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Formula One engines

This article gives an outline of **Formula One engines**, also called **Formula One power units** since the hybrid era starting in 2014. Since its inception in 1947, Formula One has used a variety of engine regulations. *Formulae* limiting engine capacity had been used in Grand Prix racing on a regular basis since after World War I. The engine formulae are divided according to era.[1][2][3]

Operation

Formula One currently uses 1.6 litre four-stroke turbocharged 90 degree V6 double-overhead camshaft (DOHC) reciprocating engines.[4] They were introduced in 2014 and have been developed over the subsequent seasons.

The power a Formula One engine produces is generated by operating at a very high rotational speed, up to 20,000 revolutions per minute (rpm). However, they are electronically limited to 15,000 as of the 2014 season.[5] This contrasts with road car engines of a similar size, which typically operate at less than 6,000 rpm. The basic configuration of a naturally aspirated Formula One engine had not been greatly modified since the 1967 Ford Cosworth DFV and the mean effective pressure had stayed at around 14 bar.[6] Until the mid-1980s Formula One engines were limited to around 12,000 rpm due to the traditional metal springs used to close the valves. The speed required to operate the engine valves at a higher rpm called for ever stiffer springs, which increased the power required to drive the camshaft and the valves to the point where the loss nearly offset the power gain through the increase in rpm. They were replaced by pneumatic valve springs introduced by Renault in 1986,[7][8] which inherently have a rising rate (progressive rate) that allowed them to have an extremely high spring rate at larger valve strokes without much increasing the driving power requirements at smaller strokes, thus lowering the overall power loss. Since the 1990s, all Formula One engine manufacturers have used pneumatic valve springs with the pressurised air allowing engines to reach speeds of over 20,000 rpm.[8][9][10][11][12]

Short-stroke engine

Formula One cars use short-stroke engines.[13] To operate at high engine speeds, the stroke must be relatively short to prevent catastrophic failure, usually from the connecting rod, which is under very large stresses at these speeds. Having a short stroke means a relatively large bore is required to reach a 1.6-litre displacement. This results in a less efficient combustion stroke, especially at lower rpm.[14]

In addition to the use of pneumatic valve springs, a Formula One engine's high rpm output has been made possible due to advances in metallurgy and design, allowing lighter pistons and connecting rods to withstand the accelerations necessary to attain such high speeds. Improved design also allows narrower connecting rod ends and so narrower main bearings. This permits higher rpm with less bearing-damaging heat build-up. For each stroke, the piston goes from a virtual stop to almost twice the mean speed (approximately 40 m/s), then back to zero. This occurs once for each of the four strokes in the cycle: one Intake (down), one Compression (up), one Power (ignition-down), one Exhaust (up). Maximum piston acceleration occurs at top dead center and is in the region of 95,000 m/s^2, about 10,000 times standard gravity (10,000 *g*).

History

Formula One engines have come through a variety of regulations, manufacturers and configurations through the years.[15]

1947–1953

This era used pre-war voiturette engine regulations, with 4.5 L atmospheric and 1.5 L supercharged engines. The Indianapolis 500 (which was a round of the World Drivers' Championship from 1950 onwards) used pre-war Grand Prix regulations, with 4.5 L atmospheric and 3.0 L supercharged engines. The power range was up to 425 hp (317 kW),

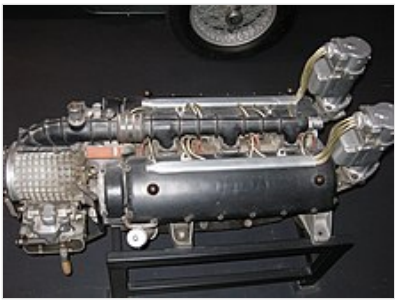
though the BRM Type 15 of 1953 reportedly achieved 600 hp (447 kW) with a 1.5 L supercharged engine.

In 1952 and 1953, the World Drivers' Championship was run to Formula Two regulations, but the existing Formula One regulations remained in force and a number of Formula One races were still held in those years.

This Alfa Romeo 159 supercharged straight-8 engine could produce up to 425 bhp (317 kW).

1954–1960

Naturally-aspirated engine size was reduced to 2.5 L and supercharged cars were limited to 750 cc. No constructor built a supercharged engine for the World Championship. The Indianapolis 500 continued to use old pre-war regulations. The power range was up to 290 hp (216 kW).



1.5 litre V12 supercharged engine from the Ferrari 125

1961–1965

Introduced in 1961 amidst some criticism, the new reduced engine 1.5 L formula took control of F1 just as every team and manufacturer switched from front to mid-engined cars. Although these were initially underpowered, by 1965 average power had increased by nearly 50% and lap times were faster than in 1960. The old 2.5 L formula had been retained for International Formula racing, but this did not achieve much success until the introduction of the Tasman Series in Australia and New Zealand during the winter season, leaving the 1.5 L cars as the fastest single seaters in Europe during this time. The power range was between 150 hp (112 kW) and 225 hp (168 kW).

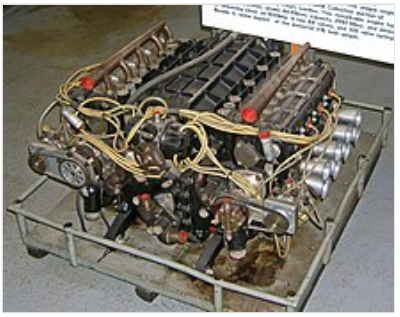
A 2.5 L V8 in a Lancia-Ferrari D50 (1955–1956)

1966–1986

In 1966, with sports cars capable of outrunning Formula One cars thanks to much larger and more powerful engines, the FIA increased engine capacity to 3.0 L atmospheric and 1.5 L compressed engines.[16] Although a few manufacturers had been clamouring for larger engines, the transition was not smooth and 1966 was a transitional year, with 2.0 L versions of the BRM and Coventry-Climax V8 engines being used by several entrants. The appearance of the standard-produced Cosworth DFV in 1967 made it possible for small manufacturers to join the series with a chassis designed in-house. Compression devices were allowed for the first time since 1960, but it was not until 1977 that a company actually had the finance and interest of building one, when Renault debuted their new Gordini V6 turbocharged engine at that year's British Grand Prix at Silverstone. This engine had a considerable power advantage over the naturally-aspirated Cosworth DFV, Ferrari and Alfa Romeo engines. By the start of the 1980s, Renault had proved that turbocharging was the way to go in order to stay competitive in Formula One, particularly at high-altitude circuits like Kyalami in South Africa and Interlagos in Brazil. Ferrari introduced their all-new V6 turbocharged engine in 1981, before Brabham owner Bernie Ecclestone managed to persuade BMW to manufacture straight-4 turbos for his team from 1982 onwards. In 1983, Alfa Romeo introduced a V8 turbo, and by the end of that year Honda and Porsche had introduced their own V6 turbos (the latter badged as TAG in deference to the company that provided the funding). Cosworth and the Italian Motori Moderni concern also manufactured V6 turbos during the 1980s, while Hart Racing Engines manufactured their own straight-4 turbo. By mid-1985, every Formula One car was running with a turbocharged engine. BMW's straight-4 turbo, the M12/13, produced around 1,400–1,500 hp (1,040–1,120 kW) at over 5 bar of boost in qualifying trim, but was detuned to produce between 850–900 hp (630–670 kW) in race spec. It powered the Brabham BT52 of 1983, with which Nelson Piquet won that year's Drivers' Championship. By 1986, power figures were reaching unprecedented levels, with all engines reaching over 1,000 hp (750 kW) during qualifying with unrestricted turbo boost pressures. This was especially seen with the BMW engines of Benetton's cars, reaching around 1,400 hp (1,040 kW) at a 5.5 bar boost pressure during qualifying. However, these

Porsche 804 had a fan to cool the air-cooled flat-8 engine

engines and gearboxes were very unreliable because of the engine's immense power, and would only last about four laps. For the race, the turbocharger's boost was restricted to ensure engine reliability; but the engines still produced 850–1,000 hp (630–750 kW) during the race. The power range from 1966 to 1986 was between 285 hp (210 kW) to 500 hp (370 kW), turbos 500 hp (370 kW) to 900 hp (670 kW) in race trim, and in qualifying, up to 1,400 hp (1,040 kW). Following their experiences at Indianapolis, in 1971 Lotus made a few unsuccessful experiments with a Pratt & Whitney turbine fitted to chassis which also had four-wheel-drive.[17]



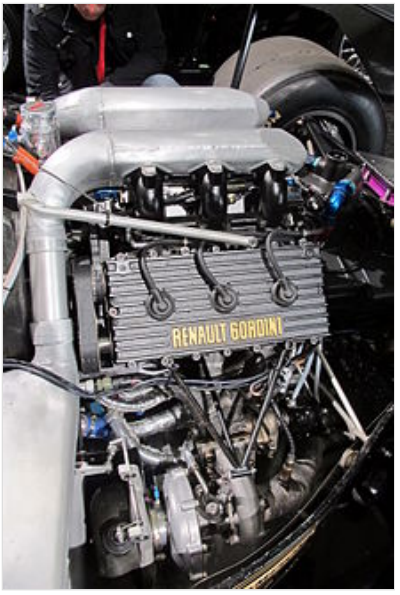
A 1968 British Racing Motors H16, 64-valve, Formula One engine

1987–1988

Following the turbo domination, forced induction was allowed for two seasons before its eventual ban. The FIA regulations limited boost pressure, to 4 bar in qualifying in 1987 for 1.5 L turbo; and allowed a larger 3.5 L formula. Fuel tank sizes were further reduced in size to 150 litres for turbo cars to limit the amount of boost used in a race. These seasons were still dominated by turbocharged engines, the Honda RA167E V6 supplying Nelson Piquet winning the 1987 Formula One season on a Williams also winning the constructors championship, followed by TAG-Porsche P01 V6 in McLaren then Honda again with the previous RA166E for Lotus then Ferrari's own 033D V6.

