3rd Naturally-Aspirated Era (3NA), Part 2, 1995 - 2000 (end of this review); Egs. 79 to 85
The 3 Litre Formula

79. 1995 Renault RS7; *2,992 cc; 675 HP @ 15,200 RPM* (See Fig. 79A)

After the FIA WMSC decision of June 1994 to reduce the allowable swept Volume (V) to 3 Litres in 1994, there was a lead time of 9 months to the start of the season.

The resultant Renault RS7, still 67V10, is believed to have dropped V *mostly* by reduced Stroke (S), so that B/S rose but this is unconfirmed. Certainly the engine length, at 623 mm, was unchanged from the RS6 (1017). The crankcase apparently was reduced in height

A 5'' instead of a 5.5'' triple-plate clutch was fitted (565).

3L vs 3.5L back-to-back track testing.

The RS7 was available for Williams to do an "Apples-to-Apples" comparison with the RS6 in an FW16 car at the shortened Paul Ricard circuit in December 1994, only about 6 months after the 14.3% V drop was mandated (quick work, suggesting only minimum changes). Driven by Emmanuel Collard the new combination was only 2% slower in lap speed (129.5 MPH vs 132.2) (574). This was a remarkable achievement which, on the typical exchange rate, implies about 8% drop of PP (see Note 104), although other sources indicated 12% reduction (see Appendix 1). Perhaps the lower engine C of G and 3 kg lower weight (1017) helped the lap speed.

Seasonal developments

The FIA "Zero-ram-pressure" rule of mid 1994 was rescinded after the 1st 1995 race.

New developments from the Renault*sport* Viry-Chatillon works were: RS7A at the 3rd race (S. Marino) with revised B/S; RS7B at the 7th (French) claiming +300 RPM; RS7C at the 11th (Belgian) (all 1017 refs.).

1995 results

In competition with Ferrari (who produced *two* all-new V12s but then probably did not develop them because a V10 was designed and tested) and McLaren (fitting an all-new Ilmor V10 with Mercedes-Benz backing) Renault obtained a dominant position by supplying engines to both Williams *and* Benetton. These teams were, of course, the respective Constructors' and Drivers' Champions of the previous year and each retained its No.1 driver.

Both awards duly came to Benetton, who obtained an 11 win share out of a total of 16 secured by RS7 power. Only Ferrari secured 1 win against it.

Although not *basic* engine failures, throttle and fuel pump problems caused 2 DNF in the season (1013).

Mecachrome

Some engines were produced for Renault by the specialist Mecachrome company, who had maintained units run by Ligier (without wins) in 1994.

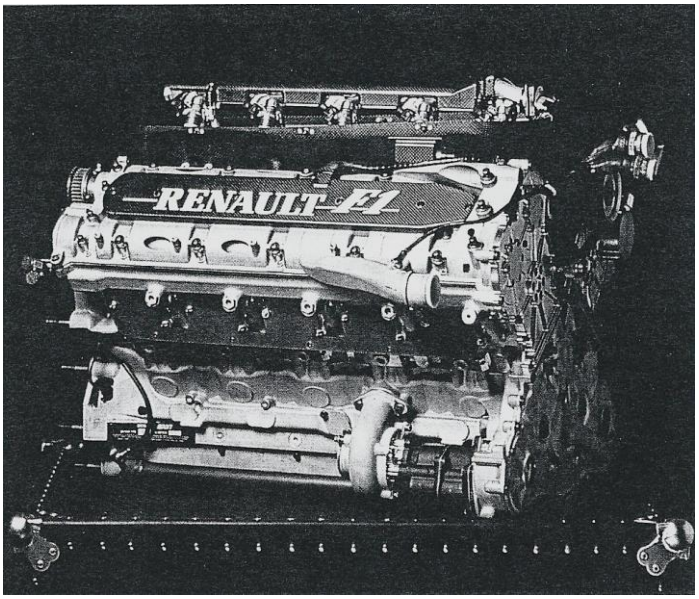


Fig. 79A
1995 Renault RS7
67V10 *91/46 = 1.978* *2,992cc*
DASO 565

80. 1996 Renault RS8; *2,998 cc; 700 HP @ 16,000 RPM* (See Fig. 80A)

The RS8, still 67V10, was apparently just a slightly higher B/S version of the RS7 (1017), there being plenty of space for a larger Bore in the unchanged length of 623 mm carried over from the last 3.5L engine (1017).

Dudot felt no pressure to reduce engine weight from 132 kg (974) although in Rugby the small-budget John Judd-led Engine Developments Ltd. were making a 100 kg V10 badged as a Yamaha OX11A. This light weight was achieved by re-adopting cylinder liners screwed into the head, last seen in a CoY engine in the 1953 Ferrari type 500, so as to minimise the bore spacing (690). [There is, of course, always the possibility that a declared weight excludes necessary external items which other makers include! A too-light engine would be unreliable – and the OX11A seemed to show that was the case.]

1996 Updates

An 'A' version ran at the 6th race (Monaco) and as usual a 'B' version appeared at the French GP (9th).

