as some surprise to many in the room, including some at the top table, that there was consideration to run a hybrid system in the car. At the time, NASCAR's chief administrative officer, Ed Bennett, who is also the CEO of IMSA, said it was the LMDh system that would be investigated for further use in the Cup series. However, with all the drama surrounding development for its primary use in LMDh, the decision has been taken to take hybrid of the table altogether for this programme.

'We were all investigating hybrid,' says Knaus. 'There was a lot of dialogue between the OEMs about running a hybrid in the Cup series, and that was there. They introduced that into the LMDh and GTP categories, so we were looking into it, but with everyone trying to launch that into the IMSA series and the WEC it was just too much to try to consume in NASCAR as well.

'We never got a system into the car. It was heavily in the design phase, working with Bosch, Williams and getting the MGU squared away. The drawings are there but we were never able to get to that point.

'For the betterment of the programme, it was decided to not go that way, and try to go out there and showcase what a NASCAR Cup car can do at Le Mans.'

'Our goal is to try to go for the 24 hours… It is a good way for [NASCAR] to explore technologies they might use in the future'

Chad Knaus

Though the basic architecture of the car remains the same, there are a myriad detail differences, including a switch to paddle shift and different ratios in the car's Xtrac gearbox – a preview of things to come perhaps?

There was some doubt that the LMDh system would even be able to fit into the NASCAR, and so a spec Williams system was also investigated. However, according to rumours, this was not only heavier than the LMDh system, it added around a second to the optimum lap time for the car, too.

With no added benefit, and with a tight development timeframe, the decision to drop the hybrid system from the project was an understandable one.

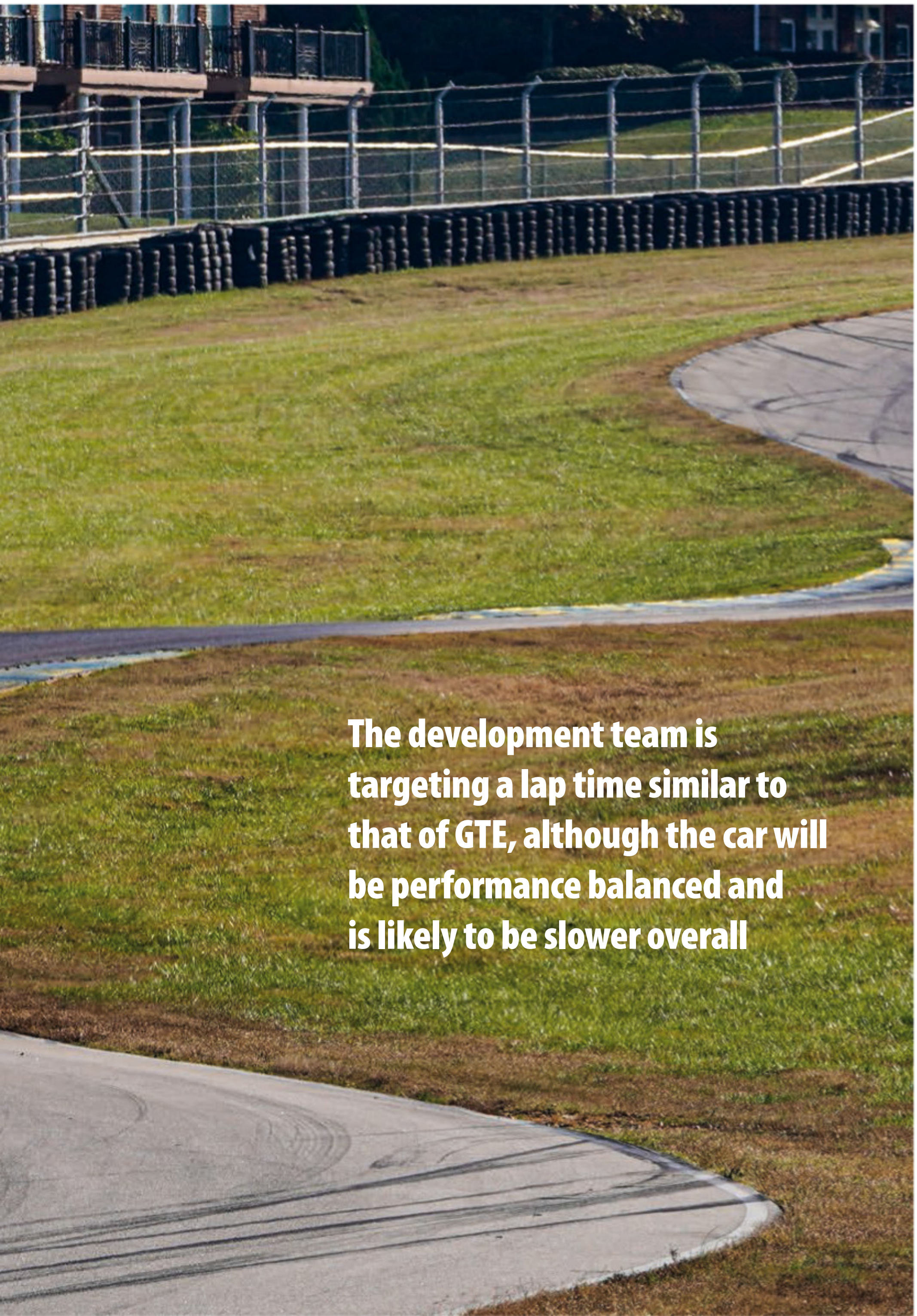
Target time

All of this has a knock-on effect on the brakes and tyres. The development team is targeting a lap time similar to that of GTE, although the car will be performance balanced and is likely to be slower overall.

Brake development is ongoing with supplier AP Racing, in order to produce a system fit for purpose in a 24-hour race.

'The lap is about 75 per cent full throttle, so braking is extremely critical when you need them, but at the same time when you don't need them you don't want them to get too cold,' notes Knaus. 'We are trying to understand that combination and get it accurate. The brake package is going to be specific to this car.'

The team is in good hands as AP is well used to running at Le Mans, and so can be leant on for guidance. Likewise, the tyres. Goodyear has had to call on its European engineers in order to develop rubber that can carry the NASCAR for at least one-hour stints around Le Mans, and preferably double stint.



It has also had to produce a wet-weather tyre for testing. However, there is significantly more to the tyre development for this project than just the compounds.

Tyre dialogue

'Goodyear has jumped in with both feet, and it is something that is a pre-thought. Tyres cannot be an afterthought,' says Knaus. 'We had a lot of dialogue early on about what the tyre should look like, and be, what tyre width and wheel width, and Goodyear has done an amazing job. It has a nice rain tyre for us to use and, if it gets wet, we are excited about that.

'There are different compounds and tyres for different conditions, so Goodyear is providing full support. We are about 1½ to two inches wider at the rear and ¾ of an inch wider at the front. We are just going to see how we can fit that in there. I don't think that from a drivetrain standpoint we are fully there yet, and we still have to learn some, but we will know more from a body standpoint.'

The last change is that of the engine, more specifically the fuel the car will use. The FIA has introduced a new fuel with its partners from TotalEnergies that is based on the waste residue of wine production. This has meant re-calibration of the engines for Hypercar, LMP2 and GTE in 2022, with varying degrees of success. For the Hendrick team, featuring a low-revving V8 it should be simple to switch, but Knaus remains cautious.

'We don't really know how that will play out in the long run, so I don't know if I can comment on what fuel, and how that works, but there is variation possibility. We are still working on all of that on the dyno.'

Big boost

The car has now run on track at various locations in the US, and there is a plan to continue testing in Daytona at the end of January and early February ahead of the Daytona 500 that will kick off the 2023 NASCAR season. For GM, it is a big boost as it will compete with Cadillac in the top class, with the Corvette C8.R in the GTE-Am category, and with the Garage 56 entry. While this may also look to be a marketing gimmick, there is a huge development programme making it all possible.

'I can't say how many are working on this, but it's a lot,' concludes Knaus. 'If you start to look at the number of people, including Hendrick Motorsports, Dallara, General Motors, NASCAR, Goodyear, ECRE and all of our partners, it is a massive venture.

'We had our very first test at VIR and there were well over 60 people there, so there is a lot of influence going into this vehicle. For us to try to push this through in the amount of time we have to do it is virtually unheard of, but we are trying.'

Send in the clones

How Welsh company, MST, is building brand new versions of a classic rally car for stage, track and road, and why you must not call them Ford Escorts

By MIKE BRESLIN

If it looks like a duck, swims like a duck and quacks like a duck, then you're pretty sure what species of waterfowl is in front of you. But if it goes like a Ford Escort, sounds like an Escort and, perhaps most importantly, slides like an Escort, don't be so sure there's a Blue Oval fixed to the grille. This is because Welsh company, MST, has taken to building its own version of the classic rally car, in Mk1 and Mk2 form, each one completely new from the ground up, and not one of them bearing the name Ford.

MST stands for Motor Sport Tools, a company that its boss, Carwyn Ellis, set up to sell tools and equipment to the motorsport community from its picturesque base on a hillside farm near Pwllheli in north Wales. Ellis is a pretty good rally driver in his own right, having competed on tarmac and gravel in original Mk1 and 2 Escorts far and wide, and is a big fan of the model.

'I grew up with Escorts,' he says. 'In this area of Wales there is a lot of rallying and they have always been very popular, while they also still perform very well. They're just great rally cars. Even though it's based on a 1960's / 1970's design, it's still as competitive today as it was back then, and it's still winning, both in historic rallying and more modern competition.'

Which means there's still a demand for these venerable cars, especially in the very market Ellis was selling tools into.

We're basically building an Escort, but it's not an Escort, even though it's identical to the Escorts you see out on rally stages

Carwyn Ellis, managing director at MST Cars Ltd

MST started off supplying tools to the motorsport market, but has recently made a name for itself building brand new versions of the legendary Ford Escort rally car

'In 2008, when I first started motorsporttools.com, which was basically supplying tools and equipment for motorsport, rallying stuff mainly, I was quite involved with rallying Escorts, so we then started introducing Escort parts to the website. That grew and grew to a stage where we stocked more or less everything you would need to build an Escort rally car.

'The next logical step, as we had all the parts on the shelf, was to start building cars.'

It's a delightful story. Everyone loves the idea of building a car from the ground up, but it's important to note that this is literally the case here. These cars are not restorations or even 'resto mods', they are manufactured around brand new, hand-crafted bodyshells, and every part fitted is new, right down to the door handles and window winders, which means MST cars have their own chassis number and current registration plates.

Ground-up build

'We build these cars from scratch, we don't use a donor car,' confirms Ellis. 'We work with Magnum Car Panels, based in Rochdale. About three years ago they manufactured all the panels, which then allowed us to go and build the cars on jigs. We build the cars exactly the same way as Ford did back in the day.

'We had an original Escort that we used to make the jig,' Ellis adds. 'The first one took the longest and now it's a bit quicker, but there's still a lot of manual work that goes into it, especially with the spot welding.

'A standard 'shell takes us about two weeks to build, but for a Group 4 Rally-spec car you're looking at four to six weeks, because with the six-link and turreted suspension, large transmission tunnels, full weld-in rollcages and wheel tubs that allow for more suspension travel, there's a lot of additional work goes into that one.'

Magnum uses regular automotive steel for the body pressings but, while these might look identical to the originals, many of the panels are double skinned and seam sealed – all to MST's own design – and the chassis is significantly strengthened in a number of areas.

Modern touches

Because these are not actual Escorts but brand new cars, they can also benefit from modern technology, which has proven especially useful when it comes to the electrics, with up-to-date wiring and electrical systems, including a power distribution module that works with the ECU. Also, as it's controlled by software, the cars can have a raft of extra options, such as data logging, limp mode and even launch and traction control – although that last bit doesn't seem very Ari Vatanen.

Beyond the modern touches, Ellis reckons it would be difficult for someone to tell the difference between an MST 'shell and an original, but it's important to emphasise again that these are strictly MST products, not Escorts, and certainly not Fords. To indicate that, where that famous name would usually be found on the original car, you now get a subtle Mk1 or Mk2.

That's the first choice any customer has to make. But, as the underpinnings of both versions of Ford's rear-wheel drive Escorts are very similar, this is often just a matter of aesthetics, and people tend to be a fan of one or other body shape, rarely both.

TECH SPEC: MST Ultimate Rally Car

Chassis / body
Hand-built bodyshell (stamped with VIN / chassis number) incorporating welded-in, FIA-spec rollcage; alloy tarmac rally wheelarches; accommodation for long suspension travel; large transmission tunnel; fully gusseted and strengthened
Available as both Mk1 and Mk2, LHD and RHD

Engine
Millington Diamond motorsport unit; 2.5-litre; 330bhp; lightweight flywheel and heavy-duty clutch; dry sump oiling; Simpson stainless steel race manifold and exhaust; ATR billet alloy fuel injection throttle bodies; handmade alloy radiator
A wide range of other engines will also fit

Transmission
Tractive six-speed sequential; rear-wheel drive; fully floating Atlas rear axle; Gripper limited slip differential; paddle shift; flat shift
Traction control and launch control available

Suspension
Front: Reiger four-way adjustable coilover dampers; suspension adjustable for camber, castor and ride height
Rear: Reiger four-way dampers; six-link, fully adjustable live axle
Öhlins, Proflex and AVO dampers also available

Brakes
Front: WRC-spec, AP racing four-pot alloy calipers; 304mm vented discs
Rear: AP Racing four-pot alloy calipers; 290mm vented discs
Ferodo DS3000 brake pads; floor-mounted Tilton adjustable bias pedal box; mechanical handbrake; stainless steel braided brake hose lines

Steering
High-ratio rack and pinion; electronic power steering system controlled by onboard ECU to give variable assistance based on speed of car

Electronics
DTA or Life Racing ECU; data logging; hi-spec wiring harness

Fuel
Alloy fuel tank in boot

Wheels and tyres
Minilite 8 x 15in front; 9 x 15in rear. A wide variety of tarmac, gravel and wet tyres can be fitted
13in and 17in alloys also available

Interior
FIA-approved race seat and six-point harness; adjustable steering column with quick release boss; motorsport-spec driver display (oil pressure, water temperature, rev counter, speedo, warning lights); battery kill switch; alloy footrests; electrical plumbed-in fire extinguisher system; hand-held fire extinguishers; intercom and in-car camera facility

Weight
Approx. 950kg

A Mk1 and three Mk2s. The bodyshells for the high-spec red and blue cars take around six weeks to build and include full weld-in rollcages

> **We build these cars from scratch, we don't use a donor car… We had an original Escort that we used to make the jig**

MST owner, Carwyn Ellis, has always been an Escort fan and races this original Mk2 version of Ford's classic. The business grew out of his love for, and involvement in, the sport of rallying

Early stages of an MST Mk1 build with the main body pressings in place. All panels are brand new and the bodyshell is spot welded together on a jig in the same way Ford built its 'shells in the 1970s. The spec from there on depends on customer requirements

Decisions don't stop there, though, and once you've chosen your 'shell – and any colour or livery you want it to come in – it's time to spec your car.

While pretty much anything goes when it comes to an MST there is a range of sorts, starting with Fast Road and Touring and Fast Road and Track – both featuring leaf spring rear suspension, as found on the original Escort – and progressing to Group 4 Rally Car, which is pretty much a clone of the world-beating Escorts of yesteryear that made stars of the likes of Roger Clark, Hannu Mikkola and Vatanen. Top of the tree sits Ultimate Rally Car.

By the book

As things stand, however, actually competing in one of these creations is not quite as simple as it might be.

'It's quite tricky trying to get people to understand what we're doing,' says Ellis. 'We're basically building an Escort, but it's not an Escort, even though it's identical to the Escorts you see out on rally stages.

We're currently speaking to Motorsport UK [the governing body in Britain] about having our car log-booked, so people are able to go rallying with it. It's not so much homologated, it's more about us being registered with Motorsport UK as a low volume specialist car manufacturer.'

Suitably spec'd cars may also see action in historic rallying, Ellis says. 'Once we get a car log-booked and out there on the stages as a modern-spec car, the next stage would be to look at historics. But it will probably then be down to the championships and individual events as to whether they accept them or not.'

There are already two or three MSTs almost ready to hit the track, says Ellis, so these cars will be in competition one way or another soon. MST has also not discounted the possibility of a one-make championship for its cars – and, frankly, it would be a crime if there weren't. Yet while the company has developed out of motorsport, and sees its future very much in the motorsport sphere, it's the softer options that have garnered the most publicity so far – particularly with YouTube motoring channels – and sales, with plenty of orders in the pipeline from all over the world.

'Most cars we have built up to now are basically Rally cars for the road,' says Ellis. 'We've got about 15 car orders, and we've sold about 18 bodyshells. We've got a car we're shipping over to California, and we've just sent a couple of bodyshells to Japan, while there's also interest from New Zealand, Australia and Europe [MST will supply cars in both right or left-hand drive to order]. People are looking for something different, and that's where we fit in.'

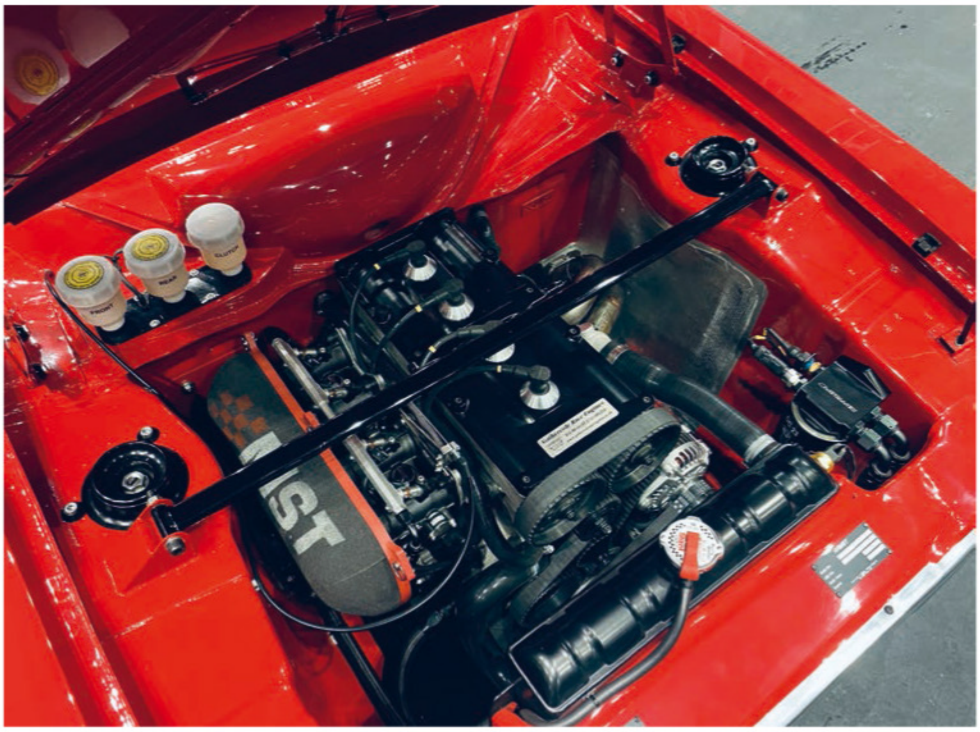
On top of complete cars and 'shells, the company offers a full catalogue of parts from which you can spec your own personal vision of a Mk1 or Mk2. Alternatively, you can buy all the components and build the car as a kit. But to get a flavour of the tech behind these cars, here we focus on MST's top range model.

Ultimate Rally Car

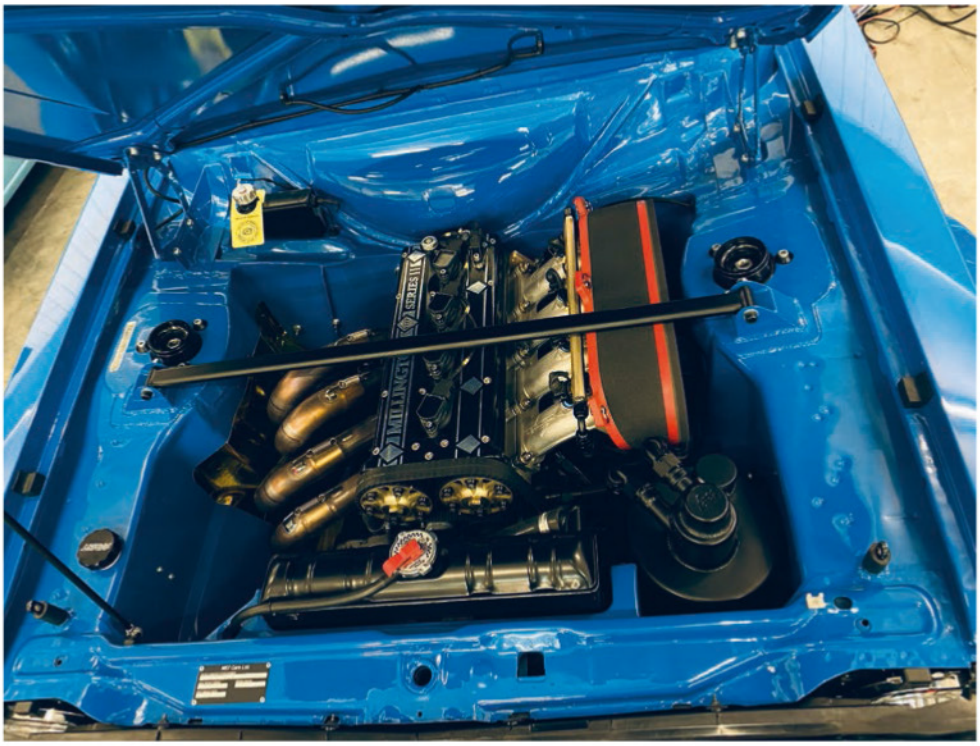
At the heart of the Ultimate Rally Car sits a Millington Diamond engine, built by Shropshire, UK-based Millington Engines. It's a 2.5-litre unit that gives 330+bhp, more than adequate in a car that weighs less than a tonne (around 950kg).

'It's the ultimate Escort rally car engine really,' says Ellis. 'It's a purpose-built rally engine with big power and big torque, originally based on the Cosworth YB, but it's been developed over the years, so it now has its own Millington-designed block and heads.

'The original Escorts had the BDG, or the BDA, which you have got to use for historic rallying, but for modern-spec Escorts these engines are available at 2.5 litres, or even up to a 2.8 or a 2.9.'



The engine bay is large enough to accommodate a wide range of power units, including BDGs for historic racing and rallying



British-built Millington Diamond 2.5-litre engine, as fitted in the top-spec MST cars, produces over 330bhp in rally spec

The power is transmitted through a six-speed sequential gearbox made by Swedish transmission company Tractive, the 'box of choice when it comes to top-level rally Escorts. 'The Tractive 'box is very reliable and works, especially with quite big power,' says Ellis.