A Cosworth DFV 3-litre V8 Formula One engine

The rest of the grid was powered by the Ford GBA V6 turbo in Benetton, with the only naturally-aspirated engine, the DFV-derived Ford-Cosworth DFZ 3.5 L V8 outputting 575 hp (429 kW) in Tyrrell, Lola, AGS, March and Coloni.[18] The massively powerful BMW M12/13 inline-four found in the Brabham BT55 tilted almost horizontally, and in upright position under the Megatron brand in Arrows and Ligier, producing 900 bhp (670 kW) at 3.8 bar in race trim, and an incredible 1,400–1,500 bhp (1,040–1,120 kW) at 5.5 bar of boost in qualifying spec.[19] Zakspeed was building its own turbo inline-four, Alfa Romeo was to power the Ligiers with an inline-four but the deal fell through after initial testing had been carried out. Alfa was still represented by its old 890T V8 used by Osella, and Minardi was powered by a Motori Moderni V6.



Renault 1.5 litre turbo engine

In 1988, six teams – McLaren, Ferrari, Lotus, Arrows, Osella and Zakspeed – continued with turbocharged engines, now limited to 2.5 bar. Honda's V6 turbo, the RA168E, which produced 685 hp (511 kW) at 12,300 rpm in qualifying,[20] powered the McLaren MP4/4 with which Ayrton Senna and Alain Prost won fifteen of the sixteen races between them. The Italian Grand Prix was won by Gerhard Berger in the Ferrari F1/87/88C, powered by the team's own V6 turbo, the 033E, with about 720 hp (537 kW) at 12,000 rpm in qualifyings [21] and 620 hp (462 kW) at 12,000 rpm in races.[22] The Honda turbo also powered Lotus's 100T, while Arrows continued with the Megatron-badged BMW turbo, Osella continued with the Alfa Romeo V8 (now badged as an Osella) and Zakspeed continued with their own straight-4 turbo. All the other teams used naturally aspirated 3.5 L V8 engines: Benetton used the Cosworth DFR, which produced 585 hp (436 kW) at 11,000 rpm;[23] Williams, March and Ligier used the Judd CV, producing 600 hp (447 kW);[24] and the rest of the grid used the previous year's 575 hp (429 kW) Cosworth DFZ.

1989–1994

Turbochargers were banned from the 1989 Formula One season, leaving only a naturally aspirated 3.5 L formula. Honda was still dominant with their RA109E 72° V10 giving 685 hp (511 kW) @ 13,500 rpm on McLaren cars, enabling Prost to win the championship in front of his teammate Senna. Behind were the Renault RS1-powered Williams, a 67° V10 giving 650 hp (485 kW) @ 12,500 rpm and the Ferrari with its 035/5 65° V12 giving 660 hp (492 kW) at 13,000 rpm. Behind, the grid was powered mainly by Ford Cosworth DFR V8 giving 620 hp (462 kW) @ 10,750 rpm except for a

few Judd CV V8 in Lotus, Brabham and EuroBrun cars, and two oddballs: the 620 hp (460 kW) Lamborghini 3512 80° V12 powering Lola, and the 560 hp (420 kW) Yamaha OX88 75° V8 in Zakspeed cars. Ford started to try its new design, the 75° V8 HBA1 with Benetton.


A 1988 Honda RA168E turbocharged V6 engine

The 1990 Formula One season was again dominated by Honda in McLarens with the 690 hp (515 kW) @ 13,500 rpm RA100E powering Ayrton Senna and Gerhard Berger ahead of the 680 hp (507 kW) @ 12,750 rpm Ferrari Tipo 036 of Alain Prost and Nigel Mansell. Behind them the Ford HBA4 for Benetton and Renault RS2 for Williams with 660 hp (492 kW) @ 12,800 rpm were leading the pack powered by Ford DFR and Judd CV engines. The exceptions were the Lamborghini 3512 in Lola and Lotus, and the new Judd EV 76° V8 giving 640 hp (477 kW) @ 12,500 rpm in Leyton House and Brabham cars. The two new contenders were the Life which built for themselves an F35 W12 with three four cylinders banks @ 60°, and Subaru giving Coloni a 1235 flat-12 from Motori Moderni


A 1990 Renault RS2 V10 engine

Honda was still leading the 1991 Formula One season in Senna's McLaren with the 725–780 hp (541–582 kW) @ 13,500–14,500 rpm 60° V12 RA121E, just ahead of the Renault RS3 powered Williams benefiting from 700–750 hp (520–560 kW) @ 12,500–13,000 rpm. Ferrari was behind with its Tipo 037, a new 65° V12 giving 710 hp (529 kW) @ 13,800 rpm also powering Minardi, just ahead the Ford HBA4/5/6 in Benetton and Jordan cars. Behind, Tyrrell was using the previous Honda RA109E, Judd introduced its new GV with Dallara leaving the previous EV to Lotus, Yamaha were giving its 660 hp (492 kW) OX99 70° V12 to Brabham, Lamborghini engines were used by Modena and Ligier. Ilmor introduced its LH10, a 680 hp (507 kW) @ 13,000 rpm V10 which eventually became the Mercedes with Leyton House and Porsche sourced a little successful 3512 V12 to Footwork Arrows; the rest of the field was Ford DFR powered.[25]


A 1990 W12 3.5 Formula One engine from the Life F1 car

In 1992, the Renault engines became dominant, even more so following the departure from the sport of Honda at the end of 1992. The 3.5 L Renault V10 engines powering the Williams F1 team produced a power output between 750–820 bhp (559–611 kW; 760–831 PS) @ 13,000–14,300 rpm toward the end of the 3.5 L naturally-aspirated era, between 1992 and 1994. Renault-engined cars won the last three consecutive world constructors' championships of the 3.5 L formula era with Williams (1992–1994).[26]

The Peugeot A4 V10, used by the McLaren Formula One team in 1994, initially developed 700 bhp (522 kW; 710 PS) @ 14,250 rpm. It was later further developed into the A6, which produced even more power, developing 760 bhp (567 kW; 771 PS) @ 14,500 rpm.


A 1991 Honda RA121E V12 engine

The *EC Zetec-R* V8, which powered the championship-winning Benetton team and Michael Schumacher in 1994, produced between 730–750 bhp (544–559 kW; 740–760 PS) @ 14,500 rpm.[27]

By the end of the 1994 season, Ferrari's *Tipo 043* V12 was putting out around 850 hp (634 kW)[28] @ 15,800 rpm, which is to date the most-powerful naturally-aspirated V12 engine ever used in Formula One. This was also the most powerful engine of 3.5-litre engine regulation era, before a reduction in engine capacity to 3 litres in 1995.[29]

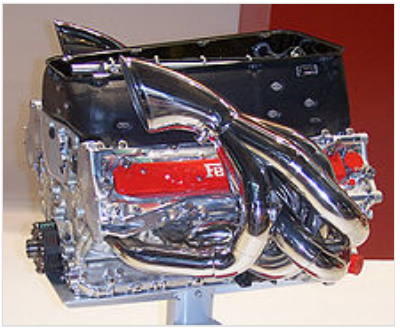
1995–2005

This era used a 3.0 L formula, with the power range varying (depending on engine tuning) between 600 hp (447 kW) and 1,000 hp (746 kW), between 13,000 rpm and 20,000 rpm, and from eight to twelve cylinders. Despite engine displacement being reduced from 3.5 L, power figures and RPMs still managed to climb. Renault was the initial dominant engine supplier from 1995 until 1997, winning the first three world championships with Williams and Benetton in this era. The championship-winning 1995 Benetton B195 produced a power output of 675 hp (503.3 kW) @ 15,200 rpm, and the

1996 championship-winning Williams FW18 produced 700 hp (522.0 kW) @ 16,000 rpm; both from a shared Renault RS9 3.0 L V10 engine.[30][31] The 1997 championship-winning FW19 produced between 730–760 hp (544.4–566.7 kW) @ 16,000 rpm, from its Renault RS9B 3.0 L V10. Ferrari's last V12 engine, the *Tipo 044/1*, was used in 1995. The engine's design was largely influenced by major regulation changes imposed by the FIA after the dreadful events during the year before: the V12 engine was reduced from 3.5 to 3.0 litres. The 3.0-litre engine produced around 700 hp (522 kW) 17,000 rpm in race trim; but was reportedly capable of producing up to 760 hp (567 kW) in its highest state of tune for qualification mode.[32] Between 1995 and 2000, cars using this 3.0 L engine formula, imposed by the FIA, produced a constant power range (depending on engine type and tuning), varying between 600 hp and 815 hp. Most Formula One cars during the 1997 season comfortably produced a consistent power output of between 665–760 hp (495.9–566.7 kW), depending on whether a V8 or V10 engine configuration was used.[33] From 1998 to 2000 it was Mercedes' power that ruled, giving Mika Häkkinen two world championships. The 1999 McLaren MP4/14 produced between 785 and 810 hp @ 17,000 rpm. Ferrari gradually improved their engine. In 1996, they changed from their traditional V12 engine to a smaller and lighter V10 engine. They preferred reliability to power, losing out to Mercedes in terms of outright power initially. Ferrari's first V10 engine, in 1996, produced 715 hp (533 kW) @ 15,550 rpm,[34] down on power from their most powerful 3.5 L V12 (in 1994), which produced over 830 hp (619 kW) @ 15,800 rpm, but up on power from their last 3.0 L V12 (in 1995), which produced 700 hp (522 kW) @ 17,000 rpm. At the 1998 Japanese GP, Ferrari's 047D engine spec was said to produce over 800 bhp (600 kW), and from 2000 onward, they were never short of power or reliability. To keep costs down, the 3.0 L V10 engine configuration was made fully mandatory for all teams in 2000 so that engine builders would not develop and experiment with other configurations.[35] The V10 configuration had been the most popular since the banning of turbocharged engines in 1989, and no other configuration had been used since 1998.

