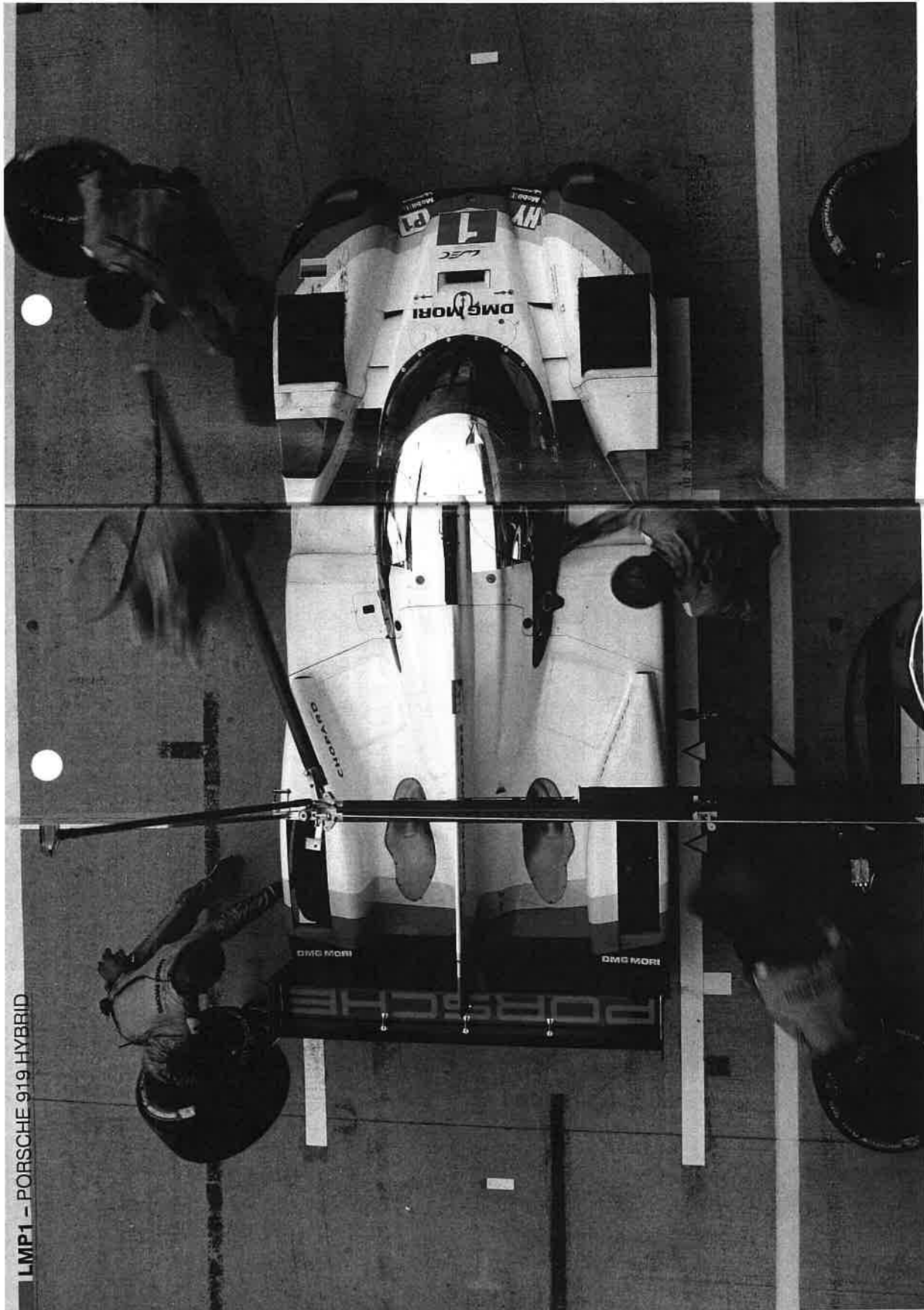




The theory of evolution

18 www.racecar-engineering.com JULY 2017

Porsche may not have won either of the two opening rounds of the World Endurance Championship, but the team goes to the Le Mans 24 Hours in confident mood having run only its low downforce kit at Silverstone and Spa, and yet still gained a podium at both races as well as a wealth of experience with its Le Mans package.

