Progress over 64 years of Grand Prix racing:- 1951 to 2014

In order to compare Grand Prix car speeds between the start of the Drivers' World Championship in 1950 and the 2014 season – which, coincidentally involves engines of about the same size, 1.5 and 1.6 litres respectively, both Pressure-Charged (PC) – a problem of circuit changes has first to be solved. In only 3 venues (Monza, Monaco and Silverstone) has the geographical location of a circuit remained unchanged but, at each of these, the diagram has been altered very significantly to reduce speeds. Many new circuits are now used.

To overcome the circuit problem a correlation was sought for a given type of car over a season against a "Track Factor" (TF) derived purely from the geometry of the diagram. Historically, the relation of Lap Speed (LS) to circuit geometry and other characteristics was something which Mercedes-Benz investigated before and after WW2 by manual calculations. They claimed an accuracy of 1% (77). Of course, they had all the data needed on car and tyre performance as well as accurate circuit diagrams. Nowadays, teams have computer programmes to do the job, also being able to input all acceleration, braking and cornering information – and perhaps an algorithm to describe the driver's ability! This complete information is not available to outsiders so a simple empirical approach has been used to find a TF which enables LS to be correlated sufficiently accurately to be able to make the multi-decade comparison desired.

Determination of Track Factor (TF)

The list of factors which can influence Lap Speed (LS) is a daunting one, as shown on P.2, Table 1. For the purpose of this review it was found possible to simplify it for one type of car across a season to a function of:-

- Lap Length (L) (metres have been used);
- Total turning per lap (T) degrees.

The value of T is measured directly from the circuit diagram (official FIA). By identifying Right and Left turns a check can be made on the accuracy of the measurement from their difference, which must be 360^0 except where the track crosses over itself, as at Suzuka, where the difference is 0.

It was quickly found necessary to distinguish between "Tracks"* with flat kerbs and wide run-offs and "Streets" with hard edges (and often poor quality surfaces). The lack of easy run-off is a powerful incentive to a driver to keep something in hand to avoid damage to the car and himself. Certain other special cases where particular conditions apply and which have to be excluded from a correlation are described in Appendix PA1.

Data used for the correlation was the 2013 season with 2.4 litre 90^0V8 Naturally Aspirated (NA) engines. This provided 12 Track examples of dry Q3 speeds. The Pole figure was used, irrespective of whether Mercedes or Red Bull-Renault or which driver, since the differences in speed were well below anything which could be expected from such a simple correlation. One particular effect which could not be allowed for was that, although only Pirelli tyres were used, they varied the frictional grip characteristics through the season. Since engine specifications were frozen by FIA rule at least power curves were constant over the year.

A log Multiple Regression Analysis (MRA) was carried out for :-

$$LS \quad v. \quad [\, L^N \times T^M].$$

After some trial and error the [Circuit Ambient Temperature]^P was also included as a small improvement (Caution! This can only be valid over the range of 15C to 35C considered).

The result of the 2013 season MRA, after simplifying the exponents, shown on Fig. 1 with data on Table 2 on P.3, was:-

$$LS = 85.73 \times \mathbf{[}(L)^{0.4}/((T)^{0.3} \times (\text{Temp. deg. C})^{0.1})\mathbf{]} \text{ kph.}$$

The bracketed term **[ ]** is the Track Factor (TF).

As before mentioned the 2 Street circuits, Monaco (TF = 1.99) and Singapore (TF = 2.28) were excluded from the MRA and the trend line of Fig. 1.

---

*Including rebuilt road circuits such as Spa from 1983.

TABLE 1

FACTORS WHICH FIX LAP SPEEDS THROUGH A RACING SEASON

- **VEHICLE SPECIFICATION**
  - Car } As originally designed and with original range of
  - Tyres } adjustments and alternatives
  - Set-Up particular to a circuit, covering choice of original adjustments or alternatives to :-
    - Engine variables (egs. Valve and Ignition timing, Fuel/Air ratio)
    - Gear Ratios (Final drive and Intermediates)
    - Chassis variables (Aerodynamics, Suspension, Steering, Braking)
    - Fuel
    - Tyre type for each wheel
  - Modifications during the season, beyond the original ranges, for all elements of Specification

- **FUEL LOAD**

- **DRIVER**
  - Inherent driving ability and courage
  - Rapport with the car and ability to describe its qualitative performance to the Engineer (nowadays telemetry gives the quantitative data)
  - Knowledge of each circuit
  - Form on-the-day and on-the-lap

- **CONSUMPTION FACTORS**

  The Engineer and Driver can maximise lap speed at the expense of the life of :-
  - Engine, Tyres, Brake-pads, Fuel
  - Driver's Physical and Nervous Energy

- **TRACK SPECIFICATION**
  - Number and Lengths of Straights
  - Number and Radii of Corners and their Turning Angles
  - Sequence of Straights and Corners
  - Changes of direction between successive Corners
  - Width
  - Surface Grip, Bumpiness and Cleanliness
  - Camber and Banking
  - Hills
  - Average Atmospheric conditions (Temperature, Pressure, Humidity) for circuit geographic location (Latitude, Longitude, and Altitude) and seasonal race date
  - Run-off Margins and Safety Features generally

- **WEATHER**
  - Dry or Wet
  - Atmospheric conditions on-the-lap, as variables from the circuit average
  - Wind Speed, Direction and Gustiness

- **RACING TRAFFIC ON-THE-LAP**

Fig 1 and Table 2 are shown on P.3

Although the accuracy of individual points is not particularly high – the average error of the 12 trend line examples being ∓2.7% from the line – it is considered good enough for the desired purpose of multi decade comparison.

Fig 1

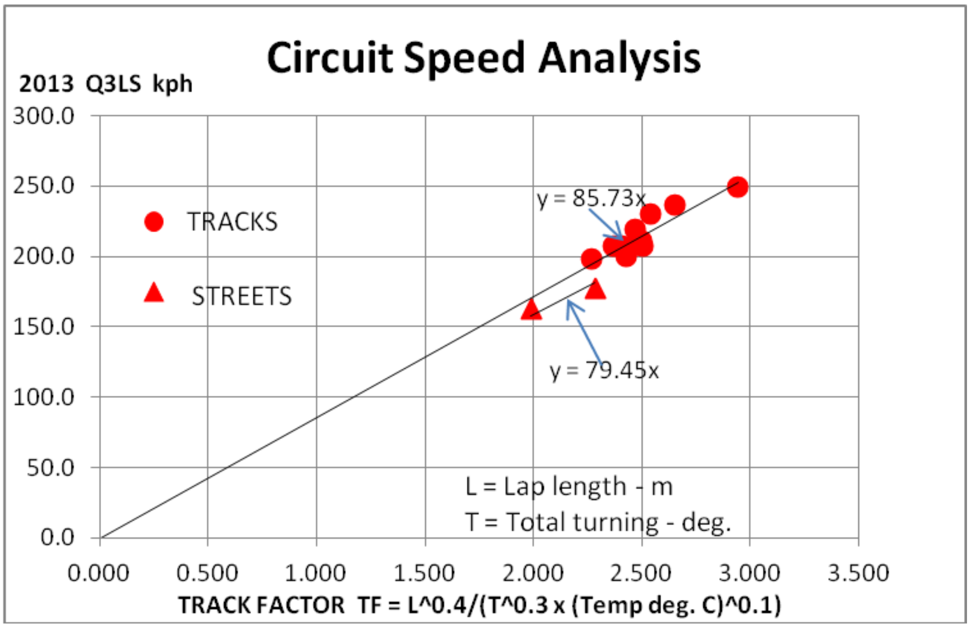


Table 2

YEAR 2013							
Tyres:- Pirelli only; Variable friction coefficients through the season							
Car:- Polesitter; RB = Red Bull; M = Mercedes	M	M	M	M	M	RB	RB
Driver:- V = Vettel; R = Rosberg; H = Hamilton; W = Webber	H	R	R	H	H	V	V
CIRCUIT	S'hai	Bahrain	Barcelona	S'stone	Hung'ring	Monza	Korea
Abbrvn.	SH	BN	BA	SI	HU	MA	KA
Altitude - Metres	4	15	123	149	232	185	0
Type - T = Track; S = Street	T	T	T	T	T	T	T
Pole Speed Q3LS - kph	207.7	211	207.6	236.7	198.7	249	207.9
Geometry							
L - Metres	5451	5412	4655	5891	4381	5793	5615
T = Turning - Degrees	1820	1372	1550	1642	1508	918	1704
Temperature - C	15	35	19	16	30	30	22
TF = (L)^0.4/((T)^0.3 x (Temp)^0.1)	2.506	2.499	2.411	2.649	2.267	2.942	2.489
Pole Speed Q3LS - kph	207.7	211.0	207.6	236.7	198.7	249.0	207.9
(Actual - Est)/Est - %	-3.32	-1.50	0.44	4.24	2.25	-1.27	-2.58
Average error disregarding sign- %	2.7						

YEAR 2013							
Tyres:- Pirelli only; Variable friction coefficients through the season							
Car:- Polesitter; RB = Red Bull; M = Mercedes	RB	RB	RB	RB	M	M	R
Driver:- V = Vettel; R = Rosberg; H = Hamilton; W = Webber	W	V	W	V	H	R	V
CIRCUIT	Suzuka	N. Delhi	Abu Dhabi	Austin	N'N'ring	Monaco	Singapore
Abbrvn.	SU	ND	AD	AN	NN	MO	SN
Altitude - Metres	36	193	0	155	586	2	10
Type - T = Track; S = Street	T	T	T	T	T	S	S
Pole Speed Q3LS - kph	229.9	219	200	206	207.3	162.8	177.3
Geometry							
L - Metres	5807	5125	5554	5513	5148	3340	5065
T = Turning - Degrees	1622	1358	1746	1780	1610	1856	1786
Temperature - C	24	33	25	22	30	20	30
TF = (L)^0.4/((T)^0.3 x (Temp)^0.1)	2.538	2.467	2.429	2.439	2.371	1.990	2.283
Pole Speed Q3LS - kph	229.9	219.0	200.0	206.0	207.3	162.8	177.3
(Actual - Est)/Est - %	5.65	3.55	-3.96	-1.47	1.99	-4.57	-9.42

The 2014 season commences on P.4

The 2014 season

The plot of LS v. TF for the 1.6litre PC cars of 2014 is given on Fig 2 and the data on Table 3. In this plot only the Mercedes AMG W05, 1.6litre TurboCharged with hybrid assistance, is considered. It was on Pole for 18 out of 19 races (a Williams FW36/Mercedes PU106A took Pole in Austria). As 5 qualifications were wet there are 11 dry Q3 W05 examples shown, *excluding* the Street circuits of Monaco and Singapore from the trend calculation and *also excluding* Sao Paulo. The latter exclusion is because the circuit is at an altitude of 770 metres and the TurboCharged engines are able to restore sea-level power in a lower-drag atmosphere (the track also had been given a new high-grip surface).

