2014 Formula One Power Unit Regulations

POWER UNIT 2014

In 2014, Formula One will undergo a major change, the most significant alteration to its technical regulations in the history of the sport. The introduction of a new 1.6 litre, turbo-charged V6 power unit, relying heavily on hybrid technologies, aims to place the world's foremost single-seat racing series at the cutting edge of automotive technology development, while at the same time preserving the culture of innovation and capacity to thrill that have been at the heart of the sport since its earliest days. The changes are comprehensive, and so via straightforward explanations and with the help of insights from FIA Head of Powertrain Fabrice Lom, this guide has been assembled as a handy guide to how Formula One will race in 2014 and beyond.

1 THE GOAL

Since the inception of the Formula One World Championship in 1950, the sport has always sought to innovate, constantly pushing the technological boundaries in order to find the quickest route to victory. Formula One has frequently pioneered technology that has been successfully transferred to everyday transport. The new regulations introduced to F1 seek to once again bring this spirit of advancement to the forefront of competition, aligning F1 with real world engine development. As FIA Head of Powertrain Fabrice Lom explains: *"It is vital to use our resources with care. The game is still to go fast, but to go fast spending less – less money and less energy. This ratio, between result (speed) and consumption (finance, fuel and resources) is called efficiency. In future, the best car in Formula One will be the most efficient. This is what the new power unit regulations are designed to promote."*

2 ENSURING EFFICIENCY

At the heart of the new power unit and the quest for efficiency is a move away from reliance on traditional power sources and an increase in the use of energy recovery. Kinetic Energy Recovery Systems, technologies that harvest energy in the car's braking phase that can then be deployed at will, have been utilised in Formula One for some years. The 2014 regulations, however, take this technology to another level. While up until now KERS produces 60kW (80hp), in future the best ERS will produce 120kW (160hp).

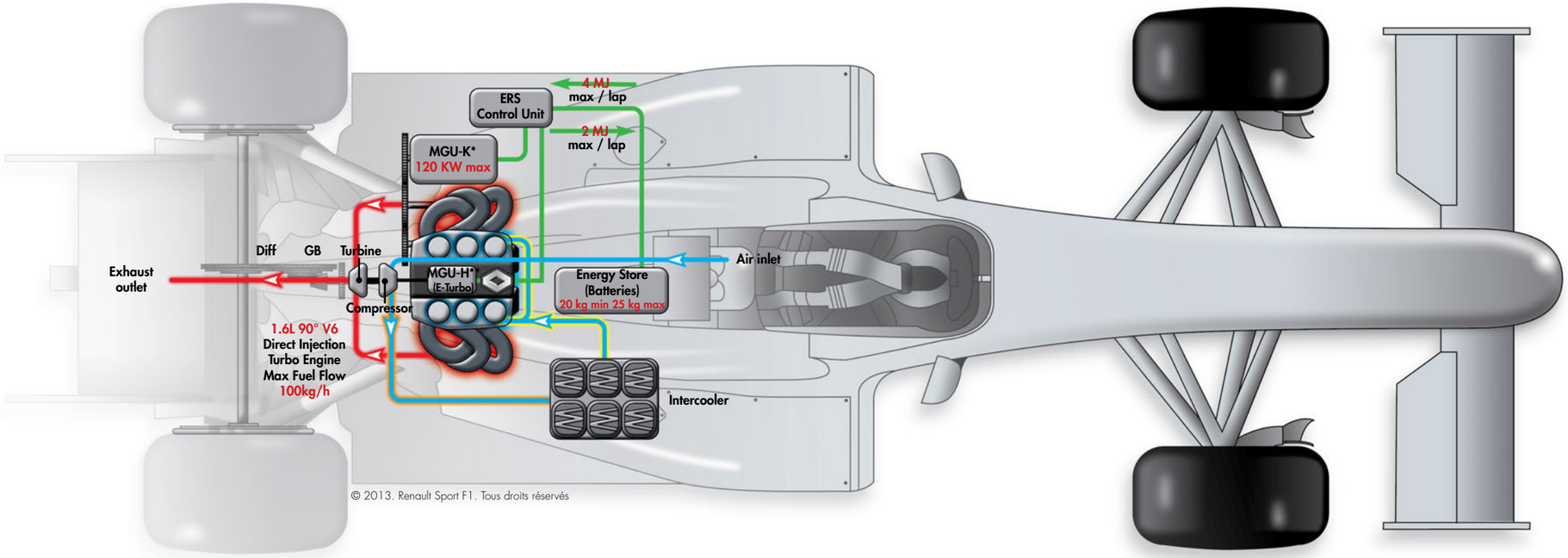
This increase in capability has been made possible via a combination of a more potent KERS and a secondary recovery system that harvests energy from the heat in exhaust gasses, a system that can be referred to as ERS-H.