1994 Ferrari Tipo 043 3.5 V12 engine; the most powerful 3.5-litre engine in F1 history

Ferrari Tipo 044/1 3.0-litre V12 F1 engine (1995)



A 2004 Ferrari model 053 V10 engine of the Ferrari F2004

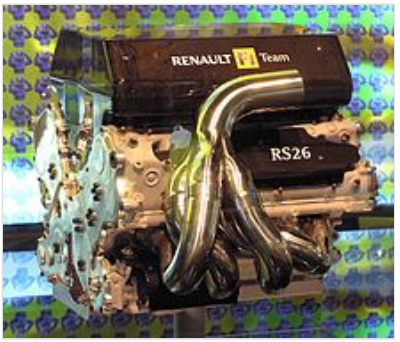
BMW started supplying its engines to Williams from 2000. The engine was very reliable in the first season though slightly short of power compared to Ferrari and Mercedes units. The BMW E41-powered Williams FW22 produced around 810 hp @ 17,500 rpm, during the 2000 season.[36] BMW went straight forward with its engine development. The P81, used during the 2001 season, was able to hit 17,810 rpm. Unfortunately, reliability was a large issue with several blowups during the season.

The BMW P82, the engine used by the BMW WilliamsF1 Team in 2002, had hit a peak speed of 19,050 rpm in its final evolutionary stage. It was also the first engine in the 3.0 litre V10-era to break through the 19,000 rpm wall, during the 2002 Italian Grand Prix's qualifying.[37] BMW's P83 engine used in 2003 season managed an impressive 19,200 rpm and cleared the 900 bhp (670 kW) mark, at around 940 bhp, and weighs less than 200 lb (91 kg).[38][39] Honda's *RA003E* V10 also cleared the 900 bhp (670 kW) mark at the 2003 Canadian Grand Prix.[40]

In 2005, the 3.0 L V10 engine was permitted no more than 5 valves per cylinder.[41] Also, the FIA introduced new regulations limiting each car to one engine per two Grand Prix weekends, putting the emphasis on increased reliability. In spite of this, power outputs continued to rise. Mercedes engines had about 930 bhp (690 kW) in this season. Cosworth, Mercedes, Renault, and Ferrari engines all produced around 900 bhp (670 kW) to 940 bhp (700 kW) @ 19,000 rpm.[42] Honda had over 965 bhp (720 kW).[43][44] The BMW engine made over 950 bhp (710 kW).[45][46] Toyota engines had over 1,000 bhp (750 kW), according to Toyota Motorsport's executive Vice President, Yoshiaki Kinoshita.[47] However, for reliability and longevity purposes, this power figure may have been detuned to around 960 bhp (720 kW) for races.[48]

2006–2013

For 2006, the engines had to be 90° V8 of 2.4 litres maximum capacity with a circular bore of 98 mm (3.9 in) maximum, which implies a 39.8 mm (1.57 in) stroke at maximum bore. The engines must have two inlet and two exhaust valves per cylinder, be naturally aspirated and have a 95 kg (209 lb) minimum weight. The previous year's engines with a rev-limiter were permitted for 2006 and 2007 for teams who were unable to acquire a V8 engine, with Scuderia Toro Rosso using a Cosworth V10, after Red Bull's takeover of the former Minardi team did not include the new engines.[49] The 2006 season saw the highest rev limits in the history of Formula One, at well over 20,000 rpm; before a 19,000 rpm mandatory rev limiter was implemented for all competitors in 2007. Cosworth was able to achieve just over 20,000 rpm with their V8,[50] and Renault around 20,500 rpm. Honda did the same; albeit only on the dynamometer.



Renault RS26 2.4 V8 engine (2006)

Pre-cooling air before it enters the cylinders, injection of any substance other than air and fuel into the cylinders, variable-geometry intake and exhaust systems, and variable valve timing were forbidden. Each cylinder could have only one fuel injector and a single plug spark ignition. Separate starting devices were used to start engines in the pits and on the grid. The crankcase and cylinder block had to be made of cast or wrought aluminium alloys. The crankshaft and camshafts had to be made from an iron alloy, pistons from an aluminium alloy, and valves from alloys based on iron, nickel, cobalt or titanium. These restrictions were in place to reduce development costs on the engines.[51]

The reduction in capacity was designed to give a power reduction of around 20% from the three-litre engines, to reduce the increasing speeds of Formula One cars. Despite this, in many cases the performance of the car improved. In 2006 Toyota F1 announced an approximate 740 hp (552 kW) output at 18,000 rpm for its new RVX-06 engine,[52] but real figures are of course difficult to obtain. Most cars from this period (2006–2008) produced a regular power output of approximately between 720 and 800 hp @ 19,000 rpm (over 20,000 rpm for the 2006 season).[53]


Ferrari *Tipo 056* 2.4 L V8 engine

The engine specification was frozen in 2007 to keep development costs down. The engines which were used in the 2006 Japanese Grand Prix were used for the 2007 and 2008 seasons and they were limited to 19,000 rpm. In 2009 the limit was reduced to 18,000 rpm with each driver allowed to use a maximum of 8 engines over the season. Any driver needing an additional engine is penalised 10 places on the starting grid for the first race the engine is used. This increases the importance of reliability, although the effect is only seen towards the end of the season. Certain design changes intended to improve engine reliability may be carried out with permission from the FIA. This has led to some engine manufacturers, notably Ferrari and Mercedes, exploiting this ability by making design changes which not only improve reliability but also boost engine power output as a side effect. As the Mercedes engine was proven to be the strongest, re-equalisations of engines were allowed by the FIA to allow other manufacturers to match the power.[54]

2009 saw the exit of Honda from Formula One. The team was acquired by Ross Brawn, creating Brawn GP and the BGP 001. With the absence of the Honda engine, Brawn GP retrofitted the Mercedes engine to the BGP 001 chassis. The newly branded team won both the Constructors' Championship and the Drivers' Championship from better-known and better-established contenders Ferrari, McLaren-Mercedes, and Renault.

Cosworth, absent since the 2006 season, returned in 2010. New teams Lotus Racing, HRT, and Virgin Racing, along with the established Williams, used this engine. The season also saw the withdrawal of the BMW and Toyota engines, as the car companies withdrew from Formula One due to the recession.[55]

In 2009, constructors were allowed to use kinetic energy recovery systems (KERS), also called regenerative brakes. Energy can either be stored as mechanical energy (as in a flywheel) or as electrical energy (as in a battery or supercapacitor), with a maximum power of 81 hp (60 kW; 82 PS) deployed by an electric motor, for a little over 6 seconds per lap. Four teams used it at some point in the season: Ferrari, Renault, BMW, and McLaren.[56]

Although KERS was still legal in F1 in the 2010 season, all the teams agreed not to use it. KERS returned for the 2011 season, when only three teams elected not to use it. For the 2012 season, only Marussia and HRT raced without KERS, and in 2013 all teams on the grid had KERS. From 2010 to 2013 cars have a regular power of 700–800 hp, averaging around 750 hp @ 18,000 rpm.[57][58]

2014–2021

The FIA announced a change from the 2.4-litre V8, introducing 1.6-litre V6 hybrid engines (more than one power source) for the 2014 season. The new regulations allow kinetic and heat energy recovery systems.[59] Forced induction was now allowed – either turbochargers, which last appeared in 1988, or superchargers – with all constructors opting to use a turbocharger. Instead of limiting the boost level, the regulations introduced a fuel flow restriction at 100 kg of petrol per hour maximum. The engines sounded very different from the previous formula, due to the lower rev limit (15,000 rpm) and the turbocharger.