Ferrari's flattery

Renault now had 8 years experience in building and testing V10 engines, so the 1st race appearance of a V10 Ferrari on the flattering principle of "*If you can't beat a V10 with a V12, make one yourself!*" probably did not worry them unduly, even although the Italian company hired away the 1995-Renault-powered Champion Michael Schumacher to drive it. He reportedly changed teams for $25M p.a.(1005)!

1996 Results

This cockpit transfer crippled Benetton (still using Renault engines). They won no races. This was made up by the RS8-powered Williams team running a pair of drivers (Damon Hill, former No1, and Jacques Villeneuve, 1995 Indy 500 winner) who spurred each other on to new performance levels so that the Championships were both obtained by the team.

The Williams FW18-Renault RS8 won 12 races, Hill beating Villeneuve by 8 wins to 4 to be Champion. His reward was to be fired.

The RS8 had 2 embarrassing failures when leading: Hill's at Monaco, which let in a Mugen-Honda Ligier driven by Oliver Panis to win; and Gerhard Berger's Benetton at Hockenheim, which was to Hill's benefit. Schumacher won the other 3 races with the new V10 Ferrari.

Renault's announced retirement

It has been reported (1005) that Renault by now were spending each year $60M (£37.5M at the then rate of $1.6/£1, equivalent to £62M in 2013 money) on their Formula 1 programme. No doubt feeling that further success would yield diminishing returns of favourable publicity, the firm announced in June 1996 that they would retire from Grand Prix racing at the end of the next season.

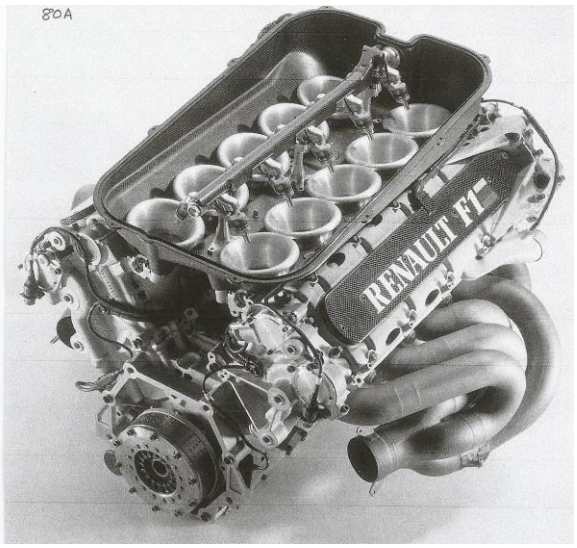


Fig. 80A
1996 Renault RS8
67V10 *92/45.1 = 2.04* *2,998 cc*
DASO 1017

81. 1997 Renault RS9; *2,998 cc; 730 HP @ 17,000 RPM* (See Fig.81A)

It is likely that the all-new RS9 had already been designed when the Renault management in June 1996 decided to leave F1 at the end of 1997. Otherwise they would hardly have gone to such expense.

The RS9 was 71^0 Vee angle, replacing the 67^0 used in the previous 8 marks. The thrust of the redesign seems to have been to lower the C of G (the unit was 25 mm lower (1017)), making use of a new 4.5'' driven-plate-diameter AP clutch, and to lighten it by 11 kg to 121 kg (1017).

The first RS9 was available for track-testing in a Williams by mid-November 1996 and 11,000 km were covered before the 1st race (1017).

During the season 2 modified versions were produced, at the 8th (French) and 14th (Austrian) races.

As before, Williams and Benetton received free engines.

1997 results

The competition from Ferrari and the improving Ilmor-powered McLaren was much fiercer than before but Villeneuve and Wiiliams secured the dual Championships.

Renault powered 9 wins (Benetton scored once). Perhaps the most satisfying race for the whole series of V10 engines to which Renault had been faithful was at the New Nurburgring in September. The two McLaren MP4/12-Ilmor FO110F cars ran 2nd and 1st until, respectively at 42 and 43 laps (64% of 67), the engines blew up in front of the main grandstand full of Daimler-Benz executives (D-B then owning 25% of Ilmor) and then Renault RS9-powered cars filled the first 4 places! "*To finish first, first you must finish!*".

Details of the RS1 to 9 Programme

It is believed that Renault spent (the French equivalent of) over $500M in the 11 years of their NA V10 programme in designing, testing, supplying and maintaining free-of-charge their engines to:-

- Williams (throughout), gaining 63 wins;
- Ligier (for 3 years 1992 – 1994), no wins;
- Benetton (for 3 years 1995 – 1997), 12 wins.

This totalled 75 wins out of 146 races (51.4% of the possible).

Drivers' Champions powered were 5:- Mansell; Prost; Schumacher; Hill; and Villeneuve.

Constructors' Championships totalled 6 consecutively, 1992 – 1997; 5 to Wiiliams, 1 to Benetton in 1995

Altogether this was the 2nd-longest successful run for a Grand Prix engine of *basically*-similar design after the Cosworth DFV.

RS Technical Direction

It is worth repeating that the Technical Director at the Viry-Chatillon plant of Renault*sport* throughout the RS programme was Bernard Dudot, with major assistance from Jean-Jacques His.

Post-1997

There was an appendix to the racing life of the Renault V10 when the French aerospace company Mecachrome bought a licence to lease and maintain the type for paying customers over 1998 – 2000. By some financial arrangement with Flavio Briatore they were badged for Benetton as "Playlife"; others in 1999 – 2000 were named "Supertec".