As mentioned, KERS itself has been refined with a more powerful generator unit, dubbed the MGU-K (Motor Generator Unit – Kinetic) and via a more automated and thus more efficient management system.

The second unit, the MGU-H (Motor Generator – Heat), is connected to the turbine of the new power-plant's turbocharger (which return to F1 for the first time since 1998) where it harvests exhaust heat, which is turned into energy to boost the engine (as with a classic turbocharger) but also into electrical energy. This type of recovery is expected to be very efficient and is expected to allow for energy recovery three times greater than the larger KERS.

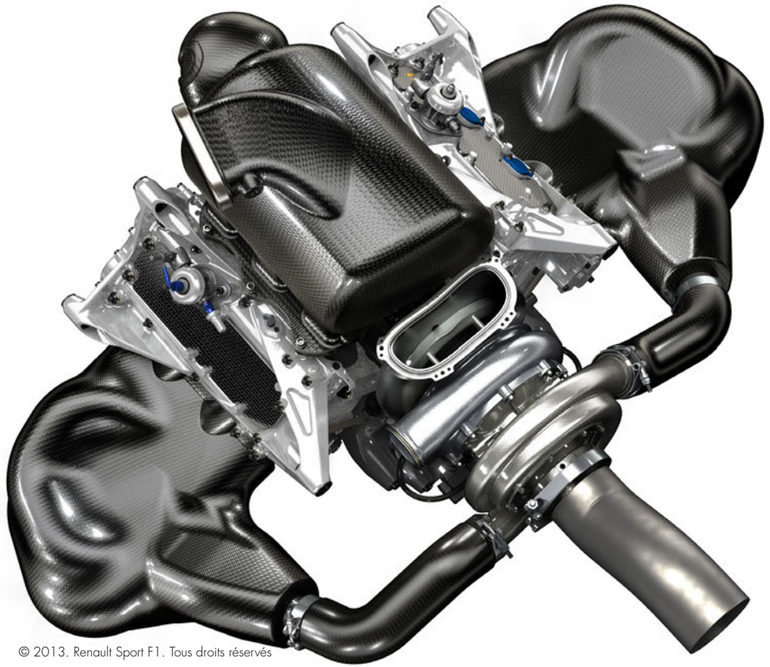
Also in 2014, engine capacity will be reduced from 2.4 litres to 1.6l in a V6 configuration. Direct engine injection has been specified, making the new units 1.6l V6 DI turbocharged engines.

The complete assembly of 1.6-litre turbocharged engine, KERS (now called ERS-K), ERS-H, the required Energy Store and the associated electronic control elements gives rise to the new term Power Unit.



3 PROMOTING EFFICIENCY

At its core the idea is straightforward: allocate the same amount of fuel to each car (100kg) and the most efficient team will extract the most power over time from this fuel. Fuel flow will also be restricted to 100kg/h. This limitation will ensure a certain amount of control over the maximum power of the engines. Formula One engineers have a great capacity for innovation and power is likely to increase as quickly as efficiency.



4 HOW IT WORKS

The new Power Unit is a complex assembly and the management of the unit is equally complicated. However, a lot more freedom has been given to the engineers to control the Power Unit in order to make using it as simple as possible for the driver. Indeed, utilising a 2014 Power Unit should be less complicated for the driver than driving the current engine as, for example, the new ERS-K will be automatic, unlike today's KERS.

The manner in which the different elements of the Power Unit interact is also being regulated. Again, in order to promote efficiency, energy flow is subject to the most regulation.