The trend calculation gives:-

$$LS = 82.83 \times TF \text{ kph.}$$

The average error for these 11 points is ∓2.6% (if Suzuka, a track described by Pirelli as "relatively abrasive" is not counted, the average error is ∓2.1%)..

Fig 2

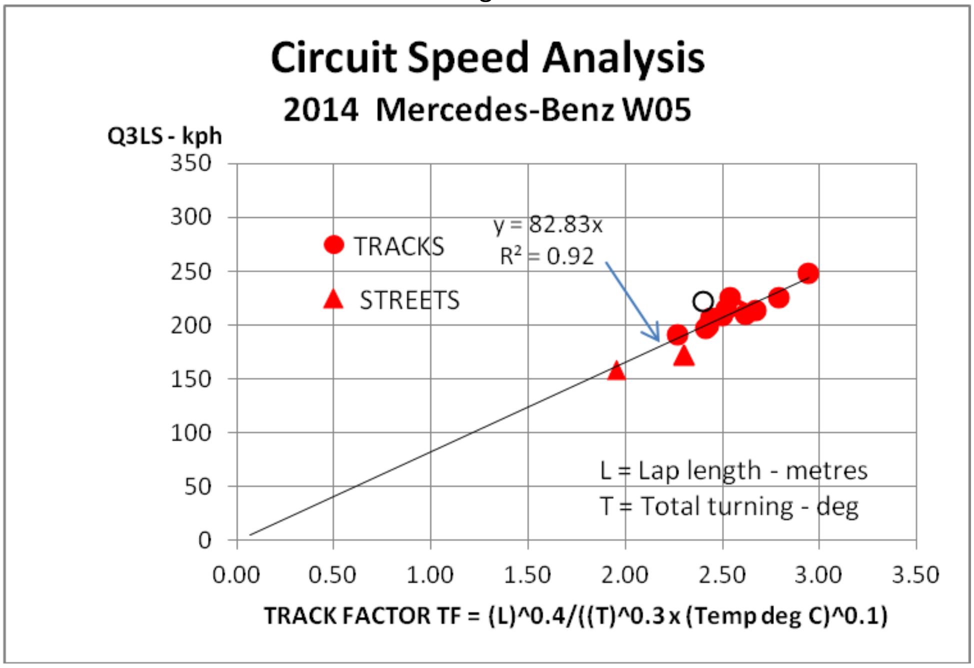


Table 3

YEAR 2014 Tyres:- Pirelli only; Variable friction coefficients through the season Car:- M = Mercedes Driver:- R = Rosberg; H = Hamilton;	M R	M H	M R	M R	M R	M R	M H
CIRCUIT	Bahrain	B'lona	Montreal	Austria	H'heim	Hungary	Monza
Abbrvn.	BN	BC	ML	AU	HO	HU	MA
Altitude - Metres	15	123	8	690	111	232	185
Type - T = Track; S = Street	T	T	T	T	T	T	T
Speed Q3LS - kph	209.1	196.6	209.7	225.9	215.1	190.7	247.9
Geometry							
L - Metres	5412	4655	4361	4326	4574	4381	5793
T = Turning - Degrees	1372	1550	1080	894	1230	1508	918
Temperature - C	35	19	19	17	23	30	30
TF = (L)^0.4/((T)^0.3 x (Temp)^0.1)	2.50	2.41	2.62	2.79	2.52	2.27	2.94
Speed LS - kph	209.1	196.6	209.7	225.9	215.1	190.7	247.9
(Actual - Est)/Est - %	1.03	-1.55	-3.29	-2.33	3.15	1.57	1.74
Average error disregarding sign- %	2.6 Without Suzuka = 2.1%						

Table 3 is continued on P.5

Table 3 continued

Car:- M = Mercedes Driver:- R = Rosberg; H = Hamilton;	M R	M H	M R	M R	M R	M R	M H
CIRCUIT	Suzuka	Sochi	Austin	A'Dhabi	S. Paulo	Monaco	S'pore
Abbrvn.	SU	SO	AN	AD	SP	MO	SI
Altitude - Metres	36	10	155	0	770	2	10
Type - T = Track; S = Street	T	T	T	T	T	S	S
Speed Q3LS - kph	226	214	207	199	221.5	158.2	172.5
Geometry							
L - Metres	5807	5853	5513	5554	4309	3340	5065
T = Turning - Degrees	1622	1470	1780	1746	1398	1856	1786
Temperature - C	24	20	22	25	20	24	28
TF = (L)^0.4/((T)^0.3 x (Temp)^0.1)	2.54	2.67	2.44	2.43	2.40	1.954	2.299
Speed LS - kph	226	214	207	199	221.5	158.2	172.5
(Actual - Est)/Est - %	7.49	-3.31	2.27	-1.09	11.48	-2.25	-9.42

The 1951 season

The 1951 season, rather than the 1st World Drivers' Championship season of 1950, was chosen for the comparison with 2014. This was because in that year the Alfa Romeo 159/159M 1.5litre Mechanically Supercharged (MSC) car was pressed to its utmost by the Ferrari type 375 4.5litre Naturally Aspirated (NA) car. Eventually the Alfa powered the World Champion, Juan Fangio. The practice speeds, or race speeds if faster, are shown against TF on Fig 3 and the data on Table 4.The 5 Track points taken into the trend calculation are 4 classic Grand Prix races plus a race at Goodwood (TF = 3.07). Monza and the Nurburgring (NU) are excluded for reasons given in Appendix PA1, as is also Dundrod (DU).This Appendix also discusses the 2 Street circuits of 1951 Bari (TF=2.90) and Barcelona Pedralbes (TF=3.56)) plus the 2 Street circuits of 1950 (San Remo and Monaco) which were added to give some illustration of the low speed area where the Alfa did not race in 1951.

The trend is:-

$$LS = 47.4 \times TF.$$

The 5 point accuracy is substantially less than for 2014 at $\mp$4.2%.

Fig 3

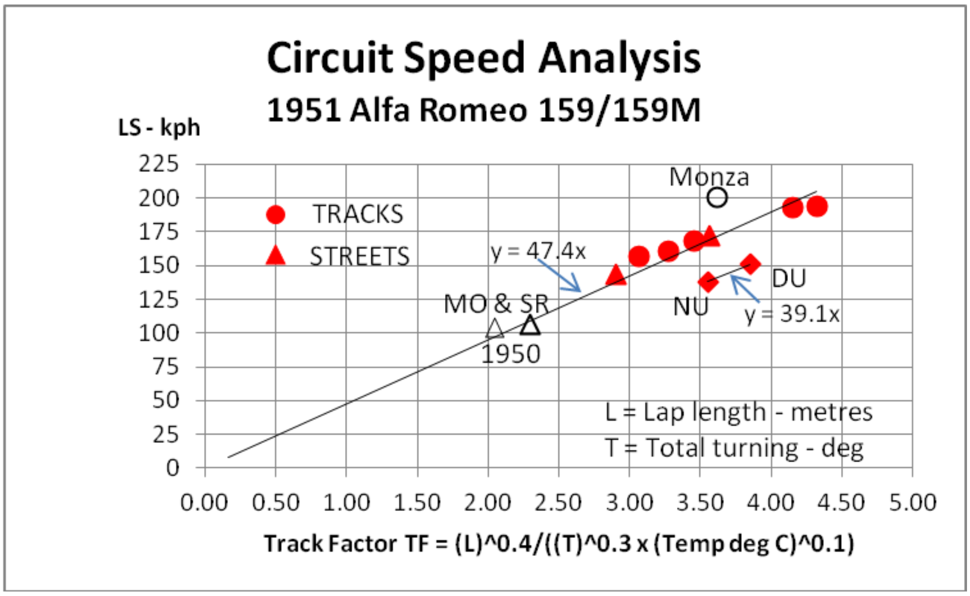


Table 4 is given on P.6

Table 4

YEAR 1951 Tyres:- Pirelli Car:- Alfa Romeo 159/159M						
Driver:- F = Fangio; Fa = Farina	F	F	F	F	Fa	F
CIRCUIT	Berne	Spa	Rheims	S'stone	G'wood	Monza
Abbrvn.	BE	SP	RH	SI	GO	MA
Altitude - Metres	567	414	88	149	28	185
Type - T = Track; S = Street	T	T	T	T	T	T
Speed in Practice P or in Race if faster R	P	R	P	P	R	P
Speed LS - kph	168.1	193.9	193.1	160.3	156.7	200.4
Geometry						
L - Metres	7280	14120	7816	4649	3863	6300
T = Turning - Degrees	920	1028	460	604	586	516
Temperature - C	15	16	25	15	15	30
TF = (L)^0.4/((T)^0.3 x (Temp)^0.1)	3.45	4.32	4.16	3.27	3.07	3.62
Speed LS - kph	168.1	193.9	193.1	160.3	156.7	200.4
(Actual - Est)/Est - %	2.63	-5.49	-2.04	3.21	7.67	16.81
Average error disregarding sign- %	4.2					

Table 4 continued

Car:- Alfa Romeo 159/159M						
Driver:- F = Fangio; Fa = Farina	F	Fa	F	F	F	F
CIRCUIT	N'ring	Dundrod	Bari	Pedralbes	San Remo	Monaco
Abbrvn.	NU	DU	BI	BP	SR	MO
Altitude - Metres	618	125	5	69	6	2
Type - T = Track; S = Street	T	T	S	S	S	S
Speed in Practice P or in Race if faster R	R	R	P	P	P*	P*
Speed LS - kph	137.8	151.3	143.3	171.9	106.8	103.9
Geometry						
L - Metres	22810	11935	5580	6316	3336	3180
T = Turning - Degrees	3840	1234	972	586	1326	1494
Temperature - C	15	15	25	24	13	24
TF = (L)^0.4/((T)^0.3 x (Temp)^0.1)	3.55	3.85	2.90	3.56	2.30	2.04
Speed LS - kph	137.8	151.3	143.3	171.9	106.8	103.9
(Actual - Est)/Est - %	- 18.21	-17.22	4.11	1.70	-1.99	7.10
						*1950

Conclusion

Comparison of 1951 with 2014

_On the trend lines shown on Figs. 2 and 3.the lap speed ratio at a given Track Factor for the Mercedes-Benz AMG W05 with PU106A Hybrid power unit compared with the Alfa Romeo 159/159M is:-

$$\frac{2014\ LS}{1951\ LS} = \frac{82.83}{47.4} = 1.75.$$

The reasons for this 75% increase in speed are discussed in the following section.