Williams had to pay $16M (£10M) in 1998 to lease engines (1005) and, although the World Champion still drove for them, they scored no wins. Neither did Benetton.

A new heavily-financed team, Brtish American Racing was then built around Villeneuve in 1999, using the "Supertec" engine. Again , none of the 3 teams with the ex-Renault V10 won a race, nor yet again in 2000 when the users were Benetton and Arrows.

This barren period illustrated very well the relentless pace of development, where the Ferrari and Ilmor competition moved ahead and, without works development of the kind shown previously by the numerous in-season versions as well as the annual re-designs, the ex-Renaults did not.

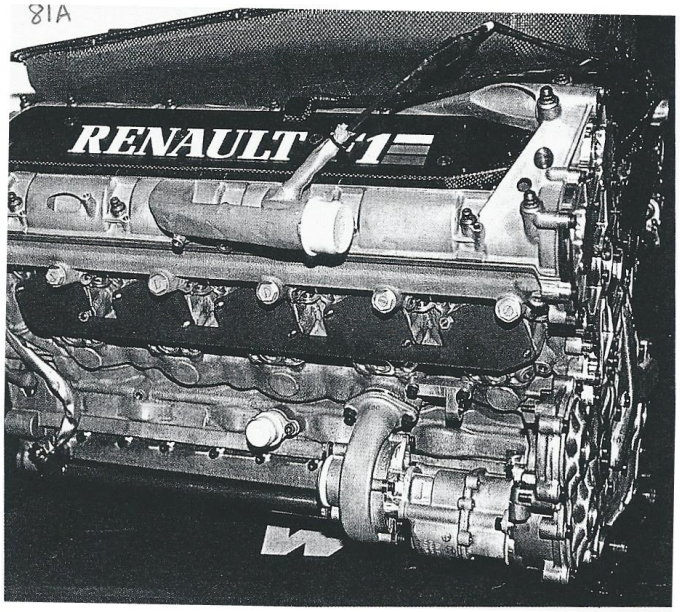
It did not help Williams that their Chief Designer since mid-1990, Adrian Newey, had left them in November 1996 after completing the 1997 FW20 design. It was reported that he had considered that he had some say in the choice of drivers and the dismissal of Damon Hill without consulting him (apparently to provide a seat for Heinz-Harald Frentzen to please BMW as a potential future engine supplier) had led him to resign. Time would show that Williams made a bad mistake because they have not won another Championship since Newey's departure.

Benetton also had lost key people: Technical Director Ross Brawn and Chief Designer Rory Byrne had followed Schumacher to Ferrari in late 1996/early 1997.

Renault secrecy

Renault would not divulge any internal details of their RS engines. Perhaps this was because they always planned to return, as they did in 2001, and wished to preserve their secrets.

Fig. 81A
1997 Renault RS9
71V10 93.5/43.67 = 2.141 2,998 cc
The only (minor) difference visible compared to the previous 67V10 RS series
is that the hot water offtake from the cylinder head was now at the middle of the engine.
DASO 958



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82. 1998 Ilmor FO110G; 2,998 cc; 750 HP @ 17,000 RPM (See Figs. 82A & 82B)

It was significant in several ways when Mika Hakkinen won the 1998 Drivers' Championship at the last race in a McLaren MP4/13-Ilmor FO110G (the engine badged as a Mercedes-Benz), the team also gaining the Constructors' Championship:-

- It was Hakkinen's 1st Championship after 8 highly-paid years in F1 (his 1st win had come only a year earlier, gifted by David Coulthard on team orders);
- It was the 1st F1 championship for Ilmor, also after 8 years;
- It was McLaren's 1st F1 Championship for 7 years, whereas earlier in the Ron Dennis era they had gained 6 Constructors' titles in the 8 years 1984 – 1991;
- It was the 1st F1 Championship for a Mercedes-Benz-badged engine in 43 years and it was the outcome of their 25% investment in Ilmor 5 years earlier, *plus* ongoing support and free engines supplied to Sauber for a year and to McLaren for 4 years.

Tyre influence

Of course, factors other than the engine had an equal influence on the result, especially the typically-shrewd choice by Ron Dennis, Team Principal of McLaren, of Japanese Bridgestone tyres in place of the US Goodyears used previously and still chosen by Ferrari, the major competitor. A rule change effective in 1998, intended to reduce lap speeds (yet again) had required a narrower track (reduced by 12½%) and circumferentially-grooved tyre treads in place of slicks (3 front wheel grooves, 4 rear). With this latter change the two tyre suppliers apparently restarted equal (Bridgestone having only 1997 in F1 with minor teams) but the Japanese company was generally acknowledged to be well ahead at the beginning of 1998. The 2 McLarens actually lapped the 3rd place Goodyear-shod Williams FW20-Mecachrome in the 1st race, a result which had not occurred for many years. It certainly stimulated Goodyear to catch up during the season!

Adrian Newey's influence

The influence of Adrian Newey as McLaren's Chief Designer on the aerodynamics of the MP4/13, especially on fast circuits, also cannot be overlooked. After completing his contract with Williams "in his garden" he had in August 1997 transferred to McLaren the ability which had helped to secure 5 Constructors' Championships for Williams.

