69. 1986C Honda RA166E; 1,494cc; Q *1,200HP** @ 12,000RPM
70. 1987 Honda RA167E; 1,494cc; Q 995BHP @ 12,200RPM
71. 1988 Honda RA168E; 1,494cc; Q 676BHP @ 12,500RPM

See Fig. 70A, Figs. 71A and 71B, attached. Power Curves for the RA167E and RA168E are also attached.

It is worthwhile to consider the history of Honda engines in other branches of motorsports before describing in detail the Grand Prix engines of 1986 -1988, because of the large impact that they made on high-power engine design.

The first Honda Grand Prix motor-cycle racing era, 1959-1967

Soichiro Honda founded his firm to make lightweight motor-cycles in 1948. In 1959 the 1^{st} entry was made in a major International race with a 125cc twin-cylinder machine. A 250cc four followed in 1960 and in 1961 each took its World Championship. From then until the end of 1967, when the company retired from Grand Prix motor-cycle racing for a time (which turned out to be 12 years), they campaigned in all classes from 50cc to 500cc in various years, providing mounts for 16 Champion riders (only the “Blue Riband” 500cc escaped them) and captured 18 Makers’ Championships (all 5 classes in 1966).

All the Honda racing motor-cycle engines were 4-stroke air-cooled and had 4 valves per cylinder (4v/c) – this latter feature was re-introduced by them into that arena (see Note 78) – which coped easily with Bore/Stroke (B/S) ratios gradually increasing from 1.07 to 1.41, but with wide included angles between valves (VIA) varying from 76^0 to 56^0 which did, however, allow airflow to the top of the cylinder head. Honda specialised in miniaturisation, raising volume specific power (HP per litre, HP/L) by reducing S and increasing the number of cylinders (CN) – except for a modest 4 cylinders for their 500cc, where the engine in any case easily gave more power than the frame and tyres could handle satisfactorily. Honda reached 263 HP/L @ 20,000RPM with their 1966 RC149 IL5 125cc design (354). The downside was an RPM range for that engine from Peak Power to Peak Torque of only 2.5% (the technical predecessor IL2 50cc engine required a 9-speed gearbox!). Naturally, all cylinders of whatever swept volume had individual inlet and exhaust tracts and, by very careful super-tuning with exhaust diffusers (“megaphones”), they were able to hold Brake Mean Effective Pressure at Peak Power (BMPP) at nearly 12 Bar on 100 Octane petrol over the cylinder range from 125cc down to 25cc (the latter in the RC149 being B/S = 35.5mm/25.1 = 1.41 in 1966 with Inlet Valve Head Diameter (IVD) of 13.5mm (354)!)(see Appendix 1, “Significant Other”SO18: also Note 78/Fig. 115/DST and Note 92 for more details). The principal performance drop to the smallest size cylinder was in Mean Piston Speed at Peak Power (MPSP).

Yoshio Nakamura was manager of the Honda Research & Development Co., a group separate from the production facilities, which built the racing motor-cycles during this period.

The first Honda racing car era, Grand Prix and F2, 1965–1968

Honda began to make cars in 1962 and naturally followed the same “Advertising + Technical Training” path as with their motor-cycles by building racing machines.

For the 1.5 Litre Normally-Aspirated (NA) Grand Prix formula Honda held serious talks early in 1964 with Colin Chapman of Lotus about his using a novel transversely-mounted 60V12 engine (which had been on the test-bed since Summer 1963) and a mock-up was supplied. However, Chapman decided to stay with Coventry Climax (855)**. Honda had meanwhile designed their own chassis and this RA271 appeared in August 1964 with the new engine.

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*This figure (Q = Qualification rating) is an estimate because, according to Patrick Head, Technical Director of Williams at the time, Honda’s dynamometer could only absorb 1,000HP, reached at 9,300RPM, where they were actually run up to 13,500RPM (984).