MST also offers Quaife sequential 'boxes, while for more road and track day-focused cars there's the Mazda MX-5 six-speed, H-pattern 'box, which gives a very pure Escort driving experience.

The company offers a full catalogue of parts from which you can spec your own personal vision of a Mk1 or Mk2

While MST sees its future in motorsport, most sales to date have been for rally-inspired road cars, such as this Mk1 striking a typical Escort pose at a Donington track day

One of the standout components in the Ultimate Rally Car transmission is the fully floating Atlas axle, a defining feature of Ford Escort rally cars. Originally fitted to Ford Capris, these were used by the Ford Works rally team, mainly to bolster reliability.

'There is the option to go independent, but this just seems to work better on an Escort,' says Ellis. 'Nearly all high-spec Escorts run with live axles. I think that you lose some of the car's handling characteristics if you go independent. You might gain a little traction, but you lose the feel when you throw the car into a corner.'

The six-link system that holds all this in place consists of four forward link bars to locate the axle and a Watt's linkage; two side facing bars to stop side-to-side movement of the axle. Damping is taken care of by a couple of vertically-mounted Reiger four-way adjustable coilovers in turrets welded into the bodyshell (other dampers are available, including Öhlins and Proflex).

At the front are more Reiger four-way adjustable dampers, while the suspension is fully adjustable for camber, castor and height. At both the front and rear there are also lightweight alloy hubs and classic 15in Minilite alloys.

Brakes are also suitably high spec, with WRC-specification, AP Racing four-pot alloy calipers clamping Ferodo DS3000 pads onto 304mm vented discs at the front and

Fully floating Atlas axle is a defining feature of Escort rally cars. There is the option to spec independent rear suspension, but MST feels a live axle works better on gravel stages

290mm vented discs at the rear. Naturally, there's also a mechanical handbrake for those all-important handbrake turns.

The high-ratio, 2.4-turn steering rack, meanwhile, is electrically powered, which comes as a slight surprise. Rally Escorts in period were physical beasts, part of the reason they were often steered on the throttle, but Ellis, and others to be fair, says the MST has all the feel of an old Escort when it matters.

'It's an electronically-controlled, power-assisted unit, mounted under the dash. It is pretty much maintenance free and is controlled by the onboard ECU, giving variable power assistance depending on the speed of the car, which gives the driver better steering feel at high speed,' Ellis explains.

Sideways at speed

There are also heavy-duty driveshafts as standard and a low final drive, for acceleration out of corners, plus a Gripper limited slip differential, a reminder that these cars are famous for perhaps one thing above all else – going sideways, fast.

'On tarmac, you probably don't need to go sideways in an Escort, but on gravel you have to throw the car into the corner to help reduce the understeer,' says Ellis. 'They are just such fun cars to drive, and that's probably why they're still as popular as ever. They are very analogue, and they do go sideways, which people enjoy. And that goes for the spectators as well. If there's an Escort out on a rally, they always love to see it going sideways.

'I mean, you have all these WRC cars which are very quick, but they can be a little bit boring to watch.'

Speed costs

All that sideways fun comes at a price, though, with the entry level Fast Road and Touring-spec car costing £100,000+VAT (approx. $148,800), while the Ultimate Rally Car will make a £150,000 (approx. $223,250) hole in your pocket. It might sound a lot, but then these are handmade cars with many hours expended on them, in terms of the body build, painting and car build, and this coupled with a steep rise in the cost of steel and parts over the last few years. It's also worth bearing in mind that original Escort race and rally cars are now very expensive, too.

As things stand, however much the asking price, there is certainly plenty of demand, with a certain demographic very much to the fore.

'Older drivers, middle aged,' says Ellis. 'They probably had an Escort back in the day, or couldn't afford a good one, but now they are a bit older, now they have a bit more money, and they want to build that car they always dreamed of.

'We've also had a couple of customers who have had McLarens, and one of them sold his to have an MST. McLaren make a very fast car, but you just don't get the same driving experience.'

For the future, it's pretty much more of the same for MST. 'We'd like to scale up production, so we can build more cars and sell more cars worldwide, and then there's also the motorsport side of things. We'd like to do more full-on rally cars and racecars,' says Ellis.

They are just such fun cars to drive, and that's probably why they're still as popular as ever. They are very analogue, and they do go sideways

MST is also looking at producing an electric version of its Escort clone, in tune with the rest of the automotive industry right now.

'It's very early days, but we've been speaking to a couple of potential partners and it's definitely possible,' Ellis says. Yet, to be honest, in a future world where daily driving is electric, autonomous and digital, isn't something like the MST Mk1 or Mk2 just the right antidote? The sort of thing people will crave when – as seems possible – ICE car driving as we know it becomes a leisure pursuit? I mean, what better way to fill your leisure time than spending it sideways?

Legend of the stage

Motorsport saw the birth of three absolute legends in the space of as many years in the late 1960s: the Lotus 49 F1 car in 1967; the Porsche 917 Sports Prototype in '69, while in rallying, Ford made the decision to put its pretty new Escort model on the stage in 1968.

There was always a realisation that the Escort had sporting potential, and from very early on it was available with the venerable Lotus twin cam engine, while later in its life it packed the legendary Cosworth BDA (in RS1600 form).

The Mk1 ruled the rally roost throughout the early '70s, winning a host of World Rally rounds, and famously the 16,000-mile 1970 London to Mexico World Cup Rally marathon.

In 1974, the Mk1 was replaced by the Mk2, a boxier looking machine in comparison to the Coke bottle curves of its predecessor, but the rally success did not dry up, the newer car simply carrying on where the older one left off.

It would be impossible to list the Escort's many victories in the space available, but it's worth noting that it won every RAC Rally from 1972 to 1980, and it didn't stop there. Indeed, the Mk2 kept on competing even after it had been superseded on the road in 1980 by the front-wheel drive Mk3, with Ari Vatanen winning the 1981 World Rally Championship, beating the all-new, four-wheel-drive Audi Quattro in the process.

The writing was on the wall, though, and soon 4WD was *de rigueur* in top-class rallying. Yet the older Ford Escort has continued to win, and not just historic rallies, its rear-wheel drive format and space for a wide variety of powerplants making it ideal for those who want to rally competitively, always with a smile on their face.

Ari Vatanen won the World Rally Championship in 1981 in an RS1800, pictured here at that season's San Remo Rally

A Starlet is born

By a quirk of fate, Enzo Ferrari and Aurelio Lampredi found themselves uniquely well prepared when race organisers abandoned Formula 1 for its smaller sister, Formula 2, in 1952 and '53. This is the story of Ferrari's Starlet

By KARL LUDVIGSEN

Statistics tell us that in the grand prix seasons of 1952 and '53, Ferrari and Alberto Ascari were the preeminent forces, winning two world championships in a row for both maker and driver. Ascari won an incredible seven championship grands prix in a row, indeed nine if we overlook Indianapolis, which in those days counted for world points. The driver was a marvel, a man of phenomenal talent and determination, in spite of anxieties driven by superstition. But he also had the benefit of being an exceptional racecar.

Ascari's dominant performance traced its origins back to a Sunday in early June of 1951. Ferrari engineering director, Aurelio Lampredi, was in his office at Maranello, as usual, when Enzo Ferrari reached a conclusion. The two men had been debating the sort of power unit to build for the coming 1954 Formula 1, which permitted 2.5-litre unsupercharged engines. Such an engine could serve in the meantime, they surmised, as a 2.0-litre F2 unit.

The pair initially considered uprating to 2.0-litres their failed supercharged, 1.5-litre, four-cam V12, the work of Lampredi's predecessor, Gioachino Colombo. Indeed, they built and tested just such an engine, but that was a heavier solution when lightness and agility were what was needed (in 1950, John Heath's Alta-engined HWMs had pressed the works team of 2.0 litre Ferrari V12s, and had done so with only four cylinders).

Enzo Ferrari grasped Lampredi's idea that a four-cylinder engine had torque and weight characteristics well suited to the twisty street circuits that predominated in European racing. For Ferrari, this was a daring concept after the success he had enjoyed with his 12s. What may have helped persuade him was he was well aware that arch rival, Maserati, was

The brains trust behind the new Tipo 500 F2 inspect the first engine. Left to right: Luigi Bazzi, Enzo Ferrari and Aurelio Lampredi

The master and his machine. At the Nürburgring in 1953, Alberto Ascari tries on his mount for size. For the rear wheels Ferrari introduced the famous three-eared knock off

at the time in the process of developing a six-cylinder engine with a similar aim in view.

Hit for four

After mulling it over, Ferrari plumped for a four, as he told Lampredi that June morning. The engineer forgot his plans for the afternoon, reached for a T-square and triangle and, in a few hours, had sketched the essentials of the Tipo 500 F2, destined to be one of Ferrari's most successful racecars.

During his design and development of the V12-engined Formula 2 Ferraris, Lampredi had already created the essentials of the new car's chassis. From a multi-plate clutch at the engine, the drive passed to a rear-mounted transaxle, whose transmission was laid out flat under the driver's seat. This evolved from the transaxle of the Alfa Romeo 158, the design of which had been created in Ferrari's Modena workshop during 1937. Its output rose up to the differential by bevel gears to a final spur gear pair

From the left of the transaxle, a shaft went forward to the gated shift lever, controlling just four forward speeds.

Although drivers of the 2.0-litre V12 Ferraris had enjoyed a five-speed gearbox, Lampredi decided to save weight by omitting one gear pair in his new car, surmising the engine's fuller torque curve rendered the extra ratio unnecessary.

Behind the differential, a 2mm thick wall de Dion tube joined the rear hubs together. Guiding it laterally was a frame-mounted vertical slide at its centre. Positioning it fore and aft were parallel radius rods at each side, as on the 4.5-litre F1 Ferraris of 1951.

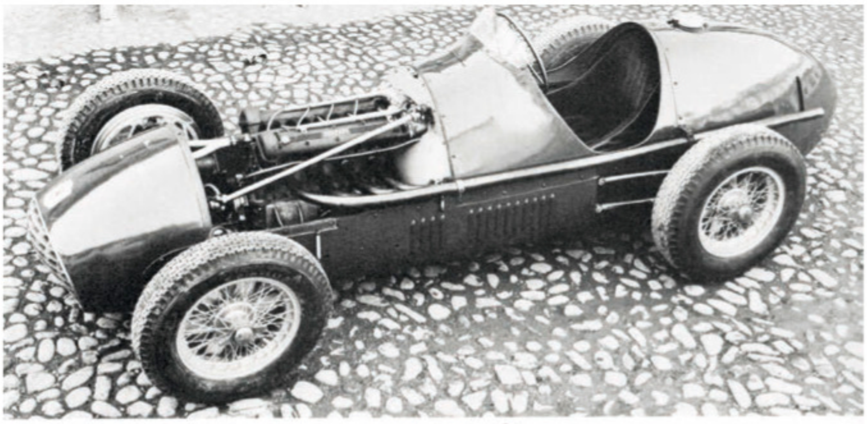
Though foreshadowed by a pre-war Delahaye chassis, this was a Lampredi innovation that eliminated the need for a flexible joint in the de Dion tube that otherwise complicated the usual use of single radius arms to the hubs.

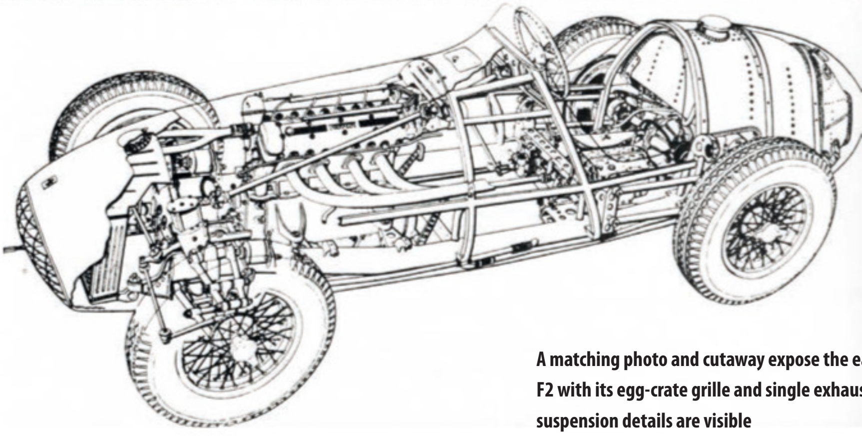
At both front and rear, Lampredi fitted transverse leaf springs with links to the hubs. Instead of the usual central clamp to the frame, though, the springs were free to move between two pairs of rollers in such a way that the springs gave an inherent anti-roll effect (in parallel, Fiat was developing this idea on the front suspension of its new 600). Adjustable Houdaille rotary dampers served at all four corners.

New drum brakes designed by Lampredi had a central pivot for each shoe. Instead of being fixed, the pivot acted as an abutment against which the shoe was pressed when the brakes were actuated. A double-ended hydraulic cylinder applied each shoe to the drum at both its ends. The design's effect was to provide a balanced braking performance because one part of each shoe was leading while the other was trailing. Although lacking servo action, this proved to offer a stable and consistent brake effort, so much so that Mercedes-Benz adopted it in 1954 for its W 196 and 300 SLR.

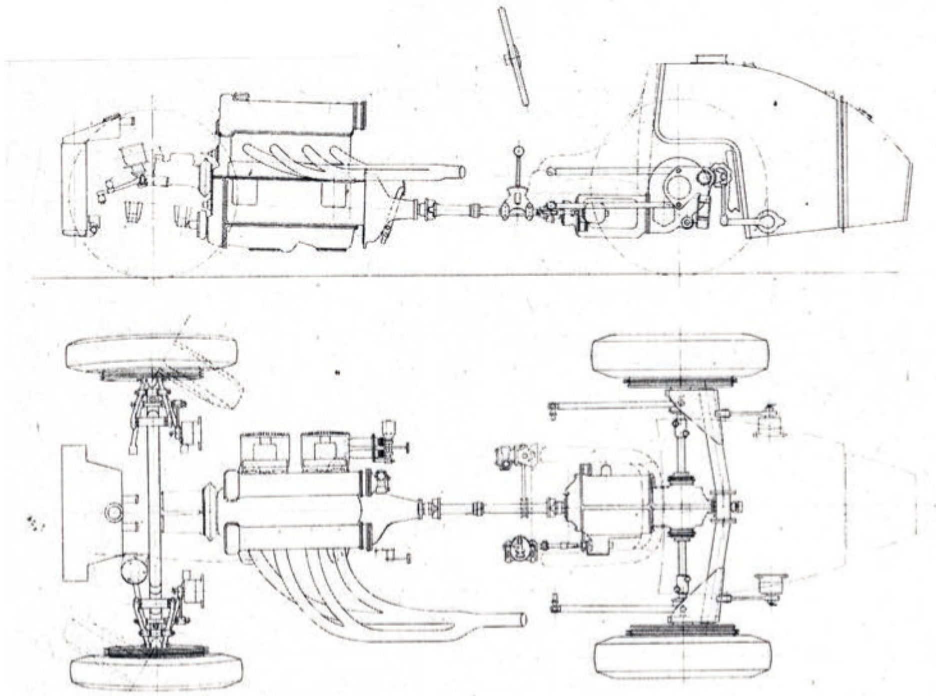
Although Lampredi would soon adopt spaceframes, for 1952 he stayed with a proven, oval-section steel, ladder-type frame for the new car. Measuring 112 by 55mm in section, the skin was 1.5mm thick.

Lateral bracing was robust between the front sets of parallel wishbones, while tubular structures at the scuttle added stiffness.

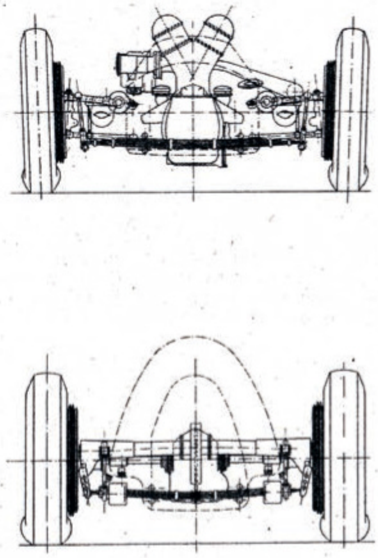


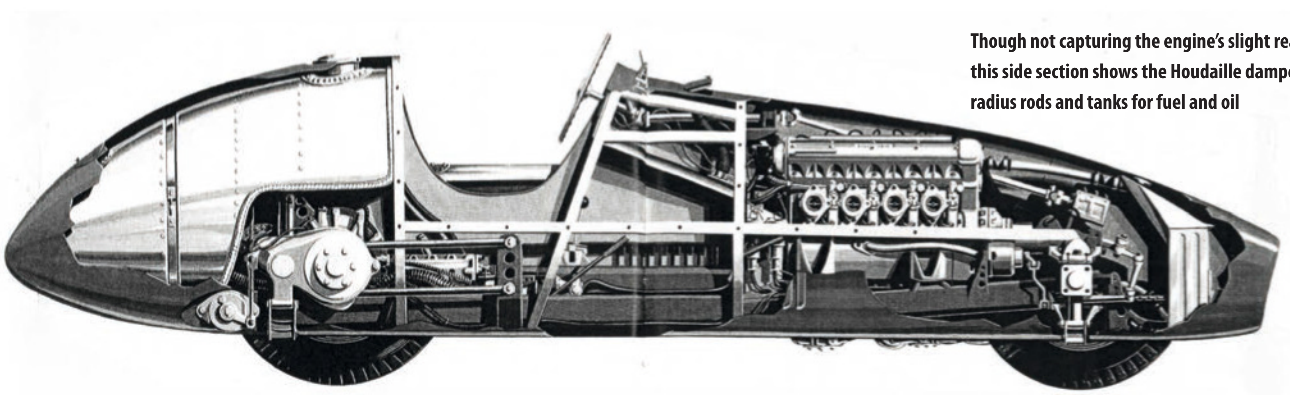


A matching photo and cutaway expose the early Tipo 500 F2 with its egg-crate grille and single exhaust pipe. Front suspension details are visible

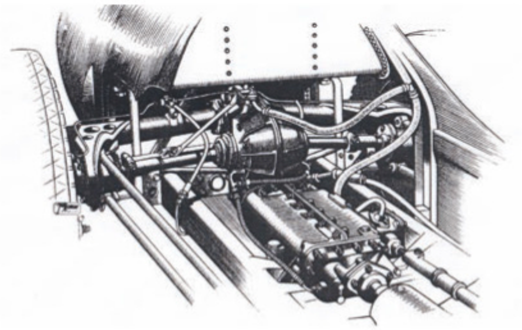


Chassis details include the pairs of rollers carrying the transverse leaf springs, front unequal length wishbone suspension and propeller shaft fuel pump drive

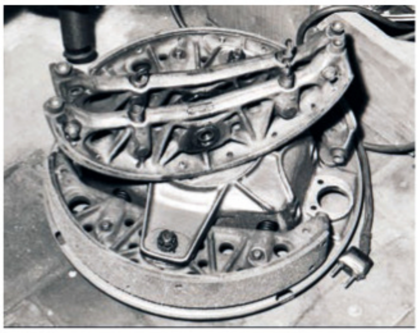




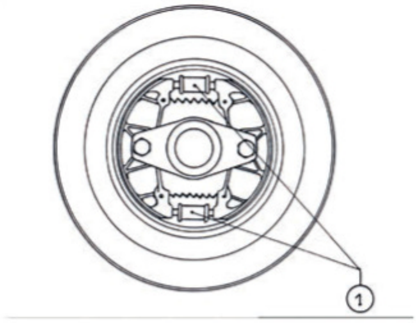
Though not capturing the engine's slight rearward slope, this side section shows the Houdaille dampers, parallel rear radius rods and tanks for fuel and oil



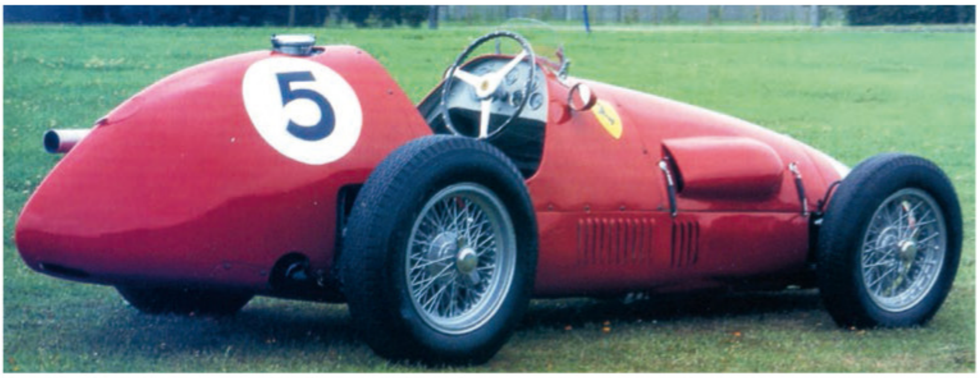
Introduced at Ferrari with de Dion rear suspension, the transaxle carries its two shafts flat beneath the seat. Halfshafts have inboard sliding universal joints



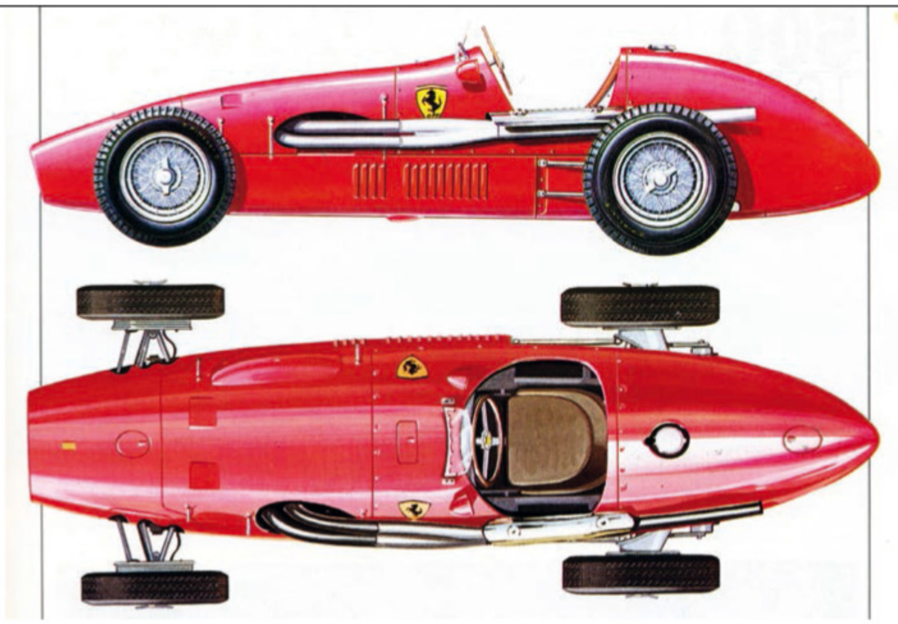
Although from a sports racing Ferrari, these brakes show the mid-shoe abutment with a central pivot that has a lubricated sliding collar



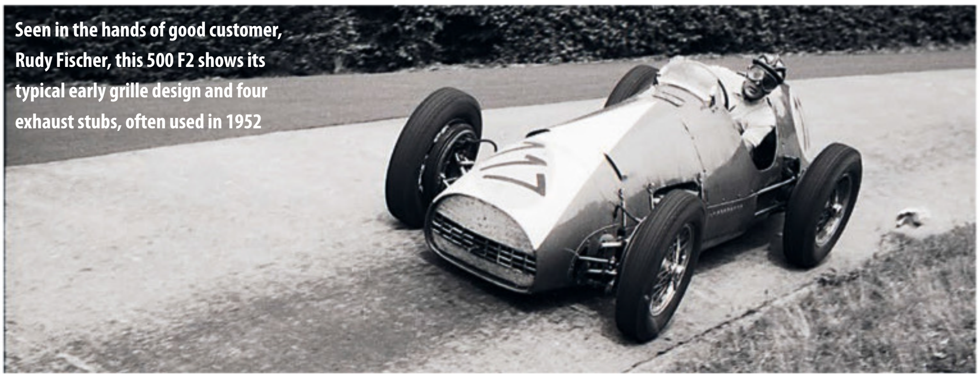
The callout indicates the two hydraulic cylinders operating the shoes of Lampredi's brake design. A coil retraction spring accompanies both



While the fuel filler is quick opening, access to the oil supply is under a hinged cover. Modest louvres are used primarily to cool the driver



Two small bonnet top inlets admit cooling air to the engine, shown here with the exhaust system most used in the '53 season



Seen in the hands of good customer, Rudy Fischer, this 500 F2 shows its typical early grille design and four exhaust stubs, often used in 1952

Aurelio Lampredi lavished all his skill and ingenuity on the Type 500 F2's engine, the first Ferrari power unit he designed from scratch

Extensions at the rear carried the 150-litre aluminium fuel tank, weighing just under 5kg. The oil reservoir was sited at the extreme rear.