The new formula for turbocharged engines have their efficiency improved through turbo-compounding by recovering energy from exhaust gases.[60] The original proposal for four-cylinder turbocharged engines was not welcomed by the racing teams, in particular Ferrari. Adrian Newey stated during the 2011 European Grand Prix that the change to a V6 enables teams to carry the engine as a stressed member, whereas an inline-4 would have required a space frame. A compromise was reached, allowing V6 forced induction engines instead.[60] The engines rarely exceed 12,000 rpm during qualifying and race, due to the new fuel flow restrictions.[61]

Energy recovery systems such as KERS had a boost of 160 hp (120 kW) and 2 megajoules per lap. KERS was renamed Motor Generator Unit–Kinetic (MGU-K). Heat energy recovery systems were also allowed, under the name Motor Generator Unit–Heat (MGU-H)

The 2015 season was an improvement on 2014, adding about 30–50 hp (20–40 kW) to most engines, the Mercedes engine being the most powerful with 870 hp (649 kW). In 2019, Renault's engine was claimed to have hit 1,000 hp in qualifying trim.[62]

Of the previous manufacturers, only Mercedes, Ferrari and Renault produced engines to the new formula in 2014, whereas Cosworth stopped supplying engines. Honda returned as an engine manufacturer in 2015, with McLaren switching to Honda power after using the Mercedes engine in 2014. In 2019, Red Bull switched from using a Renault engine to Honda power. Honda supplied both Red Bull and AlphaTauri. Honda withdrew as a power unit supplier at the end of 2021, with Red Bull taking over the project and producing the engine in-house.[63]

2022–2025

In 2017, the FIA began negotiations with existing constructors and potential new manufacturers over the next generation of engines with a projected introduction date of 2021 but delayed to 2022 due to the effects of the COVID-19 pandemic.[64] The initial proposal was designed to simplify engine designs, cut costs, promote new entries and address criticisms directed at the 2014 generation of engines. It called for the 1.6 L V6 configuration to be retained, but abandoned the complex Motor Generator Unit–Heat (MGU-H) system.[65] The Motor Generator Unit–Kinetic (MGU-K) would be more powerful, with a greater emphasis on driver deployment and a more flexible introduction to allow for tactical use. The proposal also called for the introduction of standardised components and design parameters to make components produced by all manufacturers compatible with one another in a system dubbed "plug in and play".[65] A further proposal to allow four-wheel drive cars was also made, with the front axle driven by an MGU-K unit—as opposed to the traditional driveshaft—that functioned independently of the MGU-K providing power to the rear axle, mirroring the system developed by Porsche for the 919 Hybrid race car.[66][67]

However, mostly due to no new engine supplier applying for F1 entry in 2021 and 2022, abolishment of the MGU-H, a more powerful MGU-K and a four-wheel drive system were all shelved with the possibility of their re-introduction for 2026. Instead, the teams and FIA agreed to a radical change in body/chassis aerodynamics to promote more battles on the course at closer distances to each other. They further agreed to an increase in alcohol content from 5.75% to 10% of fuel, and to implement a freeze on power unit design for 2022-2025, with the internal combustion engine (ICE), turbocharger and MGU-H being frozen on March 1 and the energy store, MGU-K and control electronics being frozen on September 1

during the 2022 season.[68] Honda, the outgoing engine supplier in 2021, was keen to keep the MGU-H, and Red Bull, who took over the engine production project, backed that opinion.[69] The 4WD system was planned to be based on Porsche 919 Hybrid system,[66] but Porsche ended up not becoming an F1 engine supplier for 2021-2022.

2026 onwards

On 16 August 2022, it was announced that new engine regulations had been agreed for 2026 and beyond. These engine regulations will see the turbocharged 1.6 V6 internal combustion engine configuration used since 2014 retained albeit with ICE power output reduced to around 400kw (approximately 530 bhp) down from 850bhp whilst the MGU-K's electrical energy capacity will be increased to 350kw (470 bhp) and the MGU-H removed. In addition, fuel flow rates will be measured and limited based on energy, rather than mass or volume of the fuel itself. There is also intended to be further restrictions on components such as MGU-Ks and exhausts imposed from 2027.[70]

Audi announced in August 2022 that they would become a power unit manufacturer from 2026 onwards.[71] In February 2023, Ford announced their return as a power unit supplier for 2026 after nearly 20 years of absence in Formula One[72] and will partner with Red Bull Powertrains as Red Bull Ford Powertrains.[73][74] Honda, under its subsidiary Honda

Racing Corporation, has also been provisionally listed as a manufacturer for 2026 by the FIA after officially leaving the sport in 2021.[75] The FIA also confirmed that Ferrari, Mercedes-AMG and Alpine are registered as power unit suppliers for 2026.[76] In March 2023, Porsche revealed that they will not be joining Formula One in 2026.[77]

Engine regulation progression by era

<table>
<tr><th rowspan="2">Years</th><th rowspan="2">Operating principle[a]</th><th colspan="2">Maximum displacement</th><th rowspan="2">Configuration</th><th rowspan="2">RPM limit</th><th rowspan="2">Fuel flow limit (Q_{max})</th><th colspan="2">Fuel composition</th></tr>
<tr><th>Naturally aspirated</th><th>Forced induction</th><th>Alcohol</th><th>Petrol</th></tr>
<tr><td>2022–2025[b][78]</td><td rowspan="25">4-stroke piston</td><td colspan="2">1.6 L[c]</td><td rowspan="2">90° V6 + MGUs</td><td>Unrestricted[d]</td><td rowspan="2">(0.009 x rpm)+5.5 up to 100(kg/h)[e]</td><td>10%[f]</td><td rowspan="11">Unleaded</td></tr>
<tr><td>2014–2021[b]</td><td colspan="2">1.6 L[g][79][80]</td><td>15,000 rpm[d]</td><td rowspan="4">5.75%[h]</td></tr>
<tr><td>2009–2013[i]</td><td rowspan="3">2.4 L</td><td rowspan="8">Prohibited</td><td>90° V8 + KERS</td><td>18,000 rpm</td><td rowspan="16">Unrestricted</td></tr>
<tr><td>2008</td><td rowspan="3">90° V8</td><td rowspan="2">19,000 rpm</td></tr>
<tr><td>2007[j]</td><td rowspan="15">Prohibited</td></tr>
<tr><td>2006[j][81]</td><td rowspan="14">Unrestricted[82]</td></tr>
<tr><td>1998–2005</td><td rowspan="2">3.0 L</td><td>V10</td></tr>
<tr><td>1995–1997</td><td rowspan="4">Up to 12 cylinders</td></tr>
<tr><td>1992–1994</td><td rowspan="4">3.5 L</td></tr>
<tr><td>1989–1991</td><td rowspan="3">Unrestricted</td></tr>
<tr><td>1988</td><td>1.5 L, 2.5 bar</td><td rowspan="11">Unrestricted</td></tr>
<tr><td>1987</td><td>1.5 L, 4 bar</td></tr>
<tr><td>1986</td><td>Prohibited</td><td rowspan="3">1.5 L</td></tr>
<tr><td>1981–1985</td><td rowspan="2">3.0 L</td></tr>
<tr><td>1966–1980</td><td rowspan="8">Unspecified</td></tr>
<tr><td>1963–1965</td><td rowspan="2">1.5 L (1.3 L min.)</td><td rowspan="2">Prohibited</td><td>Pump Gasoline[83]</td></tr>
<tr><td>1961–1962</td><td rowspan="4">Unrestricted</td></tr>
<tr><td>1958–1960</td><td rowspan="2">2.5 L</td><td rowspan="2">0.75 L</td></tr>
<tr><td>1954–1957</td><td>Unrestricted</td></tr>
<tr><td>1947–1953[k]</td><td>4.5 L</td><td>1.5 L</td><td>Unrestricted</td><td>Unrestricted</td></tr>
</table>

Notes:

a. 2-stroke, gas turbine, rotary, etc.
b. MGU (Motor Generator Unit)-Kinetic (brake) and MGU-Heat (exhaust) energy recovery systems allowed.

c. Displacement must be between 1,590cc and 1,600cc. Naturally aspirated engines are not prohibited. Boost pressure is not limited.
d. Lower rpm fuel flow restriction on the next column reaches the maximum of 100kg/hour at 10,500rpm. At this flow rate, further increasing rpm requires lower boost, or results in thinner air/fuel ratio. Due to this, engine manufacturers normally set the maximum engine speed at about 13,000 rpm.
e. Maximum fuel flow rate (Q) is limited in relation to engine speed below 10,500rpm. On or above 10,500rpm, the maximum fuel flow rate of 100kg/hour applies.
f. 10% ethanol content is required in pump gasoline.
g. Smaller displacement is allowed. Naturally aspirated engines are not prohibited, but were not used by any team. Boost pressure is not limited, but fuel flow rate (which was not regulated up to 2013) is limited to 100 kg per hour (roughly equivalent to 3.5 bar at the maximum rpm).
h. 5.75% bio-sourced alcohol content is required in pump petroleum.
i. Kinetic (braking) energy recovery system (KERS) allowed.
j. For 2006 and 2007, the FIA reserved the right to give special dispensations to teams without access to new specification engines to use 2005-spec engines with a rev-limiter. This dispensation was given to Scuderia Toro Rosso only in 2006.
k. For 1952 and 1953, World Championship races were run to Formula Two rules (0.75 L with compressor, 2 L without), but Formula One regulations remained intact.