Causes of speed improvements over 64 years:- 1951 to 2014

An Illustrative Appendix PA2 is provided

Power unit description

The cars were approximately the same swept volume:-

the Alfa (see Fig PA2-1) was 1.5litres; the Mercedes (PA2-2) was 1.6litres.

Both were Pressure-Charged:- the Alfa Mechanically Supercharged (MSC); the Mercedes TurboCharged (TC). It was part of a Hybrid power plant. This had a dynamotor coupled to the back axle which could provide electrical energy to a battery when used to assist braking and alternatively take back this recycled battery energy to add extra power to the axle. The battery could also be charged via another dynamotor coupled to the TurboCharger, when this had a surplus to engine compression needs,. Alternatively the second dynamotor could accelerate the TC after a throttle closure, using battery energy.

Progress in technical factors

The 75% increase in lap speed has come from:-

better materials;

improved design,

since "Man as Racing Driver" will not have become faster over 64 years. The Driver will, however, be a fitter man in 2014 compared to 1951 because he has to withstand lateral and longitudinal acceleration and deceleration forces several times higher (as will be discussed later). This stress is imposed 19 times in the year, whereas in 1951 there were just 7 classics, with a few non-Championship events. The offset is that classic races now only last about 1.5 hours over 300 km whereas the 1951 races averaged about 2.8 hours over an average 460 km.

An important factor is that the 2014 racing engine had to last much longer than in 1951 without overhaul because only 5 engines without overhaul were allowed per driver for all 19 races – penalties were imposed if extra engines were used.

Separating the factors involved in the 75% advance these are:-

- MORE POWER;
- LESS WEIGHT;
- LOWER CENTRE OF GRAVITY;
- BETTER BRAKES;
- BETTER TYRES;
- AERO DOWNFORCE.
- FASTER GEARCHANGING

Some of the gain must have followed from increased driver confidence arising from:-

- SAFER CIRCUITS;
- SAFER CARS.

The question of

- CHASSIS SUSPENSION

is considered to be open.

Each of these factors will now be considered in detail.

MORE POWER

The 1951 AR 159 practiced and raced with about 400HP while the 2014 M-B W05 had around 600HP from the basic engine + 161HP for 33 seconds per lap (say, about 40% of the lap) from battery energy. The level and duration of this electrical assistance was set by FIA rule. Total 761 HP.

Therefore, as a maximum, the 2014 car had **90% more power** than the 1951 **car**.

It *could* have been a great deal more but for 2 more restrictive FIA rules:-

Firstly, that the fuel flow of 87 Average Octane Number FIA fuel mix (94.25% petrol + 5.75% bio-ethanol) must not exceed 100 kg/hr;

Secondly, that the fuel ration for the 2014 standard race distance of 300 km is limited to 100 kg (138 litres). This was 46 litres per 100 km. Part of this figure was achieved by the recycling of energy from the battery.

The AR 159 had no restrictions on fuel quality or quantity and burned 98% methanol at a rate of 180 litres per 100 km, nearly 4x higher *volumetric* consumption rate, or about 2x the *energy* consumption rate allowing for the difference in fuel heat value. The high alcohol content with a very rich Fuel/Air ratio was needed to cool the (inefficiently) compressed inlet charge to prevent detonation, give a denser charge and also to cool the engine by some liquid entering the cylinders.

Running on petrol injected directly into the cylinder the PU106 required an intercooler to cool the compressed charge to provide a denser charge and permit a reasonable compression ratio.

Basic engine specifics

A glossary of abbreviations follows before listing the basic engine specifics:-

V = Swept Volume Litres
PP = Peak Power HP*
NP = RPM @ PP
BMPP = BMEP @ PP Bar
MPSP = Mean Piston Speed @ PP m/s
IVP = Inlet Valve Pressure ATA (Atmospheres Absolute)
MDR = Manifold Density Ratio relative to ambient
ECOM = [EV x EC x EM] where EV = Volumetric Efficiency
EC = Combustion Efficiency
EM = Mechanical Efficiency

$$= \frac{BMPP}{38 \times ASE \times MDR}$$

and $ASE = 1 - \left(\frac{1}{R^{0.4}}\right)$

R = Compression Ratio.

*Data is not accurate enough to distinguish between BHP and Continental HP(-1.4%).

	1951 AR159M	**2014** M-B PU106A Hybrid
	See 1st Pressure-Charged Era, Eg. 29 and also Appendix 1, column AD	
Configuration; Bore (B) mm; Stroke (S) mm	IL8; 58; 70	90^0V6; 80; 53 (Bmax set by rule)
V	1.480	1.598
B/S	0.829	1.509
PP	400	600
@ NP	9,000	10,500 where 100 kg/hr Is reached by rule
PP/V	270	375
BMPP	26.9	32.0
@ MPS	21.0	18.6
R	7.5	Say, 12
IVP	3.9	2 approx**
MDR	2.86	1.9
ECOM	45%	70%

**Calculated from fuel flow and chemically-correct Fuel/Air ratio

This shows the large gain in efficiency of the 2014 engine.

Taking each Efficiency in turn

Volumetric Efficiency (EV)

This was improved in the PU106A compared to the AR159 by the use of "ramming" impulses from tuned and individual inlet tracts coupled with suction waves from tuned exhausts. The 1st GP TurboCharged engine of 1.5 litres from Renault in 1977, which started by de-stroking their well-developed F2 2 litre engine, fitted a pressurised plenum chamber before the tuned inlets, fed by the TurboCharger (see Fig PA2-3). In contrast, pre-1951 supercharged engine designers had got all they thought they needed from their blowers and their inlet manifolds made no intentional use of resonances. All subsequent TC engines retained the Renault system. By retaining the throttles close to the inlet valves power cut-off was not delayed while the plenum chamber emptied.

Keith Duckworth in 1967 in his DFV engine (see Fig PA2-4 and "The Unique Cosworth Story") had re-introduced 4 valves per cylinder to GP racing but at a narrow included angle (VIA) and all subsequent Championship-winning engines had followed this lead. The PU106 was no exception. Duckworth had designed his inlet tracts to provide in-cylinder "Barrel Turbulence" (aka "Tumble Swirl") so as to optimise the product of [EV x EC]. It may be that the introduction of high-pressure direct-into-cylinder fuel injection (see below) in place of relatively-low pressure port injection has enabled M-B to re-optimise the inlet tract to give higher EV.

Some speculative details of the inlet valve system for the PU106A are compared with the AR159 as follows:-

	AR159M	PU106A
No. of valves per cylinder	2	4
VIA	100^0	Probably 20^0 or less
Inlet valve head diameter (IVD) mm	36	Estimate about 34 (if IVA/PA similar to Cosworth CA; see Note 108)
Valve Area/Piston Area (IVA/PA)	0.385	0.361
Max. Valve Lift (IVL) mm	8	Estimate about 13 (from IVL/IVD)
Valve Lift/Diameter (IVl/IVD)	0.222	0.382 (if similar to Cosworth CA; see Note 108)

Duckworth had found it unnecessary to use IVA/PA as large as the AR159 figure (the DFV was 0.306) but had increased the IVL/IVD ratio beyond that theoretically needed to give skirt area equal to port area (the DFV was 0.31). However, these ratios had been increased in later engines, as noted for the CA.

The increased values for IVL/IVD were made possible by a development which, in the first place, was produced in order to permit higher values of Mean Valve Speed (MVS) so that B/S ratio could be raised to increase RPM at limiting MPS and therefore power – Pneumatic Valve Return System (PVRS- a designation by Honda). Originally invented by Jean-Pierre Boudy of Renault (see Fig PA2-5) to overcome problems with the EF1 TC engine because it had B/S excessive for its steel coil spring valve return system, it really became the "way-to-go" in the early '90s. PVRS solved the problem of valve return but it needed the development of "Diamond-Like Carbon" (DLC) surface coating to allow the opening contact stresses at high values of MVS to be tolerated. This ultra-low-friction treatment was available around 1994 (see Note 103).

A comparison of 1951 and 2014 MVS is as follows:-

	AR159M	PU106A
Inlet valve Opening Period (IOD)	290^0	Estimate 320^0
Mean Valve Speed (MVS) m/s	2.98	5.12

The level of MVS estimated for the PU106 can be handled easily by PVRS. In the Cosworth type CA a figure of about 11 was achieved and stresses are proportional to $(MVS)^2$.

[In the 3rd NA period 1989-2013 the valve gear problem was eased by low-density Titanium-alloy inlet *and* exhaust valves, but it seems unlikely that the 2014 TC engines can use this material for exhausts.]