New regulations this year have forced manufacturers to reduce the number of kits to two for the season, low downforce intended for Le Mans and high for other tracks in the WEC. However, Porsche took the decision to concentrate on its Le Mans kit despite Silverstone being suited to a high downforce package and to delay its 'kit two' until after June's 24-hour race. The headline change to the LMP1-H regulations at the start of the year was one that was designed to slow the cars at Le Mans by up to two seconds. A raised front splitter, reduced width rear diffuser and a reduction in the number of tyres available to the teams were all supposed to reduce performance. But what the change in regulation has actually done is force both Porsche and Toyota into a programme to claw back that lost downforce – and now the cars are faster than ever.

Counter revolution

Aero work has of course contributed heavily to the improvement in performance, with much of the work between the front wheels and from the nose to midship taking priority and providing huge gains in performance. However, the aero team also points to other departments when it comes to taking credit for the improvement that has seen the 919 Hybrid drop only a few points to Toyota's high-downforce cars at Silverstone in April and Spa Francorchamps in May.

The engine and drivetrain engineers say that they have made huge gains in performance this year, with a higher compression ratio than ever before, and with more fuel efficiency and power. Reliability has also been a key development area.

Porsche approached this year with an evolutionary method rather than the revolution applied by Toyota. While Toyota has gone for a new aero concept and directed more air through the car, Porsche considered that to be of less importance and has stuck to its original concept of flow over the bodywork of the car.

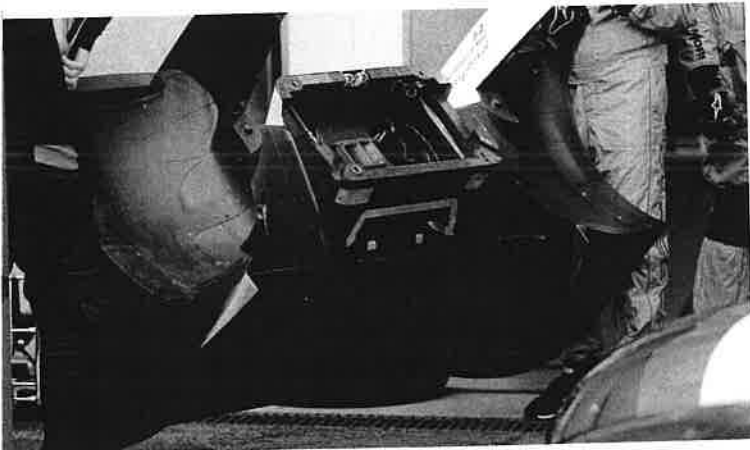
Car concept

Porsche team principal Andreas Seidl says of the overall aerodynamic concept: 'Compared to Toyota, at the rear our step looks less extreme but we were mainly focussing on the front and towards the middle of the car. Most of this was the new fenders at the front, which are quite wide, and the channelling of the air from the front to the mid-section of the car, to the radiator inlets and so on. That came together with the basic cooling concept. The arrangement of the radiators is different, and the position is obviously different, plus the way that we were guiding the air through simply to need less to do more cooling. In general we didn't have an issue so we could cope with the ambient temperatures, but the less cooling, the less drag. The loss of downforce by the regulations was the biggest target; to get the downforce back without increasing the drag too much'. Christos Pashias, leader of LMP1 aerodynamics at Porsche added: 'There was a huge downforce loss

Its 919 Hybrid has found buckets of lap time this year compared to 2016, yet Porsche insists this is purely down to evolution rather than wholesale change. Racecar went to Weissach to unlock the secrets of this car's development

By ANDREW COTTON

18 www.racecar-engineering.com JULY 2017



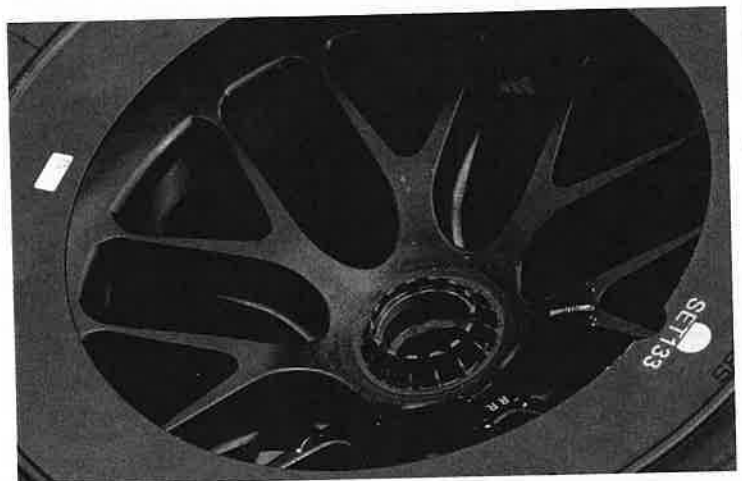
New regulations have seen the front splitter raised in the centre to reduce downforce, but Porsche and Toyota have both developed this area heavily to regain performance