History of Ilmor

Foundation of company

Ilmor Engineering Ltd. had been formed in 1984 by Mario Illien and Paul Morgan, after learning the trade of racing engines at Cosworth (where Illien designed the type DFY (see Note 88)), with 25% participation by Roger Penske* and 25% by General Motors (see Note 105). The active partners had 25% each.

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*Roger Penske was head of a US multi-billion-dollar transport conglomerate, a racing driver in earlier years, and at that date a constructor of Indy 500 cars successful in 1979 and 1981).

Engines for US racing

The initial product of Ilmor was a 90V8 2.65L TC engine to power Indy cars, badged as a Chevrolet. After 4 years and at their 3rd '500' entry in 1988 they succeeded in beating the Cosworth DFX which had reigned there continuously for 10 years. A significant improvement in the engine in September 1987 had overcome previous cam drive unreliability. This was a pendulum damper in the system – a detail not disclosed by Illien until 2006 in ref. (1066) – and used in the later F1 V10s.

There followed 5 more '500'victories to 1993. Mercedes-Benz (a distinct branch of Daimler-Benz since June 1988, as opposed to a vehicle name) then took over GM's 25% stake in November 1993 (see Note 105). Ilmor made for M-B a special TC 72V8 3.4L push-rod engine for 1994 to take advantage of new Indy rules which were *meant* to encourage modified *stock* engines. This 1,000 HP unit powered the Penske PC24 to win the '500' on the only occasion that it was allowed to compete. Further M-B-backed 2.65L TC engines followed for US racing.

Grand Prix engines

Meanwhile, after establishing the Indy engines, Ilmor started a Grand Prix design in 1989, type 2175A (a code to conceal a cylinder volume of 2 x 175 cc) as a NA 72V10 3.5L. Illien chose B/S = 86.6/59.4 = 1.46 (although he had used 1.62 in his 1988 TC engine (1006)) so as to minimise length at 593 mm and minimise weight at 126 kg (excluding the clutch (1006)). For comparison with other 1989 engines, the Honda RA109E was 620 mm and the Renault RS1 with front belt cam drive was 668 (62).

The 2175A was CVRS and generally conventional for the period – all-Ti-alloy valves may be assumed. Low-budget teams were paying customers (Leyton House in 1991; March and Tyrrell in 1992).There were no wins.

Potential Mercedes-Benz and actual Sauber applications

During the earlier years of this period Mercedes-Benz were contemplating a return to Grand prix racing in 1993 using the Swiss Sauber team as the ostensible base (just as they had done from 1984 in Racing-Sports programmes, including a 1989 Le Mans win with the cars painted silver as Sauber-Mercedes). Funds were provided for car design and the intention was to use a

development of the Ilmor 2175 as the engine. Although the parent Daimler=Benz board refused to go ahead with the full project in November 1991, M-B still had 2 years to run of a DM30M (£12M) p.a. support contract with Sauber (468) and used this to assist them to prepare for and enter F1 in 1993. Sauber had to find some additional sponsorship.

The 2175A was used by Sauber initially but in September 1993 a 'B' re-design was introduced, still 72V10 and still CVRS but with B/S = 92.2/52.4 = 1.76 (1006), within the same length, a notable achievement.

Mercedes-Benz having joined the Ilmor shareholders in November 1993, as mentioned above, they extended their F1 association with Sauber into 1994 (the cars had "*Concept by Mercedes-Benz*" on their bodywork) and there was further engine development. Also as mentioned, they were badged as 'tho from the German company. A PVRS version was ready in August, after solving a problem caused by lateral 'g' in the car (468). VIS was also adopted n 1994 (419).

Ilmor 2175 compared with Cosworth HB

Comparisons of these early Ilmor GP engines with the Cosworth HB8, also available as a customer unit, are as follows:-

Year	Late 1993	1991	Late 1994 German GP
Type	HB8	2175A	2175B +PVRS
Data Source Ref. DASO	128,574 636, 1000	468,1006	468,1006
Configuration	75V8	72V10	72V10
B mm/S mm	94/63	86.6/59.4	92.2/52.4
B/S	= 1.492	= 1.458	= 1.760
V cc	3,498	3,499	3,498
Valve gear	PVRS	CVRS	PVRS
			2175B Relative to 2175A
PP HP	*705*	696	765 +9.9%
@ NP RPM	*13,000*	12,800	14,000
BMPP Bar	*13.9*	13.9	14.0
@ MPSP m/s	*27.3*	25.3	24.5
BNP m/s	*20.4*	18.5	21.5 +16.2%
W kg	*125*	126	123
PP/W HP/kg	*5.6*	5.5	6.2
Championship wins	3		

Ilmor - Mercedes-Benz and McLaren

The Sauber team finished 8th in the 1994 Constructors' Championship, a decline from 6th in 1993. McLaren, a vastly better financed, more experienced and previously highly-successful team, using in 1994 a new Peugeot engine in the 1st year of a 4-year deal, finished 4th.

