CORRECTIONS & ADDITIONS

CORRECTIONS & ADDITIONS INDEX

Alfa Romeo: P2 (12); P3 (13); 158/47 (13); 158/50 (14); 159M (14).

Alta: (33).

Auto Union: C (1) & (15).

Auto Union: D (31).

BMW: P83 (1).

BRM: P56 (1).

Cosworth: DFV (18); (30).

Coventry Climax: FPE (16).

Ferrari: Lancia D50 (1); 312B (2) and (39); 015 (3); 156 (4); 500 (15); 312PB (18).

Ford: NASCAR (18).

Gilera: 1957 & Rondine (28).

Honda: 166E, 167E, 168E (2); RC211V (7); NR500 (31).

Maserati: 250F (26), Addendum (31).

Mercedes: 1914GP (1).

Naturally-Aspirated Era: 3NA (5).

Notes: 13 Part 2 (10); 118 Part 2 (10).

Porsche: P01 (37).

Progress over 64 Years (17).


Significant Other: and Appendix 1 (1).

Speed Correlation Function (SCF) (23).

Tresilian, S.S. (21).

Yamaha: 001A (31)
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CORRECTIONS

Appendix 1: 1962 BRM P56
Lines 49/50  PP = 197 BHP @ 11,000 RPM.
Lines 51/52  TP = 101.5 lbft @ 9,500 RPM.


Appendix 1: 2003 BMW P83 (not CoY)
Lines 18/19  B = 96mm (so S = 41.42mm for 2,998cc).
Line 54  B/S = 2.318.
Line 24  IVD = approx. 41.4mm
Lines 49/50  PP = 927 BHP* @ 19,000 RPM.
*Converted from 940 PS.
Line 124  W = 84 kg.

DASO1095. Ten Years of BMW F1 Engines. Paper by Prof. Dr-Ing. Mario Theissen et al. 2010.

Technical Innovations: 1956 Eg. 34 Ferrari-Lancia D50
● Re: Chain drive to OHC
[1922 John Weller AC 2 Litre]

ADDITIONS

Appendix 1: 1956 Ferrari-Lancia D50
Line 124  W = 170 kg.


Technical Innovations: 1936 Eg. 22 Auto-Union C
● Wet cylinder liners
[1922 Both Harry Ricardo Vauxhall TT and John Weller AC 2 Litre. Both in Al-alloy blocks]

CORRECTIONS & ADDITIONS

CORRECTIONS

Appendix 1: Eg. 6 1914 Mercedes
Line 17: R: Measured as 4.89 (was estimated as 5).
Line 23: VIA: 50° (not 60°).
Data by courtesy of Eddie Berrisford while restoring a car of this type.

2NA Era: Eg. 34: 1956 Lancia-Ferrari
P.9: 2nd line: Francesco Falco’s name was mis-spelt as Faleo.
P.10: PS2: An Italian source states that the 4WD D50 Lancia was not completed.

CORRECTIONS & ADDITIONS

CORRECTION

“Significant Other” engines and Appendix 1
SO1. The 1889 Daimler was 16V2 not 14V2.
Egs. 69, 70, 71 at p.2
The Honda Formula 2 engines were:

1965  B/S = 72/61.2 = 1.176, V = 997 cc.
      Jack Brabham estimated the power as 130 HP @ 10,000 RPM.

1966  Completely redesigned, smaller and lighter;
      B/S = 78/52 = 1.5, V = 994 cc;
      150 HP @ 11,000 RPM.  

DASO 1110; draft 1967 manuscript by K. Ludvigsen, supplied by his courtesy.

CORRECTIONS & ADDITIONS

Appendix 1  Egs. 54, 56, 57, 59  at Rows 34 & 35: Ferrari 312B, various T chassis
The steel-backed plain bearings of the Ferrari 312B/T5 of 1980 had diameters of:-
- 2 x Intermediate Main Journals (MJ)  56 mm  (the end bearings were roller);
- 12 x Crank Pins (CP)  38.5 mm.
The bearings were Clevite type CL112, able to take a pressure of 12,000 psi. These were claimed at the time to be superior to any other make.

DASO 1118, data supplied by courtesy of Bo Skånhed.

It may be reasonably assumed that previous 312B engines had the same sizes.
The ratio MJ/CP  =  56/38.5  =  1.45 was higher than usual for NA engines, egs:-
- 1965 Climax FWMV6  50.8/41.3  =  1.23;
- 1967 Cosworth DFV  60.3/49.2  =  1.23;
- 2000 Ferrari type 49  48/41 = 1.17.
The reason was that the 312B had only 2 Intermediate journals on its 6-throw crank and therefore needed a larger diameter for stiffness than the listed 1-bearing-per-throw engines. This will have offset to some extent the frictional gain from fewer bearings.