**Chapman’s biographer, Crombac, believes his negotiation with Honda was intended to put pressure on Coventry Climax (855) and presumably this helped the decision to continue with the FWMW F16 engine projected to race in 1965 (but not developed satisfactorily in time).

Developed as the RA272 this Honda won the final race of the formula in October 1965 after only 15 months and 11 races, so might have repeated the motor-cycle pattern of success if it could have been campaigned for more years. Certainly an IL4 1 Litre F2 engine, revised for 1966 with higher B/S from an inauspicious 1965 version, was virtually invincible in a Brabham chassis – but, again, this was the last year of the formula. An unusual feature of that engine was a Valve Return System with steel *torsion* bars.

The F2 engine was paralleled by a senior Grand Prix partner for the new 3 Litre NA formula, the RA273 car with a 90V12 engine which appeared first in September 1966. The Vee angle was novel and made room to place the bulky exhaust system centrally out of the airflow. No doubt for the same reason the inlet tracts were downdraught between the DOHC of each bank. They fed 4 v/c with wide VIA. The latter features and an all-rolling-bearing crank were the same as in all previous racing Hondas. The camshaft drives and power output were taken from the crank centre, a layout only used previously in the unsuccessful BRM 135V16 designed in 1948 and the 1954-1955 very-successful Mercedes M196 IL8 but which would never be seen again in Grand Prix engines. The unit, at 230kg (884), was much heavier than the Cosworth DFV which appeared in June 1967 weighing 162kg with 30HP more than the 370HP claimed for the Japanese engine.

The revised RA300 V12 which appeared in 1967 did win a race when provided with a Lola chassis but the further revised 1968 RA301 won nothing. This poor showing led to Honda retiring from car racing (although they had already designed a lighter V12 without the central power offtake and possibly plain main bearings (574)), having achieved in all 2 classic victories in 34 races (6%). Perhaps it was no coincidence that in September 1968 the "Mitsui Trading Co." bought 2 Cosworth DFV engines (60), which one feels sure were examined very carefully by Japanese firms. Nevertheless, they missed the inlet port feature designed to create *deliberate* "Barrel Turbulence" (aka "Tumble Swirl") since, as late as 1988, the Honda RA168E engine did not include this!

Resumption of Grand Prix motor-cycle racing, 1979

In 1969 Honda began to race motor-cycles again but in the sports category with their new CB750 750cc 4-cylinder production machine, for which the term "Superbike" was coined. This branch of competition has continued by Honda to the present day but is outside the scope of this review. It was not until 1979 that they re-entered the pure racing arena. They then astonished the world with a new GP 500cc 4-stroke motor-cycle to compete with the 2-strokes which had dominated the class since 1975 because it had the by-then-rule-limited 4 cylinders but with **8 valves per cylinder in "oval" (or "race-track") section bores!** The configuration was 100V4 water-cooled and S = 36mm in order to permit the extremely-high RPM which would be essential to provide sufficient power. At this time Honda were following a policy of choosing newly-qualified engineers to design new products, expecting that they would find novel and effective solutions to old problems. It was reported that these young men had designed originally a V8 500cc without knowing that the post-1969 rule maximum was 4. Lateral thinking – the quality for which they had been selected – then resulted in the combination of cylinder pairs (935)(this is a good story, but may be apocryphal!). Only Honda knew how the pistons were sealed.

This NR500, although developed in several versions over 4 years up to 268HP/Litre at 19,500RPM (354)(see Notes 78 and 92,) S by then being 28mm, never looked like winning a major race and since Honda could not beat the 2-strokes they were forced to join them in 1982. They were immediately successful and continued to be so for 20 years, the engines moving from 3 cylinders to 4 cylinders and being developed up to nearly 400HP/L @12,500RPM largely by tuning the exhaust system. The 2-stroke dream of having equal BMPP with the best 4-Strokes (14 Bar @ about 22m/s MPSP) and twice the power strokes was at last realised, but again at the price of an exceedingly narrow useful RPM range. The 2-stroke also saved the weight of the valve gear.