Current engine technical specifications

Combustion, construction, operation, power, fuel and lubrication

- **Manufacturers**: Mercedes-Benz, Renault (including TAG Heuer rebadging until 2018), Ferrari and Honda
- **Type**: Hybrid-powered 4-stroke piston Otto-cycle with efficient combustion process and greater emission engine burning
- **Configuration**: V6 single hybrid turbocharger engine
- **V-angle**: 90° cylinder angle
- **Displacement**: 1.6 litres (98 cubic inches)
- **Bore**: Maximum 80 mm (3.150 in)
- **Stroke**: 53 mm (2.087 in)
- **Valvetrain**: DOHC, 24-valve (four valves per cylinder)
- **Fuel**: 98–102 RON unleaded petroleum + 5.75% biofuel
- **Fuel delivery**: Petrol direct injection
- **Direct fuel injection pressure**: 500 bar (7,251.89 psi; 493.46 atm; 375,030.84 Torr; 50,000.00 kPa; 14,764.99 inHg)
- **Fuel flow limit**: 100 kg/h
- **Aspiration**: Single-turbocharged
- **Power output**: 850 + 160 hp (634 + 119 kW) @ 10,000 rpm through 12,000 rpm
- **Torque**: Approx. 600–815 N·m (443–601 lb·ft)[84]
- **Lubrication**: Dry sump
- **Maximum revs**: 15,000 rpm (maximum allowed by the regulations, in practice no engine goes much above 12,000 rpm as there is no practical benefit to it)
- **Engine management**: McLaren TAG-320 (2018) later TAG-320B (2019–present)
- **Max. speed**: Approximately 370 km/h (230 mph) (Monza, Baku and Mexico); 340 km/h (211 mph) normal tracks
- **Mass**: 145 kg (319.67 lb) complete
- **Cooling**: Single water pump
- **Ignition**: High energy inductive

- **Exhaust systems**: Single exhaust with central exit and extra double small exhaust

Forced induction

- **Turbocharger mass**: 8 kg (17.637 lb) depending on the turbine housing used
- **Turbocharger spin rev limit**: 125,000 rpm
- **Pressure charging**: Single-stage compressor and exhaust turbine, a common-shaft
- **Turbo boost level pressure**: Unlimited but mainly typical 400–500 kPa (58–73 psi; 3,000–3,800 Torr; 120–150 inHg) absolute
- **Wastegate**: Maximum of two, electronic- or pneumatic-controlled

ERS systems

- **MGU-K RPM**: Max 50,000 rpm
- **MGU-K power**: Max 120 kW
- **Energy recovered by MGU-K**: Max 2 MJ/lap
- **Energy released by MGU-K**: Max 4 MJ/lap from the Energy Storage, unlimited from the MGU-H
- **MGU-H RPM**: >100,000 rpm
- **Energy recovered by MGU-H**: Unlimited (> 2MJ/lap)

Records

Figures correct as of the 2023 Abu Dhabi Grand Prix

Bold indicates engine manufacturers that have competed in Formula One in the 2023 season.

World Championship Grand Prix wins by engine manufacturer

Rank	Engine	Wins	First win	Latest win
1	**Ferrari**	244	1951 British Grand Prix	2023 Singapore Grand Prix
2	**Mercedes**[a]	212	1954 French Grand Prix	2022 São Paulo Grand Prix
3	Ford[b]	176	1967 Dutch Grand Prix	2003 Brazilian Grand Prix
4	**Renault**	169	1979 French Grand Prix	2021 Hungarian Grand Prix
5	Honda	89	1965 Mexican Grand Prix	2021 Abu Dhabi Grand Prix
6	Coventry Climax	40	1958 Argentine Grand Prix	1965 German Grand Prix
7	TAG[c]	25	1984 Brazilian Grand Prix	1987 Portuguese Grand Prix
8	**Honda RBPT**[d]	21	2023 Bahrain Grand Prix	2023 Abu Dhabi Grand Prix
9	BMW	20	1982 Canadian Grand Prix	2008 Canadian Grand Prix
10	BRM	18	1959 Dutch Grand Prix	1972 Monaco Grand Prix
11	Red Bull Powertrains[d]	17	2022 Saudi Arabian Grand Prix	2022 Abu Dhabi Grand Prix
12	Alfa Romeo	12	1950 British Grand Prix	1978 Italian Grand Prix
13	Offenhauser	11	1950 Indianapolis 500[e]	1960 Indianapolis 500
	Maserati		1953 Italian Grand Prix	1967 South African Grand Prix
15	Vanwall	9	1957 British Grand Prix	1958 Moroccan Grand Prix
	TAG Heuer[f]		2016 Spanish Grand Prix	2018 Mexican Grand Prix
17	Repco	8	1966 French Grand Prix	1967 Canadian Grand Prix
18	Mugen-Honda	4	1996 Monaco Grand Prix	1999 Italian Grand Prix
19	Matra	3	1977 Swedish Grand Prix	1981 Canadian Grand Prix
20	Porsche	1	1962 French Grand Prix	
	Weslake		1967 Belgian Grand Prix	
	BWT Mercedes[g]		2020 Sakhir Grand Prix	

Most wins in a season

By number

Rank	Manufacturer	Season	Races	Wins	Percentage	Engine(s)	Winning team(s)
1	**Honda RBPT**	2023	22	21	95.5%	Honda RBPTH001	Red Bull
2	**Mercedes**	2016	21	19	90.5%	PU106C Hybrid	Mercedes
3	Red Bull Powertrains	2022	22	17	77.3%	RBPTH001	Red Bull
4	**Renault**	1995	17	16	94.1%	RS7	Benetton, Williams
	Mercedes	2014	19		84.2%	PU106A Hybrid	Mercedes
		2015	19		84.2%	PU106B Hybrid	Mercedes
7	Ford	1973	15	15	100%	DFV	Lotus, Tyrrell, McLaren
	Honda	1988	16		93.8%	RA168E	McLaren
	Ferrari	2002	17		88.2%	Tipo 050, Tipo 051	Ferrari

		2004	18		83.3%	Tipo 053	Ferrari
	Mercedes	2019	21		71.4%	M10 EQ Power+	Mercedes

By percentage

Rank	Manufacturer	Season	Races	Wins	*Percentage*	Engine(s)	Winning team(s)
1	Ford	1969	11	11	100%	DFV	Matra, Brabham, Lotus, McLaren
		1973	15	15		DFV	Lotus, Tyrrell, McLaren
3	**Honda RBPT**	2023	22	21	95.5%	RBPTH001	Red Bull Racing
4	**Renault**	1995	17	16	94.1%	RS7	Benetton, Williams
5	Honda	1988	16	15	93.8%	RA168E	McLaren
6	Ford	1968	12	11	91.7%	DFV	Lotus, McLaren, Matra
7	**Mercedes**	2016	21	19	90.5%	PU106C Hybrid	Mercedes
8	**Ferrari**	2002	17	15	88.2%	Tipo 050, Tipo 051	Ferrari
9	**Ferrari**[h]	1952	8	7	87.5%	Tipo 500, Tipo 375	Ferrari
10	Alfa Romeo[h]	1950	7	6	85.7%	Tipo 158, Tipo 159	Alfa Romeo

Most consecutive wins

Rank	Manufacturer	Wins	Season(s)	Races	Engine(s)	Winning team(s)
1	Ford	22	1972, 1973, 1974	1972 Austrian Grand Prix – 1974 South African Grand Prix	DFV	Lotus, Tyrrell, McLaren, Brabham
2	Ford	20	1968, 1969, 1970	1968 British Grand Prix – 1970 Monaco Grand Prix	DFV	Lotus, Matra, McLaren, Brabham, March
3	**Renault**	16	1995, 1996	1995 French Grand Prix – 1996 San Marino Grand Prix	RS7, RS8	Benetton, Williams
4	**Honda RBPT**	14	2023	2023 Bahrain Grand Prix – 2023 Italian Grand Prix	RBPTH001	Red Bull
5	Honda	11	1988	1988 Brazilian Grand Prix – 1988 Belgian Grand Prix	RA168E	McLaren
6	**Ferrari**	10	2002	2002 Canadian Grand Prix – 2002 Japanese Grand Prix	Tipo 051	Ferrari
	Mercedes		2015, 2016	2015 Japanese Grand Prix – 2016 Russian Grand Prix	PU106B Hybrid, PU106C Hybrid	Mercedes
			2016	2016 Monaco Grand Prix – 2016 Singapore Grand Prix	PU106C Hybrid	Mercedes
			2018, 2019	2018 Brazilian Grand Prix – 2019 French Grand Prix	M09 EQ Power+, M10 EQ Power+	Mercedes
10	Ford	9	1980, 1981	1980 Dutch Grand Prix – 1981 Belgian Grand Prix	DFV	Brabham, Williams
	Renault		2013	2013 Belgian Grand Prix – 2013 Brazilian Grand Prix	RS27-2013	Red Bull
	Red Bull Powertrains		2022	2022 French Grand Prix – 2022 Mexico City Grand Prix	RBPTH001	Red Bull

Entry of new engine suppliers

In December 2021, Audi has written to the outgoing president of the FIA, Jean Todt, advising him of their intention to enter Formula One from 2026.[86] This is when new engine regulations take effect to introduce more environmentally-friendly powertrains. The Volkswagen Group is evaluating entries from Audi and Porsche and is "close to the finishing line" in terms of its entry into F1.

This would be the first foray of Porsche in Formula One since 1991.

See also

- List of Formula One engine manufacturers

Notes

a. Built by Ilmor between 1994 and 2005
b. Built by Cosworth. Cosworth was supported by Ford for many years (which even owned Cosworth outright from 1998 to 2004), and many of the Cosworth designs – from 1966 to 2004 – were owned by Ford and specifically named as Ford engines (contrary to the sometimes seen Ford-Cosworth or Ford/Cosworth vernacular) under various contracts.
c. Built by Porsche
d. Built by Honda
e. The Indianapolis 500 was part of the World Drivers' Championship from 1950 to 1960
f. Built by Renault
g. Built by Mercedes
h. From 1950 to 1960, the Indianapolis 500 was part of the World Drivers' Championship, though the Indianapolis 500 was held to AAA regulations rather than Formula One regulations. During those 11 years, only once did a regular Formula One driver enter an Indianapolis 500 race, when eventual 1952 Formula One World Drivers' Champion Alberto Ascari competed in the 1952 race, retiring on lap 40 of 200.[85] Thus, Alfa Romeo did not attempt to achieve a 100% sweep in 1950, and Ferrari failed in its attempt to complete the sweep in 1952.