Continued below:-
**POWER CURVES**

<table>
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<tr>
<th>Eg.</th>
<th>DASO</th>
<th>YEAR</th>
<th>Make</th>
<th>Model</th>
<th>Vcc</th>
<th>Ind.</th>
<th>System</th>
<th>Confign.</th>
<th>Bmm</th>
<th>Smm</th>
</tr>
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<tr>
<td></td>
<td>54</td>
<td>1975</td>
<td>Ferrari</td>
<td>15</td>
<td>2992</td>
<td>NA</td>
<td>180V12(F12)</td>
<td>80</td>
<td></td>
<td>49.6</td>
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<table>
<thead>
<tr>
<th>N</th>
<th>P</th>
<th>MPS</th>
<th>BMEP</th>
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<tbody>
<tr>
<td>kRPM</td>
<td>HP</td>
<td>m/s</td>
<td>Bar</td>
</tr>
<tr>
<td>6.5</td>
<td>242</td>
<td>10.75</td>
<td>11.14</td>
</tr>
<tr>
<td>7</td>
<td>283</td>
<td>11.57</td>
<td>12.09</td>
</tr>
<tr>
<td>7.5</td>
<td>321</td>
<td>12.40</td>
<td>12.80</td>
</tr>
<tr>
<td>8</td>
<td>350</td>
<td>13.23</td>
<td>13.09</td>
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<tr>
<td>8.5</td>
<td>375</td>
<td>14.05</td>
<td>13.20</td>
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<td>9</td>
<td>397</td>
<td>14.88</td>
<td>13.19</td>
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<tr>
<td>9.5</td>
<td>424</td>
<td>15.71</td>
<td>13.35</td>
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<td>9.75</td>
<td>437</td>
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<td>448</td>
<td>16.53</td>
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<tr>
<td>10.5</td>
<td>463</td>
<td>17.36</td>
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<td>11</td>
<td>473</td>
<td>18.19</td>
<td>12.86</td>
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<td>11.5</td>
<td>486</td>
<td>19.01</td>
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<td>12</td>
<td>492</td>
<td>19.84</td>
<td>12.26</td>
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<tr>
<td>12.2</td>
<td>493</td>
<td>20.17</td>
<td>12.09</td>
</tr>
<tr>
<td>12.6</td>
<td>491</td>
<td>20.83</td>
<td>11.66</td>
</tr>
</tbody>
</table>

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

Eg.40  1961 Ferrari type 156/120°
DASO 1126 has provided a cross-section of this type of 6-cylinder Ferrari engine,
Bore (B) 73 mm, Stroke (S) 58.8 mm, B/S = 1.241, Swept Volume (V) 1,477 cc. This is shown on
the Figure below:-

Scaling (on an enlarged print) shows that this is not the engine described in 2nd Naturally-
Aspirated Era (2NA) Part 3 and in Appendix 1, although that data is well sourced. In particular,
the cylinder head is quite different in detail, as follows:-

<table>
<thead>
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<th>Eg. 40</th>
<th>New data</th>
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<tr>
<td>DASO 54 &amp; 711</td>
<td>DASO 1126</td>
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<tr>
<td>Bore (B) 73 mm</td>
<td>Bore (B) 73 mm</td>
</tr>
<tr>
<td>Stroke (S) 58.8 mm</td>
<td>Stroke (S) 58.8 mm</td>
</tr>
<tr>
<td>B/S = 1.241</td>
<td>B/S = 1.241</td>
</tr>
<tr>
<td>Swept Volume (V) 1,477 cc</td>
<td>Swept Volume (V) 1,477 cc</td>
</tr>
</tbody>
</table>

DASO 711 states that there were 2 sizes of inlet valve, the 2nd being 38.5 mm which by
implication was also at VIA = 60°. Correspondent Ron Rex has suggested that VIA 60° applied to
the 1961 re-vamp of the original 65° bank angle type 156 and that the 120° engine was always
VIA 74°

Ferrari have always been a prolific maker of engine types and it would be typical practice to
experiment with different configurations. It may be supposed that the Peak Power (PP) quoted
for Eg. 40 of 192 HP @ 9,500 RPM was for a “Big-valve” engine, as previously listed, and that the
“Small-valve” engine was intended to have a broader Torque curve, although less PP, to suit
twisty circuits like Monaco. If it was actually raced at Monaco in 1961 it did not win because the
Ferrari team were beaten by Stirling Moss in an old Lotus with a 4-cylinder Climax engine.

Drawing details

IVD = 35 mm, so IVA/PA = 0.23;
IVL = 10 mm, so IVL/IVD = 0.286;
EVL = 33 mm, so EVL/IVL = 0.94.