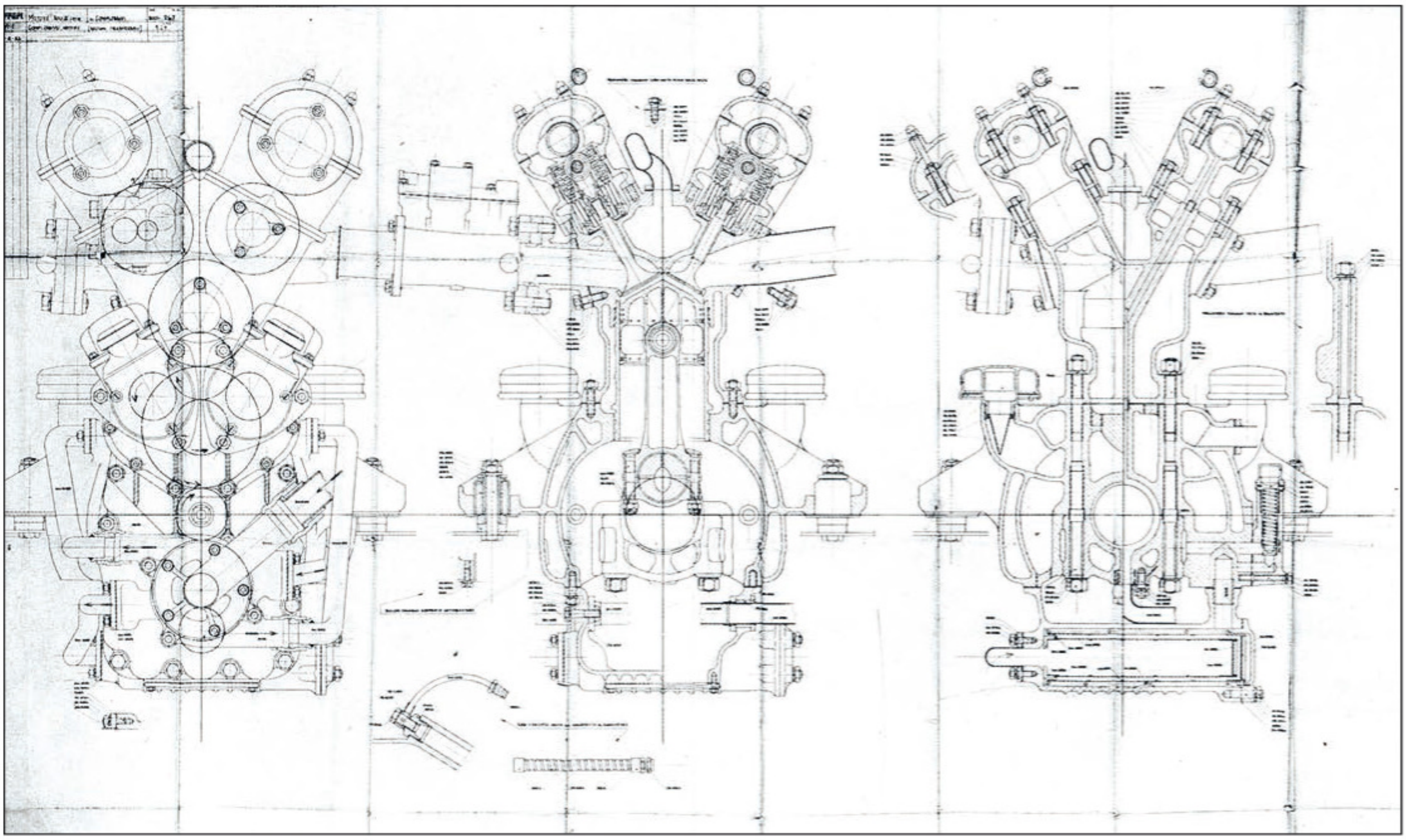
Born to race

Lampredi lavished all his skill and ingenuity on the Type 500 F2's engine, the first Ferrari power unit he designed from scratch. He was responsible for the unsupercharged 4.5-litre F1 engine of 1950 / '51, but this was a continuation of Colombo's V12 concept. To boot, it also served as a production car engine. In contrast, he said, 'The 500 was born as a racing car. I did everything possible to improve the engine's design.'

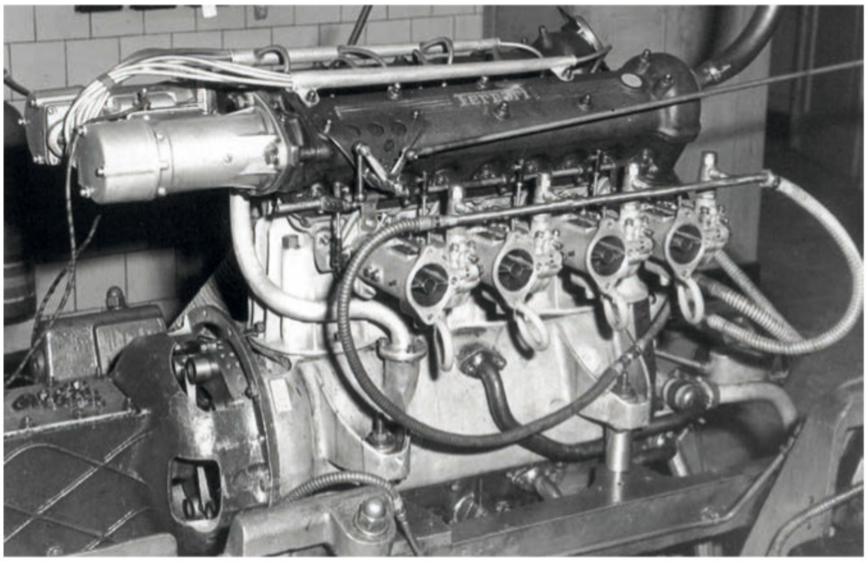
Just as he had done with his big V12, Lampredi played it safe with the 500's cylinder head construction. Like many racing engines of the 1920s and 1930s, its head was unified with the cylinder block in an aluminium alloy casting that extended down three quarters of the length of the cylinder. Screwed into this head / block unit, reaching right up into its combustion chambers, were four cast iron wet cylinders. Each had a castellated flange at its lower extremity, gripped by a special wrench to screw it in or out. Two grooves below the flange carried the rubber o-rings that sealed the bottom of the cylinder into the top of the crankcase.

Lampredi specified a bore and stroke of 90 x 78 mm to give 1985cc. He set the stems of the two valves per cylinder equally at an included angle of 58 degrees.

Thanks to the removable cylinders, the valves could easily be extracted from the head / block unit. Thin guides were inserted



Section drawings of the 500 F2 four. Most revealing is the one on the right, which shows the matching passages for studs holding down the cylinder block and holding up the main bearing caps



In its original configuration, the 500 F2 four drove its two magnetos from the rear of the camshafts. This image is of the first such engine built for the project during early testing on the dynamometer

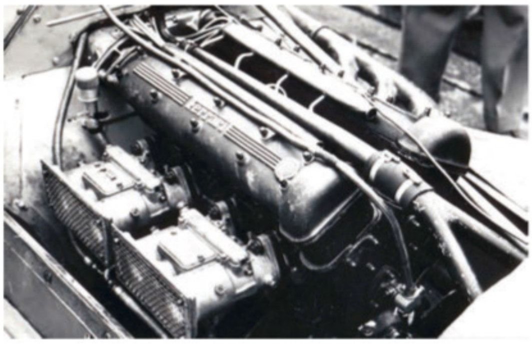
At the 1952 German GP, mechanics, Meazza and Marchetti, check the engine of Ascari's 500 F2, with its rear-mounted magnetos and quadruple carburettors

for the valves, which were thick stemmed for strength and hollow for lightness. Diameters were 48mm and 44mm for the inlets and exhausts respectively.

In the opposite of normal practice, care was taken to surround the inlet valve guide with water, but not its exhaust neighbour.

Lampredi took no chances with his valve gear. He brought to Ferrari some elements of a W18 aircraft engine he had worked on at *Officine Reggiane* in 1942 / '44, which had narrow cam lobes working against roller followers. Also credited with contributing to the selection of a roller cam follower was Enzo Ferrari's long-serving and hugely experienced technician, Luigi Bazzi.

Carried over from other Ferrari engines were hairpin type valve springs, which permitted the use of short and light valves. Above each valve was an aluminium follower with a circular top, into which was set a large diameter roller. Pressing up against this top were two relatively light concentric coil springs, whose sole task was to keep the roller in steady contact with its cam lobe at all time. The function of controlling the follower was separated from that of closing the valve.



Weber later supplied these larger twin-throat carburettors for the four-cylinder engines that competed at a capacity of 2.5-litres, ahead of the new 1954 rules

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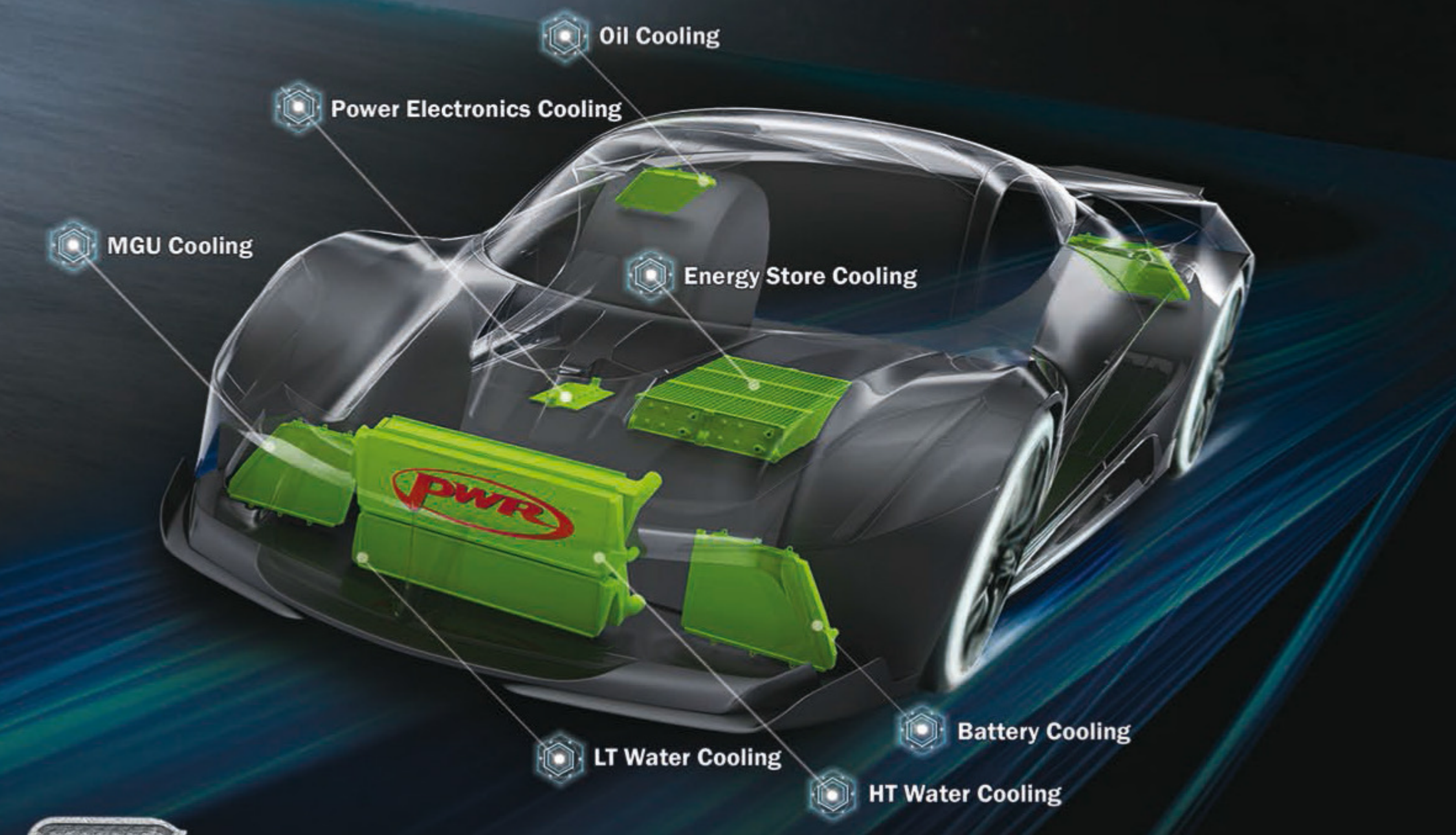

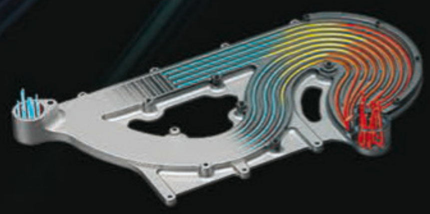

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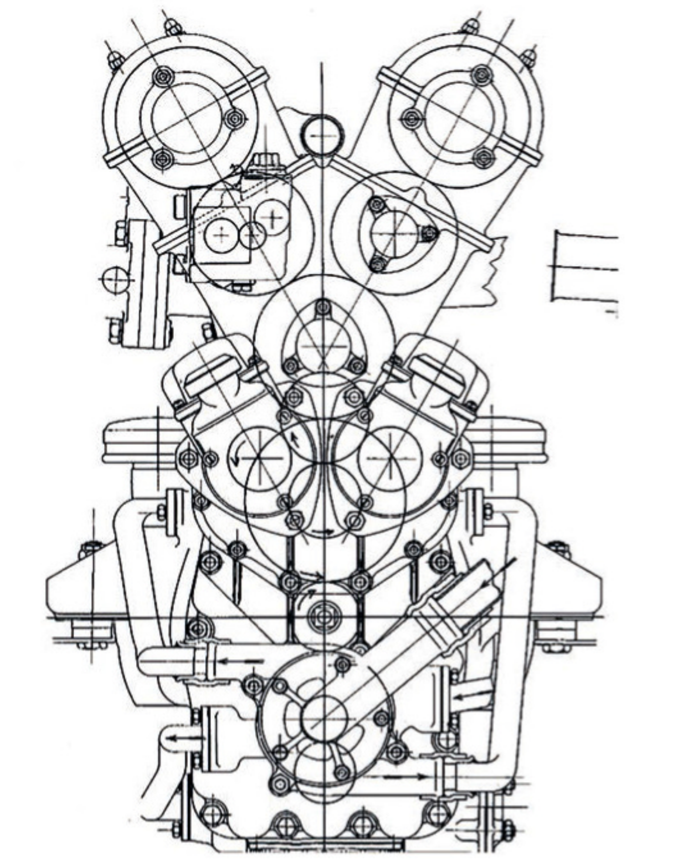
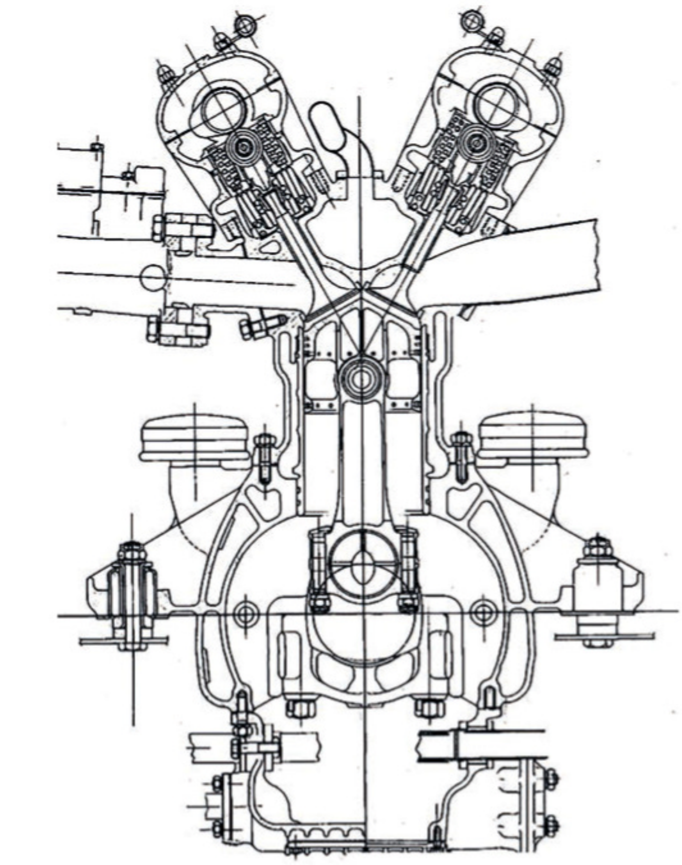
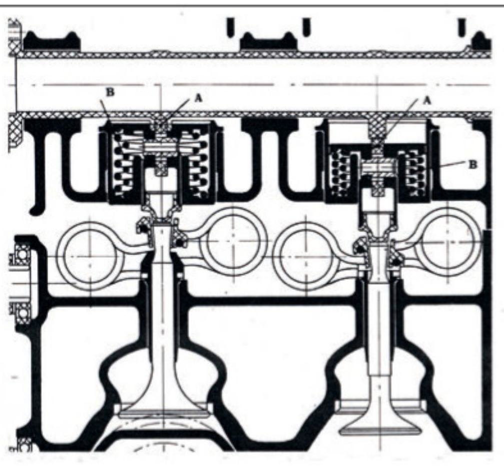


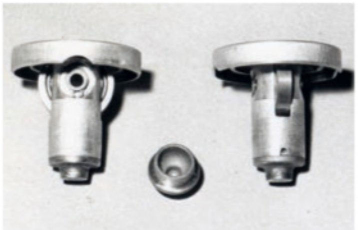
The front gear train of the Tipo 500 F2 shows rotation directions and the flow of oil and water. Pictured is the revised front mounting of the magnetos adopted in 1952



Visible in this section of the 500 F2 are the rubber-ringed engine mounts and the main bearing caps, deeply fitted into the bulkheads of the crankcase



The tappet coil springs of the engine were doubled. A narrow lobe sufficed for the cam, which contacted a steel roller running on needle bearings



The aluminium tappets of the 500 F2. At their feet are their removable caps for valve clearance adjustment

Depicted with non-500 F2 harpin springs, the Lampredi tappet was closed by its own coil spring. With this belt and braces system, he aimed for maximum reliability

This unique valve gear virtually eliminated cam and valve problems from the Ferrari lexicon. It also allowed the cam lobe to be narrow, just 8mm wide.

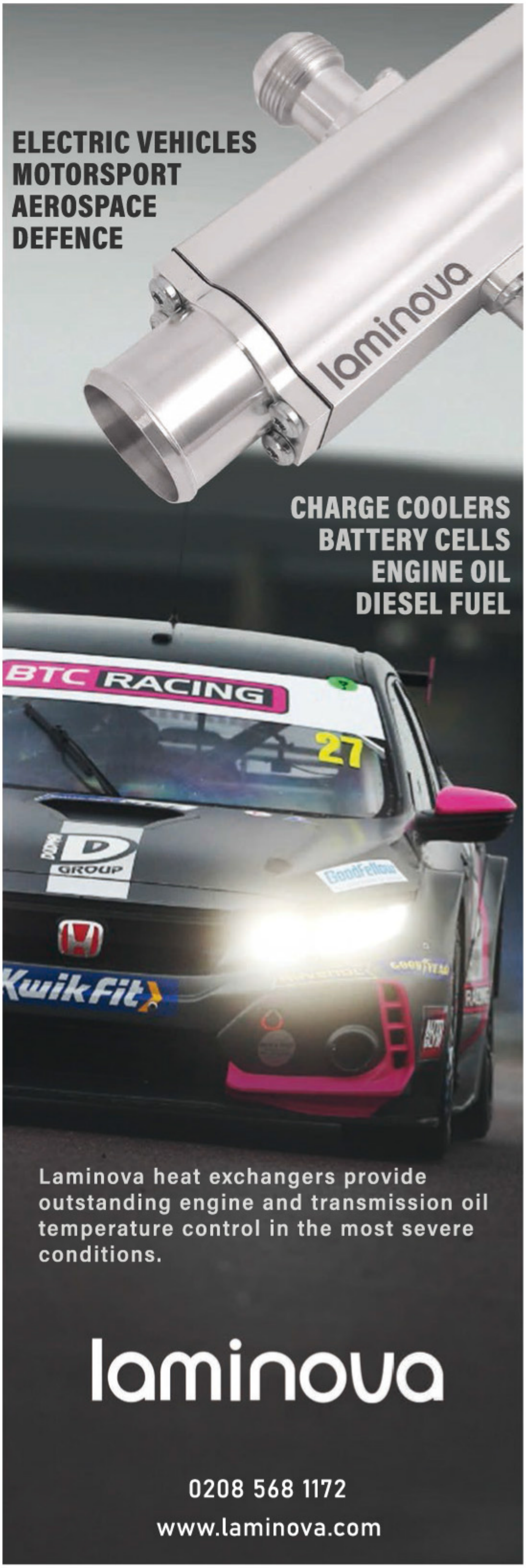
The followers slid in thin wall iron guides that stabilised both their circular top and their stem, into which a hollow steel tip was inserted at the point of contact with the valve stem. Different tips were inserted to adjust the valve clearance. The iron guides in turn were set into a magnesium tappet and cam carrier bolted to the head. Five thin babbit bearings carried each hollow-core camshaft.