Combustion Efficiency (EC)

It is probable that EC was increased substantially in the PU106A, without needing a compromise on the inlet tracts to promote Tumble Swirl, by having direct-into-cylinder petrol injection (DPI) at a pressure of 500 Bar. DPI was a requirement for the 2014 formula, not used in successful GP engines since the 1964 Ferrari, and the fuel pressure allowed was far above anything used previously in petrol racing units. The AR159 drew its fuel by suction from a 3-throat carburetter but the mixture would have received favourable "mashing" and heating in the down-stream 2-stage Roots superchargers.

Mechanical Efficiency (EM)

In the AR159 the Pressure-Charging was done by 2 stages of Roots blowers in series driven from the crank (see Fig PA2-6). Having no internal compression this type of supercharger suffered losses from its fluctuating delivery into the inlet manifold. There was a direct subtraction of 25% of crank power to produce 3.9 ATA compression (31), only part of which was recovered by the pressure on the inlet stroke. There was, of course, no recovery of the exhaust gas pressure – although it did produce a glorious boom! In a MSC engine there was therefore a lower EM than in an NA engine, if other factors were the same.

The PU106A TC engine had the advantage of higher efficiency from the centrifugal compressor and, of course, the extraction of energy from the exhaust (see Figs PA2-7 & -8). With the pneumatic boost from the pressure on the inlet stroke only partly offset by the increased exhaust back-pressure and no crank power subtraction EM was increased compared to an NA engine.

Another way of putting it, as a heat engine the AR159 efficiency suffered from 3 stages of compression and only 1 of expansion; the PU106A gained from 2 stages of compression and also 2 stages of expansion.

As already mentioned, DLC on rubbing parts reduced friction.

EM was also improved in the 2014 engine through the use of synthetic oil instead of the castor (vegetable-base) oil of the Alfa Romeo.

LESS WEIGHT

The AR159 weighed about 778 kg dry, to which 11 kg of water and 29 kg of oil had to be added to reach 818 kg without fuel or driver. The burly Fangio at 80 kg and a few laps-worth of methanol for practice, say 40 kg, would have taken the car ready for a fast lap up to 938 kg.

This compares with a rule minimum for the W05 complete with water and oil and driver of 691 kg , assumed achieved. With 10 kg of petrol for a Q3 sprint the total was 701 kg, **24% less than the Alfa**. This was despite the 2014 car having many regulation safety features:-reinforced structure to pass a specified crash test; roll-over hoop; driver belts; fire-resistant fuel tanks; fire extinguisher; medical air bottle; rear light; and an on-board re-starting system. It also carried down-force-creating aerofoils (discussed below). It was fitted with TV cameras. The minimum weight regulations did prevent engines and therefore cars from achieving the lowest figure technically possible.

Three major advances made during the 6 decades since 1951 which saved weight were:-

1. Mid-engine mounting, which eliminated the propeller shaft and long exhaust pipes (see Fig PA2-9);
2. Stressed-skin body-cum-frame in an epoxy-resin-bonded carbon-fibre-reinforced material (see Figs PA2-10 & -11). This was not only lighter than a tubular -frame plus separate body but also much stronger and stiffer and could withstand the high aero forces applied, a duty not conceived in 1951.
3. Subsequent use of the mid-engine and attached gearbox to carry chassis loads to the back axle (see Fig PA2-12);

The much better fuel consumption and 300 km race length instead of an average 460 km saved weight in tanks and supporting structure.

Torsion-bar springs instead of transverse tension-leaf springs also saved weight.

POWER/WEIGHT RATIO

The Power/Weight ratios were therefore:-

AR159 400HP/938 kg = 0.43; W05 761 HP/701 kg = 1.09, **2½ times the Italian car.**

LOWER CENTRE OF GRAVITY

The mid-engine configuration not only saved weight but it also provided a lower centre of gravity. By reducing weight transfer longitudinally during braking and laterally during cornering this made better use of the tyre characteristics for improved performance. However, FIA engine regulations for 2014 limited what was technically feasible in the matter of lowering the C of G.

BETTER BRAKES

The AR159 had drum brakes (see Fig PA2-6) with 2 leading shoes.

The 1st GP car to win a Championship (the newly-inaugurated Constructors') with disc brakes was the 1958 Vanwall (see Fig PA2-13). This was a transfer from aircraft technology. Discs had been used on the Jaguar C-type sports-racing car to win at Le Mans in 1953.

A further transfer from aviation was the use of carbon discs with pads of the same material, starting in 1978 (not *complete* discs originally), which could operate at energy input sufficient in 2014 to slow the cars under aero downforce at 5g from 350 kph (declining with reducing speed, of course). See Fig PA2-14 for a 1993 example of this type of brake glowing yellow at about 1000C.

BETTER TYRES

The 2014 car gained much lap speed from its tyres compared to 1951, starting with a. **Coefficient of Friction doubled** or more from the use of artificial tread compound instead of natural rubber. This was accompanied by:-

- Greater lateral width of tread compared to axial (see Figs PA2-15 & -16).
- Absence of water-drainage channels for dry running – "Slick treads"
- Artificial material for casings instead of cotton;
- Radial-ply carcase in place of cross-ply.

These bulleted items contributed to a lower slip-angle, i.e. to a better ratio of cornering force to tyre drag. These factors and the greater friction coefficient would have given an advantage *before* the addition of aero downforce to multiply adhesion. There was some penalty to pay for wider tyres in greater aero drag and lower top speed because of more frontal area but lap speed rose.

AERO DOWNFORCE

In 1951 external airflow was nothing but a hindrance to a racing car. It limited top speed and probably actually *lifted* the car which reduced cornering adhesion and it might also make the car unstable.

By 2014, despite the many and various ways in which the governing body sought to reduce aerodynamic aids, the science was well established of generating with aerofoils and under-body flows an extra downforce above the car's static weight to raise acceleration, braking deceleration and cornering speed before the limit of tyre adhesion was reached. Other things being equal a trebling of adhesive load would raise cornering speed by √(3) = 73%. The higher aero drag was traded off to maximise the lap speed. Nevertheless, the power of the W05 was such that a top speed of about 350 kph was achieved at Monza. The top speed of the AR159 was about 300 kph. This top speed was actually assisted in Qualification because it was permitted to use the "Drag Reduction System" – a flattening of the rear aerofoil which, in the race and under specified conditions, gave a pursuing car an advantage to overcome the updraught behind the car in front.

The use of aero down force started in 1968, firstly with nose aerofoils (see Fig PA2-17) then with a rear "wing" (upside down, of course) (see Fig PA2-18). The latter does not look very different today from the earliest examples but the front "wing" is now the most elaborate concoction of vanes in cascade (see again PA2-2). Underbody airflow was first harnessed effectively by the Lotus type 78 in 1977 (see Fig PA2-19) but its venturi shape with sliding skirts to prevent leakage was soon banned. Flat bottoms were imposed in 1983, and that is the situation today, but detailed design still means that a large proportion of the total downforce is still produced by airflow under the car.

Still standard today and affecting the aerodynamics is a feature of the Lotus type 25 of 1962 which was a highly-inclined driving position provided originally to reduce frontal area (see Fig PA2-20). This now aids airflow to the rear "wing".

Another feature still used today to assist the aerodynamics is the layout of the 1970 Lotus type 72. This had a sharp nose with the radiators divided and positioned in diverging-converging ducts alongside the cockpit to reduce drag (see Fig PA2-21). This is still a benefit and the sharp nose gives scope for the front "wing" to work efficiently at full track span. Fig PA2-22 shows how Renault envisaged the 2014 layout.

FASTER GEARCHANGING

The AR159 had 4 forward speeds in a gearbox integrated with the final drive, changed manually by a cockpit lever and rods.

This system, with advances to 5 and sometimes 6 speeds, remained general until 1989. In that year the Ferrari type 640, designed under the technical control of John Barnard, was fitted with a semi-automatic gearbox (SAGB). The gear-change was controlled electronically from 2 finger-tip levers under the steering wheel, one each side for "up" and "down" (necessarily in regular sequence). The electronics commanded the necessary servo-powered adjustments of engine RPM, clutch position and gear-wheel movement. The advantages were:-

- Faster gear-changes: from 250 milliseconds manually to 50, later to 30 m.sec, and now 15 m.sec with "seamless" changing in an 8-speed box - all cutting down the time when the car is not under power accelerating but decelerating;
- RPM over-speed on premature changing-down prevented, with improved reliability;
- Full wheel control at all times;
- Less effort from the driver.

The type 640 (see Fig PA2-23) won its 1st race – to everyone's surprise! All competitors had to follow suit with SAGB by 1991.

Having developed reliable electrical contacts between the quickly-detachable steering-wheel (necessitated for driver entry and exit by the lay-down driving position) and its column, advantage was taken over the years to add more and more control functions and data displays onto the wheel (see Fig PA2-24).

SAFER CIRCUITS & CARS

Even the bravest of drivers of 1951 had to hold something in reserve for emergencies on the mostly-narrow circuits of that era, where a serious off-course excursion at speed could easily be fatal. Today the wider tracks, flat kerbs, mostly asphalt run-off margins and soft-lined ultimate barriers, coupled with the car safety features already listed under Weight, have quite properly given drivers the confidence to drive absolutely flat-out in Qualifying – except on Street circuits.

SUSPENSION

It is felt that little credit was due to the 2014 suspension in improving performance relative to 1951. The modern GP car's design, with double transverse links at each corner, has to:-

- Resist the huge downforces;
- Not permit much variation of ride height or attitude, so as to keep control of those forces;
- Provide adjustments for the degree of stability needed for each circuit.

However, it gives the driver a very hard ride, even on the near-“billiard-table “surfaces of most modern venues.

The Alfa Romeo by 1951 had obtained sufficient stability, with negative-camber swing-axles (or de Dion) at the back and double trailing links at the front, to make good use of its power. The ride was probably no worse than today.