LIN = 315 mm, so LIN/S = 5.36.
By Note 27, the inlet resonant speed would be 8,400 RPM.
It is probably safe to assume that the “Bottom-ends” of the engines were the same:
\[
CRL = 126 \text{ mm (given in www.f1technical and as scaled)}; \]
\[
\text{so } CRL/S = 2.14.
\]
At 9,500 RPM MPDP = 3,658 g.

\[
\text{PH} = 64 \text{ mm, so } \text{PH/B} = 0.88; \text{ PH/S} = 1.09.
\]

\[
\text{MJ} = 55 \text{ mm};
\]
\[
\text{CP} = 39 \text{ mm, so } \text{CP/MJ} = 0.71 \text{ and } \text{CP/S} = 0.66;
\]
\[
\text{GP} = 19.5 \text{ mm, so } \text{GP/CP} = 0.5.
\]

**Design features**
- “Jano” tappets – a design dating from his 6-cylinder sports Alfa Romeos in 1927 (his 1924 P2 Alfa had finger followers);
- Shown with 40 mm bore carburettors, the same as the “Big-valve” engine, which had Weber 40 IF3C (given in www.f1technical).
- Inlet tract downdraft = 10\(^\circ\); exhaust 0\(^\circ\) (both relative to the plane of the piston crown).

**References**
- DASO 54 SAE 818A W. Gay Jan. 1964 (This Ford paper, principally concerned with the 1963 Indianapolis engine, had some comparative data for the Ferrari 156, presumably official).
- DASO 1126 Ferrari 156/120 drawing copied to the author by courtesy of Ron Rex.

---

**CORRECTIONS & ADDITIONS**

**CORRECTION**

(October 2015)


Since writing this section and producing the tabulated data in Appendix 1 some more information has become available on the Honda engines of the McLaren cars which were GP “Car-of-the-Year” for 1989 to 1991 (Egs. 72, 73 and 74).

Although Honda were very frank in describing their last engine in their “Second Era” of racing, the 1992 RA122E/B (DASO 69) (which is on the website in “Significant Other”), they revealed very little about the 1989-1991 units. The data now given here (references are detailed below) and compared with the original is therefore a mixture of official Honda and some of lesser authenticity. In those far-off times before the FIA imposed “virtually-non-development” rules, engine builders often modified their engines from race-to-race as well as season-to-season. Consequently, it cannot be certain that data available is consistent from dimensional to performance figures from different sources. Bearing that in mind, this Correction tries to steer a reasonably believable balance.

**Eg. 72 Honda 1989 RA109E 72V10 3½ Litre**

(1). *The V10 Balancer*

The original website text, based on (727), described the V10 balancing shaft as located in the Vee. A Honda paper published in their Technical Review (1127) shows that it was actually placed alongside the crankshaft. Fig. 72C below illustrates this. The paper refers specifically to the 1990 RA100E engine but it is presumed that the same necessary configuration applied to the RA109E.

Continued on P. 6
(2). Performance

**Appendix 1**

- B = 89 mm;  S = 56.2 mm (47)
- B/S = 1.584
- V = 3,496 cc

On review of the source (47) it now seems that this data may have applied to the 1988 precursor of the 1989 race engine.

- PP = 610 HP
  @ NP = 13,000 RPM
- BMPP = 12.01 Bar
  @ MPSP = 24.35 m/s
- W = 150 kg
  PP/W = 4.07 HP/kg

**Update**

- B = 92;  S = 52.55 (1128, plus 0.05 on S)
- B/S = 1.751
- V = 3,493 (www.allf1)

- PP = 642 (1121)
  @ NP = 12,800 (1129)
- BMPP = 12.85
  @ MPSP = 22.42
- W = 160 (1121)
  PP/W = 4.01

**Fig. 73 Honda 1990 RA100E 72V10 3½ Litre**

**Appendix 1**

- B = 92;  S = 52.55
- B/S = 1.751
- V = 3,493

**Update**

- B = 93 (1121)
- B/S = 1.809
- V = 3.493 (991)

- PP = 650
  @ NP = 13,800
- BMPP = 12.07
  @ MPSP = 24.17
- W = 146
  PP/W = 4.45

- PP = 670 (1121)
  @ NP = 12,250* (1121)
- BMPP = 14.01
  @ MPSP = 21.0
- W = 160 (1121)
  PP/W = 4.19

*Given officially by (1121) and supported by a max. of 12,500 shown officially in (1127).
Eg. 74 1991 Honda RA121E 60V12 3½ Litre

Appendix 1

B = 86.5; S = 49.6
B/S = 1.744
V = 3.498

It now seems possible that these dimensions were relevant to the
1st 60V12 raced in the early part of 1991.

Update

B = 90; S = 45.76 (1129* less 0.04 on S)
B/S = 1.974
V = 3.493 (991)

These dimensions are probably those of the complete redesign raced from
the middle of the year (tentatively labelled RA121E/B).