Attached to the front of the block and crankcase was an aluminium alloy cover that supported the outer ballbearings of the gear drive to the camshafts. The gears were strikingly thin and light to minimise space, weight and rotating mass.

Achilles' heel

Initially, the twin Marelli magnetos for the 500's dual ignition were driven from the backs of the camshafts and protruded through the firewall into the cockpit. Later, during 1952, they were relocated to the front of the engine and given their own drive from the gear turned by the crank nose. This first gear above the crankshaft rotated at less than half engine speed, so another gear pair was needed to step the magnetos up to half speed. They fired Champion 14mm plugs in splayed positions with their electrodes recessed within the hemispherical combustion chamber.

The magnetos were an Achilles' heel of the engine, Lampredi said: 'I always used to tell the drivers they could do what they liked with the gears because no matter what happened the engine would not break. They couldn't rev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the engine above 7500-7800rpm even when going flat out because of the poor ignition.'

Assisting in this unbreakability was the dry sump lubrication system, with its gear-type pumps driven from the crank nose. A triple-gear scavenge pump had inlets for two pick ups at the front and rear of the shallow magnesium sump.

Remarkably, the cylinder block was innocent of major oil galleries. Instead, Shell oil under pressure was delivered to all five main bearings through pipes in the sump and banjo-type unions at the base of each aluminium main cap. The latter were inserted snugly into their webs in the deep crankcase and retained by two studs. Mirroring these above were the studs that attached the cylinder block to the top of the crankcase.

From the grooved mains, the oil flowed into the crankshaft drillings and from there on to the rod journals. The main bearings were 60mm in diameter and 28mm wide, except the critical centre main, which was 35mm wide.

Solid foundation

Machined from solid, the steel crankshaft had four counterbalancing masses – two flanking the centre main and two adjacent to the front and rear main bearings. To minimise the mass to be balanced, the rod journals were heavily drilled internally and sealed by plugs. These drillings were part of the crankshaft's oil passages, which were continuous from one end to the other to ensure ample availability of oil. The two drillings to feed oil to each rod bearing emerged at 90 degrees to the radius of the throw to avoid the pressure-reducing effects of centrifugal force at high revs.

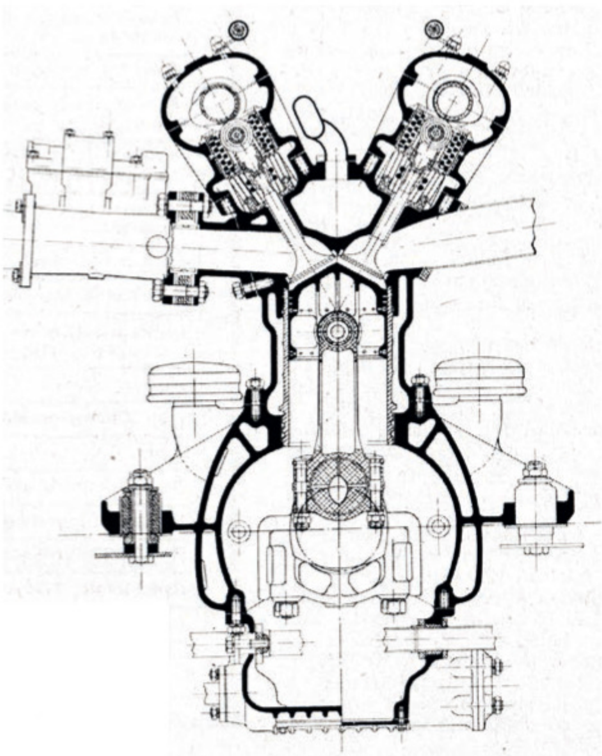
Rod journals were 50mm and 20mm wide. Thin-wall Vandervell bearings were used.

Two bolts retained the caps of connecting rods with I-section shanks, which were virtually the same in width from top to bottom. The length of the rod, forged from GNM-alloy steel, was 142mm.

Precision cast by Borgo, full-skirted aluminium pistons were ribbed under the crown for stiffness. They carried two thin compression rings and two oil rings, one above and one below the wrist pin, which was retained by aluminium buttons. The domed crown provided a compression ratio of 13.0:1 for the petrol / methanol blended Shell Super F fuel, in spite of having to be doubly flatted to provide adequate clearance for the valves at overlap.

Cast integral with the 500's rounded barrel-shape aluminium crankcase were the four legs that rubber mounted it to the chassis. The crankcase was double walled, with the interior wall closely patterning the rotating path of the big end of the conrod.

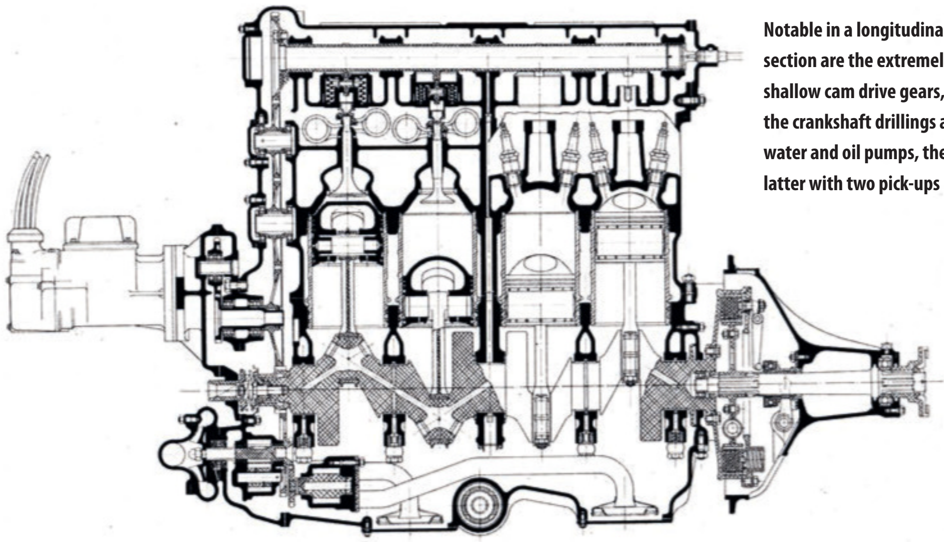
Coolant from the front-mounted pump was delivered to the right side of the crankcase, where it entered cast-in passages



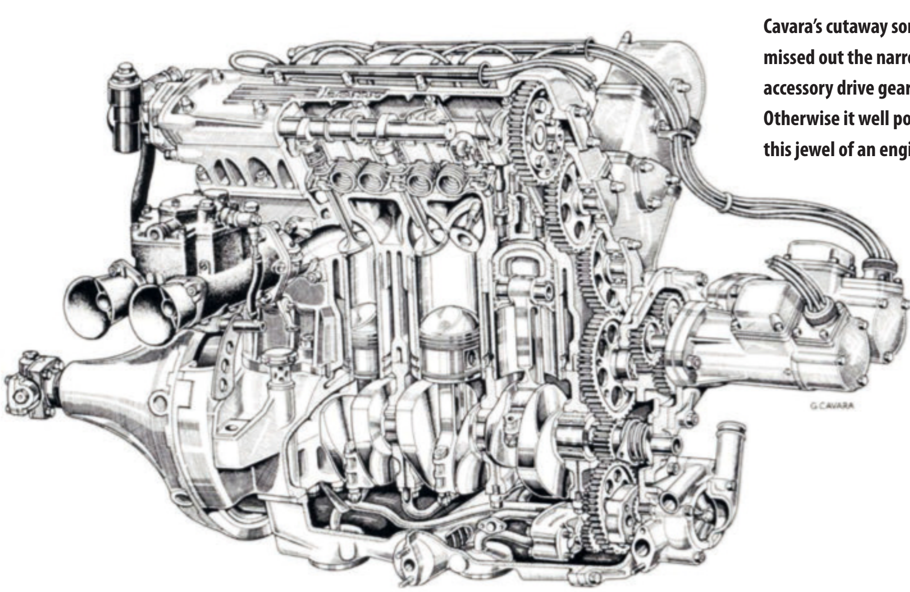
A full engine section showed the double-walled crankcase, screwed-in steel cylinder, relatively small big end bearing and slim valve guides

'[the Tipo 500 F2 was] not particularly quick on the straight. It did not handle that well and was difficult to drift. There was absolutely no 'feel' and it seemed to need a very precise driver'

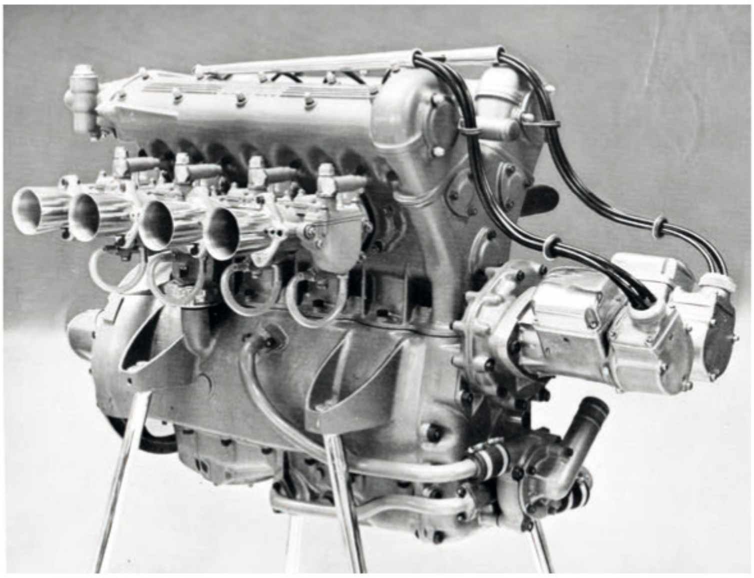
Roy Salvadori, British racing driver



Notable in a longitudinal section are the extremely shallow cam drive gears, the crankshaft drillings and water and oil pumps, the latter with two pick-ups

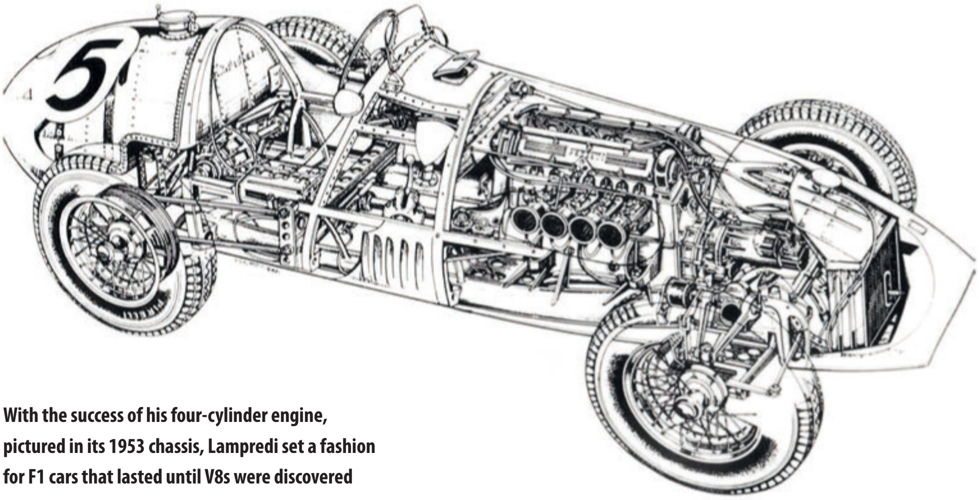


Cavara's cutaway somehow missed out the narrow accessory drive gears. Otherwise it well portrayed this jewel of an engine



Looking like the afterthought it was, a special gear case drove the twin front-mounted magnetos. The water pump delivered to internal passages on both sides

Only in a rear view are the cylinder block's hold down studs visible, extending deep into the crankcase. Inlet ram pipes are notionally screened



With the success of his four-cylinder engine, pictured in its 1953 chassis, Lampredi set a fashion for F1 cars that lasted until V8s were discovered

By introducing an unobstructed radiator air entry in June 1952, as seen on number 24 at Monza, Ferrari revolutionised racecar aerodynamics

that cooled the tops of the front and rear main bearing pairs and led upward to the cylinders and head.

Above the centre main bearing a vertical passage was drilled in the crankcase and block to carry oil up to the cam bearings and cams.

Heavy breathing

Through the 1952 season, when the new four developed 165bhp at 7000rpm, it breathed through four single-throat Weber 45DOE carburettors. In 1953, twin-throat Weber 50DCOA carburettors were often used. With these, by the end of 1953 the Tipo 500 – named for the capacity in cubic centimeters of one of its cylinders – produced 185bhp at 7500rpm. A peak torque of an excellent 152ft.lbs was achieved at 5700rpm.

Nicknamed Starlet by the press, the new Tipo 500 F2 Ferrari was destined to dominate the racing of the next two years. However, piloting it was no sinecure. British driver, Roy Salvadori, found it 'not particularly quick on the straight. It did not handle that well and was difficult to drift. There was absolutely no 'feel' and it seemed to need a very precise driver. On the credit side, it was beautifully built, it had excellent brakes and it was very reliable.'

Fortunately, in Alberto Ascari, it had just the driver that was needed.

The new Formula 2 Ferrari made its debut in a Formula 1 race over 224 miles at Bari on September 2 1951, although not in its definitive form. Enzo Ferrari ordered that it be powered by a 2.5-litre version of the new four to demonstrate the potential of engines of that size for the next grand prix formula to take effect in 1954. After placing third at Bari in the hands of Piero Taruffi, this unique car practiced but did not race at the Italian GP on September 16 1951.

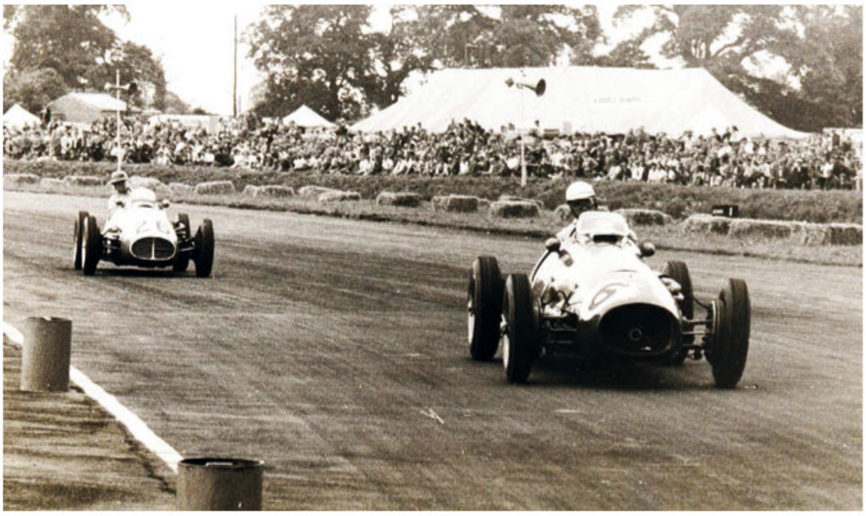
The basic Tipo 500 F2 was therefore well tested when two of them appeared in 2.0-litre form in a 156-mile Formula 2 race at Modena on September 23 1951. Of the two entries, Villoresi's retired but Ascari's won, a full lap ahead of Froilan Gonzalez in a V12 F2 Ferrari. Although expecting to continue in Formula 1 in 1952 with his revised 4.5-litre Tipo 375 F1, Enzo Ferrari was also well armed for Formula 2.

Formula future

Then, late in 1951, news broke of the future of Formula 1. The new series taking effect in 1954 would be for cars with 2.5-litre unsupercharged engines, and 750cc when supercharged. As a result, early in 1952 the existing Formula 1 was looking less viable to race organisers. Alfa Romeo, having won everything there was to win at the time, declined to continue.

By the spring of 1952, race organisers despaired of having decent fields of cars for their events so elected instead, with the blessing of the FIA, to run races counting for the world championship according to the 2.0-litre Formula 2 regulations.

Enjoying two concurrent seasons in 1952, F2 cars had plenty of chances to succeed.



Chased by a rival Maserati through a fast bend at Silverstone in 1953, Nino Farina demonstrates the straight-up stance that was a Starlet speciality

When its de Dion tube broke in a Nürburgring dip, Piero Taruffi's Starlet had only one lap to go. With its wheels akimbo, he finished fourth

Seven races were eligible for world championship points, with each driver's four best results being counted. The French qualifying event at Rouen was also included in an all-French series of eight three-hour races for 18 designated cars and drivers from specific teams, points being awarded to both drivers and car marques.

Ferrari won all the grand prix races, six of them with Alberto Ascari at the wheel. When he was away at Indianapolis in May of 1952, the Ferrari success in the Swiss GP went to Piero Taruffi. Ferrari also dominated the French series and Ascari its drivers' tally, although there the honours were more widely distributed.

Friend and frequent team mate, Gigi Villoresi, took this philosophically: 'Justly, Alberto for Enzo Ferrari became number one both in his ability and with the friendship they had. They were very close, Alberto regarding Ferrari almost like a father and becoming something of a spoiled child.

'This was then transmitted by Ferrari to his subordinates, such as team manager, Nello Ugolini, to whose son Alberto then became godfather.

Together, Ascari and the Starlet created the foundation of the phenomenal reputation of the house of Ferrari

This image of Ascari alone on the finishing straight in Germany in 1952 is symbolic of the advantage he and the Tipo 500 F2 enjoyed

'One of the secrets of a good start was to be considered as number one.'

In a non-championship 1952 GP at Monza on June 8 1952, the 500 F2 Ferraris looked dramatically different. Hitherto, Maranello's racers had the same distinctive 'egg-crate', or 'chip-cutter', grille as the road cars, a powerful identifying characteristic of Ferrari automobiles. This was still a feature of the first 1952 Tipo 500 F2s, although their noses were shaped like large open air scoops within which the egg-crate grilles were recessed.

Ferrari dropped the other shoe at Monza. There, in a longer and more rounded nose, the latest Tipo 500 F2 had a fully open air inlet that would not have looked out of place on a jet fighter. Instantly, every other car looked antiquated. This was a revolutionary change to the appearanc and function of the contemporary racecar. The era of the open and unobstructed cooling air inlet had begun.

Pretty as well as purposeful, Ferrari's Starlet was aptly nicknamed. It will always be identified with one of the greatest drivers ever to take the wheel. The Tipo 500 F2 validated the work at Ferrari of Aurelio Lampredi, who brought both rigour and a spirit of innovation to engineering at Maranello. Together, Ascari and the Starlet created the foundation of the phenomenal reputation of the house of Ferrari.

After Ascari inadvertently demonstrated its worth in July 1952, on his way to winning the British GP, Lampredi lost no time in subtly reducing and rounding his car's new frontal air entry

All motorsport wiring, such as this range of connectors from UK-based Renvale Ltd, undergo extensive reliability trials, including temperature cycling and vibration testing before they even reach a racecar

Down to the wire

Considering the increasingly complex world of motorsport wiring, and the techniques loom manufacturers are implementing to ensure reliability on track

By STEWART MITCHELL

Wiring and electronics systems remain among the most widely developed parts of the latest generation of racing vehicles. The functionality, built-in redundancy and filtering capability of a modern motorsport electronics system are far advanced from the technology seen only a few years ago.

This is partly thanks to the complexity of the latest generation of power units and the sheer number of interlinked systems on a modern racecar. However, as our understanding of the relationships between systems in a car develops further, so will the electronics and wiring between them.

Each year, the reliance on electronics and electrically-powered systems in race vehicles increases. The introduction of hybrid powertrains, in particular, has led to immensely complex systems, and the information engineers want to gather from them is now more detailed, and more crucial to a team's success, than ever before.

In some cases, the wiring itself can improve a vehicle's performance, if designed and installed correctly. Whether it is the fuel injection system or the power feed from an accumulator to an electric motor, without a reliable and well-designed wiring loom, even the most sophisticated race vehicles in the world would be deemed powerless.

Consequently, motorsport wiring systems have seen steady improvement in recent years. In most cases, this has been due to a higher level of precision in the wire manufacturing process, and also the introduction of highly accurate testing machinery to quantify the performance of a wiring loom.

Advances in wire materials, which feature higher conductivity and better shielding from interference, have also contributed to the performance and reliability of motorsport wiring.

An essential enabler of the latest generation of wiring technology is the power required for and, subsequently, the current drawn from each individual electrical component. The power necessary to operate even a simple item such as a sensor dictates the wire diameter, wire length and its location in the car. As the amount of power required has been reduced, so designers and engineers have been given more freedom to simplify, lighten and improve the performance of the wiring to it.

Design considerations

A wiring loom comprises conductors (wires) that are often batched together (cables) to carry signals, or energy, along their length via the movement of electrons. A wire must be made of a material with high conductivity – a material with low electro-resistivity – to carry the signals or energy efficiency.

For most motorsport applications, electrical wires have a copper core, copper having the lowest electro-resistivity of all metallic elements. However, copper is also susceptible to rapid corrosion from oxidisation and water degradation so, if a wire were made of pure copper, it would not survive long in any open environment.

Many wire manufacturers, therefore, either coat the copper with tin, nickel or silver, or manufacture the wire out of a non-corrosive copper alloy. The most common coating used in motorsport applications is silver, which has a higher temperature rating than nickel.

The wire thickness (gauge) in a motorsport loom is the most significant factor in the system's weight. The wire gauge used in each section of a loom depends on the specific application the wire feeds, taking into account current requirements and environmental factors.

There is obviously a weight advantage in designing a loom with the thinnest wires possible, but that relies on the ancillary components being suitably matched. In the higher echelons of motorsport, the wiring system design will specify the most efficient sensors, drives, actuators and so on to ensure the least amount of current is required to and from these systems.

For example, the wiring loom in a Formula 1 car may use 30AWG wire (AWG is the aerospace industry standard for categorising wire diameters and types, and has been adopted by motorsport) for applications such as sensor connections.

However, a 30AWG wire may be too fragile for a WRC car where the loom is exposed to much heavier shock loads and vibrations from the more uneven road surface. In this case, teams might specify a heavier gauge, such as 26AWG, for a similar sensor connection.

The current passing through a wire is the limiting factor on its minimum gauge. If a wire is too thin for the current running through it, losses occur that could eventually lead to damage to the system. In most cases, some of the current turns into heat, which causes a voltage drop.

As most non-hybrid cars use low voltage (13.8V nominal) battery systems, any voltage drop must be carefully considered, especially over longer cable runs.