SUMMING-UP

Perhaps it is possible to identify the contribution of the 2½ magnification of the **POWER/WEIGHT** ratio to the overall 75% increase in lap speed at a given Track Factor, as follows:-

For small changes on average over a season, it has been approximated that

+4% of PP/W ratio gives 1% increase in lap speed (see Note 104).

This is actually a small change result of :

$$LS \text{ proportional to } (PP/W)^{1/4}$$

If the same relation applied to large changes, then the x 2.5 increase in PP/W would give $(2.5)^{0.25} = 1.26$, ie 26% increase in lap speed. This is just a third of the overall gain.

A fairly big *if*! For the other technical advances described, plus the effect of enormously improved safety features, there can be no way for someone outside the racing teams to give an evaluation.

Ferrari, who have raced in all the 64 years covered in this review, most probably have all the gains separately logged into their computer from tests where they can calibrate, say, circuit changes at Monza plus back-to-back tests at their own private instrumented tracks at Fiorano and Mugello. This data is most unlikely ever to be made public.

The author is very happy to have seen such advances over the 64 years covered here but regrets that the huge amounts of money spent to achieve them has now led to secrecy about most of what goes on under that heavily-sponsored bodywork!

Derek S. Taulbut.
2 December 2014.

[General Note. Concerning racing regulations the abbreviation ‘FIA’ has been used for simplicity of reference where some other dependent office may actually have issued them.]

Appendix PA1 follows on P. 14

Appendix PA1

Anomalies in 1951 data

Lap speed at Monza

Compared to the average trend line for the 1951 Alfa Romeo 159 of LS = 47.4 x TF, the lap speed at Monza was 17% higher than its TF of 3.62 would have forecast.

This shows the deficiency of the simple Track Factor, which implicitly relies on a circuit having a mixture of corners ranging from slow and medium where the speed is limited by tyre-road friction and super-fast where the radius is such that the car can be driven round it flat-out*.

At Monza the value of T in 1951 included the large-radius Curva Grande (84^0) and the Curva del Vialone (42^0) which, it is deduced could be taken flat-out by the 159, even in its 1951 Monza revision to 159M ("M" for "Maggiorata" or "Increased power" specification). If these two curves and two other slight bends are deducted from T the latter value of 516 is reduced by 84 + 22 + 12 + 42 = 160^0 to 356^0. This would increase TF from 3.62 to 4.04. Relative to the trend line this would give the actual LS of 200.4 kph as 4.6% above a trend line forecast of 191.6.

While this illustrates how the simple TF *could* be improved, it involves replacing a straightforward geometric measurement with a value modified by judgement and this is undesirable in a correlation. Although it has been tried it has been rejected for that reason. It just has to be accepted that not all circuits will fit at a reasonable accuracy.

---

*TF would definitely not be appropriate for a square or a large-radius circle.

Lap speeds at Dundrod (DU) and Nurburgring (NU)

The British racing driver, Roy Salvadori, in his autobiography wrote this about Dundrod:-

> It was "*very narrow, very bumpy, all the cambers were wrong, many of the corners were blind, banks lined the road in many places..... any driver that liked Dundrod needed psychiatric treatment*".

This would seem to be a good reason why Farina's race lap was 17% below the 1951 average trend line! It is suggested that the Nurburgring was very similar in character and therefore in lap speed difference from trend. It is not implied that the many drivers who won there up to 1976 needed the treatment Salvadori suggested (he actually finished 2nd there in 1958 in a Cooper T45-Climax 2.2 litre, his highest Championship GP score, so did not let its dangers put him off).

Streets versus Tracks

The Street circuits, added after the Track trend line had been calculated, indicate no significant drop of lap speed despite their "hard-edged" nature. This is probably because, although labelled as "Tracks" these venues in 1951 were mostly just as dangerous to car and driver for off-road diversions as "Streets". In the case of NU and DU, more so.

Goodwood

Farina in the September 1951 race meeting at Goodwood lapped at 97.4 MPH, nearly 8% faster than trend (it *is* included in the trend calculation). This is probably because there was space for off-road excursions which gave him the confidence to drive at "10 tenths". The author adds a personally observed anecdote about Farina's fastest practice lap, which was slower than in the big race:- the driver was taking Paddock Bend, as it then was, accelerating full-throttle, drifting across the whole of the road and kicking up a little dust from the outer verge on the exit. This so alarmed the circuit owners, who planned to build pits just there for a 1952 9-Hour race, that they introduced the chicane which has been there ever since! This delayed the 1st 100 MPH lap of the circuit until April 1959 by Stirling Moss in a P25 2.5litre NA BRM at a private trial (also witnessed by the author).

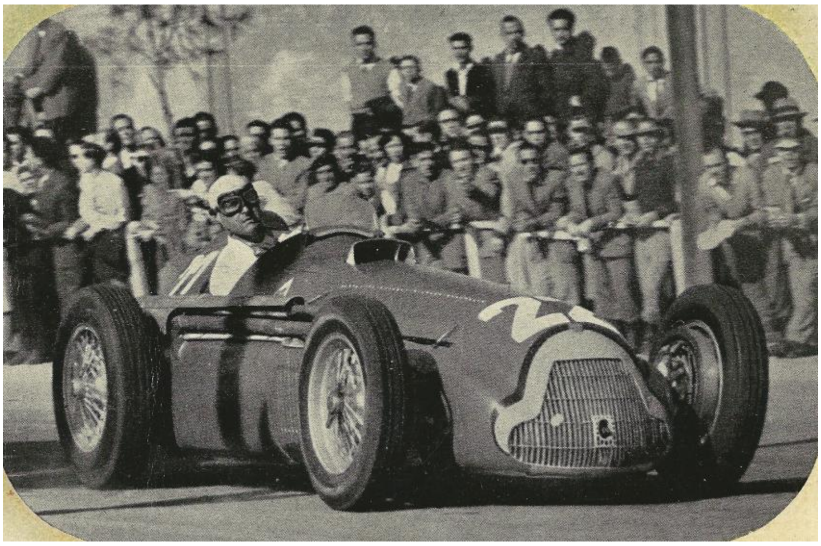
Appendix PA2 follows on P.15

Appendix PA2

Illustrations

Fig PA2-1

The Alfa Romeo 159M is shown as driven by Juan Fangio to win the last classic GP of 1951 on the Barcelona Pedralbes street circuit and thereby claim the Drivers' Championship



Motor Sport December 1951

It will be seen that on this circuit there was absolutely no spectator protection. Also noteworthy are:- no crash helmet; no adverts on the car; prominent racing numbers for all to see. The car was, of course, Italian red (with yellow black-lined nose for pit identification). The open intake before the cockpit fed the carburetter on the 159M, which also reverted to dual exhaust pipes. Apart from smooth bodywork – which probably generated lift! – there were no other aero features.

Fig PA2-2

AUSmotive.com

The 2014 Mercedes AMG W05 has numerous visible features, developed 24/342 in large-scale wind-tunnel tests, to generate within tight FIA limits the best possible Downforce/Drag ratio. These vary from the incredibly-complex front "wing", through the deflectors alongside the radiator/intercooler ducts, to the rear "wing". This last item incorporates the variable "Drag Reduction System" which can be used under specified conditions to aid overtaking. Not seen is the underbody, again designed within limits, to add downforce. The car as a whole perpetuates the layout of the Lotus 72 of 1970 (see Fig PA2-18), i.e. sharp nose and side radiators.

It has the "Standard GP suspension" of double transverse links at each corner described in Note 66

Fig PA2-3

This shows the 1977 Renault EF1 TC engine, derived by short-stroking their 2 litre NA F2 unit, with its plenum chamber, fed via an intercooler from the TurboCharger, which in turn fed tuned and individual inlet tracts. The tuned exhausts were also retained up to turbine entry.

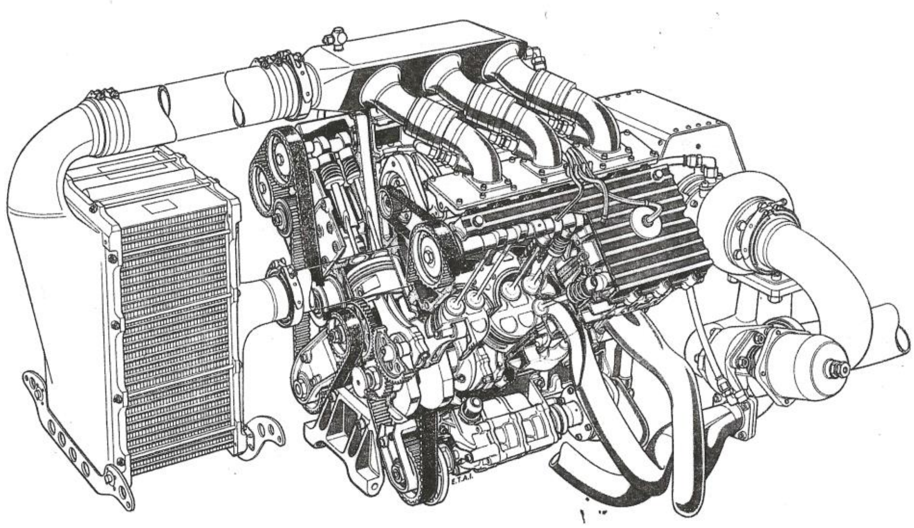
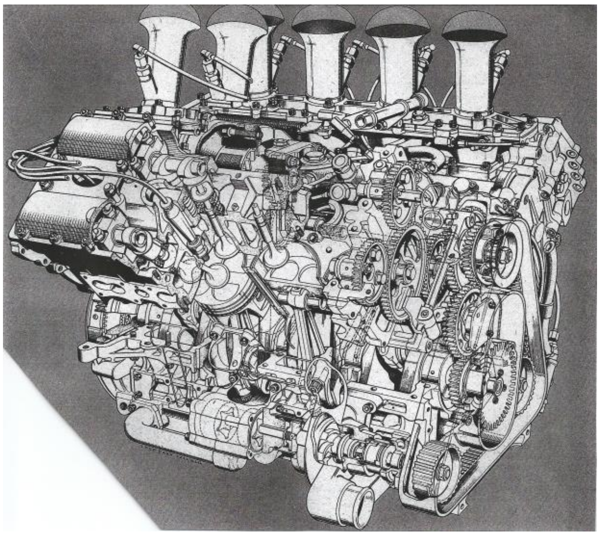


Fig PA2-4

The Cosworth DFV design and development, 1966 – 1983, are described in detail in "The Unique Cosworth Story"

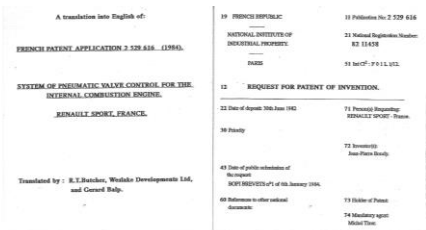


DASO 858

Fig PA2-5

Renault and J-P Boudy applied originally for a patent on the gas-spring valve return system in 1984. They named it "*Distribution Pneumatique*" but when Honda adopted it in 1990 the more descriptive "Pneumatic Valve Return System (PVRS)" was coined by them,

Although patented it seems that other engine makers did not allow that to stand in the way of using such a valuable advance!