PP = 764 [Table error; should have been 724 (69)]
724 (1121)

@ NP = 13,700 (69)
@ 13,800 (1129)

BMPP = 14.27 [Should have been 13.52]

@ MPSP = 22.65
@21.05

W = 160 (69)
154 (1121)

PP/W = 4.78
4.70

*The 1992 Honda RA122E/B 75V12 3½ Litre was officially
B = 88; S = 47.9; B/S = 1.837; V = 3,496 (69). it casts doubt on the above dimensions, as it
would be expected that B/S would be larger in the later engine.

DASO references

47 Data supplied by Brian Lovell (former MD of Weslake Developments)

69 JSAE 9301494 (in Japanese, translated by Butcher and Taniguchi)
via Brian Lovell on 11 March 1993.


Source advised to author by courtesy of Ron Rex, July 2015.

Copied to author by courtesy of Ron Rex, July 2015.

1128 Autocourse 1987-90.

1129 Captions in Honda Motegi museum.

CORRECTIONS & ADDITIONS

CORRECTION and addition

(8 October 2015)

2002 Honda RC211V
On P.17 of the section “Grand Prix Motorcycle Engine Development, 1949-2008” the best data
available was provided on the new MotoGP 2002 Honda RC211V 990 cc engine. Speculation on
the Bore (B) and Stroke (S) of this 75.5V5 was that it was a 2 mm increased-bore derivative of the
Honda RC45 90V4 750 cc Superbike engine, which was B = 72 mm x S = 46 mm, B/S = 1.565, plus
a 5th cylinder to reach the MotoGP 4-stroke regulation 990 cc.

Better data has now been extracted from a Honda R & D Technical Review seen recently (see
ref. 44 below; this continues the ref. numbers of the m/c section). While providing much
interesting information, Honda gave it mostly in relative form. However, a cross-section, shown
below on P.8 (suitably enlarged), enabled the B x S dimensions to be derived from the B/S ratio.
2002 Honda RC211V

75.5 V5  B = 72 mm;  S = 48.6 mm;  B/S = 1.605;  V = 989.4 cc

Honda, therefore, had retained the Bore dimension of the RC45, and no doubt it’s valve gear, and lengthened the Stroke, with a 5th cylinder at the front. Honda examined configurations from 2 to 8 cylinders before choosing 5 as providing the best machine Power/Weight ratio within the rules.

The Review power of the RC211C was given as:—

- PP = “over 160 kW” = “over 214 HP”

The website had accepted a figure of 220 HP (1) so that still seems appropriate for this analysis. However, (1) suggested that Power Peak speed (NP) was 15,500 RPM. The Review has one dimensional figure which shows Maximum speed as 14,000 RPM. A relative power curve indicates that this was also NP. Performance is therefore taken as:—

- PP = 220 HP
- @ NP = 14,000 RPM.

So that

- BMPP = 14.21 Bar
- @ MPSP = 22.68 m/s.

This is virtually identical to the RC45 performance (32):—

- BMPP = 14.4 Bar
- @ MPSP = 22.2 m/s.

Crankcase development

The Review reports that the power had been increased by 4% by scavenging the oil into a “semi-dry-sump” cum gearbox case integral with the engine, shown as blue on the section. This was 1 kg lighter than a full “dry-sump” system. Of course, the oil did not fill all the space. Being a 2-wheel machine the oil level would remain parallel with the crank axis when banked over and cornering steadily. Each crank chamber throw was sealed and was kept 70 kPa (10 psi) below atmospheric pressure.

Valve gear

Fig. 10 of the Review, shown RHS, has been used (suitably enlarged) to determine the dimensions of the RC211V valve gear:—

- VIA = 24°
- IVD = 30 mm;  IVL = 9.3 mm;  IVL/IVD = 0.31.
- 4 v/c;  IVA/PA = 0.347.
- MGVP = 65.4 m/s.
- If IOD = 320°, the CVRS MVSP = 4.9 m/s.
- EVD = 25 mm.
- LIN = 169 mm;  LIN/S = 3.48;
- From Note27, the resonant RPM would be 15,700, but clearly the 1.5 area ratio of the inlet tract reduces this.
Reciprocating parts

PH = 35 mm; PH/B = 0.49; PH/S = 0.72.

CP = 30 mm; CP/S = 0.62; GP = 15 mm; GP/CP = 0.5.

CRL = 98 mm; CRL/S = 2.02.

At 14,000 RPM, MPDP = 6,644 g.