References

1. "F1 Engine rule change through the years" (http://www.formula1-dictionary.net/engine_rule_changes_history.html). *www.formula1-dictionary.net*. Archived (https://web.archive.org/web/20201111173531/http://www.formula1-dictionary.net/engine_rule_changes_history.html) from the original on 11 November 2020. Retrieved 10 November 2020.
2. "Formula 1 Engine" (http://www.formula1-dictionary.net/engine.html). *www.formula1-dictionary.net*. Archived (https://web.archive.org/web/20201112035405/http://www.formula1-dictionary.net/engine.html) from the original on 12 November 2020. Retrieved 10 November 2020.
3. "McLaren Racing - History of the F1 engine" (https://www.mclaren.com/racing/car/history-of-the-f1-engine/).
4. Fédération Internationale de l'Automobile (23 January 2014). "2014 FORMULA ONE TECHNICAL REGULATIONS" (http://www.fia.com/sites/default/files/regulation/file/1-2014%20TECHNICAL%20REGULATIONS%202014-01-23.pdf) (PDF). Archived (https://web.archive.org/web/20140327054505/http://www.fia.com/sites/default/files/regulation/file/1-2014%20TECHNICAL%20REGULATIONS%202014-01-23.pdf) (PDF) from the original on 27 March 2014. Retrieved 27 February 2014.
5. Engine / gearbox (http://www.formula1.com/inside_f1/understanding_the_sport/5280.html) Archived (https://web.archive.org/web/20140222043956/http://www.formula1.com/inside_f1/understanding_the_sport/5280.html) 22 February 2014 at the Wayback Machine Understanding the Sport, Official Formula 1 Website
6. F1 Engine Power Secrets (http://www.pureluckdesign.com/ferrari/f1engine/) Archived (https://web.archive.org/web/20051129094238/http://www.pureluckdesign.com/ferrari/f1engine/) 29 November 2005 at the Wayback Machine, Ian Bamsey, June 2000 RACER magazine

7. Scarborough, Craig. "Technically Challenged: Renault Innovations in Formula One" (http://www.scarbsf1.com/Media/Renault_atlasf1-2003-dec17-scarborough.pdf) (PDF). *Atlas F1*. ScarbsF1.com. Archived (https://web.archive.org/web/20090824140227/http://www.scarbsf1.com/Media/Renault_atlasf1-2003-dec17-scarborough.pdf) (PDF) from the original on 24 August 2009. Retrieved 4 June 2012.
8. Taulbut, Derek. "Note 89 – TurboCharging background" (http://www.grandprixengines.co.uk/Note_89.pdf) (PDF). *Grand Prix Engine Development 1906 – 2000*. Grandprixengines.co.uk. Archived (https://web.archive.org/web/20120703145257/http://grandprixengines.co.uk/Note_89.pdf) (PDF) from the original on 3 July 2012. Retrieved 4 June 2012.
9. "F1 Hockenheim 2006 Q2 - Mark Webber Onboard Lap" (https://www.youtube.com/watch?v=_HwHgEWnpfs). Archived (https://web.archive.org/web/20151218074054/https://www.youtube.com/watch?v=_HwHgEWnpfs) from the original on 18 December 2015. Retrieved 4 January 2015 – via www.youtube.com.
10. "Cosworth V8 at 20,000rpm" (https://www.youtube.com/watch?v=BPdm51QwZEw). Archived (https://web.archive.org/web/20141128054126/https://www.youtube.com/watch?v=BPdm51QwZEw) from the original on 28 November 2014. Retrieved 4 January 2015 – via www.youtube.com.
11. "Renault R26" (https://sportscardigest.com/renault-r26/). 30 April 2009.
12. "Profile – Renault R26" (https://www.motorsportmagazine.com/archive/article/april-2007/45/profile-renault-r26).
13. "Why do big diesel engines and race car engines have such different horsepower ratings?" (http://auto.howstuffworks.com/question381.htm). HowStuffWorks. 16 May 2000. Archived (https://web.archive.org/web/20140329053641/http://auto.howstuffworks.com/question381.htm) from the original on 29 March 2014. Retrieved 2 April 2014.
14. "Dilute Combustion Assessment in Large Bore, Low Speed Engines" (https://saemobilus.sae.org/content/2017-01-0580/). October 2021. Archived (https://web.archive.org/web/20211027182513/https://saemobilus.sae.org/content/2017-01-0580/) from the original on 27 October 2021. Retrieved 12 October 2021.
15. Leo Breevoort; Dan Moakes; Mattijs Diepraam (22 February 2007). "World Championship Grand Prix engine designations and configurations" (http://www.forix.com/8w/6thgear/engines.html). 6th Gear. Archived (https://web.archive.org/web/20070224024047/http://www.forix.com/8w/6thgear/engines.html) from the original on 24 February 2007. Retrieved 19 May 2007.
16. "8W - What? - Eagle Gurney-Weslake" (http://8w.forix.com/gurney-weslake-grandprix-engine.html). *8w.forix.com*. Archived (https://web.archive.org/web/20211026042415/http://8w.forix.com/gurney-weslake-grandprix-engine.html) from the original on 26 October 2021. Retrieved 15 November 2021.
17. "How A Formula 1 Internal Combustion Engine Works" (https://f1chronicle.com/how-a-formula-1-internal-combustion-engine-works/). *f1chronicle.com*. 26 August 2019. Archived (https://web.archive.org/web/20200922205140/https://f1chronicle.com/how-a-formula-1-internal-combustion-engine-works/) from the original on 22 September 2020. Retrieved 21 September 2020.
18. "STATS F1 • Engines" (http://www.statsf1.com/en/moteurs.aspx). StatsF1. Archived (https://web.archive.org/web/20100831234750/http://www.statsf1.com/en/moteurs.aspx) from the original on 31 August 2010. Retrieved 9 September 2010.
19. Remi Humbert. "BMW Turbo F1 Engine" (http://www.gurneyflap.com/engine.html). Gurneyflap. Archived (https://web.archive.org/web/20070608033014/http://gurneyflap.com/engine.html) from the original on 8 June 2007. Retrieved 19 May 2007.
20. "Honda | Honda Racing Gallery | F1 第二期 | McLaren Honda MP4/4" (http://www.honda.co.jp/Racing/gallery/1988/01/). *Honda公式ホームページ* (in Japanese). Archived (https://web.archive.org/web/20210627235510/https://www.honda.co.jp/Racing/gallery/1988/01/) from the original on 27 June 2021. Retrieved 22 June 2021.
21. "Ferrari F1/87" (https://en.wikipedia.org/wiki/Ferrari_F1/87). *wikipedia.org/wiki/Ferrari_F1/87*. Retrieved 31 December 2023.
22. "Ferrari F1-8788C (1988)" (https://www.ferrari.com/en-EN/formula1/f1-8788c). *www.ferrari.com*. Archived (https://web.archive.org/web/20210624203236/https://www.ferrari.com/en-EN/formula1/f1-8788c) from the original on 24 June 2021. Retrieved 22 June 2021.
23. "Engine Ford Cosworth • STATS F1" (https://www.statsf1.com/en/moteur-ford-cosworth.aspx). *www.statsf1.com*. Archived (https://web.archive.org/web/20210628011055/https://www.statsf1.com/en/moteur-ford-cosworth.aspx) from the original on 28 June 2021. Retrieved 22 June 2021.
24. "Engine Judd • STATS F1" (https://www.statsf1.com/en/moteur-judd.aspx). *www.statsf1.com*. Archived (https://web.archive.org/web/20210627220201/https://www.statsf1.com/en/moteur-judd.aspx) from the original on 27 June 2021. Retrieved 22 June 2021.