Neither Mercedes-Benz nor McLaren were happy. As a consequence their respective partnerships were not renewed (Sauber) or cancelled (Peugeot) and in October 1994 it was announced that the two would combine in a 5-year agreement centred on an Ilmor engine to the new 3L rule. It was reported that M-B then paid Ilmor over £30M annually to improve their facilities, carry out Research and Development, and provide free engines to McLaren (727).

The reduced swept volume for Grand Prix engines had been promulgated in June 1994 and Illien had then begun work on a suitable engine, type MFC. However, McLaren insisted on external changes and the FO110* to suit them was begun in September 1994

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*FO(rmula) 1, 10 (cylinders).

FO110

The Vee angle was increased 3^0 from the 2175 to 75^0 to accommodate the car's hydraulic pump inside the Vee and the oil pressure and scavenge pumps were raised in their outside-block positions so that the car's underbody lines could be improved (1008). One fruit of the new partnership was a more-capable McLaren Electronics ECU, replacing Magneti Marelli. A detail was that the 8 ATA base PVRS used air, not nitrogen, and via a 17 ATA reservoir was fed by a reciprocating pump (1008).

The new engine was on test 4½ months from September 1994 (1006) and was available for the 1st race (in *Brazil*) in March – an astonishing feat of design, development and production.

Unfortunately there was not a fairy-tale 1st race win for the MP4/10-Ilmor FO110 and there were 6 engine failures in the season (18% of starts). Not a bad effort for an all-new engine but there *had* been 4 years of V10 development preceding it.

There were 'B' and 'C' versions at the 8th (British) and 11th (Belgian) races, respectively.

FO110D

An FO110D redesign was begun in August 1995 and was on test on 3 February 1996 (1006). There followed no less than 5 piston failures. This part was in RR58 Al-alloy (see Note 14). Assistance was sought by McLaren from Rolls-Royce, very knowledgeable of course about the material and that company's computerised analysis suggested changes to reduce stresses transverse to the forging grain. Computerised manufacturing then quickly provided sets of pistons in time for the 1st race an 10 March 1996 (561) (Australia). One MP4/11 finished 5th.

Altogether the 1996 engines were more reliable but no wins were obtained, the best result being 2nd at Monaco.

FO110 E & FO110F

What was by now the usual annual pattern of a redesign, to FO110E, started as early as May 1996 with an 'F' version begun at the same time. The 'E' was fitted with a 130 mm (5.1'') diameter Sachs clutch (419) to lower the C of G. The 'F' reverted to 72V10 and was more compact and lighter.

The 'E' *did* power the MP4/12 to win the 1st 1997 race (Australia), this being Ilmor's 1st Grand Prix victory. The 'F' type from the 7th race (Canada) then demonstrated sufficient power with uncertain reliability, powering 2 McLaren wins (13th (Italian) and 17th (European at Jerez, rather luckily)) but suffering the extremely embarrassing double failure in Germany which has been described in Eg. 81. These may have been bottom-end problems (567).

1998 FO110G

The Neu Nurburgring debacle in front of the Daimler-Benz executives *may* have triggered the ultimate success of the 1998 FO110G, whose design had started on 6 June 1997. It had its 1st test as early as 5 December (1006) and it is believed that extra testing programme was carried out in Stuttgart where an elaborate transient dynamometer was available to simulate racing conditions more closely. To quote Joe Craig, head of the famously-effective Norton motorcycle racing team from 1931 to 1954:- "*Nothing succeeds like failure!*"

Concerning development testing, (987, published in 2003) stated that Ilmor had used up to a dozen single-cylinder rig engines at Brixworth and in Germany. Ref. (1019) confirmed a similar number of such *builds* in 1999 (not necessarily completely new units for each test) with a picture showing that the main engine bank angle was reproduced. [See also Note 106.]

Although after Ilmor began to work with Mercedes-Benz there ceased to be published the same internal details as for their earlier engines, they *were* prepared to give some external data. The length of the FO110G was 590 mm and the weight 107 kg, including the clutch but excluding the ECU and the exhaust system (1006).

The weight reduction of Grand Prix engines by major manufacturers undoubtedly was stimulated by John Judd's 100 kg design (for Yamaha) in 1996, although this did not obtain success in the 2 years it was campaigned by Tyrrell and Arrows (one very near miss by the latter – Hill a close 2nd at Hungary in 1997). The advantage of a lighter engine when a minimum car weight was already easily achieved was that ballast could be positioned to lower the C of G and relocate it fore and aft as desirable for a particular circuit (the rule forbidding ballast having been rescinded, probably because chassis crash testing had been introduced to eliminate flimsy

construction). Together with lighter chassis figures up to 70 kg of ballast were mentioned (574), 12% of the 600 kg car minimum with water, oil and driver but without fuel.

Mario Illien *had* been prepared to discuss features of his 'F' type in August 1997 (419). In particular he was convinced that "Tumble Swirl" was superior to a "Dump Port" (see Notes 26 and 80). In April 2006 (1066) Illien mentioned some details which applied to the 1998 FO110G, such as DLC coatings (see Note 103), the pendulum cam drive damper, I-section con. rods and VIA less than 20^0. He also said that each crank throw rotated in its own sealed chamber, separately scavenged, to reduce windage loss.