However (to complete the story) the motor-cycle rules for the premier class were changed in 2002 to permit effectively double-size (actually 990cc) 4-strokes to compete with 500cc 2-strokes and, yet again, Honda were on top with a 4-stroke V5.

Honda did contemplate placing an oval-cylindered motor-cycle into production for sports racing in 1987 – the NR750, a 750cc 85V4. This had an effect on automobile Grand Prix rules – non-circular bores were banned from that year!

Resumption of F2 car racing, 1980

Late in 1978 Honda began design of another engine for F2 car racing, the formula then being 2 Litres and a maximum of 6 cylinders. The 1976-1977 F2 Champions had been powered by the 90V6 Renault CH1 engine and the 1978 Champion by the IL4 BMW M12/7. Honda chose an 80V6 with 90mm bore, slightly larger than the BMW, i.e. B/S =90/52.3 = 1.72, so that " *theoretically we could get 1½ times the power*" as Nobuhiko Kawamoto, then Manager of Honda Research & Development, was quoted as saying (62). This (possibly tongue-in-cheek) appeal to the "Power proportional to Piston Area" theory did not yield that result. The maximum in 1984 was about 350HP (931) at 12,000RPM (BMPP = 13 Bar @ MPSP = 21m/s) where the BMW M12/7 had about 300HP (454), i.e. a 17% advantage to the Honda, not 50%.

Perhaps bearing in mind the lack of success with their own chassis compared with the 1966 Brabham-Honda, whose chassis had been designed by Ron Tauranac, Honda agreed to supply the latter with their F2 engines for the Ralt cars he had begun to build again in 1974 after leaving Brabham. After a development season in 1980, the Honda V6 powered Ralt drivers to European F2 Championships in 1981, 1983 and 1984.

The Honda F2 unit was a conventional design to the 80s state-of-the-racing-engine-art in most respects (typed as RA263 in 1983), with 4 v/c at VIA = 40^0 and Inlet Valve Head Area/Piston Area (IVA/PA) ratio = 0.3 (680), except for a thin-wall (2 to 3.5mm (20)) cast-iron block. This was the same construction as the Renault CH1, while the BMW M12/7 had a "regular" iron block. Kawamoto said in 1981 that Honda had built a "6 cylinder DFV" (934), which was hardly accurate on construction and, as remarked above, they had not realised the significance of the port shape on power production. The 80^0 Vee-angle had been "prototyped" in the Honda 80V6 CX500 production motor-cycle (933).

Honda's return to Grand Prix racing, 1983

When asked in early 1981 if Honda would re-enter Grand Prix (F1) racing, Kawamoto replied that they had to have success in F2 first before they could contemplate it but, if they did, it would be with Turbocharging (TC) because that would provide them with, what they always sought as well as favourable publicity, new technical problems from which their engineers could learn (934). As recorded, 1981 was successful for Ralt-Honda and in early 1982 the firm associated itself with F1 team protests about arbitrary rule changes by FISA, saying " *we are on our way to rejoin*" (874), although no GP commitment had then been made. During 1982, however, the new Spirit team also received the F2 engine (3 wins were obtained against none by Ralt-Honda and BMW powered the F2 champion that year) and Spirit's desire to enter the premier class led to Honda making that commitment towards the middle of the year. This was to be by way of a TC short-stroke version of the F2 NA design. Perhaps Kawamoto was really still imbued with the "Power proportional to Piston Area" theory, despite the F2 failure to meet promise. The simple stroke reduction gave B/S = 90/39 = 2.31 (573) (the highest ratio used in this review period up to 1998 and just exceeded by the Ferrari 049 in 2000 after very significant valve-gear developments). Twin IHI turbochargers were fitted and the Engine Management system (EMS) was designed by a Honda related company. The names of Kitamoto and Hagi are also associated with the first TC engine (931).