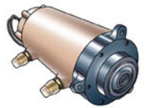
The main principles are as follows:

- All the recovered power released to the wheels must be through the single MGU-K situated at the rear of the car.
- A limited amount of energy can be stored in and released from the Energy Store to the MGU-K. This, coupled with the limitation on weight, will prevent an overemphasis on the costly development of batteries, super capacitors or flywheels.
- An unlimited amount of energy can be exchanged between the MGU-K and the MGU-H or the MGU-H and the Energy Store. In other words, the energy recovered from the turbocharger is 'free'. This is to promote the development of this technology, which could have future road car applications.

1

Motor/Generator

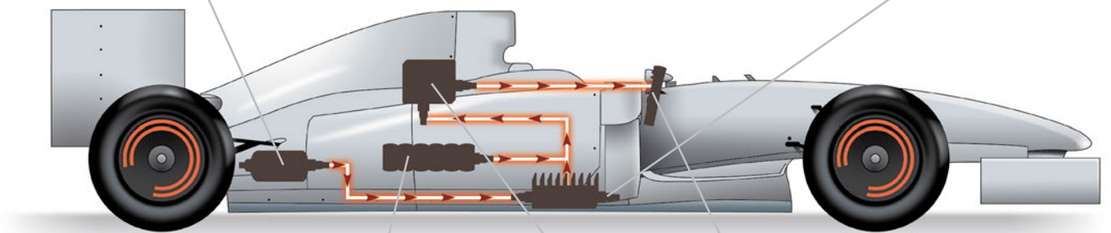
The motor/generator is coupled directly to the engine - either driven off the front of the crankshaft or off the gearbox.



2

Power Controller

The power controller is connected between the ultra capacitor pack and the motor/generator, and controls the power flow between the two. Control is likely to be integrated into the engine ECU. The power controller will require significant cooling and could be mounted in the radiator duct cowling, with fins sticking up into the air flow in the duct.



4

ECU Software

The power control strategy will be integrated into the ECU software.

3

Ultra Capacitor

The energy storage device is an FIA issued untra capacitor pack. It is about 20 litre volume.

5

Driver Control

Plus the driver will have an over-ride function on his steering wheel.

5 PERFORMANCE

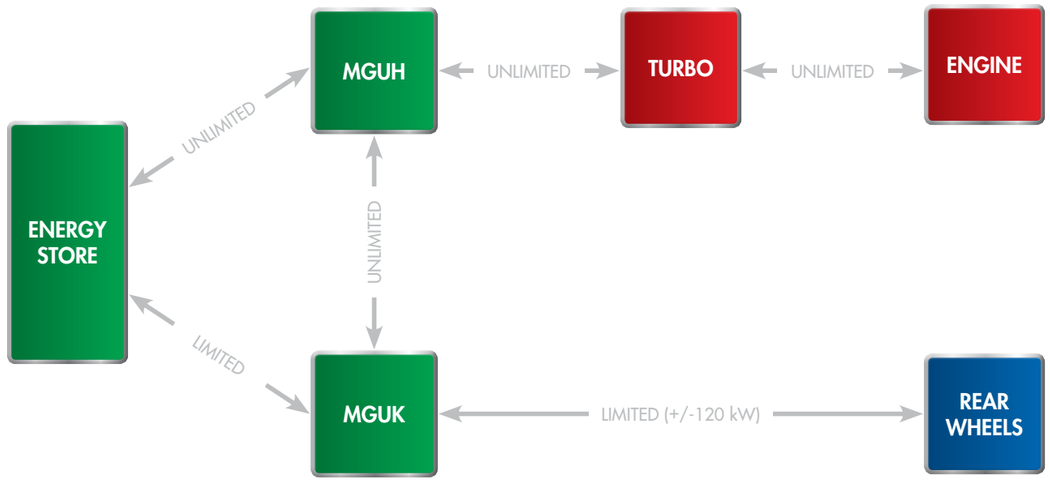
The new Power Units are expected to produce more power than the V8 powerplants used until 2014 and this is likely to increase with time. In terms of raw power, they will lack nothing in comparison with the engines they are replacing.

Additionally, the new units will consume 35% less fuel than the current V8s. This is guaranteed, as the total fuel consumption during a race will be limited to 100kg. Today's V8s use approximately 150kg.