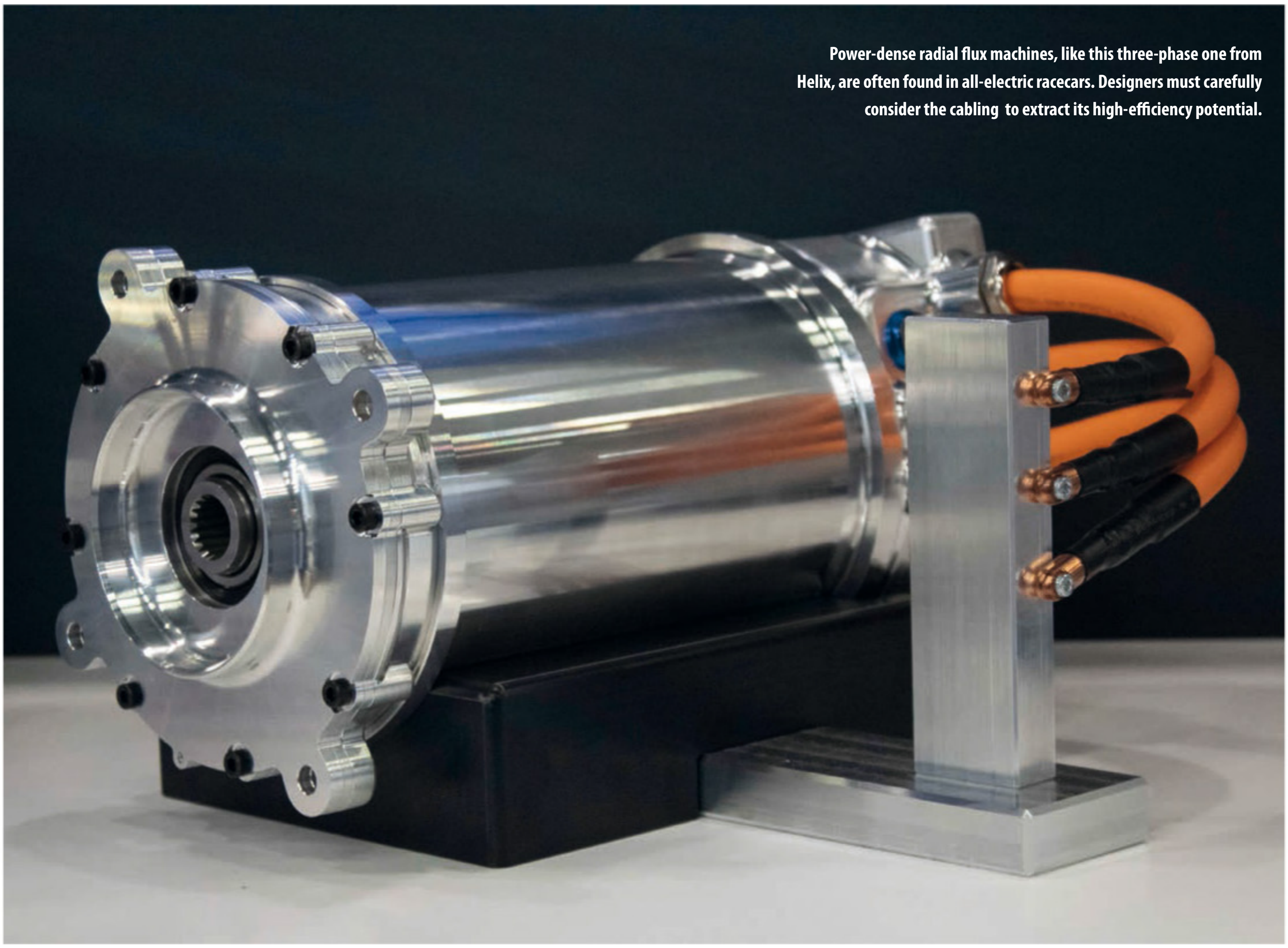
As our understanding of the relationships between systems in a car develops further, so will the electronics and wiring between them

Safety margin

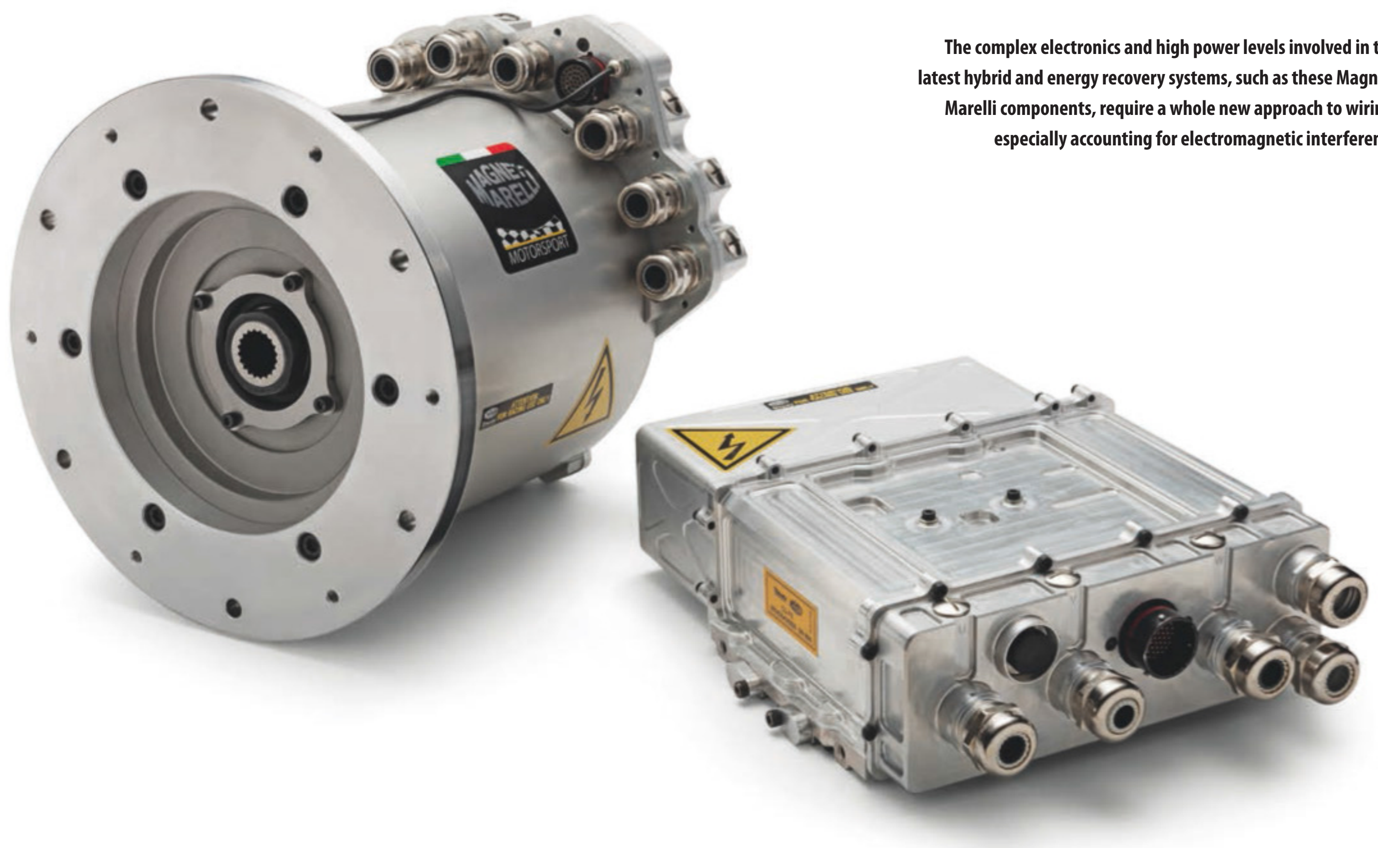
As a rough rule of thumb, most wiring loom manufacturers suggest wires should draw a maximum of 10A/mm^2 of wire. This allows for a reasonable safety margin for most of the wiring found throughout a vehicle, and ensures it operates accurately and consistently in the temperature environment a vehicle is subjected to during a season. Clearly, this also depends on the application, and where the racecar is expected to operate.

Temperature is a significant consideration here, as power dissipation through the length of a wire is considerable as it increases. High temperatures in a small-gauge wire can lead to as much as 5.5W energy loss over each metre of a loom. Consider a modern Formula 1 car contains more than 3km of wiring, and it is easy to see how systems, or components, can suffer in hot conditions.

Wires also suffer from voltage drops across their length. Loom manufacturers



Power-dense radial flux machines, like this three-phase one from Helix, are often found in all-electric racecars. Designers must carefully consider the cabling to extract its high-efficiency potential.



The complex electronics and high power levels involved in the latest hybrid and energy recovery systems, such as these Magneti Marelli components, require a whole new approach to wiring, especially accounting for electromagnetic interference

therefore work closely with design teams to position components in such a way as to keep the part of the loom running to them as short as possible. Even the best electronic engineers cannot eradicate losses entirely – the best quality wires known to man will still lose approximately 0.5V/m.

The electronics onboard must therefore compensate for these losses, particularly the components that operate as a direct voltage function. For example, a 10 per cent drop in voltage to a fuel pump can lead to a 10 per cent reduction in fuel delivery to the engine, which obviously means a reduction in efficiency.

Insulation

Each wire in a loom must also be shielded to ensure the energy, or signals, travelling through it reach the intended destination and are not transferred to adjacent wires, dissipated into surrounding parts of the car or disrupted by interference from other electrical components.

Most motorsport-spec wires incorporate surrounding insulation made from a radiation cross-linked polymer called ethylene tetrafluoroethylene (ETFE). This product also serves to enhance a wire's high-temperature characteristics, enabling the loom to withstand up to 200degC, compared with just 125degC for other types of insulation.

ETFE is also flame resistant and unaffected by all fluids it is likely to encounter in a racecar, such as fuel, oil and water.

Most motorsport applications require only single-wall insulation but, in some cases, teams may specify dual-wall wires. These have a second inner layer of insulation, often in a contrasting colour to the outer layer, so that if wires are chafing, there is a visible warning before the inner layer is damaged.

This feature is intended for systems that run wires without heat shrink protection, and are therefore more susceptible to external damage. For the majority of motorsport uses, though, single-wall insulation is deemed suitable.

One of the biggest challenges facing engineers on the latest generation hybrid and electric-powered racecars is electromagnetic interference (EMI) between different parts of their complex electronic systems.

The power, and therefore the current, flowing to and from hybrid and electric power systems creates previously unseen levels of electrical noise. Electric drive and energy recovery systems (ERS) are sources of an enormous amount of EMI, which can disturb, induce or even completely destroy signals travelling down adjacent wires.

High-power electric systems have been known to transmit so much EMI to a nearby loom that it triggers unwanted gear changes because the ECU picks up the signal travelling through the gearbox loom wires.

The most straightforward approach to tackling EMI is increasing the distance between the EMI sources, susceptible cables and electronics. However, as modern race vehicles are so

The power, and therefore the current, flowing to and from hybrid and electric power systems creates previously unseen levels of electrical noise

compact, their limited space makes that impractical in the majority of cases.

An alternative approach is to use specialised EMI shields, usually a copper or aluminium braid that is slipped over the cable and terminated at the back shell of each cable's connector. The braid forms a low-impedance path to ground EMI, which dissipates to an area in the car where no EMI-susceptible systems are located. This type of shielding is effective, but adds weight, so tends to be only used where absolutely necessary, rather than standardising all cables throughout the assembly.

Formula 1 teams also use wires, or flexible printed circuit board (PCB) material, embedded in composite parts to reduce noise, save space and eliminate the need for shielding in some electrical systems. This approach allows a higher density of connections to be used, and redundancy to be built in. Some of these composite circuit board constructions use flexible

Axial flux machines like this one from YASA are favoured for mild hybrid applications due to their compact packaging. Optimising the wiring to and from them are critical to best performance

copper foil outer layers that enable the assembly within the structure to be screened, providing EMI shielding as well.

Packaging wires within composite assemblies also means running higher than usual currents through a given wire gauge because of the composite's high thermal conductivity. Fillers, ranging from traditional carbon fibre to microspheres and carbon nanotubes, allow custom tailoring of the thermal and electro-conductivity of the enclosure, as well as high mechanical and environmental resistance.

Advanced manufacturing techniques such as additive manufacturing (AM) allow integrated connector shells, partitions and other features to be created. In some cases, designers will add selective metallisation to make circuit traces, giving even further shielding through specific frequency conduction channels, and can even embed integrated antennae into a composite construction.

For hybrid systems that generate high current draws and, therefore, a lot of EMI, the composite enclosures are designed with special EMI-resistant fillers, such as silicones and carbon mixtures. Designers can tailor the strength of these to provide specific impact resistance, tensile strength and bending resistance. A common choice composite enclosure is carbon-filled polyphenylene sulphide, which can be anything up to 40 per cent lighter than an equivalent aluminium version.

Loom design

The main component of the electronics of a modern racecar is the ECU, so it is one of the first parts to be positioned. Given its crucial importance, it is often centralised in the loom's design and within the car.

Designers will then lay out the rest of the wiring loom, usually starting with the engine loom, which is entirely separate from the rest of the car so it can be integrated and removed independently. With the ECU and engine loom complete, other systems such as the data logging and auxiliary wiring for components such as suspension and wheel sensors are incorporated.

In most forms of racing, teams are limited in the number and type of sensors they can use, and the amount of data they can gather from the car when on track. However, those limits often only apply during a race event, and teams are allowed free rein on data collection during testing. To that end, most motorsport teams will incorporate enough functionality into the wiring loom to allow extra sensors to be added when needed.

Once all the main systems are laid out, the cable connections are made between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them, usually using wires ranging in gauge from 18 to 30AWG, with various insulator properties depending on function and proximity to other systems.

The wiring inside the individual looms is typically laid out using contra-winding, where the individual wires are wound to give flexibility to the cable assembly. Contra-winding also ensures each wire is subject to the same degree of stress, regardless of the direction of the cable.

It might look neater if designers laid the wires straight in the heat shrink sleeve and the cable was put through a gentle 90-degree sweep, but the wires on the outside of the bend would be subject to greater stress, leading to potential failures.

A feature called a service loop is often incorporated where cables enter a connector to ensure the integrity of the loom. This involves adding a 360-degree loop to the cable just before termination in a connector pin so that, should an individual pin in the connector fail because of fatigue or damage, there is enough cable present to make a simple repair. Without the service loop, the whole wire would need to be replaced.

The loop also reduces the chances of a stress failure at the connector-cable interface by building an element of slack into the cable, even when bent through extreme angles.

In the past, it was not unheard of for cars to shut down completely, or drop into limp mode, if a single sensor or connection became damaged, as the ECU would see a fault and try to protect the car from potential damage. To prevent this, motorsport wiring looms are now often built in several separate parts that isolate the corners and front and rear areas of the vehicle from a centralised loom so that it can continue to operate, even after sustaining damage, or component failure.

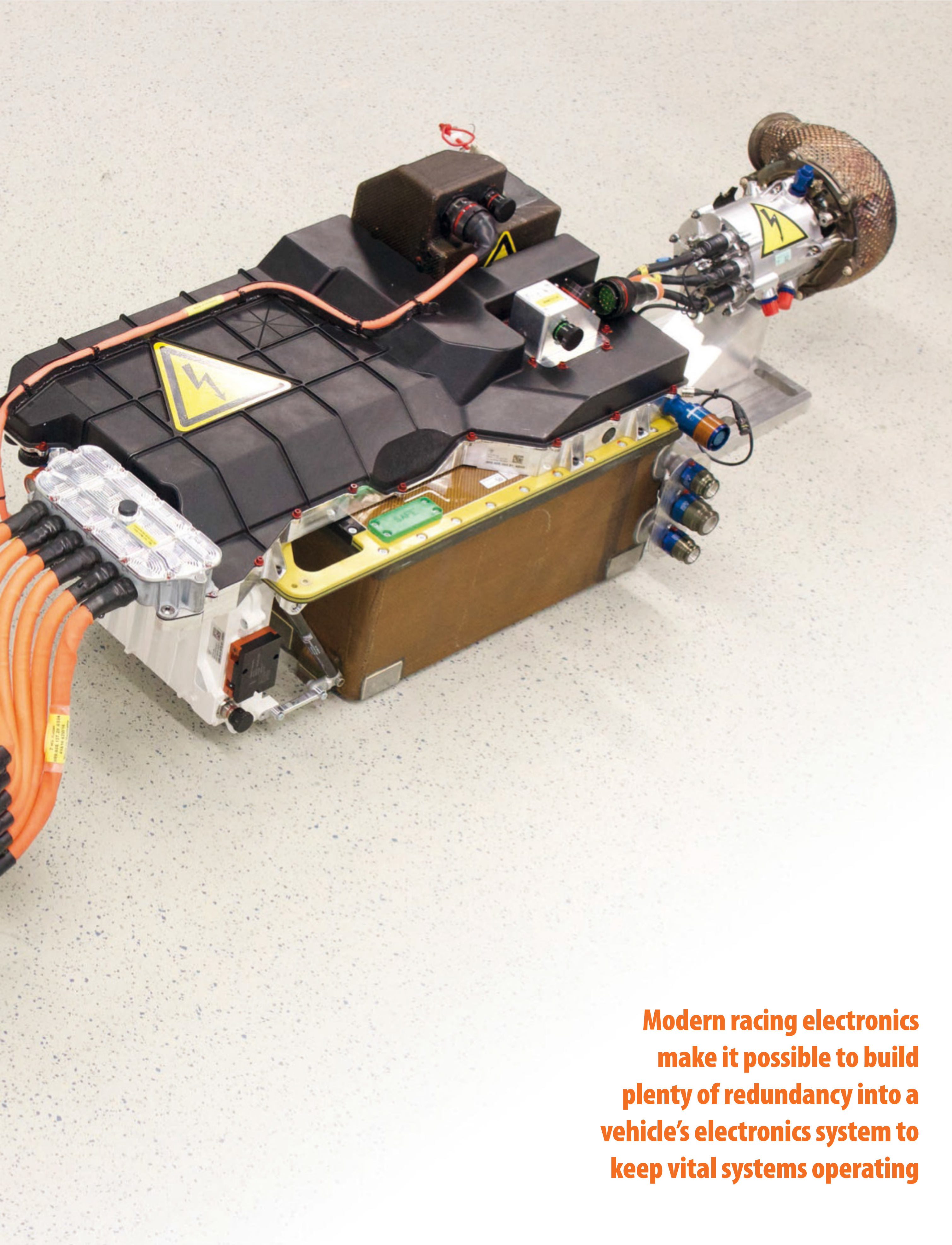
As many as 10-12 loom sections may be linked around the car. Electrical engineers will build redundancy into these sub-loom systems so that a component failure, or system damage, can be quickly identified and, where possible, the ECU can continue to work around the issue.

Redundancy package

Modern racing electronics make it possible to build plenty of redundancy into a vehicle's electronics system to keep vital systems operating, thanks to complex communications protocols that allow each electronic system to be controlled individually and, if necessary, isolated.

Most current race vehicle looms use what is known as the Controller Area Network (CAN). This onboard system enables multiple electronic devices to be connected and communicate. It is ultimately controlled by the car's ECU, which operates as the network's

Electromagnetic interference (EMI) between different parts of the electronic system is a massive consideration for high-powered hybrid systems such as this one from Porsche's 919 LMP1



Modern racing electronics make it possible to build plenty of redundancy into a vehicle's electronics system to keep vital systems operating

communications hub for each CAN-enabled device, via a power distribution module.

CAN allows an electrical system to automatically compensate for problems that may arise, thanks to the ability to individually program each electrical controller in the network. It can prioritise faults and, where necessary, create a workaround to prevent the loss of vital vehicle functions.

For example, if a racecar is fitted with wheel speed sensors, and one becomes damaged, the controller responsible for those sensors can identify the fault and, if it deems it safe to do so, ignore the reading from the failed sensor and not disable the car.

It is then possible to tell the systems using the wheel speed signals, such as a torque delivery controller, to continue operating by taking readings from the accelerometers and other sensors and using them instead. These in-built tiers of redundancy mean the car can continue racing at, or very close to, its maximum potential.

CAN modules like this Ray Service one enable multiple electronic devices to be connected and effectively communicate, via a PDM

Loom testing

Before an engineer fits the wiring loom into a car, it is subjected to a series of tests, which assures the designers of its performance. The loom tests comply with specific criteria at every stage of development through to vehicle-level validation.

They include basic requirements such as no damage caused to any part of the loom when subjected to a sweep of the voltage range of the components, no significant heat build-up around the areas that could lead to melting, or fire, in the loom, wire insulation not exceeding the maximum operating temperature specified for wires and no thermal incidence, short circuit or overload phenomena.

These basic tests are acceptable for the lower echelons of racing, but the higher ones require more accurate testing of all systems operation, ensuring it is correctly optimised for the vehicle performance. To that end, teams will use high-speed event detectors (discontinuity testers that monitor resistance simultaneously on each conductor) under controlled conditions, including temperature cycling and vibration over a range of frequencies on a shake table.

Such rigorous testing ensures that if the loom has any defects, they can be found and rectified before the car goes to the grid.

Repetitive failures – known as hard failures – are easy to detect, and effective testing eliminates them completely.

CAN allows an electrical system to automatically compensate for problems that may arise, thanks to the ability to individually program each electrical controller in the network

However, intermittent (or soft) failures can be much harder to find.

A prime example of a soft failure is where the insulation material is compromised. When the insulation is broken, there is usually only an air gap to isolate wires from each other for some parts of the cable.

A short circuit occurs when some force, such as bending, flexing or vibration, causes the conductors to come into physical contact with each other. This can generate a soft failure, which can lead to a hard failure, depending on the nature of the force.

Most intermittent failures can be identified by continual-scan flex testing, where the system is moved and tested repeatedly. A more thorough test, called non-destructive high-voltage testing, sends high-voltage pulses through the system at a low current to check the integrity of the wires and the resistance of all the cables.

In conclusion, wiring looms are the electronic spine of the race vehicle that brings it to life. Considering the points discussed in this article can bring significant performance and reliability gains to a racecar.

The wires within this TE cable are contra wound to ensure no individual wire is put under undue stress

Lighter than air

Racecar *investigates the current case for Hydrogen ICE in racing, and from there into mainstream automotive*

By LAWRENCE BUTCHER

Toyota is perhaps the strongest advocate of hydrogen technology today, competing with a hydrogen-powered ICE racecar in the Super Taikyu series in Japan and, more recently, launching its Corolla Cross H_2 Concept

It is increasingly obvious that the transition route to low-carbon transport is not clear cut. A straight switch to battery electric vehicles (BEV) is not the silver bullet some are advocating. While ideal for many applications, BEVs cannot – at least with current technology – meet every transport need. This is as true in racing as it is in general automotive. And while hybridisation has made impressive inroads into the sport, pure BEVs are still battery limited to short sprint races.

However, motorsport cannot be left behind, and must de-carbonise if it is to retain both public support and, more importantly, marketing money.