From the 1st test to the 1st race of the FO110G there were 3 months to complete development and build a set of engines to equip the MP4/13 cars for their 1st 1998 race in Melbourne on 8 March. As mentioned earlier they finished 1st and 2nd, a lap ahead of a Williams FW20-Mecachrome.

Introduction of Beryllium-Aluminium alloy

In 1998 Ilmor is believed to have introduced Beryllium-Aluminium alloy pistons in 'Q' engines and may have used them in late races (690). The advantages of this costly material have been described in Note 14*.

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*Note 14 suggested that the Be/Al-alloy might have been "Lockalloy", an aerospace material of 62% Be +38% Al. It has since been confirmed that the F1 use was a process development of that by Brush Wellman (1115).More details are given in (1116) & (1117).
DASO 1115: www Materion article by T. Parsonage on structural applications;
DASO1116: Race Tech Feb/Mar 1999;
DASO 1117: '' '' Apl/May ''

FO110G Performance

It was deduced from photographs (559) that the FO110G, which was again 72V10, had B/S = 93.5/43.7 = 2.14 but this must be treated with caution.

The power output (presumably for the end-season version) *was* given officially as 750 HP @ 17,000 RPM (559).

Performance factors are therefore:-
BMPP = 13.2 Bar @ *MPSP ≈ 24.7 m/s;*
ECOM (assuming R = 14) ≈ *53%*;
BNP ≈ 26.5 m/s.

1998 results

The Ilmor – Mercedes-Benz FO110G powered the (lucky) McLaren MP4/13 to 9 wins in 1998, with 5 1st & 2nd places.

There were only 2 engine failures while racing, once when in 1st place and again when 2nd. Both were described officially as main bearing faults (574).

McLaren 1991 – 1998

The history of McLaren in the Constructors' Championship (WCC) over the period 1991 – 1998 shows the decline of the team and *eventual* revival with Ilmor power:-

	1991	1992	1993	1994	1995	1996	1997	1998
Engine Maker	Honda	Honda	Cosworth	Peugeot	Ilmor – Mercedes-Benz			
	V12	V12	V8	V10	V10	V10	V10	V10
WCC position	1	2	2	4	4	4	4	1
WCC points	139	99	84	42	30*	49	63*	156
No. of Wins	8	5	5	0	0	0	3	9

*17 races, all others 16. Points-scoring system same throughout.

Figs. 82A & 82B are shown on P.9.

Fig. 82A
1991 Ilmor 2175A
72V10 86.6/59.4 = 1.458 3,499 cc
Representing Eg. 82
1998 Ilmor – Mercedes-Benz FO110G
72V10 *93.5/43.67 = 2.141 2,998 cc*
The 2175A illustrates the general concept of the Ilmor F1 V10 series.
In particular, the B/S ratio was lower originally than contemporary engines and Mario Illien continued to use bores less than rivals in order to permit a higher compression ratio without an off-setting loss of Combustion Efficiency (1066 and Note 54).

DASO 419

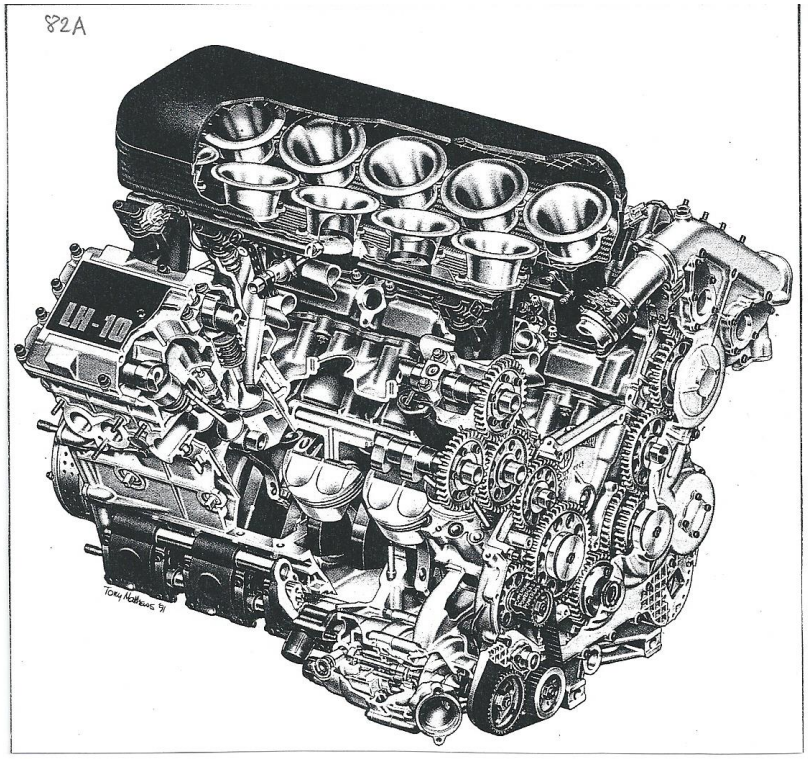
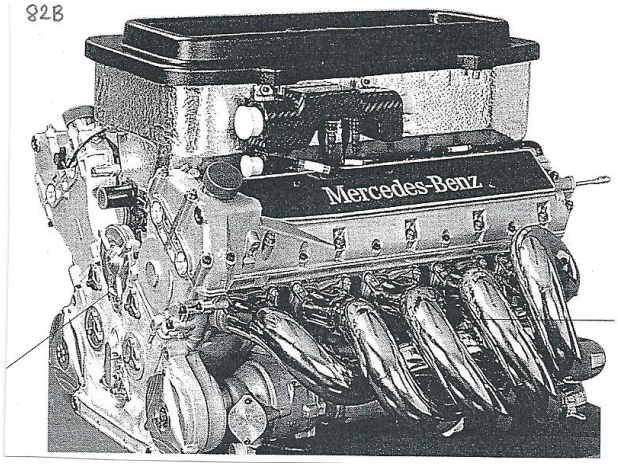


