2nd Pressure-Charged Era (2PC) 1983 - 1988 Egs 64 to 68

In CoY terms this Era over-lapped the end of the 2nd NA Era in 1982 because the PC Ferrari type 126C2 gained the Constructors' Championship that year as the NA Ford Cosworth DFV powered the last of its Drivers' Championships. The following year is taken as the start of the 2nd PC Era, however, because in 1983 both Championships were gained by TurboCharged cars

The background to the use of TurboCharging (TC) to supply increased inlet pressure is given in Note 89. Renault pioneered the move to TC in Grand Prix racing starting in mid-1977, on returning to that arena after 70 years. The Swept Volume rule ratio NA/PC being only 3L/1.5L at that date meant that it was quite easy for them *with TC* (more efficient than Mechanical Supercharging (MSC)) to match the NA Ferrari 312B or better the Cosworth DFV powers from the beginning with about 2.5 Manifold Density Ratio (MDR) (571, 909). Achieving reliability at twice the Horsepower/Litre (HP/L) of the NA engines, with adequately-fast power response to throttle opening (i.e. overcoming "turbo lag") while also lowering fuel consumption to reduce starting weight penalty were tasks still to be accomplished. The important point was that Renault, as did all later followers of TC and unlike the engines of the 1st PC Era, took an efficient NA engine with **Individual and tuned inlet and exhaust systems** and fed plenum chambers around the inlet trumpets with pressurised air. The exhaust tuning was to some extent compromised by the turbine at the end of the pipes. Disappointingly for spectators the pressure drop through that turbine much reduced the noise!

Because the rules now enforced the use of petrol fuel, having a much lower evaporative cooling drop than alcohol (see Appendix 2), which had been used during the 1st PC Era, an intercooler between the turbocharger delivering hot air and the engine was required to permit a reasonable compression ratio (R) without knocking. Also a waste-gate was needed to limit turbocharger RPM and its boost to "flat-rate" the system for road-racing.

A feature of TC was the ease with which power could be, and was, increased for special purposes by raising Inlet Valve Pressure (IVP) by delaying waste-gate opening to higher RPM, egs:-

- To compensate for circuit altitude and temperature ambient air density drop;
- To increase lap speed for practice/Qualification so as to obtain a better starting grid position (a matter of increasing importance as the use of aerodynamic downforce degraded the braking and cornering of a following car in close pursuit because it was in an *updraughting* slipstream);
- And (consequentially) to give extra speed temporarily in a race to assist overtaking along the straights.

The latter two enhancements at reduced engine life, of course. The Qualification engine would be changed before the race, as was permitted up to 2003.

63. 1982C Ferrari 126C2; 1,496 cc; 560 HP @ 11,000 RPM (See Fig. 63A)
65. 1983C Ferrari 126C3; 1,496 cc; 590 HP @ 11,000 RPM (See Fig. 65A and Power Curve)

These two Ferrari engines, CoY by gaining the Constructors' Championships in 1982 and 1983, are described together for convenience, the C3 engine being basically a developed C2, gaining 4 wins v. 3.

The Renault TC engine had its 1st win in July 1979, 2 years after its debut and, of course, after much development. It was possibly the fact that it then won the 2nd and 3rd races of 1980, admittedly on hot circuits well above sea-level (Interlagos at 2,500 ft and Kyalami at 4,800 ft) where the density drop could be compensated easily by adjusting the TC pressure ratio, which convinced other engine builders that they should push their own TC units.

Ferrari's version, the type 126CK, appeared in one practice session only at Imola in September 1980, the 12th race. It first raced the following year and won 2 races.

126CK details

The Ferrari 126CK 120V6 1.5L TC, unlike the preceding Renault, the near-contemporary BMW and the rather-later Honda TC engines was a new design *not* a short-stroke variant of an existing successful Formula Two 2L unit. Ferrari had last built a 120V6 engine in 1963, with B/S = 73/58.8 = 1.24; the TC engine was 81/48.4 = 1.67, the increase in B/S ratio made possible by using 4 v/c instead of 2 v/c.

Twin turbochargers were fitted, as had been found essential by Renault in mid-1979 to reduce throttle lag and which had brought them their 1st win. In the Ferrari they were mounted high up (see Fig. 63A), which thereby offset the low CG advantages of the main engine and also denied the opportunity of a low engine cowl to improve airflow to the rear wing. They were fed from exhausts in the Vee, the inlets being outside the cylinder banks (this layout was reversed in 1985 so that the turbochargers could be mounted *alongside* the engine, obtaining the above-mentioned advantages).

The 120^0 Vee gave some aid to the chassis diffuser channels.

No internal details are known except VIA = 38^0, much wider than the 312B at 20^0 but presumed to have been chosen to allow plenty of cooling water around the exhaust valves.

An electronically-controlled mechanical fuel injection system was fitted. Enzo Ferrari claimed in 1981 that the Specific Fuel Consumption was only 12% worse than a NA engine (569).

The Comprex experiment

Ferrari had experimented with a Brown Boveri "Comprex" "Pressure-Wave" mechanically-driven supercharger as an alternative to the turbocharger but no comparative data are known and the un-raced device was dropped very quickly.

The 1981 bypass system

In 1981, to reduce throttle lag, Ferrari fitted a valved bypass system which, when the throttles near the inlet ports were shut, then allowed residual compressed mixture in the manifold to flow directly to the turbine inlet where excess fuel burned to spin up the TC unit like a gas turbine (914). This really was the "*2nd illegal engine*" at which Keith Duckworth had protested, without avail, (see Note 76) and the system was not continued after 1981.

Limited piston speed

The MPSP of the C2 and C3 was only 17.8 m/s, 12% (i.e. 23% lower stress) below the 312B of the same cylinder volume. This reflected the higher temperature of the pistons. These *had* benefitted from development done by Mahle for Renault which introduced a splash-fed cooling-oil gallery behind the piston rings (as Bernard Dudot of Renault remarked wryly!) (569, 909).