Power curves

Honda provided relative power curves for the 2002 RC211V 4-stroke and the NSR500 2-stroke. If it is accepted that the actual powers were 220 HP @ 14,000 RPM for the former and 173 HP @ 12,000 RPM for the latter in 2001 tune (as in Appendix 4) then the curves can be completed to find the origin. This is shown on the chart below:

This chart emphasises the minute gap between Peak Power and Peak Torque of the super-tuned 2-stroke (as described on P.15 of the motorcycle section) and the broad Torque range of the 4-stroke. Also, with the relative values of FC (the absolute numbers cannot be found), it shows the much higher Thermal Efficiency of the 4-Stroke, which is also described in the section on P.17.

2006 Honda RC211V

Having won the Championships in 2002 and 2003 with Valentino Ross riding, but lost them to a revamped Yamaha after Rossi transferred to that team in 2004 and 2005, Honda redesigned both the chassis and engine for 2006 (45). It was used after beginning the season with a modified 2005 machine.

No B x S dimensions were given in the ref, paper but the engine changes accomplished the following relative to the 2005 model:-

- 60 mm reduced length
- 30 mm reduced width.

Within this smaller envelope the distance between crank and the gearbox countershaft was cut by 27 mm; each cylinder pitch was 5 mm smaller; crank width dropped by 21 mm. The con.-rods were shortened by 4 mm. The front cylinder inclination was reduced by 6°.

Weight was reduced by 7% and with less friction power increased by 3% to “over 180 kW” = “over 240 HP” @ about an extra 500 RPM. If 245 Hp at 14,500 RPM was achieved, then BMPP = 15.3 Bar.

There was a new electronic throttle control system. With the front 3 cylinders opened manually as before, the rear 2 were opened by a motor more slowly at low speeds to prevent wheel spin.
The effort brought its reward by regaining the Championships, Nicky Hayden being the rider.

References
32. Details of machines in Honda’s Motegi museum.
44. (= DASO 1130). Honda R&D web site Presentation of RC211V equipped with 4-stroke engine. October 2003.

CORRECTIONS & ADDITIONS

Note 118 Part 2
Correspondent Barrie Hobkirk has kindly cleared up a caption doubt about a bonnet bulge in the photo of Moss’ Maserati in practice at the British GP in 1956, as follows:
“That car (Chassis 2523 at the time of the photo) was tested and raced with both normal and injected 250F engines. The bulge was to clear the carb opening mechanism. For the British GP, Moss chose to use a normal engine over the injected version. If you look at the top of Page 2 of your same article, you will see a photo of that injected engine fitted to chassis 2522 for the earlier Goodwood meeting. The carb opening mechanism is visible there. That car also had a bonnet bulge for that race.”

CORRECTIONS & ADDITIONS

Note 13 Part II  Piston Ring Flutter as a limit to Piston Speed
The ref. note showed that the basic condition for the onset of flutter of a plain rectangular-section Piston Ring was:-

\[ w \cdot \text{MPD} = \left( \frac{\Delta p}{\text{DR}} \right) \]

where \( w \) = Ring axial width;
\( \text{MPD} = \) Maximum Piston Deceleration (at outward end of stroke);
\( \Delta p = \) piston groove pressure above the Ring;
\( \text{DR} = \) Ring density.

Engine data for 1931 – 1983 showed that, in practice, \( \Delta p \) did not vary significantly over a wide range of NA and PC racing engines so that the empirical result, for cast-iron rings, was:-

\[ w \cdot \text{MPD} = \text{about 4,000 mm.g} \]

Note 13 Part II then discussed how engines in the 3rd NA Era, after 1988, were operating above that figure. It was concluded in Postscript 2 from practical observations that this was achieved because the normal operating RPM were so much higher than the natural frequency of radial vibration of the top ring that it could not resonate, i.e., flutter.

Honda data, 2000 – 2008
The Honda website Technical Review F1 Special (DASO 1121) in its constituent paper F1-SP2_08e, amongst other details of the development of the engines they built over 2000-2008, discussed their Piston Ring designs. These will be described here chronologically and then discussed in relation to Note 13 Part II.

The best estimate for maximum MPD has been added to the Honda information, assuming that Con. Rod. Length/Stroke (CRL/S) = 2.5 [for comparison Cosworth CA/6 ratio was 2.57 (Note 108) and Toyota RVX-09H was 2.724 (Note 111). The latter gives only 1.4% lower MPD cf. 2.5].
The values for S, w and Max. RPM are from the ref. Honda paper.

Continued on P.11
As on production engines, with a rectangular top ring and a spring-expanded oil control ring.

The steel top ring with \( w = 0.9 \) mm (35/1000”), \( w/S = 2.2\% \), had a spring-expander (see fig. RHS from the ref. Honda paper)*. Only 1 ring was fitted at first, which gave a 10 kW (13.4 HP) power gain but increased oil consumption to about 30 km/litre. This restricted its use to short-distance Qualification runs.