25. Engineering, Racecar (25 June 2020). "Natural Aspirations" (https://www.racecar-engineering.com/news/natural-aspirations/). Archived (https://web.archive.org/web/20211114080021/https://www.racecar-engineering.com/news/natural-aspirations/) from the original on 14 November 2021. Retrieved 14 November 2021.
26. "Archived copy" (https://www.grandprixengines.co.uk/3rd_Naturally-Aspirated_Era_(3NA)_Part_1.pdf) (PDF). Archived (https://web.archive.org/web/20211115235526/https://www.grandprixengines.co.uk/3rd_Naturally-Aspirated_Era_(3NA)_Part_1.pdf) (PDF) from the original on 15 November 2021. Retrieved 15 November 2021.
27. "Engine Ford Cosworth • STATS F1" (https://www.statsf1.com/en/moteur-ford-cosworth.aspx). Archived (https://web.archive.org/web/20210415053015/https://www.statsf1.com/en/moteur-ford-cosworth.aspx) from the original on 15 April 2021. Retrieved 30 April 2021.
28. "Ferrari's Most Alluring F1 Engines" (http://www.scuderia.com/2017/06/01/ferraris-f1-engines-pursuit-power/). June 2017. Archived (https://web.archive.org/web/20210515085321/http://www.scuderia.com/2017/06/01/ferraris-f1-engines-pursuit-power/) from the original on 15 May 2021. Retrieved 30 May 2021.
29. "A Genius Named Todt" (http://atlasf1.autosport.com/98/preseason/raman.html). Atlasf1.autosport.com. Archived (https://web.archive.org/web/20120330023718/http://atlasf1.autosport.com/98/preseason/raman.html) from the original on 30 March 2012. Retrieved 13 February 2011.
30. "Archived copy" (https://grandprixengines.co.uk/3rd_Naturally-Aspirated_Era_(3NA)_Part_2.pdf) (PDF). Archived (https://web.archive.org/web/20210731073800/https://www.grandprixengines.co.uk/3rd_Naturally-Aspirated_Era_(3NA)_Part_2.pdf) (PDF) from the original on 31 July 2021. Retrieved 31 August 2021.
31. "Engine Renault • STATS F1" (https://www.statsf1.com/en/moteur-renault.aspx). *www.statsf1.com*. Archived (https://web.archive.org/web/20210213195319/https://www.statsf1.com/en/moteur-renault.aspx) from the original on 13 February 2021. Retrieved 24 February 2021.
32. "For Sale: A Ferrari 3000 (044/1) V12 Formula 1 Engine" (https://silodrome.com/ferrari-3000-044-1-v12-formula-1-engine/). 16 January 2021. Archived (https://web.archive.org/web/20210615091321/https://silodrome.com/ferrari-3000-044-1-v12-formula-1-engine/) from the original on 15 June 2021. Retrieved 3 March 2022.
33. "McLaren Racing - Heritage - MP4-12" (https://www.mclaren.com/racing/heritage/cars/1997-formula-1-mclaren-mp4-12/). *www.mclaren.com*. Archived (https://web.archive.org/web/20201129024015/https://www.mclaren.com/racing/heritage/cars/1997-formula-1-mclaren-mp4-12/) from the original on 29 November 2020. Retrieved 19 November 2020.
34. "Ferrari F310: Ferrari History" (https://www.ferrari.com/en-EN/history/garage/1996/f310). *www.ferrari.com*. Archived (https://web.archive.org/web/20211114191853/https://www.ferrari.com/en-EN/history/garage/1996/f310) from the original on 14 November 2021. Retrieved 12 December 2021.
35. "WORLD MOTOR SPORT COUNCIL MEETING – JANUARY 15, 2000" (https://web.archive.org/web/20110603232117/http://www.fia.com/resources/documents/1661500937__15_01_2000_WMSC.pdf) (PDF). www.fia.com. 15 January 2000. Archived from the original (http://www.fia.com/resources/documents/1661500937__15_01_2000_WMSC.pdf) (PDF) on 3 June 2011. Retrieved 24 January 2016.
36. "Williams FW22" (https://www.f1technical.net/f1db/cars/840/williams-fw22). *www.f1technical.net*. Archived (https://web.archive.org/web/20201116125025/https://www.f1technical.net/f1db/cars/840/williams-fw22) from the original on 16 November 2020. Retrieved 19 November 2020.
37. "Williams F1 – BMW P84/85 Engine" (http://www.f1network.net/main/s107/st66401.htm). F1network.net. Archived (https://web.archive.org/web/20101122095758/http://www.f1network.net/main/s107/st66401.htm) from the original on 22 November 2010. Retrieved 13 February 2011.
38. Roy McNeill, Copyright BMW World 1999–2005 (22 September 2003). "BMW World – Picture of the Week" (http://www.usautoparts.net/bmw/engines/p83.htm). Usautoparts.net. Archived (https://web.archive.org/web/20071219232744/http://www.usautoparts.net/bmw/engines/p83.htm) from the original on 19 December 2007. Retrieved 17 October 2007.
39. "One of the greatest engines in history of Formula 1: BMW V10" (https://www.bmwblog.com/2015/07/25/one-of-the-greatest-engines-in-history-of-formula-1-bmw-v10/). 25 July 2015.
40. Jaynes, Nick (16 July 2015). "BMW Engines in Formula 1's V10 Era" (https://www.roadandtrack.com/motorsports/a26106/bmw-engines-in-the-v10-era/). *Road & Track*. Archived (https://web.archive.org/web/20201111235844/https://www.roadandtrack.com/motorsports/a26106/bmw-engines-in-the-v10-era/) from the original on 11 November 2020. Retrieved 2 April 2021.

41. 2005 Formula One technical regulations (http://www.fia.com/resources/documents/1368441606__2005F1TechnicalRegulations.pdf) Archived (https://web.archive.org/web/20060621040900/http://www.fia.com/resources/documents/1368441606__2005F1TechnicalRegulations.pdf) 21 June 2006 at the Wayback Machine. FIA
42. "Bore and stroke on early 2000,s V10 engines - F1technical.net" (https://www.f1technical.net/forum/viewtopic.php?t=28171). *www.f1technical.net*. Archived (https://web.archive.org/web/20211010003217/https://www.f1technical.net/forum/viewtopic.php?t=28171) from the original on 10 October 2021. Retrieved 10 October 2021.
43. "Honda R&D Technical Review F1 Special (The Third Era Activities)" (https://www.hondarandd.jp/summary.php?sid=23&lang=en). *Honda R&D Research Paper website*. Archived (https://web.archive.org/web/20201112015541/https://www.hondarandd.jp/summary.php?sid=23&lang=en) from the original on 12 November 2020. Retrieved 10 November 2020.
44. "Cosworth story" (http://www.formula1-dictionary.net/engine_cosworth_story.html). *www.formula1-dictionary.net*. Archived (https://web.archive.org/web/20201118152743/http://www.formula1-dictionary.net/engine_cosworth_story.html) from the original on 18 November 2020. Retrieved 16 November 2020.
45. "10 Years of BMW F1 Engines" (https://8000vueltas.com/wp-content/uploads/2015/12/Theissen-10-years-of-BMW-F1-engines.pdf) (PDF). Archived (https://web.archive.org/web/20160414001953/https://8000vueltas.com/wp-content/uploads/2015/12/Theissen-10-years-of-BMW-F1-engines.pdf) (PDF) from the original on 14 April 2016.
46. "Formula 1's 5 Most Iconic Engines ever" (https://sportlightpro.com/2021/02/26/formula-1-most-iconic-engines-ever-powertrain-ford-cosworth-renault-turbo-bmw-mercedes-amg-hybrid-motor-motors-engine-power-unit-car-cars-motorsport/). 26 February 2021.
47. "Toyota RVX-V10 F1 Engine" (https://www.racecar-engineering.com/articles/toyota-rvx-v10-f1-engine/). 13 July 2009. Archived (https://web.archive.org/web/20210424062227/https://www.racecar-engineering.com/articles/toyota-rvx-v10-f1-engine/) from the original on 24 April 2021. Retrieved 30 May 2021.
48. "Toyota TF105B - F1technical.net" (https://www.f1technical.net/f1db/cars/896/toyota-tf105b). *www.f1technical.net*. Archived (https://web.archive.org/web/20210602213237/https://www.f1technical.net/f1db/cars/896/toyota-tf105b) from the original on 2 June 2021. Retrieved 30 May 2021.
49. Henry, Alan, ed. (2006). *AUTOCOURSE 2006–2007*. Crash Media Group. pp. 82–83. ISBN 1-905334-15-X.
50. "King of Speed: Cosworth's CA 2.4l V8" (https://www.f1technical.net/features/18858). *www.f1technical.net*. Archived (https://web.archive.org/web/20210128014715/https://www.f1technical.net/features/18858) from the original on 28 January 2021. Retrieved 1 April 2021.
51. 2006 Formula One technical regulations (http://www.fia.com/resources/documents/1603301296__2006_F1_TECHNICAL_REGULATIONS.pdf) Archived (https://web.archive.org/web/20060901003154/http://www.fia.com/resources/documents/1603301296__2006_F1_TECHNICAL_REGULATIONS.pdf) 1 September 2006 at the Wayback Machine, chapter five, 15 December 2005
52. F1 technical, Toyota TF106 Specification (http://www.f1technical.net/f1db/cars/897) Archived (https://web.archive.org/web/20090130063047/http://www.f1technical.net/f1db/cars/897) 30 January 2009 at the Wayback Machine, 14 January 2006
53. "Current Engine Ranking??? - Racing Comments Archive" (https://forums.autosport.com/topic/89958-current-engine-ranking/). *The Autosport Forums*. Archived (https://web.archive.org/web/20210118112602/https://forums.autosport.com/topic/89958-current-engine-ranking/) from the original on 18 January 2021. Retrieved 19 November 2020.
54. "F1 News: FIA agrees to engine re-equalisation" (http://www.autosport.com/news/report.php/id/78776). *Autosport.com*. Haymarket Publications. 22 September 2009. Archived (https://web.archive.org/web/20090924234140/http://www.autosport.com/news/report.php/id/78776) from the original on 24 September 2009. Retrieved 22 September 2009.
55. "Are there enough engines in F1 in 2010?" (http://www.grandprix.com/ns/ns21833.html). *Grandprix.com*. Inside F1. Archived (https://web.archive.org/web/20121015180647/http://www.grandprix.com/ns/ns21833.html) from the original on 15 October 2012. Retrieved 2 June 2011.
56. "The basics of F1 KERS" (https://www.racecar-engineering.com/articles/the-basics-of-f1-kers/). 14 April 2009.
57. "F1 2013: The last of the V8's" (https://www.racecar-engineering.com/articles/f1/f1-2013-the-last-of-the-v8s/). 11 October 2013. Archived (https://web.archive.org/web/20201111193143/https://www.racecar-engineering.com/articles/f1/f1-2013-the-last-of-the-v8s/) from the original on 11 November 2020. Retrieved 24 February 2021.