ECOM

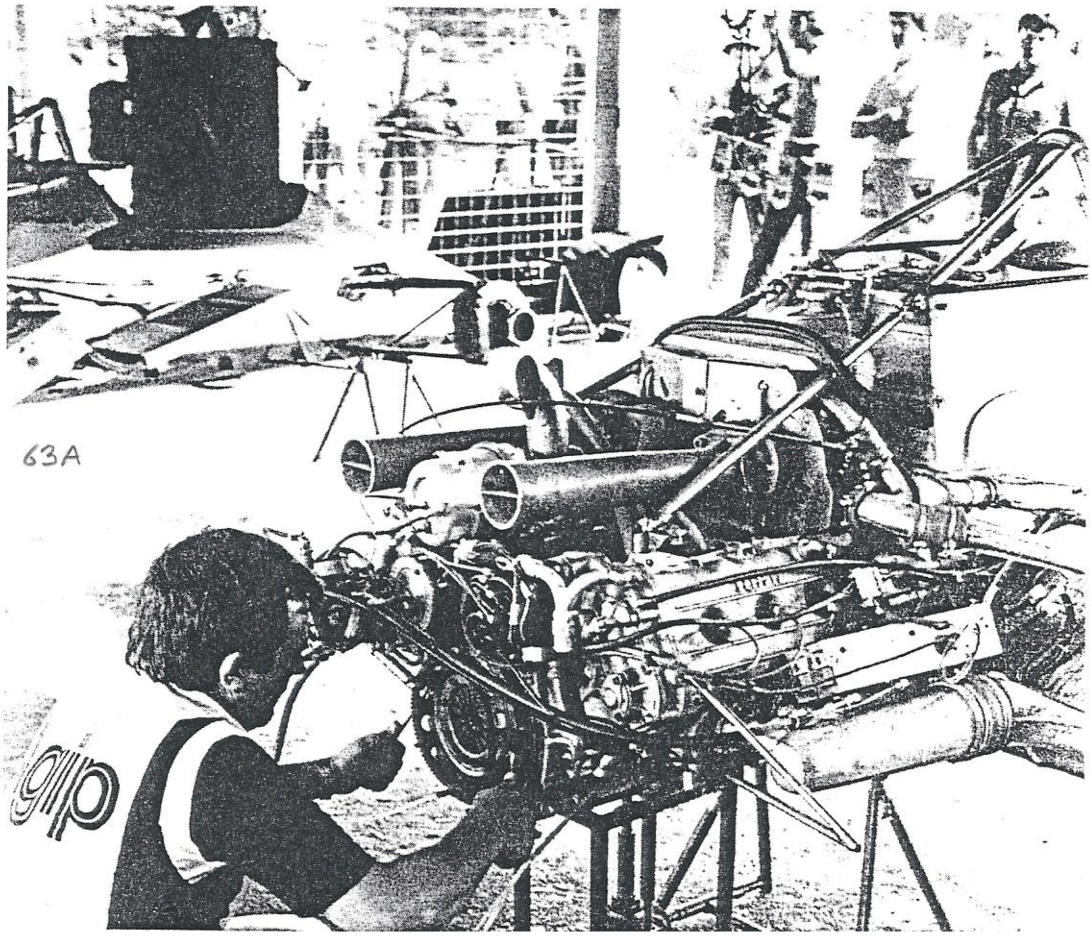
For the TC 126C2 ECOM was 61.3%, where the NA 312B of 1979 was 52.8%. The C3 value was 64.6%.

Good and very bad luck

It can be noted that *luck* played a part in denying the 1982 Drivers' Championship to Ferrari. After some *good* luck in that a dispute over the car weight-measurement method led to most Cosworth-powered British teams abstaining from the San Marino GP in April and thereby allowing Ferrari a 1, 2 finish, there was then appallingly *bad* luck that the Italian team's drivers Gilles Villeneuve and Didier Pironi suffered Qualifying collisions with slower cars in May and August, respectively. These were fatal for the former and ended the latter's GP career (he died in 1987 in a speedboat accident).

Fig. 63A is given on P.3 and Fig. 65A on P.4.

Fig. 63A
1982C Ferrari 126C2
120V6 81/48.4 = 1.674 1,496 cc
Note the twin turbochargers high above the Vee and the compressed air led to an air/air intercooler before reaching the engine inlet plenum chamber.
The vertical pipe was the exit for surplus exhaust gases when a waste-gate was opened to limit the turbine RPM and therefore limit boost pressure.
DASO 124 p.192



The extremely-forward-angled inter-cooler cum radiator cum oil cooler for the starboard side can be seen on the chassis in the background.

Fig. 65A

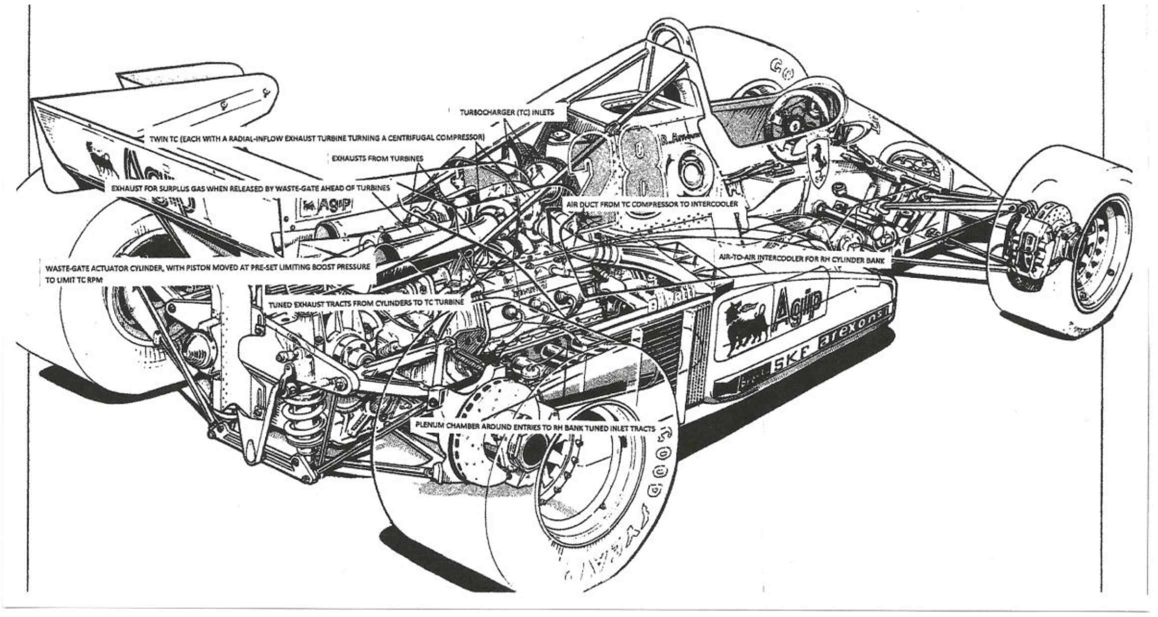
1983C Ferrari 126C3

120V6 81/48.4 = 1.674 1,496 cc

This drawing illustrates all the elements of a turbocharged engine system running on petrol, necessitating an intercooler to reduce into-cylinder charge temperature to permit a compression ratio around 7 to 8 without knocking.

The air/air intercoolers were arranged vertically in this installation.