The FIA rules changed so that the same engine had to be used for both Qualification and the race. Honda therefore adopted 2-ring pistons with the same type in both grooves. This raised flutter onset by 1,000 RPM. Oil consumption returned to about 100 km/litre. This configuration applied to 2003, 2004 and 2005.

In this year an expanded Ti-alloy top ring was adopted (see the figure*). With a density (DR in the above formula) of only 60% of steel this would be expected to raise flutter onset MPD by 74%. The effect was reported as “...tremendous, preventing the increase of pressure in the crankcase due to fluttering, not only at wide-open throttle but also when the throttle was off” [closed-throttle being the more severe case for flutter]. Measured pressure pulses in the crankcase, which were 100 kPa (14.5 psi) with steel rings [at an unspecified RPM, but probably the figure at which flutter was most severe] disappeared. Oil consumption dropped to 150 km/litre.

To provide a satisfactory surface-rubbing situation the Ti-alloy rings had to have special coatings, as shown on the figure.

Toyota made the point that, whereas in a production engine a lot of the heat into the piston had to flow out via the piston rings to the cylinder walls, in a Grand Prix engine whose piston was mostly cooled by crankcase oil jets, the poorer thermal conductivity of Ti-alloy compared to steel [about 1/3rd of stainless steel] did not cause a problem.

This design was retained for 2007 and 2008, which had Maximum RPM reduced to 19,000 by FIA rule, so that \( w.MPD \) fell by 6%.

*It is hoped that there will not be any objections to the use of figures here in a not-for-profit site whose intention is to aid study.

**Discussion**

The Honda paper does not give enough data to enable the absolute values for flutter onset of either the spring-loaded steel ring or the spring-loaded Ti-alloy ring to be determined. The Ti ring takes advantage of the density term in the theory to produce a large increase - only made possible by surface coatings to overcome the propensity of titanium to scuffing. The very-enthusiastic Honda description of the improvement suggests that it may have actually raised flutter onset above the 2006 engine Max. RPM of 19,600 – it would not have been very helpful to raise it into the normal operating range! If so, the spring-loaded Ti-alloy ring flutter was possibly \((0.9 \text{ mm} \times 10,500 \text{ g})\) ,say, 9,500 mm.g. This is nearly 2.4 times the established plain iron ring figure of about 4,000.
The above is highly speculative and must await release of better figures to show if it is correct or not.

Whether other engine makers used any of the techniques described by Honda is, at present, also unknown. Renault, Ferrari and Mercedes all succeeded in running engines of similar dimensions up to nearly 20,000 RPM with much greater success.

Disuse of the Dykes’ ring

It is curious that the Dykes’ L-shaped piston ring, invented in 1947 and which prevents flutter at any value of MPD, has apparently not been used since about 1966. This was when Keith Duckworth adopted the “super-thin” plain ferrous ring for the DFV (0.030/1000”, 0.76 mm) (see The Unique Cosworth Story).

One possible reason for this disuse of the Dykes’ ring – apart from cost which, until recently, was no objection in a racing engine – may be that it is prone to fatigue failure. The necessary re-entrant corner of the L-shape must give rise to a high local stress-raiser as the inner leg of the ring is thrown against the top of its groove to restrain the outer leg (see Note 13 Part II sketch). The steady rise of RPM post-1988 to 2006 may have meant too-short a fatigue life as a consequence.

In theory the ring corner stress concentration could be eased with a radius and a corresponding chamfer on the groove. In practice this might be too difficult on such a small part.

CORRECTIONS & ADDITIONS

18 November 2015

Eg. 10 1924 Alfa Romeo P2

DASO 1133 (see refs. below) provides data not seen before.

CORRECTION

Power

The power number given in previous references was actually in Italian CV. The peak figure of 145 HP @ 5,500 RPM was therefore 143 BHP.

As an ADDITION a Power Curve is shown at RHS:-

Other data

<table>
<thead>
<tr>
<th>Appendix 1</th>
<th>DASO 1133</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVD mm</td>
<td>38*</td>
</tr>
<tr>
<td>Overall head</td>
<td>= Port dia.</td>
</tr>
<tr>
<td>VIA0</td>
<td>102</td>
</tr>
<tr>
<td>IVP ATA</td>
<td>1.71</td>
</tr>
</tbody>
</table>

0.75 kg/cm² boost = 1.73 ATA

*This figure (and many others in Appendix 1 where no specific dimensions were available) was derived by scaling from the Bore on an enlarged print with a rule graduated in 60 units to 1 inch.
Eg. 18 1932 Alfa Romeo B ("P3")
From DASO 1133

CORRECTION

Power
The power was also CV and the 215 HP @ 5,600 RPM is therefore 212 BHP.