The low-downforce 'kit one' rear wing is ready for Le Mans. Porsche has experience of adjusting it for different track conditions and temperatures after Silverstone and Spa



Mirrors are embedded in the wheel arch. Toyota challenged this, on whether it could affect driver visibility, but Porsche says this has improved thanks to reduced vibration



Porsche has introduced an F1-style wheel nut retention system that is supposed to increase speed and accuracy of its wheel changes. It's a risk with new tyre limits this year

due to the regulations front and rear and there was no getting around it. We started [the development cycle] with a hybrid of our high downforce package [of 2016] on the low downforce kit. The front was much closer to the sprint package than the Le Mans kit to get the loads back. We spent a lot of time working to get the car to work as a good package, and make sure the front is behaving in a suitable way.'

Rear view

Pashias continues: 'At the rear it is more challenging. As with all racecars, it is difficult to break the lift to drag ratio that is inherent in the rear. It is more challenging to find the downforce for free. We had to recover downforce from other areas. We did quite a bit of work on the front area between the wheels to maximise the clean flow to the rear, and the sidepod is substantially different which was

also done with the aim of helping the rear, as well as details next to the wheels, where small changes make a big difference.'

As Pashias says, the sidepods are radically different to those of previous years, not least due to a regulation change that calls for a channel between the cockpit and the wheel arch that helps to increase the take off speed for the cars in the event of an accident. A lot of work has also gone into the radiators and the air that is expelled from them, and around the wheels to reduce the wake signature of the car, and improve efficiency. One key difference to previous designs is that the sidepods now house the mirrors. While they are tucked away, helping to reduce the drag, their location had an unexpected benefit. 'We worked hard to do that, and we are happy with the result,' says Pashias. 'It is a small drag gain, but a side-effect is that the mirrors vibrate a lot less now, so you can actually see through them!'

While Pashias acknowledges the potential advantages of the 'through-flow' concept, he was put off by the potential drawbacks, including changes to cooling. Porsche has instead developed last year's concept and worked particularly hard on the underfloor, between the front wheels and the mid-floor section. One of the weak points of the 2016 car

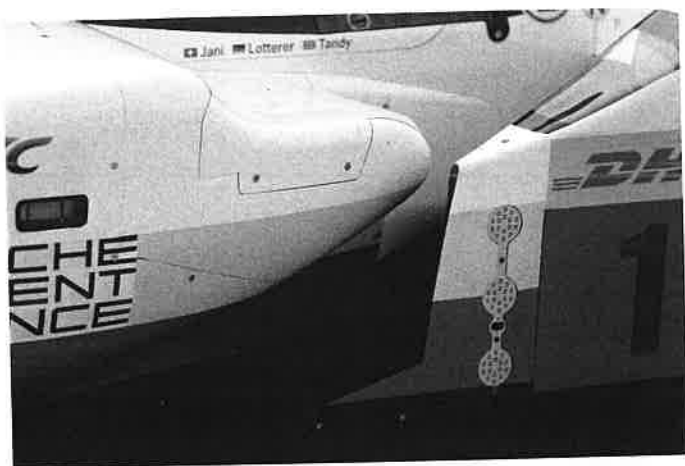
was a rubber build up in the front wheel arch that upset the balance of it, which the team appears to have fixed in the 2017 version.

'Having the confidence of the previous cars, we could push harder in the areas that we were confident in and go even more extreme, and back off in some areas where we thought we pushed too hard,' says Pashias. 'It is more the front and the middle [of the car] which is where all the big gains come from. At the rear there is a standard diffuser. You can do a lot under the wheel arches with small details, which have a big effect, but the front is where, if you get it right, the car behaviour is good [when the driver is] pushing to the limit.'

Pitch perfect?