DASO 877 p.37

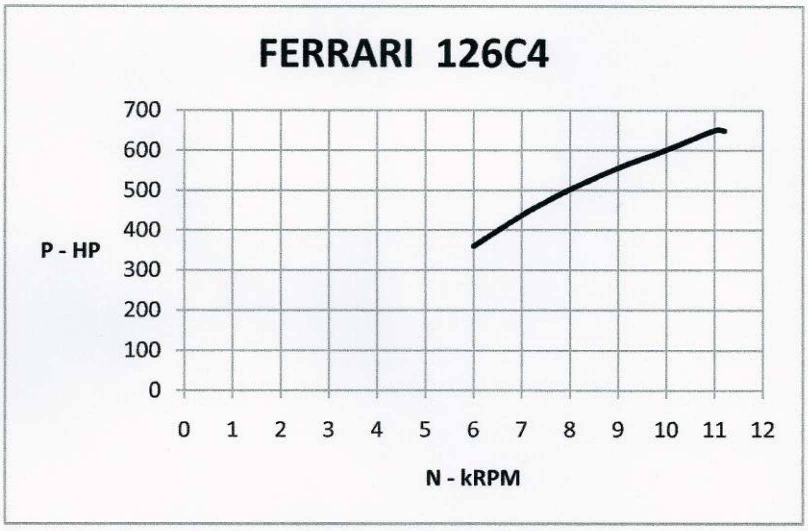


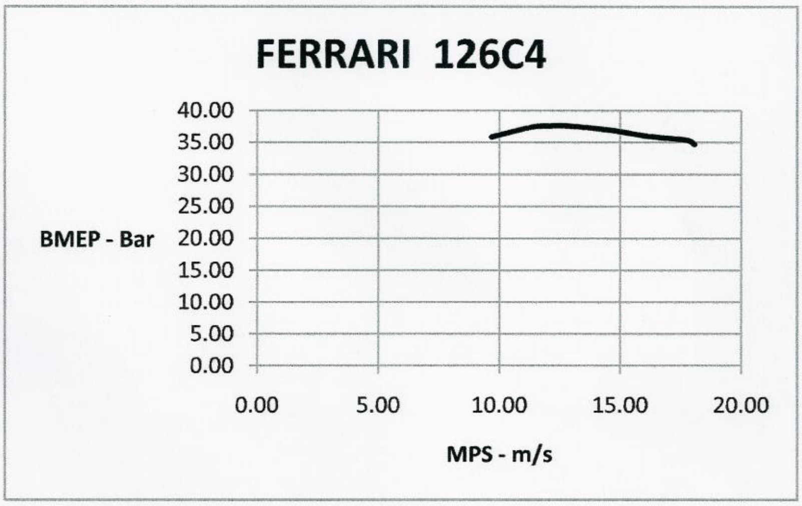
This figure can be enlarged to read the descriptive labels.

A Power Curve for the 1984 type 126C4 is shown on P.5 and the C3 would have been similar.

POWER CURVES

Eg.	For comparison with Eg.65			
DASO	544			
YEAR	1984			
Make	Ferrari			
Model	126C4			
Vcc	1496			
Ind. System	TC			
Confign.	120V6			
Bmm	81			
Smm	48.4			
	N	P	MPS	BMEP
	kRPM	HP	m/s	Bar
	6	360	9.68	35.89
	7	438	11.29	37.43
	7.5	472	12.10	37.64
	8	503	12.91	37.61
	9	557	14.52	37.02
	10	602	16.13	36.01
	11	651	17.75	35.40
	11.2	650	18.07	34.71





Powers as published were Italian CV and have been divided by 1.014 to convert to HP.

64. 1983D BMW M12/13; 1,500 cc; 740 HP @ 10,500 RPM (See Figs. 64A & 64B)

BMW had built a TC production-racing engine as long ago as 1969, applying the system to their type 2002 series IL4 2L and it won the relevant European Championship against NA opposition. TurboCharging was then banned in that class (569).

It was nearly a further decade before more BMW TC work was done on 1.4L versions of the IL4 for production racing (the rules then allowed it to compete with 2L NA). The powers obtained encouraged them to go ahead in 1979 with a 1.5L Grand Prix engine to compete with Renault, already 2 years down that road.

The basis for this was their extremely-successful M12/7 Formula 2 engine, which had powered the European F2 Champion 5 times over 1975 – 1979*, with production of several hundred units (it reached 500 by the end of 1981 (741) and scored another F2 Championship in 1982). It was B/S = 89.2/80 = 1.11 with a 4 v/c VIA = 40^0 cylinder head based on the Ford Cosworth FVA (see "Significant Other" SO19).

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*Including a Schnitzer-developed unit in 1975 (567).

M12/13

For Formula 1 the M12 was fitted with a 60 mm crank to give B/S = 89.2/60 = 1.49, the necessary lengthening of the con.-rod giving CRL/S = 2.56. A single KKK turbocharger, intercooler and wastegate were fitted. There was Bosch electronic control of ignition and of Kugelfischer mechanical pump fuel injection. Unusually for a modern GP engine the *cast iron* cylinder block, as in the M12/7, was a production part shorn of surplus bosses and flanges. This was preferably an old, used 89 mm bore block in which all casting strains had been relieved so that when enlarged to 89.2 mm the bores remained round and friction was reduced (741).

Development

A great deal of testing was done on the bed from early 1980 and in a Brabham chassis specially built for the M12/13 (which was not a stressed component). From October 1980 the power was 557 HP @ 9,500 RPM (567). A 1st race practice appearance was in mid-1981. Despite this testing and the solid F2 base the 1st participation in a race was not until 1982. A very mixed season ensued, with a failure to qualify in June followed by a 1st win in the next race! Much of the trouble lay in the electronics (569).

Toluene-base fuel

The 1983 engine gained much power after mid-season when BMW pioneered the use of Toluene-base fuel to permit higher boost. As described in detail in Note 90 this fuel obeyed the 102RON restriction in the specified low-speed NA test engine but behaved at a much higher anti-knock value in a racing engine at high-speed with high-boost and modern in-cylinder turbulence.

This fuel was decisive in enabling the Brabham-BMW BT50 to power Nelson Piquet to the Drivers' Championship in 1983 (Note 91). Later on (1986) there was an intriguing comment by Geoff Goddard of Cosworth that engine temperatures *fell* with the use of Toluene-base fuel compared with "real petrol" (21). This may have been because a higher compression ratio = *expansion* ratio was used.

Limited piston speed

The TC M12/13 ran at MPSP = 21.0 m/s where the NA M12/7 had 24.7 m/s, so the pressure-charging had forced a reduction of 15% (28% of stress), although the piston crowns were cooled underneath by oil sprays (569).