There are several options for lowering emissions from racing beyond sprints (side stepping the glaringly obvious issue of flying cars and hundreds of people around the world to compete). Sustainable fuels are a feasible solution, with those produced using renewable energy theoretically having a lower carbon footprint.

Then there is hydrogen (H_2), touted by some as the panacea for emissions reduction, and dismissed by others as an expensive red herring. H_2 fuel cell EVs are available on sale (though, depending on where you are in the world, fuelling then can range from impossible to tricky) and being investigated in racing. The FIA and ACO are pushing for an H_2 FC class at Le Mans from 2025, with the Dakar Rally also flying the flag for the fuel. The topic of this feature, however, is much closer to 'traditional' racing powertrain technology, hydrogen-fuelled ICE.

Old as the hills

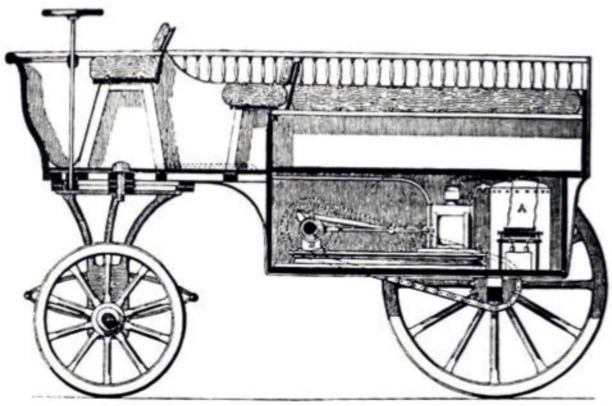
As with so many 'cutting edge' technologies, there is nothing new about the idea of running an ICE on hydrogen. In the Victorian era, Belgian inventor, Etienne Lenoir, developed the Hippomobile – a vehicle with a hydrogen-fuelled combustion engine – which successfully completed a test drive from Paris to Joinville-le-Pont in 1863.

Moving into the 20th century, there are many examples of H_2 being used to power combustion vehicles. The USSR converted several GAZ trucks to run on the fuel during WW2, and the fuel crisis of the 1970s spurred renewed interest in gas instead of petrol. BMW went so far as to build a prototype 520H with a 3.5-litre, direct injection engine, while the Musashi 2, developed by the Musashi Institute of Technology in Tokyo, even competed in the 1975 SEED Rally in the US, using a two-stroke powertrain.

Fast forward to the current day, and there are several large OEMs pursing H_2 ICE for both passenger car and HGV applications. Toyota has grabbed the majority of headlines of late, thanks to its racing efforts with an adapted Corolla in the Super Taikyu series (including competing the Fuji 24-hours) and the recent launch of its Corolla Cross H_2 Concept. Others, including Renault's Alpine brand, also see a future for the fuel.

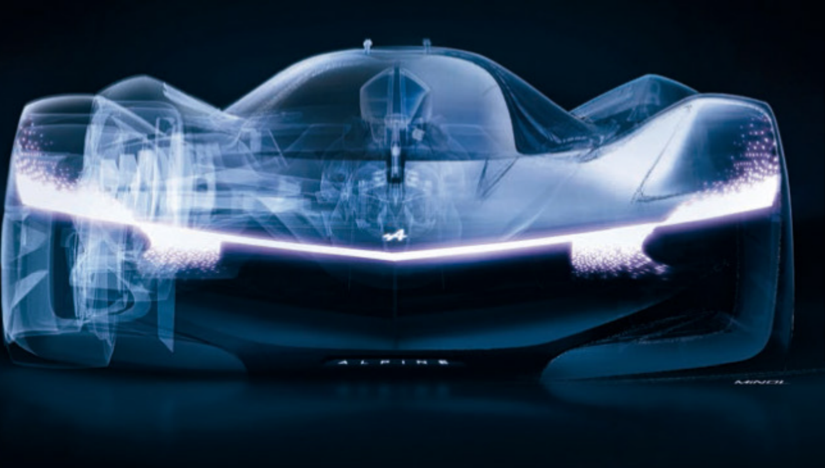
As with so many 'cutting edge' technologies, there is nothing new about the idea of running an ICE on hydrogen

There are currently four active H_2 ICE projects ongoing with what could be classified as top-tier players in the motorsport arena. In addition to Toyota's efforts (a turbocharged, 1600cc I3, sourced from the GR Yaris), Alpine has expressed a desire to pursue H_2 for racing applications and, at the end of 2022, revealed its Alpenglow concept, which it hopes to develop into a working prototype.



The first recorded use of hydrogen as a fuel source is Etienne Lenoir's Hippomobile of 1863

Alpine, Renault's sporting arm, is also investing significant resource in hydrogen-fuelled racing development, unveiling its dramatic, H_2-powered Alpenglow concept at the end of 2022



Outside of OEMs, both AVL Racetech (a 2.0-litre turbocharged I4) and Pipo Moteur (another 2.0-litre turbocharged I4) in Europe are working on the development of racing powertrains.

Mixed messages

In Alpine's opinion, H_2 ICE is a viable alternative for high performance applications: 'We believe that hydrogen engines are an option. We believe future mobility will be a mix of carbon neutral technologies,' says Pierre-Jean Tardy, chief engineer, hydrogen at Alpine Racing.

Meanwhile, Toyota president, Akio Toyoda, speaking at the competitive debut of the Corolla in 2021, tied the development of H_2 ICE directly to the company's core ethos.

'Making things easier is also about making them more enjoyable. Enjoyment in work spurs kaizen [improvements], making it easier and even more enjoyable,' said Toyoda. 'We have the same mindset in pursuing the development of hydrogen-powered engines, which began with the sole aim of increasing carbon-neutral options. We've made improvements at unprecedented speed by working earnestly and enjoying ourselves in motorsports. Seeing what we're doing, many like-minded partners from various industries have also come on board.'

For AVL Racetech, the motorsport arm of the Austrian engineering giant, its decision to develop a 2.0-litre H_2 engine in house, without any customer lined up, is unprecedented. Ellen Lohr, director of motorsport at AVL, explains: 'Why a hydrogen combustion engine and why a 2.0-litre with around 300kW power? Because we want to make sustainable motorsport possible on all levels. When we talk about electrification, hybridisation and fuel cells [all of which AVL is actively involved in] they are, in comparison, immensely expensive on a high-performance level.'

Green benefits

Obviously, the big draw of H_2 is the lack of tailpipe emissions. However, on many fronts it is superior to petrol as a fuel for combustion engines. Tardy highlights that hydrogen is ideal for combustion, permitting a better specific power, improved combustion and superior mixture preparation over petrol.

'It burns very quickly, which is good for efficiency, and it diffuses quickly, which gives a good mixture calorific value [in DI engines].'

On the face of it, it appears to be an ideal solution for clean racing. Compared to a fuel cell (the only other viable option for longer distance races), an H_2 ICE requires less cooling and reduced volumes of inlet air, reducing vehicle drag, and is also more tolerant to less than pure gas (FCEVs require very pure H_2). Significantly, under high load conditions,

AVL Racetech's 2.0-litre H_2 engine is being developed with no specific usage in mind, other than to show there are alternatives to BEV

an H_2 ICE also has the potential to be more efficient than a fuel cell.

Though not strictly an engineering requirement, an H_2 engine also *sounds* right. Anyone who has listened to racing EVs would struggle to argue they are aurally emotive, and emotion is an important part of racing's draw for fans so, from a business perspective, cannot be ignored.

The appeal of being able to draw upon decades of transferrable ICE development experience is also highly desirable. Yes, there are differences with H_2 combustion, but many mechanical aspects, such as ensuring reliability of reciprocating components at high rpm, or oil control under cornering loads, do not need to be re-learned. Along the same lines, many of the costs for ICE development are already amortised, so a developer is not going to need to spend millions proving an entirely new engine concept.

Challenges ahead

That said, there are still plenty of challenges to using H_2 as a fuel in ICEs. 'Many people misunderstand and think it is an easy technology,' says Lohr. 'Yes, it is easy compared

'We've made improvements at unprecedented speed by working earnestly and enjoying ourselves in motorsports'

Akio Toyoda, president of Toyota

to fuel cell technology, for example, but we are talking about motorsport, not just efficiency and range with low power. We need range and a lot of power. It also needs to be reliable at a high power level for a whole season. That makes it more complicated.'

As lead engineer on the Toyota's Corolla project, Naoaki Ito, explained in early 2022, conversion of the Yaris GR's turbocharged engine was not a completely straightforward operation. Further complicated by Toyota's focus on assessing the production viability of hydrogen, efforts were made to retain as many standard parts as possible.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'We believe that attaining carbon neutrality will require not only building new cars, but also utilising and improving the cars and technologies that already exist'

Naoaki Ito, lead engineer on Toyota's H2 Corolla project

'We thought that achieving this would enable the conversion of existing car engines to hydrogen, providing a powerful weapon in the quest for carbon neutrality,' says Ito. 'Although we said that we have 'converted' an engine from the GR Yaris, it would be more correct to say that we have been working to enable conversion.

'We believe that attaining carbon neutrality will require not only building new cars, but also utilising and improving the cars and technologies that already exist. To that end, we sought to make conversion possible with minimal component changes and control technologies.

'We've been working at this for several years now, and it certainly hasn't been easy. Initially we tried a bi-fuel approach, using 50 per cent petrol and 50 per cent hydrogen. From there, we attempted 100 per cent hydrogen, but initially the engine broke down within five minutes. Thinking back to those days, taking on a 24-hour race seemed beyond even our wildest dreams.'

Ensuring combustion stability, for example, is tricky. 'It [H_2] can burn in concentrations of between four and 76 per cent, which is a very wide range compared to petrol,' says Tardy. 'The required ignition energy is also very low, so a hot spot within a combustion chamber can cause abnormal combustion like knock and pre-ignition.'

In the early stages of its project, Alpine is conducting extensive simulation work in CFD to ascertain the ideal mixture preparation.

'Homogeneity between the H_2 and air is very important,' continues Tardy. 'You also have to be careful with combustion chamber walls temperature, so cooling is important.'

He also points out that oil contamination within the combustion chamber, from droplets thrown off the piston rings, can also easily trigger pre-ignition.

'Some of the additives in lubricants are more prone to pre-ignition, so there is work to be done with suppliers to make formulations more compatible with H_2 combustion.'

Developed in conjunction with Yamaha Motor, Toyota's hydrogen-fuelled 5.0-litre V8 is said to deliver around 450bhp at 6,800rpm and prove other fuel options are tenable for the ICE


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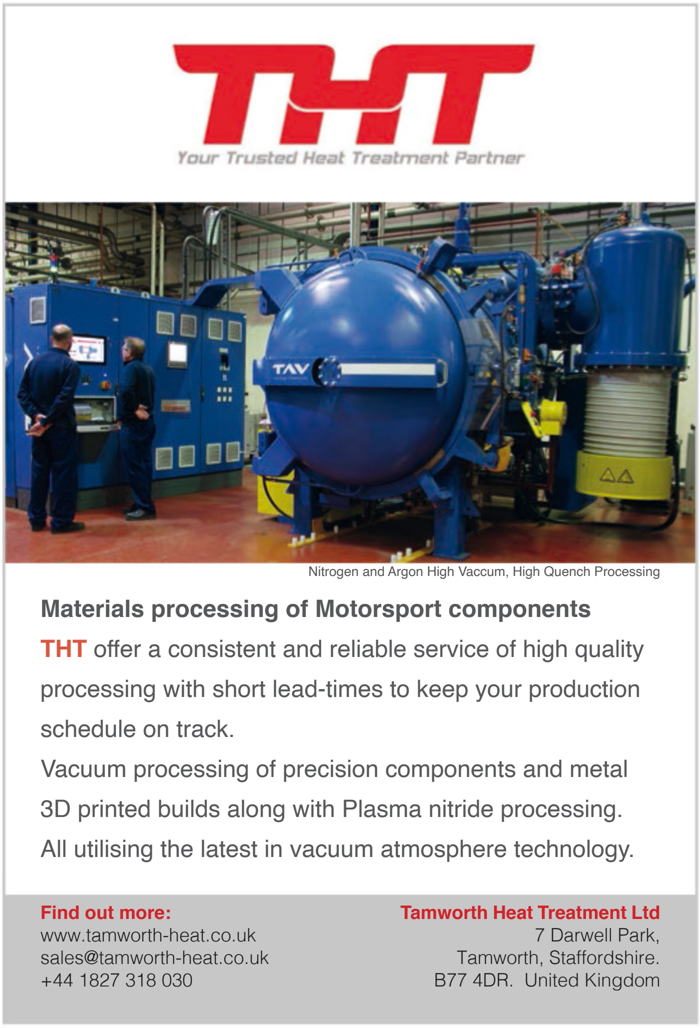
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Turbocharger design must also be carefully considered. For example, if very lean burn is used to minimise NO_x (more on which later), then a large compressor is required. As has been demonstrated under the current F1 rules, where ultra-lean combustion is desirable, a larger compressor increases efficiency. However, although H_2 combustion is relatively efficient, particularly in an engine which is running very lean, there are also high wall heat losses, which costs efficiency, and an H_2 engine produces lower exhaust gas energy than in a conventional petrol engine.

'The turbine energy is also low, so you need specific aerodynamic development as the balance is not the same as with current turbo compressors,' confirms Tardy.

Another factor to be accounted for is the issue of hydrogen embrittlement of materials. This is where the ductility of a metal is reduced due to the absorption of hydrogen, reducing the level of stress at which cracks begin to form. Take copper alloys which contain oxygen. These can be embrittled if exposed to hot hydrogen. Therefore, special attention must be paid to material selection, and also the development of coatings for components that could be prone to this phenomenon. Materials producer, Materion, has developed various solutions, such as its PerfoMet alloys, which are particularly well suited for use in hydrogen-rich environments, such as valve seats and guides in an H_2 ICE.

NO_x matters

One of the main arguments against H_2 as a green fuel in engines is that under normal combustion conditions, while CO_2 emissions are miniscule, NO_x levels are not due to the high combustion temperature of the gas. However, NO_x reduction can be achieved via various different approaches, which can be deployed individually or in combination.

Taking advantage of the very low concentrations the gas will ignite at, ultra-lean burn combustion, with a lambda around 2.3-2.5, minimises NO_x production, albeit at the cost of power.

Paul Kapus, SI engine development and concept vehicles manager at AVL: 'An alternative to lean burn is dilution by burned gas (EGR). The trade-off between required boost pressure and NO_x is better than for lean burn. In order to minimise boost pressure requirement, AVL chose a different approach: near stoichiometric operation with water injection. In AVL's H_2 engine, an injector shoots water into the intake ports. The water evaporates, providing a substantial cooling effect in the combustion chamber. This cooling effect moderates combustion, reduces NO_x and eliminates irregular combustion phenomena.'

Amongst manufacturers, Toyota is leading the hydrogen charge, racing a 1.6-litre, turbocharged Yaris in the Super Taikyu series

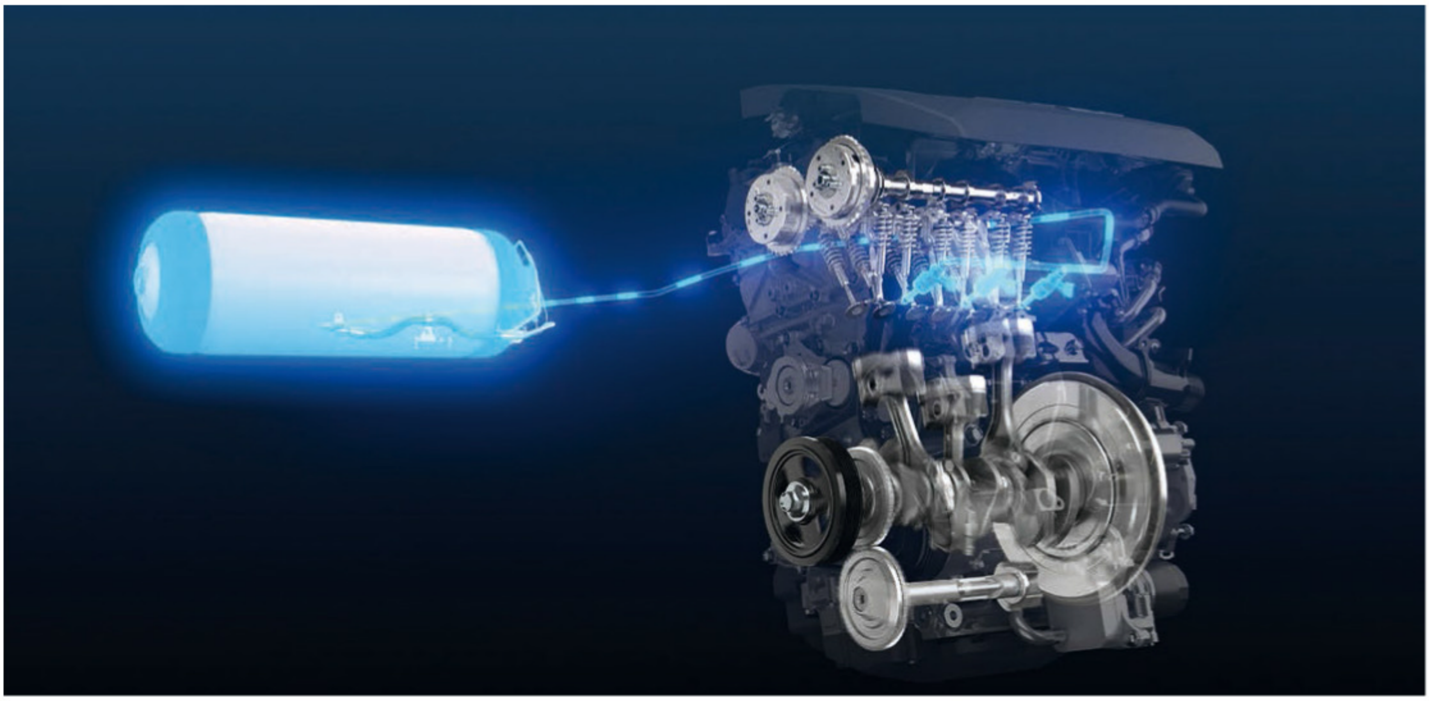
Development by Toyota has seen refuelling times reduced from over four minutes to around one and a half minutes for 180 litres

The elephant in the room for H_2 as a fuel is, of course, storage. Hydrogen is the lightest molecule in the universe and, though it is very energy dense – one kilogram of H_2 contains three times the energy of an equivalent mass of petrol – at ambient temperature it requires 1500 times the volume to accommodate it. The solution is to store it either at high pressure or as a liquid.

The current standard for gaseous hydrogen is storage at a pressure of 700bar in the vehicle. This requires the use of exceptionally strong tanks and, even at this pressure, it still takes up a lot of space compared to petrol.

'At 700bar, you get around 40g of H_2 per litre,' highlights Tardy. 'Petrol is around 750g/l so H_2 is still much lower. You can increase the density with liquid H_2, but you need very low temperature, 20 Kelvin (-253degC).

One of the main arguments against H_2 as a green fuel in engines is that under normal combustion conditions, while CO_2 emissions are miniscule, NO_x levels are not due to the high combustion temperature of the gas



One of the issues with hydrogen as fuel is storage. Converting it to a liquid reduces density and pressure but requires extremely low temperature storage. Cryo-compression may offer a solution

That requires super insulated vessels, but it has the advantage of being low pressure, which requires less structural strength in the storage vessels.'

Tardy points out that there is a solution that combines these two approaches, cryo-compression. 'With that, you can reach around 80g/l, but it still has some of the drawbacks of the other approaches.'

Tardy presents the example of how feasible it would be to use H_2 in current Formula 1. Working on the basis that 110kg of petrol is required to run an F1 race, an equivalent H_2 ICE would require 40kg of H_2. However, even in liquid form, that would require 600 litres of storage space, which is clearly not available in an F1 car.

'That means you need refuelling,' says Tardy, 'but that could be a showstopper for the use of gaseous hydrogen, because there are temperatures and pressures you cannot exceed. This limits the mass flow you can achieve when refuelling.

'Currently, we couldn't refuel a 10kg hydrogen tank in less than two minutes. That is not compatible with a pit stop in F1, and is why we feel cryogenic tanks would be the solution for F1. They have the advantages of low pressure, which means lower weight, and also the potential to use more complex shapes than cylinders.'

Flow chart

Looking at Toyota's efforts in Japan, it has worked extensively on the (currently gaseous) refuelling process for its Corolla, in an attempt to bring pit stop times closer to those for petrol cars. Alongside the use of larger nozzles on its refuelling rigs, and an increase in fuel port diameters, it has steadily raised refuelling pressure from 40MPa to 60MPa. This saw refuelling time shortened to just under two minutes by the end of the car's debut season in 2021. With even greater flow rates, the team shaved off a further 20 seconds in 2022, filling its 180-litre tanks in one and a half minutes.

If hydrogen was to be introduced into current racing series, refuelling would almost certainly be required. Development is ongoing

It is noteworthy that Toyota deployed two mobile refuelling systems during competitions, with the car moving from one to the next during a pit stop.

Despite its challenges, there is a very strong argument for the use of H_2 ICE powertrains in racing, and its arrival in the mainstream may come sooner rather than later. Lohr sums up: 'I see the need is there. Diversity in powertrain technologies in motorsport is necessary. Battery vehicles and fuel cell cars are part of that diversity. With H_2 ICE, we widen the possibilities for a sustainable future in racing and, at the same time, keep the sound, which is a big plus from my perspective. The lower costs will make this technology achievable for many categories, meaning we kind of democratise motorsport with investment in H_2 ICE.'

'Currently, we couldn't refuel a 10kg hydrogen tank in less than two minutes. That is not compatible with a pit stop in F1 [which] is why we feel cryogenic tanks would be the solution for F1'

Pierre-Jean Tardy, chief engineer, hydrogen at Alpine Racing

Risk management

IMSA race engineer and strategist, Jeff Braun, shares further insight into specific pre-event work that helps handle the often stressful situations that occur during an endurance race

By ANDREA QUINTARELLI

Photos: Michael L Levitt; Richard Dole

Pre-race homework is key to making the right decisions, particularly around fuel saving numbers

In last month's article about race strategy and preparation, Jeff Braun, race engineer with decades of experience and with victories in every major race in North America, illustrated the importance of understanding the rules, and helped put into context some specific features of endurance racing within the IMSA Weather Tech Championship, such as how neutralisations are handled, how teams can regain laps and how tyre management is regulated and can be managed to gain an advantage.

In this second instalment, he focuses on how racecar set-up can be adapted to the specific needs of long duration endurance races, where sometimes professional and non-professional drivers share the same car.

'I always try to do my strategy backwards,' explains Braun. 'First points I consider are how long is the race? And how long is a stint, in normal conditions? Based on these bits of information, I know already when I should do the last pit stop, to have enough fuel to finish the race without a splash. So I look to the end of the race and figure out where I want to be, and then go backward to the race start.'