The competitive context was then that Ferrari were about to win the 1982 Constructor's Championship with their type 126C2 TC car, the first Championship by a Pressure-Charged car since 1951; Renault (the TC pioneers in 1977) and BMW were also in TC action (both using short-stroke derivatives of their previous F2 engines, the same route followed by Honda); and Porsche financed by Techniques d'Avant Garde were designing from scratch a bespoke engine of that type for McLaren. Although their undertaking to supply Spirit with GP engines existed, Honda also opened negotiations with Williams in late 1982 (877) for free engine supply. That team were, of course, far stronger than Spirit although the latter track-tested the new TC Honda RA163E engine first at about the date the Williams-Honda agreement was reached.

However, unlike John Barnard's rigid installational specification to Porsche, Patrick Head, Technical Director of Williams, found he was virtually on his own in fitting the given engine into a car.

Spirit raced their TC car 6 times in 1983 with the best result a 7th place and were dropped by Honda in October 1983, (although Honda did help them to have Hart TC engines for 1984)(929) while Williams got two FW09 RA163E-powered cars into the last 1983 race and one finished 5th.

1984 Williams FW09/09B-Honda RA164E

The following purely-Williams season, 1984, although it produced one low-speed win, proved beyond doubt that:-

- The B/S ratio was far too high and resulted in the "Top end" limiting the RPM (so that the Mean Gas velocity @ Peak Power (MGVP) fell from the RA263 figure of 69m/s to only 52 and the net output would have been affected adversely (se Notes 34 and 94));
- The 90mm bore allowed too much heat into the piston (leading to many failures);
- The very-limited useable RPM range, the steepness of the power curve and turbo lag were together producing a nearly-undriveable car. (Keke Rosberg, their No. 1 driver in 1984, found it hard to pinpoint the problem but, after Nigel Mansell joined the team in late 1984 after 1½ seasons of Renault TC power at Lotus, that driver opined that the turbo lag was a major cause of bad handling. A test then with lowerpower and less lag produced faster laps (574));
- Insufficient rigidity in the chassis was stressing the engine and compounding the handling difficulties.

1985 Williams FW10-Honda RA165E

All these things were addressed by a new Honda engineering team under Ichida (931) in the first half of 1985 and, although Head admitted no lack of rigidity in his 1984 chassis (which was still Al-alloy sheet with sandwiched Nomex honeycomb), Williams produced a better Carbon Fibre Composite (CFC) tub design for the new season.

The RA165E with B/S altered to 82mm/47.2 = 1.74 (573) (the same as the competing and very successful Porsche (TAG) PO1 in the McLaren) and smaller VIA (574), probably 32^0, raced first in June 1985 and was immediately a great improvement. Four races were won with it, including the last 3 of the year, i.e. 33% of the races entered with the "82 Bore" engine where the "90 Bore" had only a 4% wins/races ratio. The other changes had also helped, of course, and the new driver Mansell took 2 of the victories.

Eg. 69. 1986 Williams FW11-Honda RA166E – winning the Constructor's Championship

Having established that the B/S move from 2.31 to 1.74 was in the right direction, the RA166E moved down to 79mm/50.8 = 1.56 (573) (Honda kept all these dimensions a secret at the time). After the team with Nelson Piquet and Mansell had won 9 races out of 16 (56%) the team lost the Driver's Championship when Mansell was leading it at the last race because of a tyre failure not anticipated by the supplier. However, the Constructor's Championship was won for the first time by this chassis-engine combination. This result was despite the team losing its principal, Frank Williams, before the season began in a road accident which left him heavily paralysed, a calamity which he overcame with amazing courage to resume his place in 1987. It is thought generally, however, that Honda were disturbed by the team not having a completely fit man in charge and their feeling was exacerbated by a team policy of not controlling two drivers who competed bitterly and took points off each other – very good for the "circus" spectators, of course, who ultimately pay directly or indirectly for the racing!

The 1986 season was the last in which there were no rules to restrict power and the Qualification figure of 1,200HP estimated for the RA166E was the highest level reached by any Car-of-the-Year in this review – or, indeed , up to the present time of writing (September 2011) and now unlikely ever to be exceeded.