Single turbocharger

The M12/13 was the only TC CoY engine to race with a single turbocharger and 5 butterfly valves were used to control the engine. In its original 1981 form Paul Rosche stated that Piquet in his Brabham could change gear in about ¼ second but it took another 0.4 sec. for the TC to restore ¾ maximum boost and a further 0.3 sec. to reach full boost (741). Clearly that situation was improved before 1983.

Engine Price

The 1983 price of the M12/13 was 153,000 DM (938) (£41,000, equivalent to £122,000 in 2013 money). This would have been to customers such as ATS and Arrows, since Brabham were partners with BMW and would have received free engines.

1982 Cosworth DFV v. 1983 BMW M12/13

The engines which powered the Drivers' Championships in 1982 and 1983 can be compared as follows:-

Engine	Cosworth DFV	BMW M12/13	M12/13 v DFV
PP HP	515	740	+44%
@ NP RPM	11,300	10,500	-7%
BMPP Bar	**13.65**	**42.05**	**+208%**
MPSP m/s	**24.4**	**21.0**	**-14%**
S mm	64.77	60	
100/Smm	**1.54**	**1.67**	**+8%**

Consequently

PP/V HP/L	**172**	**493**	**+186%**

(See "The General Design of Racing Piston Engines", p.3) (3.08 x 0.86 x 1.08 = 2.86)

MDR	**1 (NA)**	**3.04 (TC)**	**+204%**
BMPA Adj. Bar	**13.65**	**16.36**	**+20%**
ECOM	**57.0%**	**68.3%**	**+11.3%points**

Differing philosophies in racing practice

The concluding and decisive Grand Prix of 1983 was at Kyalami in South Africa, which is at 4,800 ft above sea level so that standard air density is 13% lower; coupled with higher-than-standard temperature the combined result is 19% lower density than Sea Level Standard (877).

This ref. source gave an interesting comparison of two national approaches to this situation; Paul Rosche of BMW said that they had simulated the atmospheric conditions in bench tests and found that on the circuit they had more power than expected; Michel Tetu of Renault stated "*There is no need to test the engine in thinner atmosphere. You simply adjust your boost settings...*" and then admitted "*...the power falls off more rapidly than we expected*".

So much for thorough Teutonic testing and complacent French theory in the early days of Turbo charging!

Figs. 64A & 64B are given on P.8.

Fig. 64A
1983D BMW M12/13
IL4 89.2/60 = 1.487 1,499.8 cc
Note the inverted-cup tappets shrouding the single-coil valve springs;
the slipper pistons; and H-section con.-rods.
Also the single turbocharger. Waste-gate and intercooler omitted,
but the plenum chamber over the inlet trumpets is shown.
DASO 21 p.53

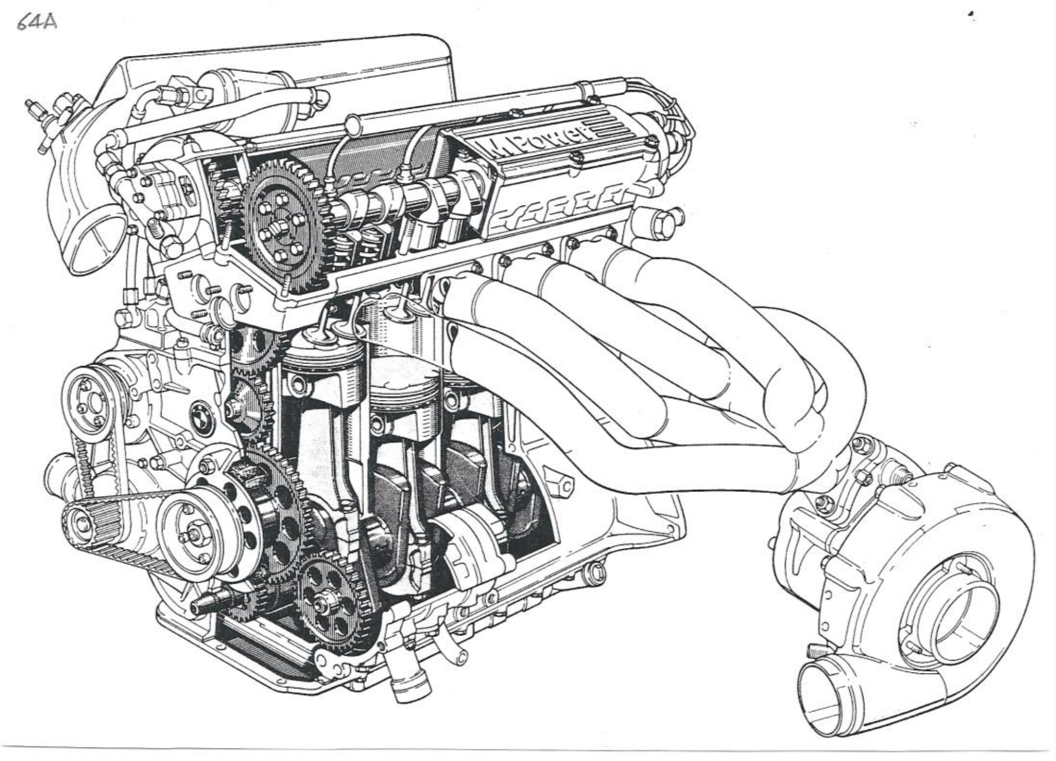
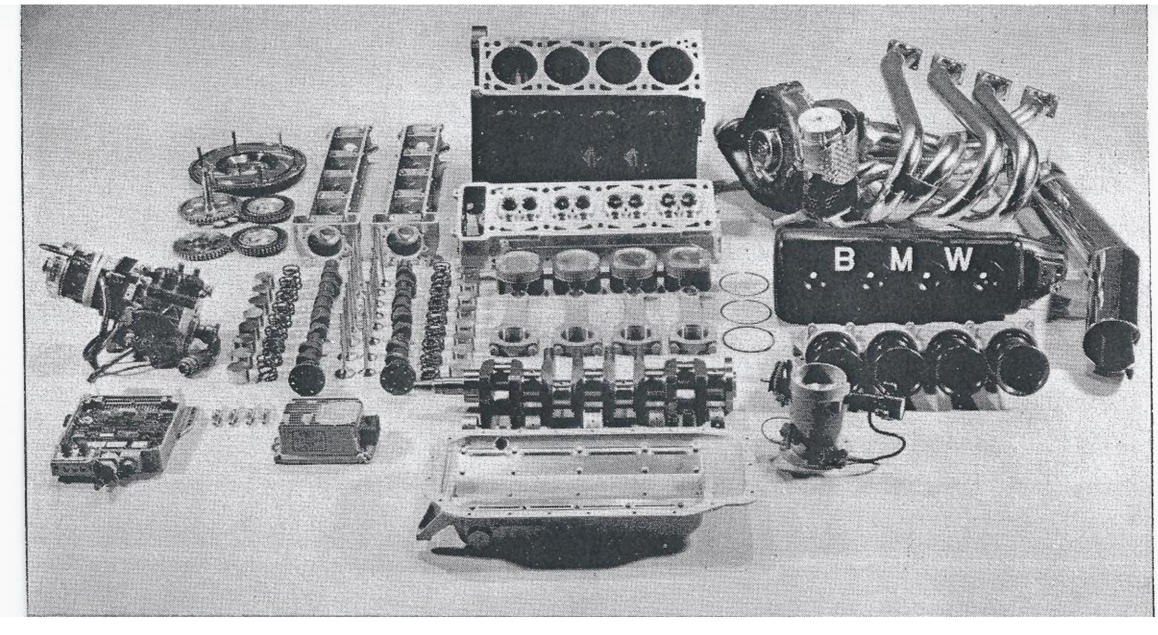