Flexible variables

It often happens that, depending on the length of the race, not all stints will have the same length. This introduces a further variable, which can offer more flexibility in deciding which stint could be cut short, for example, to account for safety cars or load less fuel into the car.

'Ideally, you want to be the first car to make your last pit stop. This would put you in a better position, should a yellow flag come out. In such a situation, if all the other cars pitted already but you still need to do that,

you would be forced to stop during the neutralisation, while the others would stay out. After the pit stop, you would then be last, with just one stint left to run.

'The minute you know you can make it to the end, you want to pit,' adds Braun.

First milestone

This is why it is important to fix the first possible time, or lap, for the last pit stop as a milestone for the race strategy. Braun, for example, likes to use sheets he prepared before each event to always have this and other important information readily available, without the need to calculate anything during the hottest phases of a race.

> **'I always try to do my strategy backwards… I look to the end of the race and figure out where I want to be, and then go backward to the race start'**

Part of the pre-race preparation work is therefore to estimate how much these key moments of the race can be moved, depending on fuel consumption and any fuel saving approach. The latter can ensure a further element of flexibility, but also requires a level of confidence in the driver to be able to effectively save fuel without compromising lap times too heavily.

In general, Braun says the foundation of his preparation work is not to have a strict plan he must stick to, whatever it takes, because there are always events during any race that cannot be foreseen.

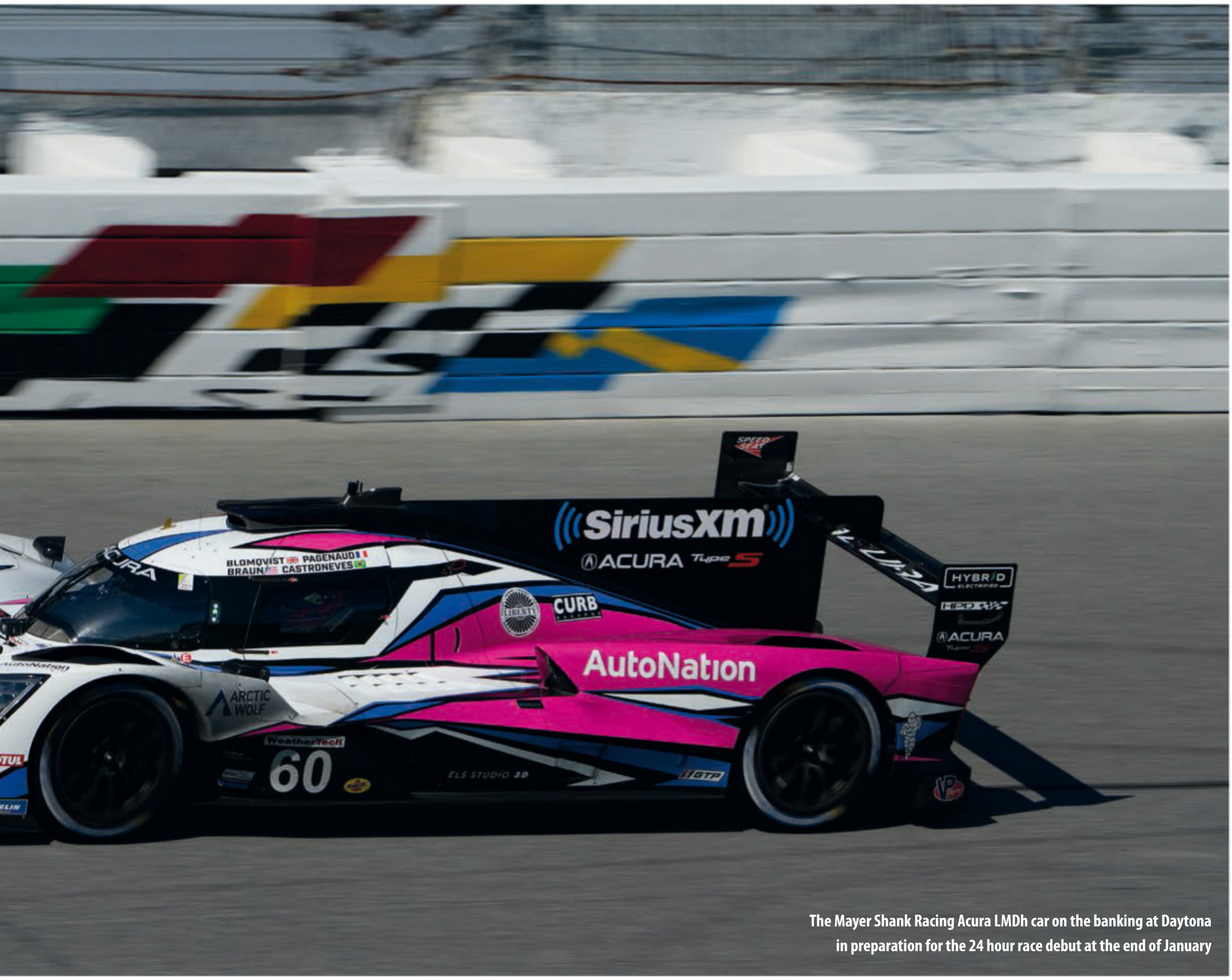
'A race changes all the time. You can never predict when a yellow flag could come out, what your exact pace is, what your tyre degradation is or any penalty you could get because of an infringement that would put you far behind. You simply don't know exactly what is going to happen.

'A yellow flag in the first laps is enough to compromise your plan. So, you need to have information and numbers in mind, or on a sheet of paper, that you can call up quickly. The last thing you want to do is calculations, or build Excel sheets, during a race. I rather like to have 'rules of thumb' I can base on for quick decisions,' says Braun.

The questions a race engineer wants to answer up front form a list that has been built up through experience and pre-event analysis.

'How many laps under yellow flags do we need to make it to the end from here? If my driver was to save fuel aggressively, can we end the race without any other pit stop? You want to have the answers to similar questions right away, without the need for complicated calculations,' underlines Braun.

Things happen fast during a race and there is no time to analyse the situation as it is happening. A good example is the Weather Tech Championship race at Road America in 2018. Incidentally, the author was supporting CORE Autosport, the team Braun was working for, on simulation that year. CORE ran an Oreca 07 in LMP2 specification and won the race, to the surprise of the DPi Works teams.



The Mayer Shank Racing Acura LMDh car on the banking at Daytona in preparation for the 24 hour race debut at the end of January

'We won that race on fuel mileage,' explains Braun. 'We made the decision early on to start saving fuel with about an hour and 20 minutes to go, in a race of only two hours and 40 minutes.

'Luckily for us, no one on any of the other teams thought about doing that, maybe because they didn't think they could make it!'

The driver in the car, Colin Braun (Jeff's son, incidentally), started to use any means he had to save fuel, in order to avoid one of the initially planned pit stops, and succeeded in finishing first, despite not having the pace of the fastest cars in the race.

Having a capable driver in the car is, of course, a key factor in deciding if similar, aggressive decisions can be taken or not. After all, saving fuel without compromising lap performance too dramatically is not easy, and tricks like drafting, or coasting, are just some of the tools good drivers employ.

Fuel management

Drivers can read the amount of fuel used per lap on their dashboard. At the end of each lap, that value is flashing and they can use this information to adapt their driving style, depending on the fuel saving targets communicated to them by the team.
On the other side of the pit wall, the engineers receive this and other data within the telemetry stream that is part of some classes' electronics system, and can then use this information in real time to adjust and adapt the strategy accordingly.

Incidentally, this is not the case in all classes – for example the LMP3 cars CORE Autosport ran in 2021 – as regulations forbid the employment of such telemetry systems.

The work related to fuel includes all calculations, keeping the situation under control and assessing how this matches the team's overall strategy, but it is also related to the preparation work done up front, mainly in the workshop before reaching the track.

'In our case at CORE, our assistant engineer was in charge of the exact amount of petrol that was loaded into the fuel cell, measuring this both at the workshop and at the track, knowing the exact flow rate of the refuelling system, being able to predict how much time would be needed to put a certain amount of fuel into the car, calculating the exact fuel mileage, and making sure that what car-logged data reported was accurate to what the car was actually using.

'This last point is particularly important. If the data system reported a certain fuel consumption for a certain session, but this did not match to the fuel pumped out of the tank after the same session, he had to re-calibrate the system to report the correct information.

'All of this data needed to be absolutely perfect, because critical strategy decisions had to be based on trusting the accuracy of this information.

'The reason you cannot have a fixed strategy, where you know exactly what you are going to do on a certain lap, is because often you do not know your pace compared to the other cars'

'If I asked, "Can we make it to the end from now with the fuel?" He had to be sure, and have the answer accurately and right away.'

Another important factor when analysing how long the car can go on a tank of fuel is understanding by how much fuel consumption can be reduced on a single lap, and what that means in terms of performance. On the engineering side, it is imperative to understand the impact this has on lap times because this is critical in deciding if saving fuel is worth it at all.

An important part of the engineering work, therefore, is taking individual driver-related factors into account in the most accurate way possible.

'There are many factors that make it difficult to precisely calculate how much

Colin Braun drove the defending champion MSR Acura at the Daytona 24 hours in January. A good relationship between engineer, strategist and driver is crucial to a successful race strategy

Different circuits lead to different strategies and fuel consumption management techniques. Endurance races require more complex strategies as they have to account for different driver styles

slower you would be by saving a certain amount of fuel,' confirms Braun. 'As a rule of thumb, saving ten per cent of fuel per lap is probably a realistic upper limit. If you try to save more, you would probably need to reduce your pace too much. This obviously changes from track to track, and experience plays an important role in this respect. Combining historical data with actual race preparation can normally indicate if a race could become a 'fuel saving matter' or not.'

Maximum save

'So, when preparing a test plan for practice sessions, engineers often put in some laps at 'maximum fuel save', where drivers are asked to try their best to limit fuel consumption. The team can then use the collected data to make informed decisions during the race.

'The most effective way to save fuel is still to coast [lift the throttle] at the end of the straights, before effectively braking into the corner,' notes Braun. 'The reason for this is that current engine technology allows manufacturers to completely cut the supply to the fuel injection if the throttle is closed.'

'The key is to save fuel and still go fast. This is where good drivers make a difference'

However, to limit the impact on lap times, such a technique requires a complete redefinition of driver reference points because, ideally, the minimum cornering speed should not be affected, in order to not unduly compromise the acceleration phase into the following straight.

'The key is to save fuel and still go fast. This is where good drivers make a difference. We had several LMP1 drivers in our cars at CORE Autosport over the years and they were normally extremely good at saving fuel by coasting because it's a technique they use a lot with the hybrid cars in the WEC. We experienced just how quick they were to adapt their driving to save fuel while still producing competitive lap times.'

Once all these factors have been considered, ideally based on pre-race calculations and estimations, it is the race engineer's call to decide if it is worth trying to save fuel or rather to go on pushing and stick to the 'normal' pit stop cycle. Again, that's where experience comes in.

'Sometimes you are right, sometimes you are wrong,' admits Braun candidly. 'There are a great many factors that are not under your control that also influence what the best strategy could be and, as much as you try, you can never know for certain in advance what will happen in a few laps time.'

Taking risks

'There is something else people often forget,' continues Braun. 'The reason you cannot have a fixed strategy, where you know exactly what you are going to do on a certain lap, is because often you do not know your pace compared to the other cars.

'What would make your strategy nearly a no brainer is if you knew you had the fastest car. Then you simply push the whole time and the other cars would *need* to follow you. If they all do exactly what you do, you win, because they cannot beat you.

'Where the strategy gets tricky is when you do not have the fastest car.'

When a car lacks performance, that's when a team needs to take more risks on the strategy side, if they want a better result than they could achieve on pace alone. Most times, this is something crews and engineers cannot know up front, but only learn during the race.

'In such a situation, you need to come up with something to beat the fastest car. In Road America 2018 we were probably the fifth fastest car in the race. We knew we could save fuel and, at a certain point, I recognised we could make it to the end of the race with one pit stop less than the other teams.

Working backwards from the end, being the first to make the last pit stop can avoid a traffic jam in the pit, as it often becomes hectic in the final throes of a race, and can compromise race strategy

'My numbers matched relatively well with the calculations of my assistant engineer, but we both knew it was going to be really tight. Colin [the driver] had to save a really big amount of fuel every lap but, if we didn't try, we would finish fifth.

'The alternative was having a go for a win, or finishing in eighth place. The team owner [and second driver], Jon Bennet, was also listening to us on the intercom and immediately said, "Let's go for it! Fifth or eighth? It makes no difference."

'We started saving fuel pretty early during the race and, at the flag, we beat four cars that were clearly faster than us,' recounts Braun, with a smile. 'In that particular situation, the target was really just to save fuel, no matter the impact on performance, and Colin was using every trick in the book. Whatever happened, we had to make it to the end.

'That is just one of many examples to explain why I don't think you can plan your strategy too strictly up front. Maybe in Formula 1 it's different, because they don't need to refuel and they have different tyre compounds with different performance and longevity to play with.'

Moreover, an endurance racing team have more drivers in a car, and need to ensure all of them get enough seat time during practice. That makes set-up solutions and strategy elements harder still to test as rarely do two drivers have exactly the same driving style.

'Also, in multi-class racing, traffic is another critical element, and its influence on performance and strategy changes from track to track,' Braun expands. 'In 2021, for example, with the LMP3 car, one crucial element of our strategy was how to deal with GTLM cars. With pro' drivers on board, they had a similar pace to our LMP3 cars with non-professional drivers at the wheel. The two classes were *really* racing each other.

'As fuel mileage is affected by traffic, as much as it is by driving style, we needed to account for how different the fuel usage of our non-professional driver was because this determined our refuelling windows, based on when our last pit stop could be to make it to the end. of the race'

Stable set-up

Analysing how to set up a racecar before and during an event is a further element that can influence, and be influenced by, a team's approach to race strategy.

In general, for long races, especially those with professional and amateur drivers, it is important to have a predictable car, able to keep its balance and performance stable, even with changing fuel loads and tyre degradation. Besides this, there are still specific aspects that are crucial to help the drivers to extract the best out of their cars and be fast and consistent.

In general, for long races, especially those with professional and amateur drivers, it is important to have a predictable car, able to keep its balance and performance stable

'It is all about how much risk you want to take with respect to how much reward you would get,' notes Braun. 'Daytona is a good example. It is a 24-hour race and driving crews have to deal with traffic. If you also have non-professional drivers in the car, as a race engineer you must consider that adding all the factors mentioned above can produce a high workload for the drivers.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Close quarters in a tight pit lane can lead to a loss of time, damage to your car or injury to a mechanic or driver, all elements which would obviously rather be avoided. Pit stop strategy is crucial

They use most of their concentration just to drive the car, so there is not too much left to handle traffic or complex strategy situations. So, from a set-up point of view, you cannot give them any surprises.

'In my experience, where this plays the biggest role is not so much in corners, but rather braking. Even non-professional drivers can handle a bit of mid-corner understeer or oversteer. But braking is also where it is harder to deal with traffic, because of the different speed of cars of different classes. If the drivers need to use all their mental power to control the car, they can quickly get into trouble with other vehicles. A car that brakes well and consistently is crucial to help a non-professional driver. For cars equipped with carbon brakes, this also means they have to warm up quickly, for example.

'Downforce level is also very important. Normally, more downforce makes non-professional drivers more comfortable, but this does not necessarily make the car faster. In this respect, Daytona is really a problem, because most of the lap time is spent on the banking where top speed is critical and you want to trim your aerodynamics out for that.

'On other tracks, like Sebring, your optimal set-up would probably be a high downforce one anyway, so it's not too much of an issue.'

Set-up and race strategy are undoubtedly interconnected, all the more so when teams do not have the fastest car. But it is interesting to note how set-up can actually become an integral part of race strategy.

Braun recalls another anecdote from his vast experience: 'In 2014, I was engineering a Ferrari 458 in the GTD class at Daytona for Level 5. I don't remember the reason, but we were horrible in the infield. Likely it was my bad set-up engineering, so I had to find another solution. On the banking, though, we were about equal to the other teams.

Stable set-up

'After practice and qualifying, we realised we had to change our approach, because we really were nowhere in terms of pace. So, instead of being average on both the straights and the infield, we thought we'd at least try to have one strength.

'I was not smart enough to make the car fast in the infield, so we tried to go faster still on the banking. We trimmed the wing completely out and, as a result, were even more horrible in the infield, but incredibly fast in a straight line.

'This was only possible to do because we had very good drivers, who could handle that particular situation of having even less downforce than with a normal Daytona set-up, where you normally trim out the aerodynamics to reduce drag. This made driving in the twisty section of the track even trickier, but nobody could get anywhere near us on the straights and that's where it is easier to overtake.

'During the last lap, we were battling with an Audi and they nearly overtook us in the infield, but Pier Guidi managed to resist the attack. They came close again at the Bus Stop chicane, but Pier Guidi resisted again and then, once on the banking, they couldn't catch us. In the end, we won by about a car length,' beams Braun.

Set-up and race strategy are undoubtedly interconnected, all the more so when teams do not have the fastest car. But it is interesting to note how set-up can become an integral part of race strategy

Back to the future

Motorsport has lost its way and needs a rethink

By DANNY NOWLAN

XPB

A great deal has been written about Balance of Performance in these pages over the years, and it's an ongoing topic of conversation, but does it *really* improve the world of motor racing?

In recent discussions I have had with colleagues and customers, the one thing that is being most hotly debated, and resented behind closed doors, is spec formulae and Balance of Performance. While not being able to officially speak about this, the almost universal view I'm hearing amongst colleagues involved in this is it represents the worst aspects of socialism and goes against the grain of what motor racing really should be about. This is a topic I therefore must return to because motor racing is at a crossroads, and right now is the time for these matters to be discussed openly and forthrightly.

I must therefore apologise to any readers who are expecting a barrage of formulae as I quantify the many aspects of vehicle dynamics. The reason I am writing this article is feel very strongly that motor racing is plunging headlong down a dead end road and action needs to be taken, otherwise it will devolve into club and rich guy racing and a handful of elite formulae perched on very shaky ground.

Firstly, then, it's worth setting the scene for the situation we now find ourselves in.

Attention grabber

If we wind the clock back 30 or so years, motorsport commanded attention. As a teenager, I remember the media firestorm that descended on Adelaide in 1985 when the grand prix circus came to town.

Entire countries used to stop to watch events like the Bathurst 1000, the Daytona 500 and the Indy 500.

The response of motorsport regulatory bodies to this changing landscape has done nothing to stem the tide

Formula E has the capacity to put the racing back into motor racing, and to provide an unprecedented test bed for new, renewable technologies that will feed into the road car market of the future, but not if it's constrained by being essentially a spec formula

Bottom line: if you want passing, the cars *have* to have differential performance

Also, the global outpouring of grief at the death of Ayrton Senna in 1994 was something totally unprecedented.

If we fast forward the tape to now, though, the situation is not pretty. We have a good deal of the population concerned about climate change, and the internal combustion engine is seen as one of the key culprits. We also have a large percentage of the population exhibiting some incredibly Pollyanna views (otherwise known as positivity bias) on electric vehicles, and Silicon Valley is getting itself all hot and bothered about self-driving vehicles.

In the meantime, countries no longer stop to watch events like the Bathurst 1000, the Indy and Daytona 500s or the 24 hours of Le Mans. As a case in point, the actor who played Ken Miles' son in *Ford vs Ferrari* actually had to Google what the 24 hours of Le Mans was! If that doesn't tell you something is up, I don't know what will.

The cost of loss

The response of motorsport regulatory bodies to this changing landscape has done nothing to stem the tide. The 'answer' has been more spec formulae and the dreaded Balance of Performance. All this does is makes it less expensive to lose. Let me illustrate that statement with some examples from an earlier article I wrote about the erosion of the motorsport industrial base.

The first consequence of all this is, rather than controlling costs, it's made things more expensive. I remember spending some time with Dave Williams on the Multimatic rig in Thetford, UK in mid-2008. For the uninitiated, Dave was the father of Lotus' Formula 1 active suspension. He is one of the sharpest minds you'll ever deal with in this business. He made the point that when you tighten regulations, you *always* spend more money. Because you need to spend a lot more money, and employ more engineering effort, to figure out how to make a front wing flex by, say, 4mm instead of 2mm and pass a ridiculous load test that will gain you half a tenth. Compare this to, say, spending a week or two brainstorming a hydraulically-actuated third spring that is worth 0.5s per lap. Don't believe me? Cost it out.

Also consider the following case studies. In IndyCar, in the golden era of CART and ChampCar, Penske and Chip Ganassi Racing ruled the roost. That said, they had a lot of other good operations that could keep them awfully honest. The initial spec series of IndyCar did nothing to change this. However, credit to IndyCar for recognising this and freeing up some of the technical regulations. Now, you have a real contest.

To counter this, let's review Formula 2. In 1995, the last season of the free technical era of F3000, the operating budget per car was about £600,000. These days, the operating budget of a typical F2 team is in the order of £2-4m, and that is being conservative.

So, the assertion that single spec, or tight technical regulations, save costs is quite simply an untenable one.

The other argument is that if the cars all have similar performance, it will improve the show. This a dangerous fallacy that has infected the sport in recent times. The reasoning is if we make the cars perform the same, the drivers can compete on level terms, so we get passing and everyone is happy. This has zero basis in fact.

Passing performance

One of my regulatory body customers asked me to develop an overtaking simulation feature, and the process was an eye opener. For the development, I was modelling an F3 car and, to keep things simple, I modelled no wake and gave the pursuing car an additional 50bhp. Even giving the cars a 100m separation, it still took 1000m to make the pass. I was gobsmacked.

It also confirmed what one of my other customers involved in another spec formula had said that, due to the combination of poor tyres and equal performance, most of their races had become processions.

Bottom line: if you want passing, the cars *have* to have differential performance.

The use of DRS in Formula 1 all but confirms this. Yes, DRS was introduced as a band aid to what happens to the aerodynamics of the trailing car yet, despite CD¬A drops of at least 0.2-0.3, it's still not enough to get the job done. Put into sharper relief, the current generation F1 cars were *designed* to make passing easier, yet still need DRS. If this isn't a signal to what is required for genuine motor racing, I don't know what is.

The job of anyone working in motorsport is to go fast. If a competitor goes *faster*, the job becomes how to catch, and ideally pass, them. The show is a consequence of this, not the other way round

The very nature of motor racing is that sometimes you'll be behind, but other times you'll be in front, and motorsport regulatory bodies ignore this at their peril. To quote a mentor of mine when he was working for Toyota F1 in the early 2000s: 'It is our job to catch up to Ferrari, not for the FIA to peg Ferrari's performance back to us.' Those words are as relevant today as they were 20 years ago.

So, how do we that work in motorsport get ourselves out of this mess?

Show or go?