Eg. 70. 1987 Williams FW11B-Honda RA167E – winning both Championships

The internecine competition between Piquet and Mansell got worse in 1987 but, fortunately, the RA167E of that year under Yoshitoshi Sakurai (945), unchanged in B/S at 1.56 (573) and tuned to the new race rules of Inlet Valve Pressure (IVP) of 4 Bar and a fuel limit of 195 Litres, had sufficient superiority to gain both Championships anyway. Williams won 9 times again in 16 races (56%). Lotus, who were also Honda-powered in 1987, gained 2 more races on slow circuits, Ayrton Senna driving.

The Honda EMS gave their cars a distinct advantage over McLaren-Porsche (TAG), the runners-up in the Constructors' Championship, in eking out the limited fuel at superior power. A specially good result was in taking the first 4 places at the British GP at extremely high speed (146.2 mph)(2 Williams followed by 2 Lotus).The advantage of the Williams FW11B chassis on fast circuits was seen here as they finished a lap (1.6%) ahead of Senna's Lotus 99T in 3rd place. The EMS since 1986 had been linked by radio telemetry to the pits so that the staff there (greatly augmented by specialists) had real-time knowledge of many engine and chassis parameters and, in some cases, via the now-standard 2-way radio intercom could advise the driver of desirable adjustments to available in-car controls.

The RA167E had nearly 1,000HP available for Qualification (20). This Q rating represented BMPP/MDR = 48.0/3.63 = 13.5 Bar at MPSP = 20.7 m/s, MGVP = 67.1 m/s and MVSP = 3.9 m/s burning 84% Toluene + 16% normal-Heptane fuel with Compression Ratio (R) = 7.4. This fuel, while passing the FISA slow-speed laboratory engine test as though it was the regulation 102 Research Octane Number (RON) petrol actually gave far superior performance in the high-speed racing engine with sophisticated aids to avoid detonation and improve Combustion Efficiency. The RPM drop from Peak Power to Peak Torque was a normal (for a racing engine) 20% and the "Red Line" was 13,000RPM (= 22 m/s MPS (20)). Interestingly the RA167E 80V6 was a rougher engine than the Renault EF15 90V6, although it was heavier which should have helped to absorb the vibration. When Lotus first changed in the 1987 type 99T from the latter engine to the former and Senna first tested this car(after 2 seasons driving the EF15) he pitted immediately in concern that the engine was in trouble. Satoru Nakajima, who had just joined the Lotus team with Honda's sponsorship after much test-driving of their engines, then tried the car and pronounced it normal (933). This Honda roughness which, like the Cosworth' DFV's roughness, did not prevent it from great success, contrasts with the smoothness which Niki Lauda had reported for the Porsche (TAG) PO1 80V6.

The normal race rating was probably about 900HP (to judge by 1988 data to be given next (20)) and the drivers had a 4-position switch to vary the power via the EMS, comprising:-

Fuel saver (cockpit instruments included a "Laps-of-fuel-remaining" gauge;

Low Power; Normal Power; and "+100HP"for overtaking, i.e. adopting Q rating.

During the 1987 British GP already mentioned Mansell used Q power continuously for the last 6 laps to catch and make a daring pass of his "team-mate" Piquet (935), disregarding the fuel display which at the finish read "Minus 2.5 laps" (937). The car stopped 2 corners beyond this and it was reported at the time to be out of fuel but, 4 years later, the driver admitted that the engine had blown up (936).This incident may well have been the last straw for the patience of the Honda management, since it had threatened their easily-attainable 1, 2 result.

Being sure of powering both 1987 Championships it was announced by Honda in September that they would break their agreement with Williams one year early and supply their 1988 engines to McLaren instead (Lotus continuing to receive them) for the final year of the Turbocharged era, as ruled by FISA. There *was* a financial settlement with Williams and that team used it to buy Judd 3.5 Litre NA engines (ironically originally based on a Honda F3000 formula design). A wag wrote that for Williams, like Cinderella, on the stroke of midnight at the end of the year their turbocharged coach would turn into a normally-aspirated pumpkin!