Pashias was particularly coy when talking about the pitch sensitivity and weight distribution of the 2017 model. Clearly a lot of work has been done to improve the balance of the car, particularly to accommodate the new tyre regulations that have seen a reduction to four sets, plus two joker tyres, for qualifying and race. This is designed to encourage double stinting and reflect the endurance element of the sport, and has been particularly relevant to Porsche's low-downforce approach at the opening two races. 'We worked on the pitch sensitivity, but

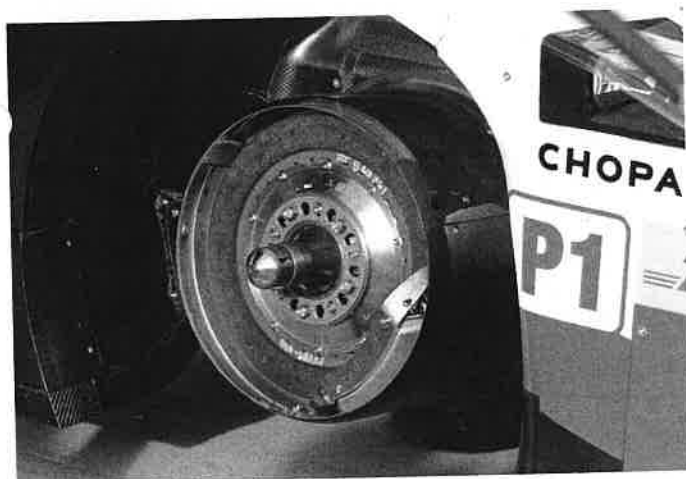
'We have achieved all of the goals that we have set for ourselves in terms of development'



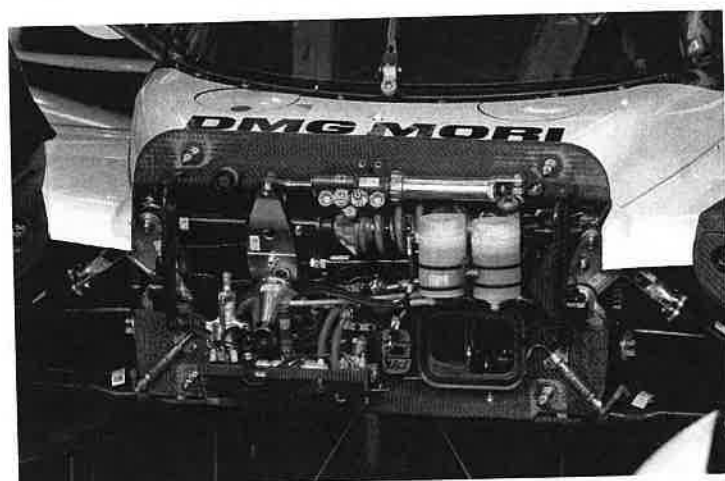
Sidepods have been revised to improve air flow to the rear and a new channel has been opened up between the cockpit and wheel arch to improve safety at high speed



A great deal of detail work has been undertaken to reduce the wake signature of the racecar and clean up airflow to the rear, particularly around the front wheel arches



Braking systems in hybrid cars have been developed to prevent a driver from noticing when the system is in recovery or not; this system can also be adjusted by the driver



The manufacturers agreed to retain their monocoques until 2019, although Porsche says it could have saved a lot of weight had it changed it. It introduced current chassis in 2015

what we did I cannot talk about,' says Pashias. 'When you change the regulations, the first step looks like a disaster and it was a big hit, four to five seconds at Le Mans, but with the work that you do you recover a lot of it. If you divide how many months by wind tunnel sessions, if you gain five seconds and divide it by the number of sessions, say 10 sessions for the development a year, every session is worth half a second. If I have an extra session and that's half a second, it's a game changer.'

Porsche has introduced a Formula 1 style retained wheel nut system this year in a bid to speed up wheel changes. It is a risk, particularly with the new tyre rules that also encourage sets to be kept together for a second stint, and a cross threaded nut would be particularly problematic, but Porsche believed that this was the right time to introduce it.

ICE sage

One of the major achievements of the race engine department is the development of the exhaust heat recovery system. But the ICE has, by the team's own admission, been the area of the most development. Seidl says: 'The

MGU side of it is almost at saturation. From our engine side we had two main points to tackle. One was reliability because we had some areas last year where we didn't feel 100 per cent safe so we worked on that. It was affecting basic parts of the engine, and on the other hand, we saw from the development testing on the dynos that we could manage a big step in terms of performance and efficiency coming from various areas of the engine. We could reduce the friction side of the engine, working on things like bearing friction, oil system and so on. We could make a good step on the gas exchange and on the combustion side we made quite a good step and that increases the efficiency of the engine even with the given fuel flow. That is also a reason why we can make these steps.'