Fig. 82B
The camshaft gear drive of the FO110G was at the front, as in all Ilmor F1 Engines, where their V8 Indy engine had it at the rear.

DASO 964



83. 1999D Ilmor FO110H; 2.998 cc; 800 HP@17,500 RPM
(This engine is not included in Appendix 1)

The outturn of the 1999 Drivers' Championship was affected by an accident to a World Champion, as it was in 1994, fortunately not fatal in this case. Michael Schumacher, No. 1 for Ferrari, had a leg broken in an accident at the 8th race at Silverstone which removed him from competition for the next 7 races out of the season's 16. However, the (unofficial) No. 1 for McLaren, the reigning World Champion Mika Hakkinen, lost his form in many races and the No.2 Ferrari driver, Eddie Irvine (with the help of a returning Schumacher in the final two races) took the contest to the final event. There the Ilmor – Mercedes-Benz FO110H powered the McLaren MP4/14 to a repeat Drivers' crown for Hakkinen but the Constructors trophy went to Ferrari for the first time since 1983.

FO110H

The FO110H was a complete redesign from the 'G', as the 'G' had been from the 'F' (700), except for nuts and bolts. Nothing has been released concerning internal dimensions but it was still 72V10, the same length, slightly lighter (under 100 kg (574)) and had a lower C of G (1006, 1010). It ran 1st on 4 November 1998, after 8 months in design and build giving an extra month's lead time to the 1st race compared to the 'G' (1006).

Beryllium/Aluminium parts

The FO110G raced from the start with Be/Al-alloy in its pistons and also in its wet cylinder liners. The latter were 35% lighter than the preceding Al-alloy parts and – with thinner barrels – permitted closer cylinder spacing to reduce overall weight.

The Ilmor use of Be/Al-alloy was then ahead of Ferrari (700). It continued in Ilmor specifications in 2000, after which it fell under an FIA ban on the grounds of excessive cost of any engine metallic part with an **Elasticity/Density ratio above 40 GPa/(gm/cc).** Illien then disclosed that it had *not* been a costly solution because the Be/Al parts had lasted longer (700). Of course, in the nature of racing, development would very soon have used thinner sections to reduce piston mass and so raise RPM, taking parts life back to one race!

Finger cam followers

Finger cam followers may have replaced inverted-cup tappets (doubling as PVRS pistons) in the 'H' as a way of reducing friction when PVRS enabled Mean Valve Speed (MVS) to be increased – this system of resisting cam side thrust was certainly in use by Ilmor in 2000 (700). It was necessary to use hard-coating on the followers to resist the high surface pressure and "Diamond-like Carbon" (DLC) became available shortly beforehand (see Note 103) and had been used in the FO110G (1066).

FO110H Performance

A power of 800 HP was quoted by Mario Illien as achieved by the end of 1998 (700), which corresponds to the early dyno tests of the 'H', and 17,500 RPM was quoted by (1011).

Therefore BMPP = 13.6 Bar.

Assuming R = 14, *ECOM ≈ 55%.*

1999 Results

The 'H' powered 7 wins by the McLaren MP4/14 and it had no basic engine failures in races.

At the 5th race (Spanish at Barcelona) the car averaged a fuel consumption of nearly 77L/100km (3.7 MPG) at an average speed of nearly 196 kph (121.5 MPH).

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84. 1999C Ferrari 048; 2,997 cc; *750 HP @ 16,500 RPM* (574)
(This engine is not included in Appendix 1)

85. 2000 Ferrari 049B/2; 2,997 cc; 795 HP @ 17,500 RPM

These two engines are already posted on the website, see:-
Eg. 84 Ferrari 048 and Eg. 85 Ferrari 049.

The 3rd NA era reviewed (to end 2000)

Swept Volume (V)

Only two regulation swept volumes were specified in the 3rd NA era up to the end of 2000:-

- 3.5L for 1989 – 1994;
- 3.0L from the start of 1995 and onward in this review period.

The reduction was one consequence of the double fatalities at Imola in May 1994. They had shocked a racing world which had not suffered a death in 12 years because of the great advances in car and circuit safety.

Configurations

The dominant engine configuration of this period was the V10, with only 2 exceptions in CoY:-

- The Honda 60V12 of 1991;
- The Cosworth 75V8 which powered the Drivers' Champion (D) in 1994.

The V12 and V8 configurations had struggled hard to resist the V10, up to the 1995 Ferrari in the case of the former. The Cosworth's partial success of 1994 was the "*last hurrah*" in Grand Prix racing of a distinguished V8 line which began with the DFV in 1967.