Honda, who had used Engine Developments Ltd (under John Judd) at Rugby as a base for their F2 activity from 1980, then had built a special overhaul plant next to Williams at Didcot in 1985, had already prepared for the switch away from that team by opening a new F1 centre in Slough. These were large extra expenses forced on the company to enable it to operate successfully in a largely European scene (wholly European in chassis construction) half-a-world away from the parent.

The alternative Normally-Aspirated formula in 1987

The October 1986 FISA Congress, which had introduced the 1987 and 1988 (q.v.) rules to limit IVP and fuel quantity and to terminate all TC at the end of 1988, 2 years earlier than previously promulgated (for "Safety reasons"*) in favour of 3.5 Litre Normally-Aspirated, had also allowed the latter to compete in those 2 years with a 40kg (7.4%) car weight advantage and no fuel limit in 1988.

In 1987, only, separate trophies were offered by FISA for the NA class:- the "Jim Clark Cup" for the driver and the "Colin Chapman Cup" for the constructor, two very fitting tributes. The winners of these awards were Jonathan Palmer and his mount the Tyrrell-Cosworth DFZ. For comparison with the (very-easily-triumphant in the main TC class) RA167E the details of the DFZ are given in Note 95.

Eg.71. 1988 Mc laren MP4/4-Honda RA168E – Winning both Championships again

For 1988, when the TC formula limits were IVP = 2.5 Bar (2.47 Atmospheres Absolute (ATA), meaning that the Manifold Density Ratio (MDR) after a practical intercooler would be 2.27 x ambient) and 150 Litres of fuel, nominally 102RON petrol, it was thought initially that with a NA/TC swept volume ratio of 3.5L/1.5L i.e. 2.33 the NA car would be competitive under these restrictions (on the crude basis that 1.5L x 2.27 = only"3.4L", and with a 40kg car weight and unlimited fuel advantages to NA). However, the TC fuel restriction compared to 1987 at 150/195 = 0.77 was less harsh than the likely power reduction in line with the MDR reduction of 2.27/3.63 = 0.63. Also, the TC fuel was *not* "Real" petrol.

With RA167E test data at variable IVP in hand (20) Honda knew that a simple reduction from 4 to 2.5 Bar would reduce the Q rating from 995HP to 645 (ratio 0.648) which, allowing for a 10% drop to Race (R) rating would give them 580HP. The 1987 Cosworth DFZ 3.5 L NA had given about 570HP and the rival firm were known to be developing for 1988 another DFV variant (DFR) with Yamaha-designed 5 valves-per-cylinder (5v/c – 3 Inlet and 2 Exhaust) heads for which the Japanese firm forecast 630HP (207)(see Note 95). Honda presumably decided that they could beat this with a modified RA167E since a higher Compression Ratio (R) would be tolerable with the lower IVP and the mixture could be richer. They certainly decided on that course of action for 1988, producing the RA168E (while designing a new 3.5 L NA engine for 1989), and agreeing to supply it to McLaren for the first time instead of Williams and also to Lotus as in 1987.

Basically the 1988 RA168E was unaltered from its predecessor, i.e. B/S = 79mm/50.8 = 1.56 and, having so much less power with the same major parts, it was certain to be reliable. By adopting the new AP carbon-carbon 3-plate clutch of 5.5'' (140mm) driven plate diameter (ca. 6.4'' outside diameter (OD)) instead of the previous 7.25'' (184mm) 2-plate sintered-bronze-lined clutch (8.4'' OD) the crank axis was lowered28mm (574), with the sump redesigned to conform by relocating the oil pumps and filter.

With the lowered IVP and fuel unaltered from 1987 at 84% Toluene + 16% n-Heptane (20), R was raised to 9.4 (if Compression Pressure is approximated by:- (IVP)x $(R)^{1.3}$, this factor was 46 ATA instead of 53).