Fig. 64B
The cylinder block was basically a cast-iron production part, stress-relieved by ageing and machined to remove surplus bosses, etc.
DASO 21 p. 51



66. 1984 Porsche P01; 1,499 cc; 750 HP @ 12,000 RPM (See Fig. 66A)
67. 1985 Porsche P01; 1,499 cc; 800 HP @ 12,000 RPM.
68. 1986D Porsche P01; 1,499 cc; 850 HP @ 12,800 RPM

By mid-1981 Ron Dennis had:-

- Just combined his small Marlboro-Project 4 (MP4) junior formulae team with McLaren, which was also receiving Marlboro sponsorship but had rather lost its way since 1977;
- Started racing the new Cosworth DFV-powered MP4/1 Grand Prix car designed by John Barnard, who had pioneered carbon-fibre-composite (CFC) construction for its semi-monocoque "tub" (which provided 70% greater torsional rigidity for 25% less weight compared to Al-alloy sheet + honeycomb structure);
- Persuaded Niki Lauda, double World Champion, to return from 2 years retirement to drive for him in 1982;
- Decided he must have a TurboCharged (TC) engine for the near future.

Renault had by then 4 years TC GP race experience (5 wins to July 1981) and Ferrari had won twice with their TC car while Brabham-BMW TC was being circuit-tested.

McLaren + Porsche + TAG

Therefore Dennis asked Porsche if they would build him a TC engine. This firm had already built TC Racing-Sports cars very successfully, including winning the Can-Am Challenge Cup in 1972 and 1973 and Le Mans in 1976, 1977 and 1979 (a privately-owned car). All these engines had been air-cooled, making it harder to achieve reliable Pressure-Charged power. Post-1977 works Porsche sports-car engines had moved on to 4 v/c VIA = 30^0 water-cooled cylinder heads (i.e. "Duckworth architecture") and so were nearer contemporary Grand Prix design.

Porsche accepted the order on the basis of all work to be paid for and a 6 month design contract was signed in October 1981 (21). Dennis then made another coup before the end of this contract by attracting (from Williams!) sponsorship by the Saudi Arabian investment company Techniques d'Avant Garde (TAG) to cover the cost of building the engines (926). The arrangement was for a new joint company, TAG Turbo Engines, to buy the units from Porsche for McLaren and they were to be badged as "TAG".

P01 configuration

The configuration of the new Porsche P01, chosen in late 1981, was very much a joint effort by Barnard and Hans Metzger, who had been designing Porsche racing engines for over 15 years. Barnard provided a cross-section (and probably a plan view) within which the unit had to fit without any concessions and he specified a narrow crankcase and a Vee angle of no more than 90^0 in order that his large under-body diffuser channels could be optimised (21). The twin turbocharger system also had to permit the McLaren designer's "trade-mark" in-swept body ahead of the rear wheels, 1st used on the MP4/1 and subsequently much copied. The crankcase width limit meant that the water and oil pumps were front-mounted, where most post-DFV engines had them at the sides. Also the exhaust ports left at an upward angle to clear the proposed diffusers although this was a benefit in itself and followed the practice of the Ferrari 312B of 1969. It became the standard practice for later engines.

Metzger pondered a V8 design but selected an 80V6, one reason being purely political – if too successful it could not fall victim to an FISA cylinder number limit while Renault and Ferrari had 6 (21)!

As a new design Metzger could select what he considered to be the optimum B/S ratio for the "Top-end" and "Bottom-end" layout and material limits of the time, at 82/47.3 = 1.73 (near Ferrari's 126C ratio of 1.67 which had also been a new design). This B/S ratio remained unchanged during the engine's 4½ years racing life, unlike Renault's and later Honda's forced reductions (q.v.).

When the 1st engine was nearly ready Barnard's reason for controlling its envelope so tightly was made nearly pointless at the October 1982 FISA congress. With no prior notice and despite the 2 year warning for major technical changes specified in the Concorde Agreement* a flat under-car surface between the wheels was mandated for 1983 cars – the first race of the season being only 6 months away.

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*Signed in March 1981 between FISA and FOCA (Formula One Constructors' Association).

The reason given, which trumped the lead time factor, was "safety" since the cornering forces and therefore corner speeds would be much reduced.

Of course, there was still time for McLaren to build flat-bottom 1983 cars. However, it is probable that Metzger, if it had been left to him originally, would have chosen a better-balanced 120V6 like Ferrari (and as Cosworth were to do in 1984). Barnard might have agreed to that because of the chassis advantages of low CG and better airflow to the rear wing. Actually, regarding engine balance in *practice* as opposed to *theory*, Lauda reported later that the 80V6 Porsche TC was smoother than any NA engine he had experienced (571) (which included the DFV, a known rough engine, and various 12-cylinder engines from BRM, Ferrari and Alfa Romeo in Vee and Flat formations).

FISA also imposed a 220 Litre total fuel cell capacity for races in 1984, with refuelling in a race banned, to reduce power although this did not limit Qualification settings.

<u>P01 Details</u>

The detail design of the P01 in layout and materials was conventional to the 1982 state-of-the-art, with 4 v/c and VIA = 29^0. The valves also had a slight fore-and-aft inclination and the cams were shaped to suit this (711). The IVA/PA ratio was 0.28, slightly on the low side of the optimum probably then represented by the 1982 Cosworth DFV at 0.32*.

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*There is some reason to believe that the P01 IVD figure from ref.(21) is too low – see Note 107.