58. "F1: Take a look at what's inside a Formula 1 engine | Car News | Auto123" (https://www.auto123.com/en/news/f1-take-a-look-at-whats-inside-a-formula-1-engine/33688/).
59. "FIA Formula One World Championship Power Unit Regulations" (http://www.fia.com/en-GB/mediacentre/pressreleases/f1releases/2011/Pages/f1-2014-engine1.aspx). FIA. 29 June 2011. Archived (https://web.archive.org/web/20111208064506/http://www.fia.com/en-GB/mediacentre/pressreleases/f1releases/2011/Pages/f1-2014-engine1.aspx) from the original on 8 December 2011. Retrieved 30 November 2011.
60. Allen, James (20 April 2011). "F1 set for electric only in the pit lane?" (http://www.jamesallenonf1.com/2011/04/f1-set-for-electric-only-in-the-pit-lane/). *JamesallenonF1.com*. Archived (https://web.archive.org/web/20110623150039/http://www.jamesallenonf1.com/2011/04/f1-set-for-electric-only-in-the-pit-lane/) from the original on 23 June 2011. Retrieved 2 June 2011.
61. "Teams are keeping revs under 12000 rpm" (http://blog.axisofoversteer.com/2014/03/teams-are-keeping-revs-under-12000-rpm.html). Archived (https://web.archive.org/web/20141016192650/http://blog.axisofoversteer.com/2014/03/teams-are-keeping-revs-under-12000-rpm.html) from the original on 16 October 2014. Retrieved 11 October 2014.
62. Haupt, Andreas (30 July 2019). "Motorleistung der Formel 1 (2019): Renault erreicht die 1.000 PS" (https://www.auto-motor-und-sport.de/formel-1/motorleistung-f1-2019-renault-1000-ps/). *auto motor und sport*. Archived (https://web.archive.org/web/20210128161348/https://www.auto-motor-und-sport.de/formel-1/motorleistung-f1-2019-renault-1000-ps/) from the original on 28 January 2021. Retrieved 11 December 2020.
63. "Red Bull To Take On Honda F1 Power Unit Technology From 2022" (https://www.redbull.com/int-en/redbullracing/red-bull-take-on-honda-f1-pu). *Red Bull*. Archived (https://web.archive.org/web/20210301003515/https://www.redbull.com/int-en/redbullracing/red-bull-take-on-honda-f1-pu) from the original on 1 March 2021. Retrieved 16 March 2021.
64. "Formula 1's 2021 regulations: What's new for 2021?" (https://www.autosport.com/f1/news/formula-1s-2021-regulations-whats-new-for-2021-5115288/5115288/). *Autosport.com*. 15 January 2021. Archived (https://web.archive.org/web/20210913104046/https://www.autosport.com/f1/news/formula-1s-2021-regulations-whats-new-for-2021-5115288/5115288/) from the original on 13 September 2021. Retrieved 13 September 2021.
65. "Formula 1 unveils 2021 engine plans" (https://www.speedcafe.com/2017/11/01/formula-1-unveils-2021-engine-plans/). *speedcafe.com*. 1 November 2017. Archived (https://web.archive.org/web/20171107131517/https://www.speedcafe.com/2017/11/01/formula-1-unveils-2021-engine-plans/) from the original on 7 November 2017. Retrieved 8 September 2020.
66. "F1 2021: Liberty's 4WD, Porsche & Spec PU's" (https://thejudge13.com/2018/05/08/f1-2021-libertys-4wd-porsche-spec-pus/). *thejudge13.com*. 8 May 2018. Archived (https://web.archive.org/web/20200927041808/https://thejudge13.com/2018/05/08/f1-2021-libertys-4wd-porsche-spec-pus/) from the original on 27 September 2020. Retrieved 8 September 2020.
67. Noble, Jonathan (26 October 2017). "Analysis: Why 4WD is on Formula 1's agenda" (https://www.motorsport.com/f1/news/analysis-why-4wd-is-on-formula-1-s-agenda-970296/1372054/). *motorsport.com*. Archived (https://web.archive.org/web/20201111210504/https://www.motorsport.com/f1/news/analysis-why-4wd-is-on-formula-1-s-agenda-970296/1372054/) from the original on 11 November 2020. Retrieved 8 September 2020.
68. Jamie Woodhouse (28 February 2022). "All the major changes for the F1 2022 season" (https://www.planetf1.com/features/major-changes-f1-2022-season/).
69. Cooper, Adam (10 July 2018). "F1 manufacturers push back on 2021 engine proposals" (https://www.autosport.com/f1/news/f1-manufacturers-push-back-on-2021-engine-proposals-5297298/5297298/).
70. "F1's 2026 power unit regulations approved by FIA's World Motor Sport Council · RaceFans" (https://www.racefans.net/2022/08/16/f1s-2026-power-unit-regulations-approved-by-fias-world-motor-sport-council/). 16 August 2022.
71. "Audi to join Formula 1 from 2026 | Formula 1®" (https://www.formula1.com/en/latest/article.breaking-audi-to-join-formula-1-from-2026.yr9pFVd5nSQBbZ7EZZDLJ.html). *www.formula1.com*. Retrieved 26 August 2022.
72. "Ford announce plans to return to F1 from the 2026 season | Formula 1®" (https://www.formula1.com/en/latest/article.breaking-ford-announce-plans-to-return-to-f1-from-the-2026-season.4X1AqB0KMlp8iXka9ngPJ8.html). *www.formula1.com*. 3 February 2023.
73. "Ford announce new technical partnership with Red Bull for 2026 and beyond | Formula 1®" (https://www.formula1.com/en/latest/article.breaking-ford-announce-new-technical-partnership-with-red-bull-for-2026-and.177bB2z0b7Iw6C79l1YQ9b.html). *www.formula1.com*. 3 February 2023.

74. "BREAKING: Ford to partner with Red Bull for the 2026 season and beyond" (https://twitter.com/F1/status/1621527091425742849). *Formula 1 Twitter*.
75. Cooper, Sam (3 February 2023). "FIA confirm six engine suppliers, including Honda and Ford, signed up for F1 2026" (https://www.planetf1.com/news/fia-eningw-suppliers-honda-ford-f1-2026/). *PlanetF1*. Retrieved 3 February 2023.
76. "FIA Confirms 2026 Formula 1 Power Unit Supplier Registrations" (https://www.fia.com/news/fia-confirms-2026-formula-1-power-unit-supplier-registrations). *Federation Internationale de l'Automobile*. 3 February 2023.
77. Brittle, Cian (22 March 2023). "Report: Porsche rules out F1 entry in 2026" (https://www.blackbookmotorsport.com/news/porsche-rules-out-f1-red-bull-mclaren-audi-2026). *www.blackbookmotorsport.com*.
78. Fédération Internationale de l'Automobile. "2022 FORMULA ONE TECHNICAL REGULATIONS" (https://www.fia.com/sites/default/files/2022_formula_1_technical_regulations_-_iss_1_-_2020-03-30.pdf) (PDF). Archived (https://web.archive.org/web/20200501101647/https://www.fia.com/sites/default/files/2022_formula_1_technical_regulations_-_iss_1_-_2020-03-30.pdf) (PDF) from the original on 1 May 2020.
79. "How Formula One's Amazing New Hybrid Turbo Engine Works" (https://jalopnik.com/how-formula-ones-amazing-new-hybrid-turbo-engine-works-1506450399). 22 January 2014. Archived (https://web.archive.org/web/20140814082742/http://jalopnik.com/how-formula-ones-amazing-new-hybrid-turbo-engine-works-1506450399) from the original on 14 August 2014. Retrieved 9 August 2014.
80. Fédération Internationale de l'Automobile (23 January 2014). "2014 FORMULA ONE TECHNICAL REGULATIONS" (http://www.fia.com/sites/default/files/regulation/file/1-2014%20TECHNICAL%20REGULATIONS%202014-01-23.pdf) (PDF). Article 5.1 on p.21. Archived (https://web.archive.org/web/20140327054505/http://www.fia.com/sites/default/files/regulation/file/1-2014%20TECHNICAL%20REGULATIONS%202014-01-23.pdf) (PDF) from the original on 27 March 2014. Retrieved 12 August 2014.
81. "2006 Formula One Technical Regulations" (https://docs.google.com/file/d/0B5usQbzMMNVTWE5udlBtMGlOWkk/edit?pli=1&usp=embed_facebook). Archived (https://web.archive.org/web/20201111094047/https://docs.google.com/file/d/0B5usQbzMMNVTWE5udlBtMGlOWkk/edit?pli=1&usp=embed_facebook) from the original on 11 November 2020. Retrieved 10 November 2020.
82. "How Long do F1 Engines Last? | F1 Chronicle" (https://f1chronicle.com/how-long-do-f1-engines-last/). 17 June 2020. Archived (https://web.archive.org/web/20210425111801/https://f1chronicle.com/how-long-do-f1-engines-last/) from the original on 25 April 2021. Retrieved 25 April 2021.
83. "F1 rules and stats 1960–1969" (http://www.f1technical.net/articles/24). 1 January 2009. Archived (https://web.archive.org/web/20140812204537/http://www.f1technical.net/articles/24) from the original on 12 August 2014. Retrieved 9 August 2014.
84. "Spicer Horsepower and Torque Calculator" (https://spicerparts.com/calculators/horsepower-torque-calculator).
85. "F1: A brief history of the US Grand Prix" (https://racingnews.co/2012/11/14/f1-a-brief-history-of-the-us-grand-prix/). *F1.com*. 14 November 2012. Archived (https://web.archive.org/web/20181021174918/https://racingnews.co/2012/11/14/f1-a-brief-history-of-the-us-grand-prix/) from the original on 21 October 2018 – via Racing News.
86. "Audi set to announce 2026 F1 entry early next year" (https://www.autocar.co.uk/car-news/motorsport-news-f1/audi-set-announce-2026-f1-entry-early-next-year). *Autocar*. Retrieved 8 January 2022.

External links

- Formula One Engines (http://www.f1technical.net/articles/4) In-depth article covering facts, evolution and tech specs of F1 engines 2009
- Racecar Engineering (https://web.archive.org/web/20081106195349/http://www.racecar-engineering.com/articles/f1/273555/inside-an-f1-engine.html) F1 Engines

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