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*Citing "Safety" always allowed FISA to alter rules within time spans previously specified for their racing formulae. As the rules were being changed already for TC engines in 1988 to restrict the power to about half of the 1986 level and since a 3.5 NA engine was expected to produce a similar power the banning of TC post-1988 on "Safety" grounds was not logical. This *volte face* penalised Ford of America who had financed Cosworth to begin on a 1.5L TC engine in 1984 after the personal assurance of FISA President Balestre that the existing formula would run to the end of 1990. Probably already committed to supply Benetton for 1987 they completed that season and then stopped the project.

Ref. (20) gives many details of how the RA168E was optimised separately for R and Q ratings, not, in this case entirely for different reliability versus power considerations but because the engine could not complete the average race on 150 litres of fuel at its highest power (the ratings would be on physically different units since the Q engine would be changed before the race). The figures are tabled below.

Rating	R	Q	
Both at IVP = 2.5 Bar & Peak Power Speed (NP) = 12,500RPM			
Cylinder Inlet Temperature	70C	40C	
Controlled by adjustment of Intercooler bypasses			
Fuel Temperature	80C	40C	
With water Heat-exchanger in line or not			
Mixture strength (relative to Stoichiometric)	+2%	+15%	
Peak Power (PP) BHP	611	676	+10.5%
Specific Fuel Consumption (SFC) (Lb. Of fuel)/BHP. Hour	0.467	≈ 0.523	≈+12%
Brake Mean Effective Pressure @ Peak Power / Manifold Density Ratio (BMPP/MDR) Bar	29.3/2.07 = 14.1	32.4/2.27 = 14.3	
Mean Piston Speed @ Peak Power (MPSP) m/s	21.2	21.2	

The power gain from R to Q rating was obtained, apparently, in the following way*:-

Richer mixture	5.4%	
30C lower air temperature	4.7%**	
40C lower fuel temperature	0.4%	
TOTAL		10.5%

*These gains are shown separately in (20) but the overall power rise is 0.82 of the component addition and this ratio has therefore been applied to get the elements shown.

**This figure agrees with the usual empirical power correction of :

$1/\sqrt{(\text{Absolute Air Inlet Temperature})}$, i.e. $\sqrt{(343K/313k)} = 1.047$. Of course, it is possible that Honda *worked back* from that formula!

With the modifications of the RA168E from the RA167E the Q power was 4.8% higher than the 1987 engine would have produced at the same restricted IVP.

Peak Torque (TP) RPM at R rating was 16%below NP and “Red line” speed was again 13,000RPM but the engine had been bench-tested to 13,600 (574).

A cross-section provided in (20)(see Fig. 71A) gave the following details:-

- VIA = 32^0 (reduced from the original 40^0, probably in the “82 Bore” mid-1985 engine);
- Cam side thrust taken by finger followers;
- Thin-wall cast-iron block with separate Nikasil-coated Al-alloy(62) wet liners;

(The last two features probably carried over from the original 1980 F2 engine);

- Inlet downdraught 43^0, exhaust updraught 32^0;
- No , or little, inlet port shape to promote deliberate “Barrel Turbulence” (aka “Tumble Swirl”);
- IVA/PA = 0.31, the same as in the original F2 head, so that MGVP = 68.7 m/s, restored to the RA263 level.

The IHI turbo-chargers had ceramic turbine wheels and ceramic ball-bearings. While withstanding exhaust temperature around 1,000C these lower-than-steel-density components reduced "drastically" the inertia and therefore cut turbo lag.

Honda were obliged to supplement an original 6 butterfly throttle valves in the engine inlet tracts after the FIA-supplied 2.5 Bar dump valve with 2 further butterflies in the intercooler exit pipes before that valve so as to avoid the sudden closing of the downstream throttles from triggering the FIA valve by a pressure-wave reflection, because that emptied the manifold just before re-acceleration was demanded.

Dual injectors were used for each cylinder, both spraying downstream and opening in sequence according to the fuel flow needed.