The V10s were provided by:-

- Honda (1989 – 1990);
- Renault (1992 – 1997, excluding 1994D; Constructors' (C) only in that year
- Ilmor (badged as Mercedes-Benz) (1998 – 1999D);
- Ferrari (1999C – 2000).

The V10 Vee angle varied from 67^0 to 90^0 pioneered by Ferrari in 2000 to reduce C of G height and so aid cornering.

Funding and Technical advances: the increase in Power/Volume and Power/Weight ratios

The 3rd NA era to end 2000 saw an enormous increase in annual funding, provided essentially from the advertising opportunities of the increased TV coverage organised by Bernie Ecclestone which stimulated companies within and without the car/fuel industries to sponsor teams.

The share of this money expended in engine development over 12 seasons produced great advances. Comparing the 1989 Honda RA109E to the 2000 Ferrari 049B/2:-

- Peak Power (PP)/V: rose from 174 HP/L to 265 HP/L: = +52%;
- PP/Weight (W): rose from 4.1 HP/kg to 7.5 HP/kg: = +84%.

These resulted largely from increasing Bore (B)/Stroke (S) ratio from 1.58 to 2.32 so that Reciprocal Stroke increased by 36%. There was a small increase of 13% in Brake Mean Effective Pressure at PP (BMPP). Mean Piston Speed at PP (MPSP) was virtually unchanged at about 24 m/s so that with the reduction of S the RPM rose from 13,000 to 17,500 (see "General Design of Racing Piston engines.

The average BMPP over the 12 years was about 13.3.∓ 1.2 Bar.

In the pair quoted, ECOM rose from about 50% to about 57%. The 12 year average was about 55%.

"Top-End" improvements

The increase in B/S ratio was made possible by solving the problems of increasing Mean Valve Speed at PP (MVSP)* in 3 ways:-

1. All Ti-alloy valves (see Note 15 for details;
2. Pneumatic Valve Return Systems (PVRS) (see Note 15);
3. Diamond-like Carbon (DLC) coating on valve-gear rubbing surfaces (see Note 103).

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* The surrogate Bore Speed (BNP) (see Note 13 Part II) rose by 45%.

The successful valve arrangements continued to follow the Duckworth architecture, as amended in the DFY re-design from the DFV, i.e. 4 valves per cylinder (4 v/c) with Valve Included Angle (VIA) reduced to 20^0or less. Substantial updraught on the exhaust ports was introduced to reduce flow turning.

Engines using 5 v/c (3 inlet, 2 exhaust) were tried but only Ferrari obtained wins with that layout before they reverted to 4 v/c.

"Bottom –End" improvements

The 12 year average Mean Piston Speed at PP (MPSP) was 24.2 ∓ 1.5 m/s.

Significant changes were:-

- Con.-rods in Ti-alloy;
- Pistons of slipper pattern were used in which height was reduced pro rata with stroke and all non-pressure surface areas below only 2 rings were cut away, with shorter gudgeon pins (see Note 13 for illustrations of late-type pistons);
- In Ilmor engines a Be/Al-alloy of higher Stress/Density ratio than RR58 Al-alloy was used (see Note 14 for details and comments in Eg. 83);
- Increasing Con.-rod Length/Stroke ratio (CRL/S) to reduce side-force. Details are scarce but the 2000 Ferrari 049 CRL/S was 2.68 where the 1982 DFV had been 2.05;
- Improved lubricants.

Piston-ring Flutter

It seems that the engines in the 3rd NA era soon ran fast enough to operate normally above piston-ring flutter frequency without needing to reduce axial widths below 0.8 mm, despite Maximum Piston Deceleration at PP (MPDP) rising from about 6,600 g to 8,400 (+27%) (see Note 13 Part III).

Flexibility and Gearboxes

The rise in PP/V meant a drop in Flexibility =

$$\frac{[\text{Peak Power RPM (NP)}-\text{Peak Torque RPM (NT)}]}{\text{NP}}$$

For the 2000 Ferrari this was only 11%, where the 1982 DFV had been 20%. This was despite the introduction of Variable Inlet Systems (VIS). However, ECU development enabled engines to pull away from half NP.

The invention of the Semi-Automatic Gearbox (SAGB) with 6 or 7 forward speeds in 1989, enabling extremely-quick gear changes to be made without the driver having to remove a hand from the steering wheel or to operate a clutch pedal, also meant that peakier power curves could be accepted. The necessary ECU with Drive-by-Wire meant that over-revving on a premature change-down was prevented and engine reliability was extremely high. This was assisted by lifing the pistons and valves to one race each.

Clutches

Smaller clutches made possible by triple-plate carbon-carbon contributed to C of G lowering. The era began with 5.5'' driven-plate diameter and Ferrari in 2000 use 4.5'' (although 3.84'' was available and may have been used by Ilmor).

Engine weight and Ballast

Ever-lighter engines, probably mainly a result of higher B/S ratio as crank webs diminished, enabled substantial ballast to be carried within the rule minimum car weight. This, located in the floor, further lowered the C of G. The ballast could be moved fore and aft to alter the car weight distribution to suit each circuit – forward to add some understeer for fast circuits; back to improve traction and give more responsive steering for slow circuits.