The first thing is for all of us in motorsport to embrace what we are good at, and that is going fast. One of the things that infuriates me about this business is when I hear people talk about improving the show. Make no mistake folks, the show is a consequence, not your primary goal. Let me illustrate with some further examples. Thousands don't catch the ferry to the Isle of Man every summer to see a bunch of mopeds going through Ballagarey in a line at 80km/h. Nor do they turn up to Bathurst every October to see a line of sedans cruising the mountain at 60km/h. They go to these events to be blown away by speed and acts of derring do.

If you let the engineers and drivers go fast, the results – and, by nature, the show – will take care of themselves.

The other thing motorsport is brilliant at is being the ultimate Research and Development department for the whole automotive industry. Disc brakes, the use of aero aids in road cars and multiple safety features have found their way onto road cars as a direct result of cutting motorsport engineers loose. The reason for this is our job is to push our equipment to the edge, and it's amazing what you learn in the process.

This gives road car manufacturers a vested interest in being involved in motorsport, not just when it suits them from a marketing perspective. Yet we are rapidly losing that involvement.

Let me also add that if motor racing as an industry is to survive, we must get over the resident technophobia / hysteria that has always been present in the sport, but seems even more prevalent these days. Whenever anyone writes about what is wrong with motor racing today, someone somewhere screams, 'Too much technology!' and so we have to drop electronic and aerodynamic advancements and go back to a 1950's era of thin tyres and carburetted motors (with the exception of muscle cars).

It's not just confined to motorsport writers either. This pervading line of thought has also infected the fan base as well.

If you want to see the ultimate folly of this, just look at the open-wheel formulae that have pursued the mantra that aero is evil. You wind up with processional racing, and set-ups where the front wing is set to maximum and the rear wing to minimum. Yawn.

So, to say that technology spoils the show has no basis in reality. The most acute example of this is the Leyton House F1 car of 1990. Here was a car that looked nothing like its contemporaries and, despite some teething issues, punched ridiculously above its weight. Yet how are the lower budget teams in F1 supposed to perform similar feats today with a rule book the size of the Bible, the Quran and the Torah combined?

Many people in motor racing today will counter with the argument that this doesn't apply to us, but you only have to review categories of World Time Attack Challenge to see this is not the case. To prove the point, let's look at the costings of one of my Time Attack customers, Nick Ashwin, when he went from P17 to P3 at the 2016 event. This is shown in **table 1** and figures are in Australian dollars.

Table 1: Costings of NA AutoEng tweaks for the Evo 6

Item	Cost
AMB aero package	$15,000
ChassisSim set-up service	$1500
Front dive plane	$500

All-up price was AUS$17,000 (I corrected the figures here to show the full price of the aero package). This enabled an amateur driver like Nick to give a professional driver, who would eventually win the event, a very good run for his money.

Our job is to push our equipment to the edge, and it's amazing what you learn in the process

The attitude needs to be as follows: here is you tub, here are your regulations and here is the sandbox that you play in… Go out there and win

So, I ask again. How exactly does technical freedom spoil the show, or not allow lower budget teams to compete with better resourced counterparts?

Turning the tide

There must be some good news, though, right? Well, there are some very specific measures all of us working in motor racing today can put in place right now to turn things around.

Firstly, we need to abandon the joint fallacies of spec formulae and Balance of Performance. For sportscar / open wheelers, the attitude needs to be as follows: here is the tub, here are your regulations and here is the sandbox that you play in, with well-defined regulations and fixed-price parts. Go out there and win.

For GT racing, you rate minimum weight with engine class and, provided you are dealing with a derivation of a road car as the starting point, go off and race.

One key thing lost in motor racing is I have an Audi, you have a Mercedes, now let's go to the track and sort out who is fastest.

If you think that approach will scare manufacturers away, sorry, but that's life. If you can't stand the heat, get out of the kitchen.

For the more senior formulae, though, more drastic action is required.

Firstly, Formula E needs to abandon the single spec battery supplier mentality it's had since day one. The series has always had some rather peculiar regulations, and a lot of this is driven by some poor understanding of what counts in an electric powertrain.

Anyone involved in high performance electric applications, whether it is racing radio-controlled cars, pylon racers or extreme 3D aerobatic craft, knows that *everything* flows from the cells you choose. Ignore this fact at your peril. So, rather than saying you must use *these* cells, the regulations should say your powertrain mass is, say, 400kg, and it is priced capped. Go for it.

The net effect of that would be to dangle a very big carrot in front of companies such as Tesla to get in the game, instantly making Formula E more than just a marketing platform, and a genuine leader in the development of renewable technologies.

For Formula 1 and sportscars, some hard thinking and even bolder steps are required because we face significant headwinds. Not least the perception that motor racing, and F1 in particular, has lost touch with mainstream motoring, and the public in general.

If these high-profile formulae are to survive, they must consider embracing non-fossil fuel-based sustainable fuels. I realise this is much easier said then done. The E85 adventure in V8 Supercars was short lived, and to ignore the difficulties faced in producing biofuel like ethanol, and the associate drop in energy density, would be naive at best. But given the totally unsustainable nature of moving to solely battery-powered EV *en masse*, someone needs to step up to the plate.

Bolder action

In fairness, the FIA and F1 have recognised this, but bolder action still needs to be taken. In 1961, when the Americans were drastically behind the Soviet Union in the Space Race, President Kennedy realised a big goal needed to be set, which is why he didn't blink about the moon announcement.

We in motor racing are facing the same situation. If we go down the current road in one fell swoop, not only would F1 / sportscars render itself a valuable commodity to mainstream automotive, but any PR company worth its salt would be rushing to the door to publicise this. This is the oxygen we desperately need.

In closing, then, motorsport is facing some very challenging times, but the problems *are* solvable. Firstly, as an industry we need to re-discover what we are good at. Secondly, we have to grow up and embrace technology. Lastly, we need to get back in the fight. The time for talking is over. Action is required.

The Adrian Newey-designed Leyton House F1 car of 1990 is a graphic example of how engineering, when unconstricted by regulation or external balancing, leads to technical innovation

IN BRIEF

Formula E has extended its multi-year agreement with **DHL** that will see the company continue to find green logistical and cutting-edge freight solutions for the electric series.

Steve Eriksen, formerly of Honda Performance Development, has been named as the new COO of **Rahal Letterman Lanigan Racing**. Eriksen will oversee RLL's sportscar programme and three-car IndyCar effort.

Courtney Crone has won IMSA's Diverse Driver Development scholarship and landed a full time drive in the IMSA VP Racing Sportscar Challenge. The sprint series uses LMP3 cars in a single-driver format.

The **Automobile Club de l'Ouest** has confirmed the 24 Hours of Le Mans is sold out. The event will celebrate the centenary of the first race in 1923, and will see the debut of Ferrari, Cadillac, Peugeot and Porsche.

Racecar was saddened to learn of the death of former contributor **Forbes Aird**, who died at his home in Toronto before Christmas.

Mike Flewitt has been appointed as chairman of **Briggs Automotive Company** (BAC) as the company continues to expand through its road-legal, single-seat Mono range. Flewitt, formerly vice president of Ford Europe and CEO of McLaren Automotive, said: 'With BAC's recent successful expansion across Europe, North America and Asia, the brand is rapidly expanding as a *bona fide* global player.'

McLaren Applied has confirmed **Richard Saxby** as its new motorsport director. Saxby has worked in F1 for Stewart GP, Renault, Red Bull and Mercedes in electronics, systems and testing and development applications.

Stellantis is in negotiations to acquire a 'substantial' stake in **Symbio**, a world leader in zero-emission hydrogen mobility. 'Symbio's technical road map perfectly matches Stellantis' hydrogen roll-out plans in Europe and the US,' said Stellantis CEO, Carlos Tavares.

IndyCar confirms Mahle

It was not a surprising appointment, but Mahle has been confirmed to supply the single-seat US IndyCar series with hybrid powertrains, having met several of the milestones set by the racing series' technical team.

The new hybrid system is part of a project to reduce the environmental impact of racing, with the series switching to 100 per cent renewable race fuels, while support transporters will use 100 per cent renewable diesel to move from race shops to events.

'We are delighted to have supported the NTT IndyCar series to develop the new push-to-pass hybrid system,' said Mahle Powertrain managing director, Hugh Blaxill. 'We're particularly appreciative of the expertise and support we have received from IndyCar, HPD and Chevrolet during the system's development, much of which took place during the significant global supply chain issues that demanded even closer collaboration between ourselves, the entire IndyCar team and our suppliers to help resolve.

'I would like to thank the Mahle Powertrain team for their hard work and dedication to reaching this milestone, and we look forward to watching the hybrid system perform on track to deliver the exciting racing IndyCar fans enjoy.'

IndyCar president, Jay Frye, responded: 'We appreciate the innovative solution initiated by Mahle Powertrain and their hard work in the development of our new hybrid system.

'We are also grateful for Chevrolet and HPD, as well as the whole IndyCar team, for their close collaboration in this important project and continued work as we proceed toward implementation of the system for the 2024 NTT IndyCar series season.'

Mahle Powertrains

The premier US single-seat series will introduce a push-to-pass hybrid system in 2024, using a solution developed by Mahle Powertrain

Vowles moves from Mercedes to Williams

James Vowles has taken the helm as team principal at Williams Grand Prix following the departure of Jost Capito in December.

The former Mercedes strategist was the right hand man to Toto Wolff at Mercedes, and the Austrian has said the loss will be keenly felt within the team.

The 43-year old Briton will start work for Williams in February, ahead of pre-season testing in Bahrain.

He worked previously for Honda Racing, Brawn GP and British American Racing. It was with Brawn that, as race strategist, Vowles helped Jenson Button to win the Formula 1 World Drivers' Championship in 2009. At Mercedes, he has been a key contributor to the eight Constructors' titles and six drivers' titles the team has amassed with Lewis Hamilton and Nico Rosberg.

Wolff, quoted in the Williams' press release announcing Vowles' move, has not ruled out a return for the Briton to the Mercedes' team. The Austrian has confirmed he will remain in the post for years to come, but that Vowles could return when Wolff decides to move on to other business ventures.

John Wickham

***Racecar Engineering* was saddened to learn of the death of former Spirit F1 team owner, John Wickham, at the age of 73 after falling ill with motor neurone disease in 2018.**

The Briton was also the team boss of Bentley when the British manufacturer last won the 24 hours of Le Mans in 2003.

Wickham had been team manager at March, and Audi Sport UK, while he took up the role as general manager, technical and operations at A1 Grand Prix. He was also involved in Bentley's GT3 programme.

ABB to improve Formula E efficiency

ABB will this year integrate its innovative Ability Optimax energy management software solution into the ABB FIA Formula E World Championship, helping to maximise the energy efficiency of the series.

Season nine of the all-electric racing series, of which ABB is official charging partner, started in Mexico in January, where ABB Ability Optimax was used in a live racing environment. Following successful trials during Season eight, ABB Ability Optimax will allow the championship's engineers to monitor and analyse total race-specific energy output, helping drive more efficient usage.

Up to 14 metering boxes will be located at host venues, collecting data on how much electrical power (kW) is being used by teams and other race partners at any given moment, and how much electricity (kWh) is consumed over any given time period. This information will then be relayed back to race control via the Microsoft Azure cloud.

Total consumption across entire E-Prix sites will also be monitored, encompassing operations including the TV broadcast suite, E-Village fan zone, media centre, catering facilities, the paddock and the teams' pit garages.

Daniela Lužanin, head of the ABB Formula E partnership, said: 'For ABB, the partnership with Formula E has always been more than a race, it is a test bed for innovative technologies, and we aim to continue to bring more of our solutions to the series.

'Energy efficiency is key to reducing emissions and meeting sustainability targets and ABB Ability Optimax will be fully implemented this season to help improve this within the championship.'

The varied street circuits used by Formula E present the added challenge of having to use a range of power sources across different locations. ABB Ability Optimax helps address this with a central dashboard, which gives live visibility of all power usage at the racetrack, enabling Formula E's technical teams to make all on-site activity more efficient, regardless of the power source.

Jamie Reigle, CEO of Formula E, commented: 'As the first sport to be certified as net-zero carbon since inception, we are always looking for more ways to make the series as sustainable as possible. With ABB Ability Optimax we are able to better monitor our energy consumption across the board and see where potential savings could be made.'

ABB's Ability Optimax software will enable teams and organisers of the BEV series to monitor and analyse energy output across an entire race event

All change at NASCAR operations

NASCAR has introduced a raft of new technical appointments, promoting many of its existing employees. Dr Eric Jacuzzi has been promoted to NASCAR vice president vehicle performance, Dr John Patalak is the new NASCAR vice president safety engineering and Brandon Thomas is now NASCAR vice president vehicle design.

Meanwhile, John Probst has been promoted to NASCAR chief racing development officer, while Elton Sawyer has been named senior vice president of competition, replacing Scott Miller who will assume the newly-formed role of competition strategist within the NASCAR Competition team after more than 40 years in motorsports.

'Elton Sawyer has shown incredible versatility throughout his four-plus decades in motorsports,' said Steve O'Donnell, NASCAR chief operating officer. 'Following his lengthy driving career, Elton held key leadership positions for several race teams and here at NASCAR for the last eight seasons. He will excel in this role, and we look forward to watching him continue to grow the Competition team during this crucial era in our sport's history.

Brandon Thomas, NASCAR VP vehicle design

'We are thrilled that Scott Miller has chosen to remain a key part of the NASCAR Competition team. When he joined NASCAR in 2016, Scott lent immediate credibility to the position. A trusted voice in the garage, Scott used his decades of experience to lead our Competition team to new heights during a time that saw a new race format, a new play off format and a new racecar. The mark he leaves on the organisation is significant.

'John Probst's leadership and tireless devotion in the development of the Next Gen car over the last three years has been extraordinary. This project was among the most challenging and important endeavors in NASCAR history, and leaders like Probst, Dr. Eric Jacuzzi, Dr. John Patalak, Brandon Thomas and many others worked incredibly hard to not only put this car on the race track, but to make it a success for our industry and our fans.'

FIA do the shuffle

Changes to the FIA's structure have been implemented a year after Mohammed ben Sulayem was voted in as president of the organisation.

Nikolas Tombazis, who has led the FIA's Formula 1 technical team since 2018, has now taken the role of single seat director. Reporting into him will be the sporting, technical, financial and strategy and operations directors.

Steven Nielsen will join the FIA as sporting director, moving from his job at FOM, and will be responsible for overseeing all sporting matters including the development of Race Control and the Remote Operations centre.

Tim Goss moves from his role of deputy technical director to director.

Federico Lodi is the new financial director, while Francois Sicard has taken the new role of Formula 2 strategy and operations director.

Autosport 2023 show review

Stewart Mitchell

The cars were the stars at Autosport International this year, with a focus on future technologies, a burning topic at the moment. Meanwhile, business forums led discussions behind the scenes

Show season drew to a close at Autosport International in Birmingham in January after a busy winter period. The MIA hosted its second CTS show at Silverstone in October, although that is not open to the public; the PMW show was successful in Germany in November and the PRI show was as popular as ever at Indianapolis in December.

The return of the UK's Autosport International Show, after a two-year hiatus, was welcomed by fans and exhibitors alike. Fans flocked back to the NEC in Birmingham over the four days. There was a strong focus on future technologies, with exhibitors such as the Dutch Forze Motorsport team, which demonstrated its latest hydrogen-powered prototype.

The Business Forum gave an insight into the potential future of the sport, with the discussion led by Pat Symonds, while, looking beyond 2026, the next generation of engineers competed against each other in the F1 in Schools National Finals.

Many of the big players in the motorsport industry did still attend, though there were some notable exceptions that have been in previous years

There was also a celebration of the strong UK racing scene, and focus on campaigns such as Sir Jackie Stewart's Motorsport Memories gallery, which raised funds for his Race Against Dementia charity.

The UK still enjoys incredible influence in the worldwide motorsport arena. International racing series have largely chosen components built in the UK, while the majority of the Formula 1 grid continues to be made up of British-based companies. Meanwhile, hubs of engineering excellence are being built around the country, including at Silverstone and at Bicester.

The British Touring Car and British GT Championships also remain robust series, showing strength in grid numbers, as is the case with the Porsche Carrera Cup and national series around the country.

That said, the Autosport Show was missing the usual stands from prominent racing companies in the UK, including Porsche, Radical and TVR, and it was clear the two-year, Covid-induced break has had an effect. Its return was nevertheless welcome, and no doubt the show will come back stronger in the coming years, though it also has to contend with the elongated racing calendar, which runs pretty much through the whole year now.

That's the same for all shows, of course, and will continue to force exhibitors to choose between events.

The Autosport Engineering Show was a showcase for some of the latest technology used in racing, and UK firms are doing well at home and overseas

Despite the elongated racing schedules that now take into account the months of December and January, the shows were well attended by fans. Exhibitors reported good business at each of the main events that took place this winter, and no doubt will be back more strongly in the future

STANDING OUR GROUND

***Racecar Engineering* had a presence at Autosport International with its team over the two days of the Autosport Engineering Show. The UK continues to build on its technical excellence and, despite clashing race dates, the Engineering show was popular with exhibitors and fans**

UK-based engineering remains at the forefront of the world motorsport stage

However, UK motorsport fans were delighted with the return of the show and, despite the £16.50 per day parking charges, arrived in their droves to enjoy the celebration of British racing, its drivers, cars and technology, that was on show in the Autosport Engineering Show on the Thursday and Friday.

Hugh Chambers, CEO of the sport's national governing body, Motorsport UK, endorsed the show: 'Thank you very much to Autosport and Motorsport Network for bringing the Show back to the NEC. I think everybody is excited to see old friends and new friends in the corridors and on the stands.'

Racecar engineering
Inside the world of modern motorsport technology

PIT CREW

Editor
Andrew Cotton
@RacecarEd
Email andrew.cotton@chelseamagazines.com

Deputy editor
Stewart Mitchell
@RacecarEngineer
Email stewart.mitchell@chelseamagazines.com

Sub editor
Mike Pye

Art editor
Barbara Stanley

Technical consultant
Peter Wright

Contributors
Mike Breslin, Lawrence Butcher, Karl Ludvigsen, Andrea Quintarelli, Danny Nowlan, Dieter Rencken

Photography
James Moy

Group sales director Catherine Chapman
Email catherine.chapman@chelseamagazines.com

Head of sales operations Jodie Green
Email jodie.green@chelseamagazines.com

Advertisement manager Lauren Mills
Tel +44 (0) 20 7349 3796
Email lauren.mills@chelseamagazines.com

Marketing executive Bret Weekes
Email Bret.weekes@chelseamagazines.com

Publisher Simon Temlett
Managing director James Dobson
Chairman Paul Dobson

Editorial and advertising
Racecar Engineering, Chelsea Magazine Company, Jubilee House, 2 Jubilee Place, London, SW3 3TQ
Tel +44 (0) 20 7349 3700

Subscriptions
Tel: +44 (0)1858 438443
Email: racecarengineering@subscription.co.uk
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Post: *Racecar Engineering*, Subscriptions Department, Sovereign Park, Lathkill St, Market Harborough, Leicestershire, United Kingdom, LE16 9EF

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Fence sitting in a desert

Mid-event changes on the Dakar rally set tongues wagging

The Dakar Rally once again proved why it is one of the toughest races in the world. There are others that have equally harsh terrain, and present a similar test of team and machine, but Dakar is special. It has lost much of its original challenge, that cannot be denied, but the 10,000km run from Paris to the African city that gave the event its name simply became too dangerous, not only in terms of competitors crashing and needing to be rescued, if they were lucky, but also the threat of terrorist attacks grew to a level that even the rally guys figured it was not sustainable. Dakar was consequently cancelled in 2008, and since then organisers have tried new homes for the event, including South America, before settling in Saudi Arabia.

This year, the rally ran from a new base at Yanbu on the Red Sea coast and, for the first time, crossed the vast Empty Quarter. I haven't seen it, but it sounds epic for motorsport.

Dakar presents a technical and engineering challenge, and remains a true test of driver grit and determination. What I really enjoyed was watching the driving team try to get their cars back up and running after a heavy crash. That spirit of getting to the end of the race, no matter what, is the true spirit of racing.

The rally was tough enough that outright performance was not the deciding factor

A tweak too far

Dakar this year was not without its controversy. The T1.U class, including the Audi RS Q e-tron, was given a performance balancing tweak mid-race, ready for the fifth stage. The organisers said it was a change to the Equivalence of Technology, but to others it was an attempt to balance the cars running at the front.

To my mind, changing the performance parameters of cars mid-event is just not racing. Furthermore, it suggests the analysis of technology, and its full potential, was not done properly prior to the event. There should have been a better understanding of what the cars were capable of, given that equivalence of technology is not about the performance shown by the competitor, more what the maximum should be extractable from the vehicle.

The flip side is these cars are rarely seen in competition, and the organisers have to rely on what the entrants tell them in terms of performance potential. The FIA does not have the time or resource to test everything ahead of a rally, and there is little opportunity to prove the theory.

The statement from the FIA was clear, too. It had the support of the competitors to make the change.

'The Equivalence of Technology adjustment is part of the Cross-Country Rally Sporting Regulations,' it read. 'It was introduced at the request of the manufacturers and teams, who wanted a correction mechanism during the Dakar Rally given the unusually long nature of the event. The FIA agreed to implement the Equivalence of Technology mechanism in a process which lasted several months and involved all T1.U and T1+ competitors. Teams provided simulation or test data to allow the FIA to calibrate its calculation tools. The final Equivalence of Technology process was agreed by all manufacturers.'

Power up

Therefore, at the request of the competitors, the FIA analysed the data from the first three stages and found a gap in the performance potential in the region of 9.3kW, so increased the power of the T1.U class cars by 8kW.

This makes sense, but still does not sit right with me, and I am sure the FIA will not make a habit of it.

Ultimately, the change did not affect the outcome. The rally was tough enough that outright performance was not the deciding factor. Had it been so, it would have been hard to accept the mid-race change for all, including the winners.

I for one appreciated the fact the nature of the rally led to the overall result instead.

What is notable however, in the Sporting Regulations for the FIA World Endurance Championship, is the banning of all competitors and team members from trying to influence the BoP. At the discretion of stewards, penalties will now be applied to those who seek to criticise decisions. Endurance races over six, 12 or 24 hours are not the same as racing in the desert. In these events, outright performance *is* relevant to the outcome. Yet there have been changes mid-meeting there too, notably at Le Mans last year when Alpine was deemed to have hidden performance ahead of qualifying. That the team didn't stand a chance against Toyota in the race was irrelevant, its performance was better than expected and the team was therefore penalised.

Not being able to talk about BoP by regulation, with the threat of sanctions if you are deemed to have spoken out of turn, is an uncomfortable position for teams. Thankfully, the ban does not extend to the media, and teams are allowed to say what has been done to their car, so we will continue to report on that until a better solution is found.

ANDREW COTTON Editor