Exhaust valves were Na-cooled internally. The Mahle pistons benefited from the oil-cooling gallery devised by that firm earlier for Renault. A channel machined behind the ring grooves, then sealed with a welded-in piece, received oil via one hole from a pressure jet and ejected it from a 2nd hole as the piston reciprocated (1055).

<u>Inroduction to service</u>

The 1st P01 engine ran in December 1982 (21) (i.e. 14 months from design start under Metzger). It was 1st tested in an adapted MP4/1 chassis in July 1983 (926) and 1st raced in August 1983. Unsurprisingly there were no finishes (including a disqualification) from 7 starts in the season although only 4 DNF were engine-related. The last retirement was from an improving 2nd place at 94% distance.

It is interesting that this late-1983 adapted-chassis racing was despite the objections of Barnard who wished to start in 1984 with his MP4/2 TC-customised car. It proved its worth in "bugs" uncovered.

<u>Engagement of Alain Prost</u>

Ron Dennis made another important decision before the purpose-built TC McLaren MP4/2-Porsche P01 assaulted the 1984 season. In October 1983 he engaged Alain Prost immediately after he was sacked by Renault for criticising the team in public when he failed to win the 1983 Championship by 2 points. This meant letting John Watson go, quite ruthlessly, despite his having taken 4 of the 6 DFV-powered McLaren MP4/1 wins over 1981 - 1983.

Engine Management System

An important advance on the Porsche P01 was a new Bosch all-electronic/electrical Engine Management System (EMS), custom-designed under the direction of Dr Udo Zucker for the P01 – and so very expensive, according to (926). With this EMS the dual-flow fuel injectors were solenoid-operated. This differed from the less-sophisticated BMW-Bosch-Kugelfischer electronic-mechanical system. It could even allow for the fuel temperature, which became helpful in 1984 when teams were partially offsetting the 220L ration by cooling the liquid to increase its density. Typically refrigerating to -30^0 C from ambient 15^0 gained 4 to 5%, i.e. ≈10L (938); pre-cooling was banned for 1985 onwards.

This new system had its early troubles but Bosch brought it *au point* by the 1st race of the 1984 season which the MP4/2 won.

To complete the EMS story, it included in 1985 a fuel-flow monitoring function with a cockpit display to advise the driver how much of his 220L remained. Renault and Ferrari did not have this valuable feature.

In 1986 the EMS was heavily-revised and the programming was unreliable until the last race (927). Prost had some EMS problems in all but 6 races of the season and both McLarens ran out of fuel in the German GP on the last lap when 2nd and 3rd due to inaccurate readings of the reduced 195L ration imposed in that year (927).

[The author cannot resist making the point that, with technical advances, “*You win some – you lose some!”.*]

McLaren-Porsche results, 1984 – 1987

The McLaren team, with an exceptional chassis designer (although Barnard left in August 1986), with two exceptional drivers in Niki Lauda and Alain Prost and with gradual Porsche power development, achieved the following CoY results over 1984 -1987 (the latter added to complete the P01 history):-

	1984	1985	1986	1987	Total
Car	MP4/2	MP4/2B	MP4/2C	MP4/3	
	CoY	CoY	CoYD		
Drivers’ Championship	Lauda	Prost	Prost		
Constructors’ Championship	✓	✓			
Races	16	16	16	16	64
Wins	12	6	4	3	25
Wins/Races	75%	37.5%	25%	18.8%	39.1%

This was against the race-winning competition of:-

	Wins over 1984 - 1987
• Ferrari	5
• Lotus-Renault	5
• Lotus-Honda	2
• Brabham –BMW	3
• Benetton-BMW	1

and especially strong after mid-1985,

• Williams-Honda	23

The 1984 successes created a new record for a double-digit race season, surpassing the previous Lotus 1978 mark of 8 wins out of 16 events (using Type 78 for 2, Type 79 for 6). Prost’s back-to back Championships in 1985, 1986 equalled for the first time in 25 years the Brabham double in 1959, 1960. As so often, *luck* played a part in the 1986 title. In the last race the points-leading driver (Nigel Mansell, Williams-Honda) when holding a sufficient 3rd place for the Championship, had a tyre burst at 78% distance. This was despite the pre-race assurance of the supplier that their product could last non-stop. The next points leader (Nelson Piquet, also

Williams-Honda) was then called in for a tyre change. Prost, on the same make of tyre, had changed very early after a puncture-causing collision and went on to win the race and the title.

McLaren's Qualification policy

Originally McLaren did not use *special* high-power engines for qualification, partly because Dennis thought it more rewarding to use practice time to prepare the race set-up and partly that the budget did not permit it since all engine work had to be paid for. His confidence that the TC-powered MP4/2 could win from other than a front row grid slot was justified based on the 1981 – 1983 performance of the MP4/1–DFV against much TC opposition. At 13 races these cars had obtained podium finishes, including 5 wins, from the 3rd row or further back; the most amazing result was 1st and 2nd starting from 22nd and 23rd grid places at Long Beach in 1983! The 1984 Championship was won by Lauda without ever starting from the front row, his average grid position being 8th. Qualification power *was* raised sometimes with larger turbochargers and, from mid-1984, by externally water-spraying the intercoolers (a system banned for 1987 onward).

Later the increasing competition of Williams-Honda led McLaren to run Qualifying engines having about 200 HP more than the race specification, i.e. up to 1,100 HP in 1987 (21). By then a 4 Bar (3.95 ATA) limit on IVP was in force for both race *and* Qualification engines (announced in May 1986) but this did not affect Porsche power since the engine was raced at 3.2 Bar and 3.8 for Qualification (21).

P01 Development history

The P01 race engine development over 4 years was as follows:-

	1984	1987
Sources	21, 569, 571	21
Fuel	102RON Petrol	Toluene-base (not used until mid-1985 (926))
R	7.5	8
MDR	2.9	3.2
Race PP HP	750	900
@ NP RPM	12,000	13,000
BMPP Bar	37.3	41.3
@ MPSP m/s	18.9	20.5
BMPA/MDR Adj. Bar	14.6	14.4
ECOM	60.4%	60.2%
MGVP m/s	68.4	74.1*

*Assuming IVD unchanged at 30.5 mm; it may have been enlarged (see Note 107).

Full valve-gear details are not available but the quality of the P01 compared with other CoY engines can be judged on a BNP basis as described in Note 13 Part III. Figures are tabled below:-

All engines DOHC, 4 steel v/c and steel CVRS:-

	1982D	1982C	1983D	1983C	1984	1985	1986D	1986C
Engine	Cosworth DFV	Ferrari 126C2	BMW M12/13	Ferrari 126C3	Porsche P01	Porsche P01	Porsche P01	Honda RA166E
BNP m/s	16.1	14.9	15.6	14.9	16.4	16.4	17.5	15.8

The DFV was known to have had fragile valve-gear so the 1986 P01 was doing well at 9% higher BNP (18% higher stress).