Porsche has rather underplayed the introduction of 'jet ignition', though, and is coy about when the team started to use it, and while Stefan Moser, leader of LMP1 engine testing says 'we have made the biggest step ever this year,' he didn't provide too many details as to what they have improved. 'Obviously we worked on combustion, as did everyone, and there was a lot of talk about 'jet ignition', and

this we also worked on for quite a while,' says Moser. 'We never really talked so much about it because what you read in the newspapers, that it was developed in F1, actually this technology is around for almost 20 years in gas engines, and the technique is nothing new. It is just applied to race engines now and this is important. We could talk about improving efficiency and higher pressure but all of these phrases are out already. The important thing is durability, and in 24-hour races that becomes a big issue.'

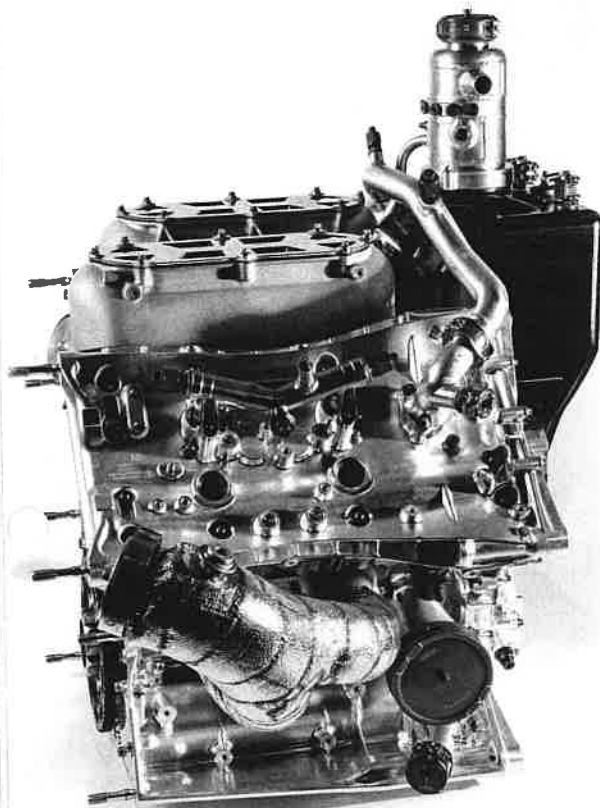
Durable parts

Moser's colleague, Thomas Kramer, leader of LMP1 engine design, says: 'We just took the parts and applied them to the engine. That was the easy bit. The most difficult bit was the durability and for doing this for 24 hours, for 6000 to 7000km, that's the most challenging [task] we had in the last few years or months.'

'There are some components in the engine, when you look at the conrod bearings they are the first ones to suffer from the higher pressure,' Kramer adds. 'The usual methods to solve these things don't apply anymore. Diesel engines in the past had higher pressure but with the revs

The sidepods are radically different to those of previous years

The engine team is particularly proud of the fact that the 919's intake is so small, and they can't work out why it isn't smaller



Much of the development has been focussed on the tiny V4 internal combustion unit that sits at the heart of the 919, Porsche working on its reliability, performance and efficiency

TECH SPEC

Porsche 919 Hybrid

Category: LMP1-H competing in the World Endurance Championship, including the Le Mans 24 Hour race

Monocoque: Composite material structure consisting of carbon fibre with an aluminium honeycomb core. The cockpit is closed.

Combustion engine: V4 engine (90-degree cylinder bank angle), turbocharged; 4 valves per cylinder; DOHC; one Garrett turbocharger; direct petrol injection; fully load-bearing aluminium cylinder crankcase; dry sump lubrication. Displacement: 2-litre. Max revs: 9000rpm. Power 500bhp at rear axle.

Engine management: Bosch MS5

Hybrid system: KERS with a motor generator unit (MGU) mounted on the front axle; ERS for recuperation of energy from exhaust gases. Energy storage in a liquid-cooled lithium-ion battery (with cells from A123 Systems). MGU power: 400 PS, front axle

Drive system: Rear-wheel-drive; traction control (ASR); temporary all-wheel drive at the front axle via the electric motor when boosted; hydraulically operated sequential 7-speed racing gearbox

Chassis: Independent front and rear wheel suspension; pushrod system with adjustable dampers

Brake system: Hydraulic dual-circuit brake system; monoblock light alloy brake calipers; ventilated carbon fibre brake discs (front and rear), infinitely variable control of the braking force distribution by the driver

Wheels and tyres: Forged magnesium wheel rims from BBS; Michelin Radial tyres, front and rear: 310/710-18

Dimensions: Length, 4650mm; Width, 1900mm; Height, 1050mm

Weight: Minimum 875kg

Fuel tank capacity: 62.3 litres

like a gasoline engine, and to combine these things, it was completely different. Therefore we had to work in new ways, and find out the hard way to get these things to work.'