As an ADDITION a Power Curve* is shown at RHS:-
*The figures at lower RPMs are suspect.

Other data

<table>
<thead>
<tr>
<th>Appendix 1</th>
<th>DASO 1133</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVD mm</td>
<td>39</td>
</tr>
<tr>
<td>VIA(^0)</td>
<td>100</td>
</tr>
<tr>
<td>IVP ATA</td>
<td>1.76</td>
</tr>
</tbody>
</table>

0.75 kg/cm\(^2\) boost
1.73 ATA

ADDITION
A cutaway drawing from (4) is shown below.
(Artwork credit L.C. Cresswell)

Eg. 26 1948 Alfa Romeo 158/47
From DASO 1133

CORRECTION

Power
The ref. has 275 CV @ 7,500 RPM, = 271 BHP, where the App. 1 figure was 310 HP.

Other data

<table>
<thead>
<tr>
<th>Appendix 1</th>
<th>DASO 1133</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>“7.5”</td>
</tr>
<tr>
<td>IVP ATA</td>
<td>“3.2”</td>
</tr>
</tbody>
</table>

“2.5 kg/cm\(^2\) boost”
= 3.42 ATA.

This DASO 1133 figure is out of step with the power and boost data given (below) for the later 158/159 engines, and is therefore disregarded. The App. 1 figure is more likely.
Eg. 28 1950 Alfa Romeo 158 (per DASO 1133; previously considered to be 159)
From DASO 1133.

CORRECTION

Power
The ref. has 350 CV @ 8,500 RPM, = 345 BHP, where the App. 1 figure was 370 HP @ 8,900 RPM.

Other data

<table>
<thead>
<tr>
<th>Appendix 1</th>
<th>DASO 1133</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVP ATA</td>
<td>2.5 kg/cm² boost</td>
</tr>
<tr>
<td></td>
<td>= 3.42 ATA.</td>
</tr>
</tbody>
</table>

Eg. 29 1951 Alfa Romeo 159M
From DASO 1133.

CORRECTION

Power
Appendix 1 had 400 HP @ 9,000 RPM.
The DASO 1133 figure for the Barcelona spec. engine is 425 CV @ 9,300 RPM, = 419 BHP. The figure at 9,000 RPM is 411 BHP.

As an ADDITION a Power Curve* is shown at RHS:-
The figures at lower RPMs are suspect.

Other data

<table>
<thead>
<tr>
<th>Appendix 1</th>
<th>DASO 1133</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>7.5</td>
</tr>
<tr>
<td>IVD mm</td>
<td>36</td>
</tr>
<tr>
<td>IVP ATA</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Port 30</td>
</tr>
<tr>
<td></td>
<td>3 kg/cm² boost</td>
</tr>
<tr>
<td></td>
<td>= 3.9 ATA.</td>
</tr>
</tbody>
</table>

ADDITION
A section of the 159M from (1133) is shown below.
**ADDITION**

**CORRECTIONS & ADDITIONS**

**Eg. 22 1936 Auto Union C-type**
From DASO 1132
A Power Curve is shown at RHS.

<table>
<thead>
<tr>
<th>RPM</th>
<th>kRPM</th>
<th>HP</th>
<th>Bar</th>
<th>MPN</th>
<th>BMEP</th>
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<tbody>
<tr>
<td>1.75</td>
<td>200</td>
<td>4.96</td>
<td>17.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>235</td>
<td>5.67</td>
<td>17.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>300</td>
<td>7.06</td>
<td>17.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>360</td>
<td>8.50</td>
<td>17.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>413</td>
<td>9.92</td>
<td>17.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>466</td>
<td>11.33</td>
<td>19.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>494</td>
<td>12.78</td>
<td>19.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>520</td>
<td>14.17</td>
<td>15.49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AUTOMOBILE UNION C-type**

**CORRECTIONS & ADDITIONS**

**Eg. 31 1953 Ferrari 500**
From DASO 1135 a cutaway drawing is shown at RHS.
2nd Naturally-Aspirated Era (2 NA) Part 2

Eg. 38: Concerning the Coventry Climax type FPE 90V8 2.5L

Connaught and Kieft both spent money preparing to race the Climax FPE engine in 1955. Their efforts were, of course, abortive.

Connaught

This company’s first Grand Prix car was the B-type, front-engined with an IL4 2.5L Alta, which was shown in August 1954 with streamlined bodywork. The fitting of the Climax FPE had been contemplated but Denis Jenkinson in Racing Car Review (RCR) 1955 (covering the 1954 season) reported:- “During the summer a V8 Coventry Climax engine was put through some test-bed running by Connaughts but it was found to have an entirely unsuitable power curve for the….new car. There was slightly more power...than...the Alta engine, but a less useful torque curve...the engine was subsequently discarded for use in the new car for the time being”.