A translation into English of:

FRENCH PATENT APPLICATION 2 529 616 (1984).

SYSTEM OF PNEUMATIC VALVE CONTROL FOR THE INTERNAL COMBUSTION ENGINE.

RENAULT SPORT, FRANCE.

Translated by : R.T.Butcher, Weslake Developments Ltd, and Gerard Balp.

19 FRENCH REPUBLIC

NATIONAL INSTITUTE OF INDUSTRIAL PROPERTY

PARIS

11 Publication No: 2 529 616

21 National Registration Number: 82 11458

12 REQUEST FOR PATENT OF INVENTION.

71 Person(s) Requesting: RENAULT SPORT - France.

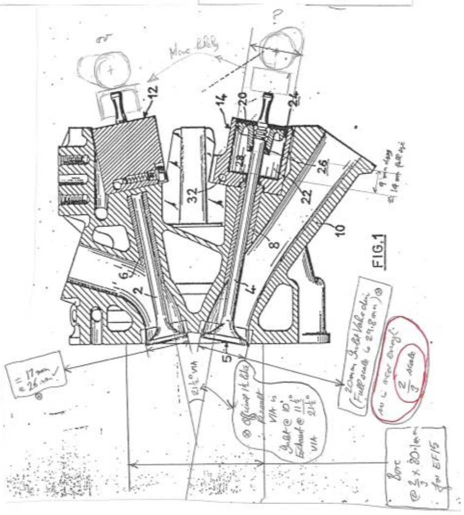
30 Priority

72 Inventor(s): Jean-Pierre Boudy

60 References to other national documents

73 Holder of Patent

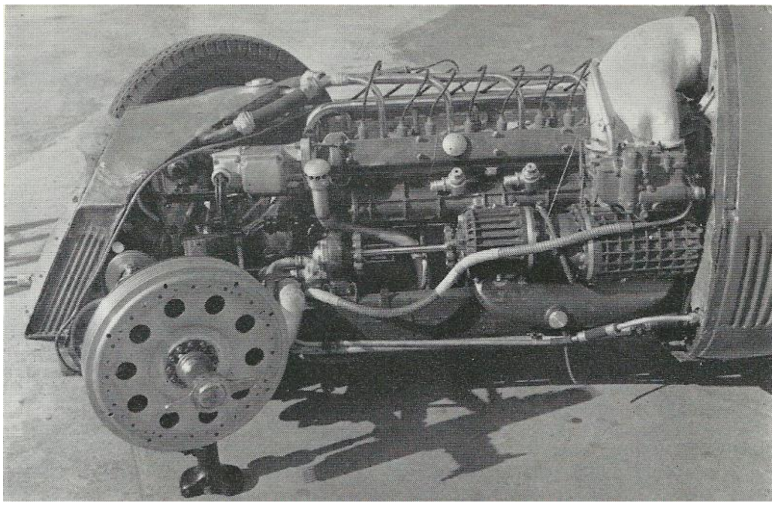
74 Mandatory agent



DASO 474

Fig PA2-6

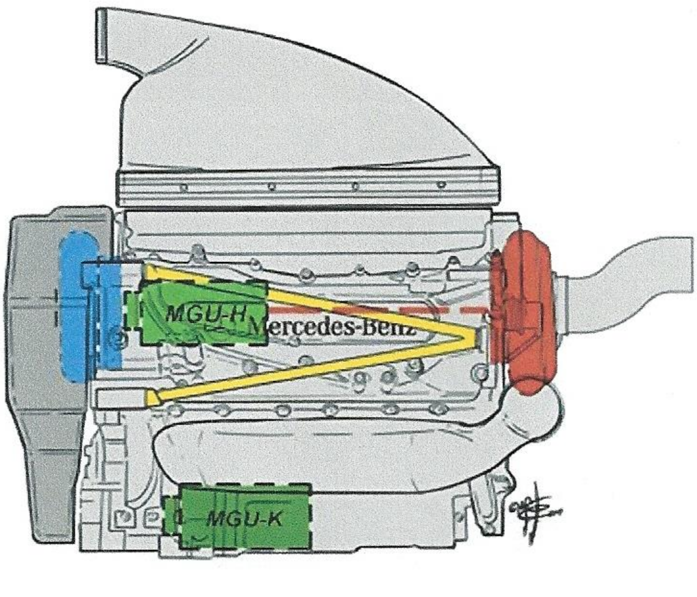
Showing the 2-stage Roots supercharging system of the AR159M. Note the trunking from a fresh air intake in front of the cockpit to the 3-choke Weber carburetter.



DASO 31

Fig PA2-7

Officially, even up to September 2014, Mercedes illustrated a Turbine + Dynamotor+ Compressor set mounted together at the back of the PU106A. This may have been an early proposal but from the 1st 2014 race the system used mounted the Compressor at the *front* of the block. It was driven by a shaft running through the Vee of the V6 engine, with the Dynamotor partway along this. Probably this lowered the whirling speed below the operating range. The front compressor location was cooler than the usual TC location adjacent to the Turbine and, with a given amount of intercooling, should have provided higher density air to the engine for more power



Credit: uncertain

The "MGU-H" is a Dynamotor driven by the Turbine and charging a Lithium-ion battery on command ***or*** on command using the battery energy to accelerate the Turbine.

The "MGU-K" is another Dynamotor driven by the back wheels on command when braking and charging the battery ***or*** on command using the battery energy to drive the back wheels as a boost to the basic engine drive.

Fig PA2-8

This shows the PU106A Compressor at the front of the engine (entry covered).
Note also the very-simple (shrouded) exhaust manifold feeding the Turbine at the rear, with no attempt to have individual and tuned pipe lengths. This is also completely different from the official Mercedes illustration! It can only be assumed that the engineers have been too busy to advise their PR department of the changes to the Compressor mounting and exhaust system.

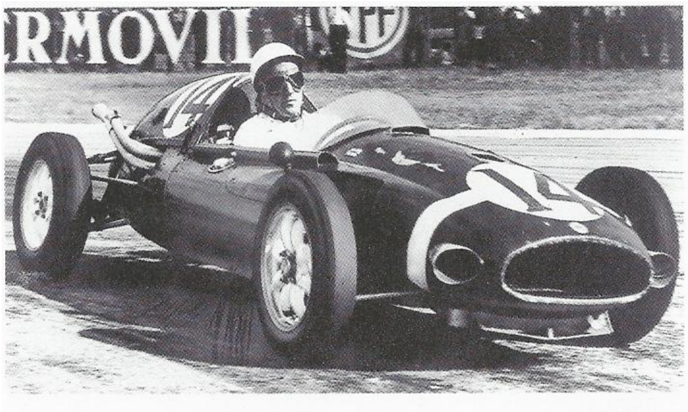
RaceCar Engineering April 2014

Mercedes seem to have gone to a lot a of trouble to fit the engine oil tank around the Compressor, which emphasises the tight packaging of the power unit.

Fig PA2-9

The 1st mid-engined car to win a classic Grand Prix post-WW2 was a modified Cooper T43 with a 1,960cc Coventry Climax engine specially enlarged from their 1,460cc F2 FPF. It was privately-entered by Rob Walker, prepared by Alf Francis and driven by Stirling Moss. The event was the Argentine GP in January 1958. The car is shown here.

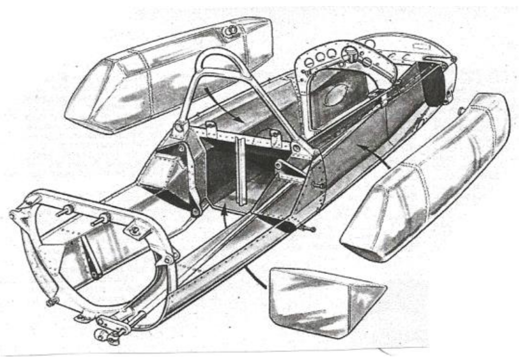
The same car won the next classic race at Monaco, driven by Louis Trintignant.



DASO 929

In 1959 and 1960 Jack Brabham drove Cooper-mid-engined-Climax cars of full-formula-size 2.5 litres to win both Championships each year. That completed the demise of the front-engined Grand Prix car.

Fig PA2-10



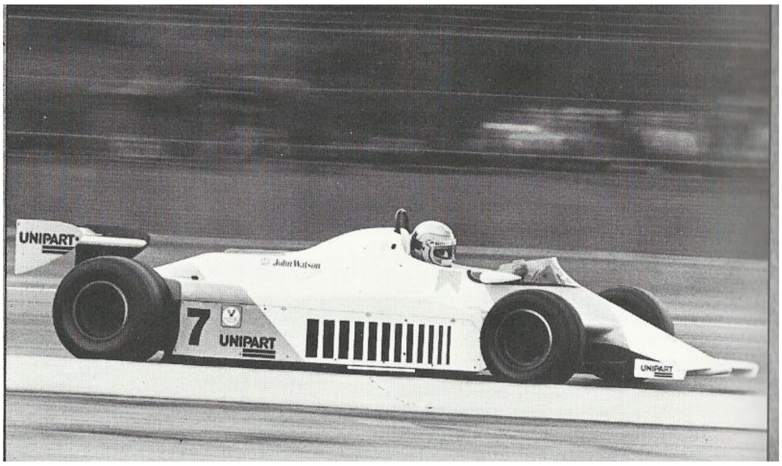
The 1st stressed skin body-cum-frame GP car was the 1962 Lotus type 25, winning its 1st race in Belgium driven by Jim Clark.