The 1987 P01 was not CoY. It was bedevilled by vibration problems. These are reported to have originated from heavier R = 8 pistons (from 7.5 in 1986) (21) (the fuel limit was still 195L and the change would have been to improve Specific Fuel Consumption), but may also have come from a slightly higher RPM (13,000 v. 12,800). This could have caused a torsional mode which showed itself in broken alternator drive belts on 2 occasions when Prost was in 1st or 2nd place (with 2 other known belt failures), one of these *after* the crank balance was revised in mid-season. The cure was a duplex belt drive (21).

P01 engine price

The price of a P01 was £120,000 in 1984 (£340,000 in 2013 money). This would have included an amortisation of the development costs as Porsche were not absorbing those. The price was therefore nearly 3 times higher than the BMW unit. As a total of 30 engines had been bought by McLaren up to 1986 (927) this float had cost at least £3.6 M (£10M).

Summary for the P01

In conjunction with Ron Dennis' entrepreneurial and management skills, John Barnard's chassis design ability, Bosch's EMS contribution and ace drivers Niki Lauda and Alain Prost, Porsche gained great prestige on their return to the Grand Prix arena, 22 years after they retired from it with only 1 win to their credit – and they were paid for it!

The immense resources of Honda gradually brought Williams to the fore again as the power and fuel consumption development of the P01 became subject to diminishing returns.

The rules announced by FISA in October 1986 had reduced permissible TC IVP for 1988 to 2.5 Bar (2.47ata) from 4 Bar in 1987 and reduced fuel ration to 150L from 195L, while allowing in parallel NA engines of 3.5L with 40 kg lower minimum car weight and no fuel limit in 1988. For 1989 and onward only NA 3.5L engines would be permitted.

Honda intended to develop a variant of their TC engine to the 1988 rules for just one year's racing. It is not known if Porsche contemplated doing the same but, in any case, their McLaren buyer had decided to go elsewhere. From his now very-strong McLaren reputation Dennis negotiated a deal with Honda for free 1988 engine supplies.

Porsche therefore retired from Grands Prix again after 1987, this time with many laurels, and concentrated once more on their very-successful Racing-Sports cars.

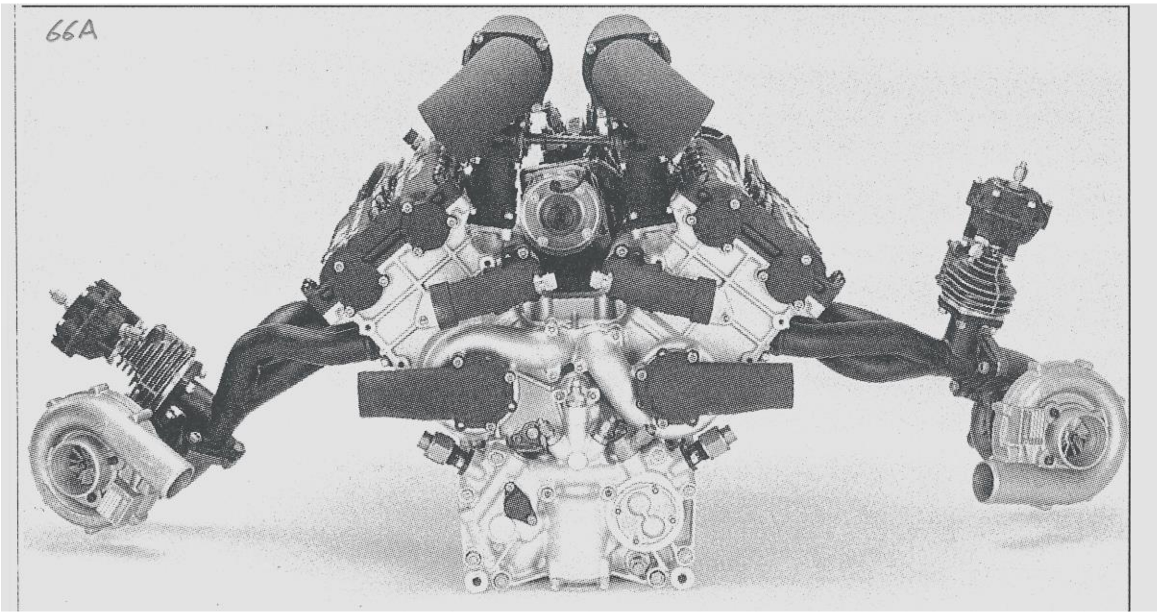
A Porsche Grand Prix postscript

Unhappily there *was* a GP sequel with an 80V12 3.5L NA engine built in 1991 for Footwork (ex Arrows, a notably win-less team after many years trying) but it was unreliable, although heavy, and it had to be withdrawn after only a few events.

Fig. 66A is given on P.14.

Fig. 66A
1984 82/47.3 = 1.734 1,499 cc
The turbochargers were placed to suit John Barnard's chassis design
being within the side pods frontal areas.
The intercoolers are not shown in this illustration.
Note the updraught on the exhaust ports.
In mid-1985 a "mirror Image" of the turbocharger shown here on the LH side was available from KKK to improve the gas/air flow paths.

DASO 711



Egs 69, 70, 71 Honda RA166E, RA167E, RA168E

are available separately on this site.

The values of ECOM for these engines compared to the other TC engines in the 2nd PC Era are:-

	1982C	1983D	1983C	1984	1985	1986D	1986C	1987	1988
Engine	Ferrari	BMW	Ferrari	Porsche	Porsche	Porsche	Honda	Honda	Honda
	126C2	M12/13	126C3	P01	P01	P01	RA166E	RA167E	RA168E
ECOM	61.3%	68.3%	64.6%	60.4%	64.4%	62.0%	62.1%	64.3%	63.4%

Recap on ECOM

(A "Short Glossary of Abbreviations" is given with the section **"An Overview of Performance"**)

It is shown in the preceding section on "**The General Design of Racing Piston Engines**" and the related Note 10 that:-

BMEP = 38 x MDR x ASE x [EV x EC x EM] Bar
at STP ambient conditions of 15C and 1.013 Bar

Taking out the effects of MDR and ASE, very much (but not wholly) dependent on fuel quality available at a date, eg. Toluene-base fuel, the engine's combined efficiency "chargeable" to the designer is therefore:-

$$[EV \times EC \times EM] = ECOM = \left(\frac{BMEP}{38 \times MDR \times ASE}\right)$$

The combined efficiency values are available in Appendix 1 by dividing Row 80 by 23.94 (= 0.63 x 38) and multiplying by 100 to give a convenient %age.