Having said that, at start of the new formula's life cycle car performance will be lower than at the end of the life cycle of the V8 units. This is largely due to the increased weight of the new Power Unit and changes to the sport's regualtions covering car aerodynamics. It is expected this will change as development continues.

	2013 V8 + KERS	2014 Power Unit
Power	730 Hp + 80hp for 7s/lap	>760 Hp
Fuel consumption for a race	Approx 150 kg	100 kg
Empty Car weight	642 kg	691 kg
Race start car weight	802 kg	791 kg
Number of units/season/driver	8 Engines + unlimited KERS	5, then 4 in 2015

POWER UNIT ENERGY FLOW



Legend:
Engine ERS Car

6 COST CONCERNS

Development of such a complex new Power Unit inevitably gives rise to questions of cost. A number of limitations have been built into the regulations to help keep costs down, while at the same time promoting the efficiency at the heart of the new formula.

These limitations can be split into four main categories: number of parts, technology, limits on the use of certain elements and development restrictions.

LIMITATIONS IN NUMBER OF PARTS

In recent years the number of V8 engines available to each driver was limited to eight per season. The number of KERS units was unlimited, as was the number of control electronics. In 2014, the number of power units will be limited to five per season, per driver and this will be further reduced in 2015 to four units. This not only includes the engines but also the turbochargers, the energy store, the MGU-K, MGU-H and the control electronics.

LIMITATIONS OF THE TECHNOLOGY

New materials and complex systems could help efficiency but these could also increase costs. As such, the new regulations impose some limitations. These include:

- The petrol engine element of the power unit must remain conventional. No exotic materials are allowed. Ignition must stay standard for example.
- Only one turbocharger is allowed and it must be a simple single stage unit with no variable turbine.
- Use of exotic materials is not allowed.

LIMITATIONS PLACED ON INDIVIDUAL ELEMENTS

Restricting how Power Unit elements can be used will limit extreme and expensive solutions. For instance, the engine's main dimensions are standardised (including capacity, bore, number of cylinders, type of turbocharger). Also, the maximum revs of the main components (engine, MGU-H and K) are limited, and the weight of the battery must be within a certain range (20 to 25kg).

LIMITATION OF DEVELOPMENT

To control costs over the life cycle of the new formula, development will be subject to a series of restrictions over a seven-year period. These restrictions have been developed to form a defined path that will allow manufacturers to fully develop the Power Units.

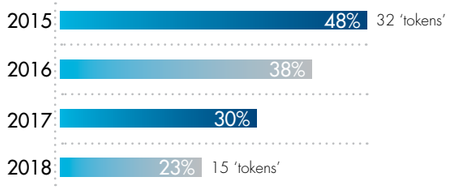
"The most efficient way to reduce development cost is to stop it. This is known as a 'freeze'," explains Lom. *"This was partially done with the V8 engines. It works well with mature technologies but could be risky when imposed on new technologies, as it can lead to a team/manufacturer whose initial product is superior, leading to them achieving a dominant position from the outset and this domination would then naturally persist for the duration of any development freeze. Therefore, we have set out a schedule that will keep costs down but still permit development."*

The development cycle is scheduled according to an available set of elements that can be developed each year.

The Power Unit is divided into families of functions, with each family being given a certain importance, labelled as category 1, 2 or 3 components. For example, the pistons are ranked 2, while the ignition system is ranked 1. The complete Power Unit is made up of the sum of these ranked items, with the complete Power Unit being represented by the total number, 66. Each year, each Power Unit manufacturer will be allowed to choose what parts

of the engine they wish to develop and will spend a set 'budget' of 'tokens'.

This development budget decreases each year across the seven-year schedule. For 2015 the budget available to teams is 32 tokens (close to 50% of possible development) but for 2018 the budget drops to 15 tokens (less than 25% of possible development).



7 THE PRICE OF CHANGE

Inevitably, altering the specification of the powerplants used in Formula One comes at a price. Change costs more than stability.

However, while the cost of initial development of the new Power Units will be significant it will inevitably decrease as the unit reaches maturity.