The internal rubberised-fabric bag fuel cells are shown separate from the body.
See also Fig PA2-18.

Autocar 29 June 1962

Fig PA2-11

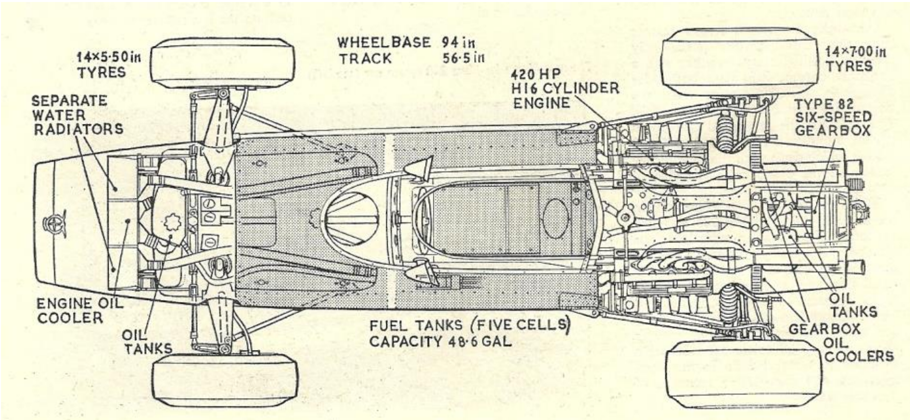
The 1st use of epoxy-resin-bonded/carbon-fibre-reinforced material to form the stressed-skin body-cum-frame structure, as pioneered in Al-alloy by the Lotus 25, was the McLaren MP4. Its 1st race win was at Silverstone in 1981, driven by John Watson (seen here).



DASO 926

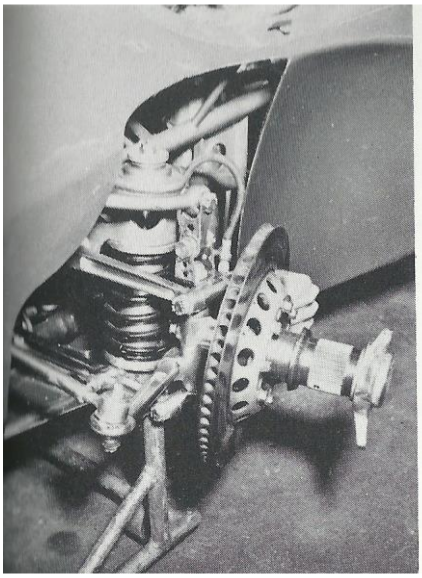
Fig PA2-12

The 1st GP car to use its mid-mounted engine on its own to carry loads from the front to the back axle was the 1966 BRM P83. The engine was well-suited to this duty, being a "Lazy-H" 16 cylinder.



Autocar 29 April 1966

PA2-13



Front disc brake on the 1958 Vanwall. Tony Vandervell had originally fitted Goodyear-derived disc brakes, with technology transferred from the aircraft industry, to his Ferrari type 375 4.5 litre NA "Thinwall" car in 1953. These had callipers mounted on swinging links so as to accommodate axial disc float. The Vanwall brakes were similar. The discs were drilled to reduce unsprung weight and for cooling.

DASO 68

Fig PA2-14

Showing the carbon-carbon disc brakes glowing while braking on a 1993 Ferrari F93A. The 1st win for a car with brakes of this material (by Dunlop) was by the 1978 Brabham-Alfa BT46/6B (ref DASO 884) at the Swedish GP. These early carbon-carbon brakes had a number of separate rotor pads incorporated into a steel disc. [The success of the brakes on the Brabham was overshadowed by the controversial use of fan-induced downforce.]

media-cache-ecO.pinimg.com

Fig PA2-15

This shows, with Dunlop examples, how tyres were developed very rapidly from 1964 to 1969 so as to increase the ratio:-

$$\frac{\text{Contact patch transverse width}}{\text{Contact patch axial length}}$$

In aerodynamics this would be described as "Increasing Aspect Ratio" so as to reduce the angle of incidence for a given lift. In automobile terms it was called "*Lower* Aspect Ratio" because the (Tyre Height/Tyre Width) ratio was smaller. The effect, in either description, was to increase the ratio of (Cornering Force/Drag).

Other significant dates marked on the figure are:-

- 1958 1st nylon casing (replacing cotton);
- 1961 1st high-hysteresis tread compound (initially for wet races);
- 1965 1st tubeless tyre for racing;
- 1971 1st slick tread for GP racing (a transfer from the US drag- racing scene);
- 1977 1st radial-ply carcase (replacing cross-ply).


TYRES AND WHEELS 27

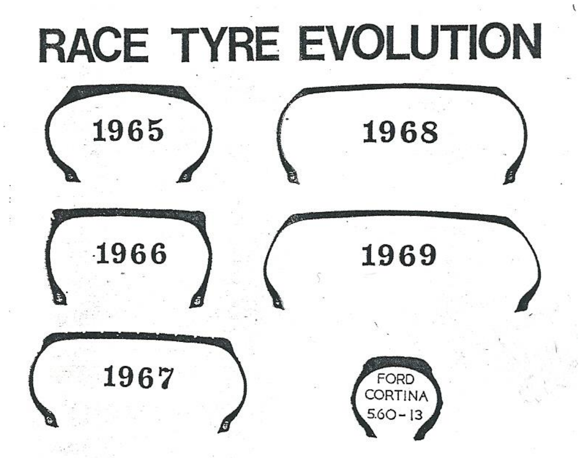
Fig 2.1 Half a century of Dunlop racing tyres: Top row from the left: Beaded edge (1920s); '5-stud' pattern (1930s); R1 (1946–58) R3 (1955–58); R4 (1956–58); R5 (1958–64). Bottom row from the left: R6/CR48 (1963–65); R7/CR65 (1965–67); CR70 (1967); CR81–special tyre for racing Minis (1968–72); CR82 (1968); CR84 (1969–71).

Fig 2.2 A history of change in contact patches.

DASO 661

Design of Racing Sports Cars C. Campbell. 1973.

Fig PA2-16



This illustrates with Goodyear cross-section examples the same change of Aspect Ratio over 1965 – 1969.

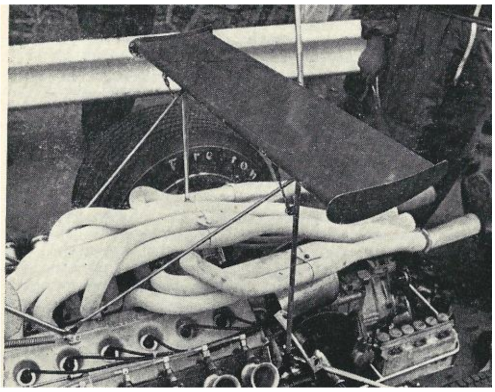
Motor Sport March 1979.

Fig PA2-17

The 1st use of stub aerofoils on a car nose in GP racing was on the Lotus type 49B when it won its first race at Monaco in May 1968, driven by Graham Hill. The rear of this car had a slightly-angled cowling which would also have provided some downforce. Colin Chapman had built wedge-shaped cars for the 1968 Indianapolis '500' and this was a carry-over.

Motor Sport July 1968.

Fig PA2-18



Only 2 weeks after the Lotus 49B raced at Monaco Ferrari came to the 1968 Belgian GP with a rear "wing". The car finished 3rd. From that date onwards this addition to racing cars, of various areas, at various heights and various longitudinal locations, was a permanent fixture, though constantly altered to obey constantly changing rules.

Motor Sport July 1968.

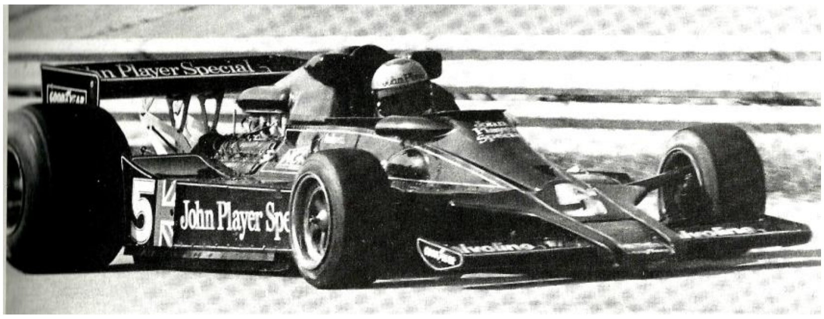
The credit for 1st use of a "wing" to create downforce to increase cornering speed, although not in GP racing, belongs to the Swiss engineer Michael May. He fitted one, mid-mounted and with variable incidence , to his Porsche 550 sports-racing car in 1956 for a race at Monza. Because it was faster than the works Porsches they protested it on the grounds it blocked a following driver's view when deployed and was therefore unsafe. This was upheld by the stewards and the car did not race.

Jim Hall of the USA built a sports-racing Can-Am Chaparral 2E in 1966 which had a high-mounted rear "wing" which could be feathered to reduce drag when downforce was not required. Reliability limited its success to one win in the series. It took another 2 years for the Europeans to copy the idea.