Lean machine

Like the car itself the engine development is an evolutionary process, with higher compression ratio, lean burn (which has been a feature of the engine since 2014 when a major step was taken that brought it close to the limit of the window in which the engine can work without major redesign) and driving efficiency all at the centre of the development programme. 'The lean burn is nothing new,' says Moser. 'We are talking low numbers of per cent improvement, but still you can optimise that level of how lean the engine is with the BSFC [brake specific fuel consumption]. We have been running lean since 2014, and in 2014 we had changed this quite dramatically and it took some time, but then we have been at the level where we run as lean as is most efficient and we couldn't change much. That has not changed since jet ignition. We have been looking at this for a long time now. You always have to change the entire engine around it. You cannot just put one thing up. You have to change the intake ports and exhaust otherwise it doesn't bring a benefit.'

Breathe easy

One of the key visual features of the car is the small air intake above the cockpit, particularly when compared to that of Toyota. The engine team is particularly proud of the fact that the intake is so small and can't work out why it isn't smaller. The engine design work started in 2011, before the regulations were fixed, and so it was originally designed for an air-restricted engine. However, once the rules were finalised in 2012, it was clear that there would be a fuel flow limit instead, and that meant the air was free ... which then led to a far larger turbo. Clever design has reduced the size of the turbines, which helps to reduce turbo lag. 'For us, this is efficient, no question,' says Kramer. 'For the bigger turbo, we had the AER, the exhaust heat recovery system. To package this in the rear is a bit challenging. Christos [Pashias] wants a tight engine cover that tails off early in the line, so we had to package everything [tightly]. The bigger turbo because of the change to the fuel flow meter did not make a big difference.'

Another change that is coming to the regulations involves the fuel supplier. Shell has supplied the fuel to the WEC as the sole supplier, with fuel that is close to pump values, which has rather limited the power that can be developed compared to, say, Formula 1, where the fuel blend can be adapted to the particular

needs of the engine. 'Formula 1 can develop their own blends,' Kramer says. 'We had to find a compromise. Of course, because of the knocking it is a different thing. You have more freedom if you can do your own blend. From a design point of view, for us it is a maximum load which occurs, and in the V4 the cylinder pressure and load is very high. If you can spread this on more cylinders it is easier.'

Moser adds: 'In terms of fuel, in Formula 1 they have the fuel flow meter and can develop their fuel and they try to get more energy from every kilo, and this we couldn't do. The MJ per kilo is fixed but then we tried to optimise the engine best for that fuel, so injector, compression ratio and combustion chamber.'

Lag reduction

One other difference is that Formula 1 uses the hybrid power to reduce turbo lag, but Porsche's solution to the lag problem is a special design for the compressor layout, which is very light and able to be made extremely small. The turbo sits between the bank of cylinders while the hot exhaust flows around the side of the engine, and so is not the 'hot side inside' concept that was favoured by Audi.

An element of the design of which the engine department is particularly proud is the development of the exhaust heat recovery system, which is all done in-house. 'The heat exchanger is done at Porsche from the drawings to building it,' says Kramer. 'The whole process of building these, the balancing of the shafts because this thing is turning at high speed, and to bring this to a 24 hour race and be durable was a separate big challenge, but it was done in-house and it is something that we are proud of. We did the turbine, the housing, the electrical elements. It is all done and developed here, and we test it, and do the balancing, so it is quite demanding. It has quite a high power output and from a weight point of view it is nothing. We are quite proud of this and the whole team, from the mechanics to the guys building it, it is a nice chain.'

When Porsche first returned to Le Mans in 2014 there was a power struggle between the two VW brands competing. Porsche and Audi were vying for overall technical development rights for the group and while Audi bought in much of its technology other than the diesel engine, Porsche was clearly geared up to providing much more expertise in-house. Perhaps this is why it is still in the WEC?

As for Porsche's own thoughts on its 2017 car, Seidl has the last word: 'I am happy that we have achieved what we set out to achieve. Whether that is enough, we will only find out on Sunday afternoon at Le Mans.'