"What is often forgotten is the initial development cost of the V8," says Lom. *"We are far away from that period now but the cost of developing the new Power Units is no more impactful than that of developing the V8. We have to accept that these new Power Units are young and that the initial development cost, which is substantial, will impact upon the price in the first years."*

The price of the last V8 engines did not reflect the true cost of those power plants. The most recent prices were imposed in 2008 as part of a cost-cutting exercise in the sport, with the reduction being accepted by manufacturers even though it did not cover the cost of production. In the current economic climate and with fewer manufacturers involved in the sport than in 2008, this model is not sustainable.

V8 engines are today becoming less relevant to most of the engine manufacturers who are large producers of cars with six, four or even three-cylinder engines. For these manufacturers, continuing with the V8 could have put at risk their future participation in the sport.

"It is also important that the balance between the cost and the potential marketing value of the Power Unit is taken into consideration," says Lom. *"It could be that a Power Unit manufacturer sees the sponsorship of a team that uses its engine as relevant to its marketing plans. Additionally, the new image of sustainability provided by the new Power Unit may also attract a number of new sponsors to the sport."*

SUPER SONICS?

One of the main talking points surrounding the new Power Units has been the sound they make. Some have fixated on the idea that the noise made by current F1 is part of the allure and while the sonic signature is certainly part of the thrill it is but one element of the sport's appeal, allied to technical innovation, glamour, skill and heroism – all contribute to the 'noise' that constantly surrounds the sport.

Having said that, it is true that the 2014 Power Units will make less noise than their current counterparts. However, it is worth putting this decrease into perspective.

INTENSITY OF SOUND

F1 engine manufacturers estimate that the intensity of sound of the F1 powerplants with the current V8s is around 145dB. With the new units it is expected to be around 134dB.

QUALITY OF SOUND

"Quality of sound is a very difficult thing to assess, as we all have different taste," says Lom. *"Some like rock, others classic music. In 1988, V6 turbo F1 engines were revving lower and had less capacity. Ayrton Senna and Alain Prost both had fans in those days and the show, as far as we remember, was quite good."*

The table below illustrates the difference in sonic intensity:

Source	Intensity	Intensity Level	# of Times Greater Than TOH
Threshold of Hearing (TOH)	$1*10^{-12}$ W/m^2	0 dB	10^{0}
Rustling Leaves	$1*10^{-11}$ W/m^2	10 dB	10^{1}
Whisper	$1*10^{-10}$ W/m^2	20 dB	10^{2}
Normal Conversation	$1*10^{-6}$ W/m^2	60 dB	10^{6}
Busy Street Traffic	$1*10^{-5}$ W/m^2	70 dB	10^{7}
Vacuum Cleaner	$1*10^{-4}$ W/m^2	80 dB	10^{8}
Large Orchestra	$6.3*10^{-3}$ W/m^2	98 dB	$10^{9.8}$
Walkman at Maximum Level	$1*10^{-2}$ W/m^2	100 dB	10^{10}
Front Rows of Rock Concert	$1*10^{-1}$ W/m^2	110 dB	10^{11}
Threshold of Pain	$1*10^{1}$ W/m^2	**130 dB**	10^{13}
Military Jet Takeoff	$1*10^{2}$ W/m^2	**140 dB**	10^{14}
Instant Perforation of Eardrum	$1*10^{4}$ W/m^2	160 dB	10^{16}

The delta of 11db, according to the physics of attenuation of sound in air, is equivalent to 2.5m if you are at 1m distance from the car, meaning that the difference will be hardly heard in the garage.

If you are 15m from the car, it attenuates to 35m - that roughly represents the difference you can hear from seating in the first row to seating in the last row of a grandstand.

THE RACE IS ON:

This, then, is Formula One for 2014 and the years to come. It is a sport where speed remains at the heart of the matter, with drivers still seeking to maximise the performance available from the machine at hand. But, it is also a sport where the traditional pursuit of technical excellence has been reinvented for the 21st century. The engineering challenge now is to go as fast as possible while consuming as little fuel as possible. It's a task that will call for true inspiration and innovation and which will require strategic brilliance on the pit wall and supreme intelligence and skill at the wheel. The game has changed but the thrill remains the same.

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