Review of the 2nd Pressure-Charged Era

After the BMW IL4 powered the Drivers' Champion in 1983 and the Ferrari 120V6 the Constructors' title of that year, only 80V6 configurations produced Champions in both classes:-

- 3 Drivers' to Porsche plus 2 to Honda;
- 2 Constructors' to Porsche plus 3 to Honda.

Including the 1982 "Pre-Era" Constructors' to Ferrari 120V6 the score for TC overall was:-

V6 12 Championships; IL4 1 only.

Renault TC in Grand Prix racing – failure of a pioneer

The TC pioneer in Grand Prix racing, Renault, never took a Championship with its 90V6 (which most other manufacturers copied, with detailed variations of course eg. Vee angle), either in their own car or in specialist chassis (Lotus, Ligier, Tyrrell). This may have been partly the result of "*big-firm-culture*" – an inability to respond fast enough to competitive racing needs which changed every fortnight or so; certainly a refusal to accept informed – but *public* – advice from an employee. When Alain Prost criticised Renault engineering in late 1983 after taking the best Championship position that Renault ever achieved – 2nd – the company's response was instant dismissal (877)! That driver went on to miss the following year's Championship in a McLaren by ½ point, gained 2 titles back-to-back in 1985 -1986 and then secured 2 more in 1989 and 1993!

One Renault pioneering detail in GP engines which no other front runner ever copied in races* was belt drive for the camshafts.

____

*Honda used camshaft belt drive for their prototype V10 3.5L in late 1988 but changed to gear drive before the unit raced in 1989.

Renault's engine also began with too-high a B/S ratio of 2.01 as a result of simply de-stroking their CH2 V6 2L Formula 2 engine. It had to be redesigned to 1.62 in 1985. [Honda made the same mistake for the same reason, starting in 1983 at 2.31, revised to 1.74 in mid-1985 and then settling at a very-successful 1.56 for 1986 – 1988.]

Another Renault novelty for 1986 was the "*Distribution Pneumatique*" valve return system invented by J-P Boudy. This had gas compression in a static cylinder surrounding a piston on the valve stem taking the place of steel coil valve springs so as to eliminate surge. Undoubtedly this had been stimulated by the "Top-end" problem of the original excessive B/S ratio. A valuable serendipitous by-product was a reduction in top-end weight (474). It did not result in any great success for the TC Renault *but* in the 3rd NA Era after 1990 it became the standard *"way-to-go"* for all CoY engines and permitted ever-increasing B/S ratios. It had been Patented but, it seems, no one took any notice of that in copying the concept!

Other non-CoY engines

Other TC engines which never powered a GP winner were:-

Two V6s:-

1. Motor Moderni 90V6, designed by Carlo Chiti but under-funded;
2. Cosworth 120V6, too late before TC was banned inside an official assurance of useful formula life to Ford before they funded it.

One V8:-

Alfa Romeo, a somewhat surprising failure which did confirm that a V6 was optimum for '80s 1.5L TC – when the B/S ratio was moderate.

Three IL4s:-

1. Hart, with a minimal budget. They *nearly* had a moment of glory in a very wet 1984 Monaco race when a rookie Ayrton Senna in a Hart-powered Toleman was within 7 seconds of overtaking Prost, leading in a McLaren, but the race was then stopped under half distance!;

2. Zakspeed, also with a minimal budget;
3. Alfa Romeo, who cancelled this V8-replacement project abruptly after a driver for the chassis user, Ligier, criticised it in public.

Boost and fuel limits

After TC Qualification engines, which were unaffected by race fuel limits of 220L in 1984 – 1985 and 195L in1986 – 1987, reached up to 1,300 HP in 1986 (estimated for BMW (21)), the racing authorities imposed a maximum IVP of 4 Bar (3.95 ATA) for 1987 and dropped it still further to 2.5 Bar (2.47ATA) for 1988 coupled with a reduction in race fuel ration to 150L (see Table 1 of "The Sporting Limits"

Prost's summary of the 2nd PC (TC) Era

Alain Prost, double World Drivers' Champion with TC cars, in 1988 summed-up 8 years of progress in TC engines as follows:-

"*We had about 520 HP when I started with Renault*" [in 1981] "*and we went up to 1,200 and 1,400 with the TAG*" [Porsche] "*engine in Qualifying 2 years ago*" [i.e. in 1986]. "*Now we have....700 with 150 litres of fuel*" [Honda 1988; actually 676 HP in Qualification specification and 611 HP in 150L race tune (20)] "*....at Renault we had 250 litres for 550 HP*" (574).

The relative Specific Fuel Consumptions of these two ends of TC development are:-

$$\left(\frac{250\text{ litres}}{550\text{ HP}}\right) \quad \text{v.} \quad \left(\frac{150\text{ litres}}{611\text{ HP}}\right)$$

$$\text{Datum} \quad \text{v.} \quad 54\%$$

The keys to this improvement were:-

(1). Full electronic/electrical Engine Management Systems. The computing power provided by silicon chips coupled with solenoid-operated indirect fuel injectors enabled every combination of engine parameters to be provided with just the right mixture, unlike mechanical systems where an over-fuelling compromise had to be accepted;

(2). Toluene-base fuel (see Note 90) replacing "Real Petrol" which had been used initially with very-rich mixture ratios for internal cooling. The higher anti-knock quality of the new fuel was taken up at first in higher boost at low compression ratio to raise power. Later on, as IVP and the fuel ration were regulated downwards, compression ratio was raised so as to reduce Specific Fuel Consumption.

Higher efficiency of TC v. NA

The average value of ECOM for the 9 TC CoY engines, 1982 – 1988, was 63.4%.
This compares with 12 Cosworth DFV NA CoY, 1968 – 1982, which averaged 56.3%.
The 10%point ECOM gain of TC v. NA was due to a combination of factors:-

- A higher Combustion Efficiency (EC) because the lower Compression Ratio (R) enforced by the boost pressure gave a combustion chamber with a lower (better) Surface Area/Volume ratio: average DFV R = 11.4; average TC R = 7.4;
- The "Pneumatic" advantage of TC from inlet charge pressure exceeding exhaust back pressure without mechanical power deduction (see Note 76); a gain in Mechanical Efficiency (EM)
- Lower friction losses (a further gain in EM) because Mean Piston Speed (MPSP) was restricted in TC engines to provide an adequate piston life at the higher pressure and temperature loading:
  friction a function of $(MPSP)^2$:
  average DFV MPSP = 22.4 m/s; $(MPSP)^2 = 501\ (m/s)^2$;
  average TC MPSP = 19.7 m/s; $(MPSP)^2 = 390\ (m/s)^2$; 78% of DFV.