A full historical account of aerofoil downforce development can be found in www.formula1-dictionary.net/wings.html

Fig PA2-19

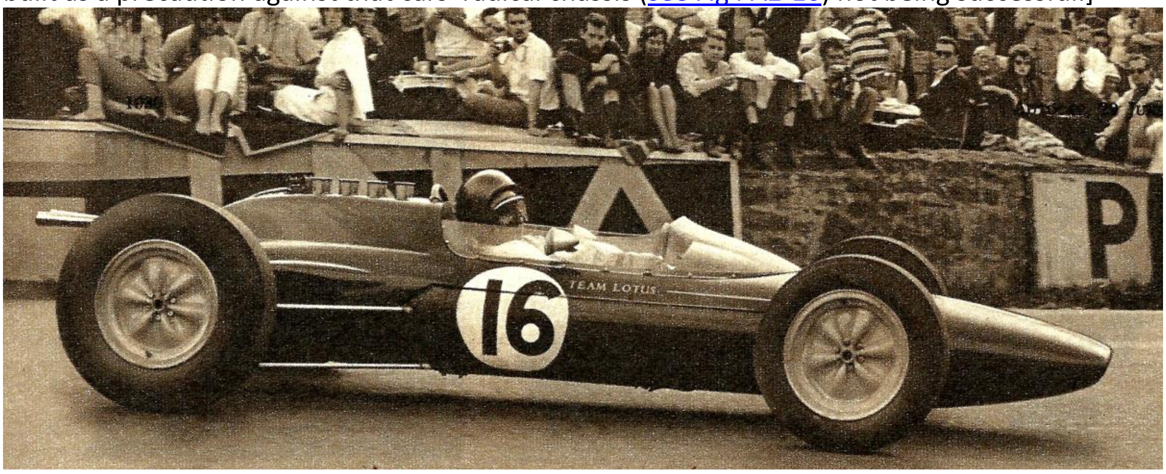
DASO 908



The Lotus type 78 of 1977 was the 1st car effectively to have shaped underbodies to create, with the road, venturis so that reduced pressure airflow under the car would create downforce. Essential parts of the scheme were skirts at the side of the shapes to prevent leakage at ambient pressure. These skirts had to touch the road and slide vertically to accommodate body roll and take up wear. The L78 won 5 races in 1977 and Mario Andretti missed the Championships only because of engine unreliability. The following year the improved L79 would take him to that success.

Fig PA2-20

This illustrates the 35^0-to-the-horizontal driving position introduced in the Lotus type 25, Jim Clark winning the car's 1st race in the 1962 Belgian GP.
[Strictly speaking, this "lay-back" seat was used 1st in the Lotus 24, a space-frame clone of the 25 built as a precaution against that cars' radical chassis (see Fig PA2-10) not being successful.]

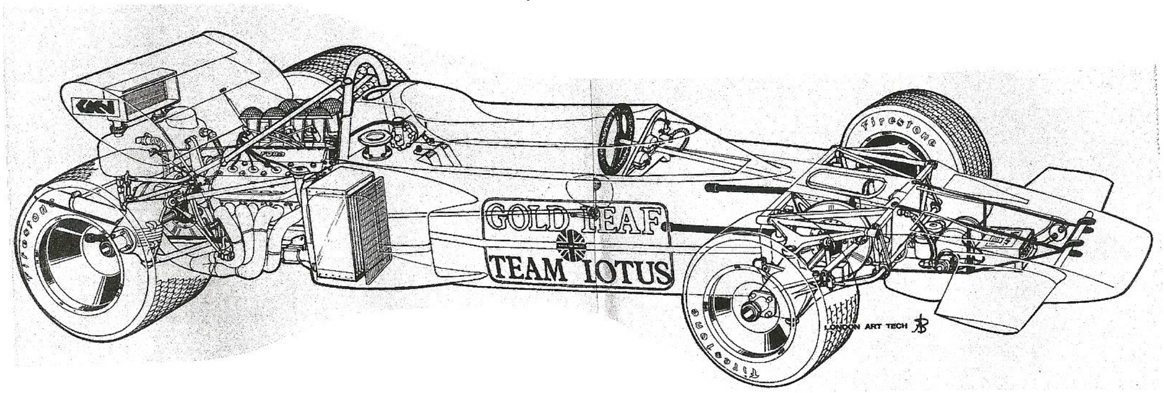


Autocar 29 June 1962

Spectator safety was not much improved 7 years after the Le Mans disaster.

Fig PA2-21

This radical Lotus type 72 appeared in 1970 but a suspension designed to prevent body pitch on acceleration and braking was not liked by the No1 driver, Jochen Rindt. It had to be returned to the usual layout before the car was successful on its 4th race. Rindt then won 4 races in succession but was killed 2 events later in a practice crash.

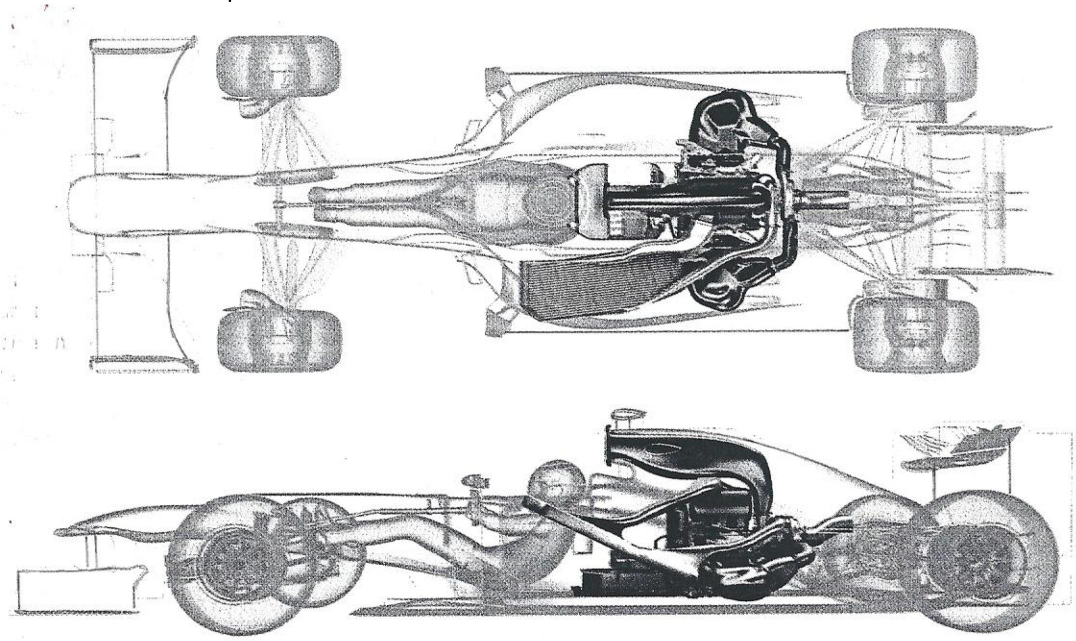


Motoring News 16 April 1970

Fig PA2-22

This Renault drawing from late 2013 of a car for the 2014 formula shows:-

- A layout similar in general to the 1970 Lotus 72 (PA2-21).
  One side duct is now used to provide air to the air-air intercooler;
- "Lie-down" driving position like the 1962 Lotus 25 (PA2-20);
- How Renault expected to mount the TurboCharger as a unit behind the engine block (contrast this with the Mercedes PU106A arrangement on PA2-7);
- The elaborate individual, tuned exhaust pipes (again contrast with the PU106A on PA2-8
- The GP suspension "standard" since 1959 of double transverse links at each corner.



Renault official:*F1 Racing* September 2013

Fig PA2-23

Planetf1.com

1989 Ferrari type 640, driven by Nigel Mansell, winning its 1st race in Brazil. It was also Mansell's 1st Ferrari win in his 1st race for the firm in the 1st race of the 3rd Naturally-Aspirated Era and the 1st win for a car with a Semi-Automatic Gearbox. The steering-wheel had to be changed in the race to restore the electrical connections, causing Murray Walker to exclaim that it was the first time he had seen a 5-wheel pit-stop!

Fig PA2-24

DASO 621

Alfa Romeo 159

A typical 2014 F1 steering wheel

The function of each 2014 control and the meaning of the displays are explained in http://wonderfulengineering.com/f1-steering-wheel-explained/

A curious problem occurred on Nico Rosberg's Mercedes W05 at Singapore in 2014 when a "foreign substance" interfered with the electrical contacts. A change of wheel did not solve the problem and the car DNF.

Passing phases

There were some very-interesting technical advances during the review period which, although no longer present in the Mercedes W05 because they were banned by the FIA, are thought to be worth mentioning.

ACTIVE SUSPENSION

In 1992-1993 the Williams-Renault FW14B and FW 15C had electronically-controlled hydro-mechanical means to adjust the body level and angle so that the underbody airflow produced the optimum Downforce/Drag ratio according to the car's position on the circuit. Driven by Nigel Mansell and Alain Prost, respectively, both Championships were won each year. Other makers began to follow suit. The FIA banned active suspension for 1994 and onwards.

BERYLLIUM-ALUMINIUM ALLOY

This alloy of 62% Be/38% Al, originally developed by Lockheed for spacecraft, was first used for brake callipers in 1996 because of its superior Stiffness/Density ratio. It was banned in that application by the FIA from the start of 1998 on cost grounds. Ilmor used it during 1998 – 2000 for pistons and cylinder liners where its high temperature properties were also valuable. The FIA stepped in again to ban the alloy from engines from the start of 2001 (see Note 14, p. 4).

DOUBLE DIFFUSER The double diffuser was a way of improving underbody downforce which was used by the Brawn-Mercedes car to enable Jensen Button to win the 2009 Championships before others copied the feature. It was used generally in 2010 but was then banned.

BLOWN DIFFUSER

The blown diffuser made use of the exit energy from the 2.4 litre NA engine to improve underbody airflow effect in 2011, particularly on the Red Bull-Renault designed under Adrian Newey's leadership and driven by Sebastian Vettel to win the Championships. It was then banned.

Other Still-Born novelties

Two other potential advances never saw a race before the FIA stopped them.

CONTINUOUSLY VARIABLE TRANSMISSION

Developed by Williams, banned at the end of 1993, after much expense (see Note 33).

BISHOP ROTARY VALVES

Banned at the end of 2005 when Ilmor had spent much money solving their problems.