Ref. (20) reports that during development the cylinder pressure of the RA168E was measured directly at 1^0 crank intervals and then averaged over 500 cycles to yield Indicated Mean Effective Pressure at Q rating of 38 Bar, equivalent to 793IHP, so that the Mechanical Efficiency (EM) was 676/793 = 85.2%. The peak pressure was 167 Bar or 3.63 times the approximate Compression Pressure.

At R rating the Specific Fuel consumption (SFC) was 284 g/kW.Hr (0.467 lb/BHP.Hr) with Toluene – base fuel of 9,817 kg.cal/kg (17,669 BTU/lb) (plus Latent Heat of Evaporation of 149 BTU/lb) so that Brake Thermal Efficiency (BThE) was 30.6% (see Note 37).

There is therefore sufficient data to complete with confidence the internal analysis method described in the General Design section of this review:-

Date	1988
Make	Honda
Type	RA168E @ R rating

TC; Fuel 84% Toluene (C_7H_8) + 16% n-Heptane (C_7H_{16}); @ STP.

MDR 2.5Bar.(14.5/14.7). (288/343) =	2.07
V cc	1,494
NP RPM	12,500
Compression Ratio (R)	9.4
ASE	0.592
EV	1.217 (Note i)
EC	0.606 (Note ii)
EM	0.852 (Note iii)
PP BHP	611

Note i: With BThE calculated from the measured SFC and given fuel calorific value, as above, EV is the balancing entry in this PP equation.

Note ii: Given BThE and EM, EC is the balancing entry in the equation:-

BThE = ASE.EC.EM.

Note iii: EM was determined, as shown above, at Q rating but it is expected to be the same at R rating since NP and IVP are the same.

The values of EV and EM are improved in this TC engine relative to a NA engine by the factors described in Note 96.The calculated EV multipliers are:-

- For inlet temperature, 1.09;
- For residual exhaust gas compression, 1.01;

so that the equivalent NA figure for EV is 1.217/1.09.1.01 ≈ 1.1.

A "guesstimate" for the advantage to EM from the pneumatic power contribution to TC over NA is 10 points.

RA168E track performance.

The R rated performance was useable with Wide Open Throttle (WOT) on a circuit such as Imola with the smooth driving of Alain Prost for 64% of the lap (20). The Load Factor (= Average Power/Peak Power) would be rather less than that, since an engine, although on WOT, must have power gaps during gear changes and also must run over a range of RPM through the gears, small though this range would have been with the MP4/4's 6-speed gearbox.

The McLaren MP4/4 with the Honda RA168E engine, driven by Alain Prost and Ayrton Senna won 15 of the 16 season races, 94%, and only lost the odd race through Senna's impatience to get past a backmarker when leading caused a collision. To the time of writing (September 2011) this is an unbeaten record. The McLaren team had only 1 DNF which was engine-related – a faulty spark plug which finally caused a valve failure when the misfire was ignored by the driver (941) (see Note 97).

Unlike the MP4/4, the Lotus 100T also with the RA168E suffered 4 engine DNFs in a very poor season, being only 4th in the Constructors' Championship although driven by the 1987 World Champion.

Overall 1986-1988 the "79-Bore" Honda TC engine had a 35/48 = 73% wins/races ratio.

The alternative Normally-Aspirated formula in 1988

The Honda decision to race a redeveloped 1.5L TC engine proved overwhelmingly successful *when in the McLaren chassis.* The 3.5L NA Benetton-Cosworth DFR did come 3rd in the Constructors' Championship behind the TC Ferrari type F1/87-88C, despite not receiving the 630HP forecast to them in September 1987 (941). Details of the DFR are included in Note 95.The NA cars (Cosworth and Judd-engined) defeated non-McLaren TC cars (Ferrari, Lotus, Arrows, Osella and Zakzpeed) on 8 occasions, the best results being 3 2nd places with Judd.power which "came good" in the 2nd half of the season.