The FPE Power Curve shown here [from Motor 9 December 1959] illustrates the kink between 5,000 and 6,500 RPM which Connaught disliked. This kink was probably from unfavourable inlet tract resonances.

In parallel Connaught had designed a completely different car to take the FPE, intended for the 1955 season, the mid-engined C-type. Autosport 4 December 1953 had a drawing of this project, shown at the RHS:-

Since Climax decided not to go on with the FPE the C-type Connaught never appeared. RCR 1958 reported that, after rough assembly, it was broken up.
A special 5-speed pre-selector gearbox/rear axle unit had been designed by Connaught for the higher-revving FPE. When the company was forced to give up and the assets were auctioned in September 1957 a prototype of this unit was included in the sale.

The auction included a serial number “C 8” car which was actually a space-frame version of the front-Alta-engined B-type with (probably) the revised De Dion back axle and inboard disc brakes of the original C-type.

If Climax had known that their engine had a superior Power/Weight ratio to the continental competition (see Note 61) they could have re-tuned it for less top-end power and a better torque curve to meet Connaught’s objection.

**Kieft**

This firm built two chassis in 1954 to take the FPE. When Kieft gave up racing these were sold into private hands. Similarly Climax disposed of their FPE engines.

In September 2002, after 48 years, and much effort (including some chassis mods. and the replacement of parts whose life was doubtful, the chassis and engine were united as had been intended. It was then campaigned in VSCC events. A full account of this saga can be read on the internet in the provenance article prepared for Bonhams when the completed car was auctioned in September 2012. It is still racing. The car is illustrated below:

An interesting detail is that Climax had redesigned the FPE cylinder heads to 2 plugs/cyl. during development (and these was fitted to the Kieft unit, although only 1 plug/cyl. was used). On the later derivative FPF IL4 1.5L engine, 1 plug/cyl. was found to give the best results (Motor 10 October 1956) and this was kept during subsequent enlargements up to 2.5L.

**CORRECTIONS & ADDITIONS**

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**CORRECTION**

21 January 2016

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

Fig. PA2 – 9

The R.R.C. Walker Cooper driven by Maurice Trintignant which won the 1958 Monaco GP was actually a new T45, not the modified T43 driven by Stirling Moss which won the preceding 1958 Argentine GP. It was fitted with a Climax FPF engine slightly enlarged further on the bore from 1,964 cc to 2,014 cc (M. Sport June 1958). This must have been an Alf Francis modification, since it is not referred to in Hassan’s FPF paper (33).
CORRECTIONS & ADDITIONS

ADDITION

21 January 2016

Egs. 47/62. 1968/1982 Cosworth DFV: The Unique Cosworth Story
The new authorised biography of Keith Duckworth by Norman Burr (DASO 1136, see ref. below) provides some extra details on the Cosworth DFV.

1967
- (p.87). The first engine (701) was written-off because BSA “Gold Star” steel wire coil valve springs were fitted and one of these failed and a valve went through a piston. Later valve springs were made by the German specialist Schmitthelm (p.88).
- (p.87). The lash-up needed for oil scavenging was despite having run extensive tests on a 1-cylinder rig before the system design was finalised. This adds to the caution about rig-tests given in Note 106.
- (p.89). The electro-mechanical rev-limiter fitted initially was not a success because it needed to count 10 firing strokes to act and before that the over-revving would have damaged the engine.

1971
- The crankshaft damper fitted as a mod.in 1970 when in valve-gear vibration trouble was removed after the quill hub was successful.

1981/1982
- Ti-alloy was introduced for valve-spring retainers and later for inlet valves.

DASO 1136. FIRST PRINCIPLES. The official biography of Keith Duckworth, OBE.

CORRECTIONS & ADDITIONS

ADDITION

23 January 2016

Eg. 54. Introductory remarks on the 1972 Ferrari 312PB
These remarks described the crank problems of the Ferrari 312 engine, reporting that when this was fitted in the 1971/1972 312PB sports-racing car the 4 bearing GP crank had to be replaced with a 7 bearing crank to obtain more than 24 hour life.

Actually, in 1972 the other-wise all-conquering 312PB team, although entered for Le Mans and run in the Test Weekend, was withdrawn a week before the race. Denis Jenkinson reported (Motor Sport July 1972) “the flat-12-cylinder engine failed to stand up to very long flat-out tests”. In the 10 312PB wins/10 races contested in the Prototype Sports Car Championship the longest race was the Sebring 12 Hours (finished 1st and 2nd), the usual time being about 6 hours.
It seems 24 hours at Le Mans speeds was thought by Enzo Ferrari to be “A race too far”!

CORRECTIONS & ADDITIONS

ADDITION

29 January 2016

Significant Other

Eg. SO 24 Ford-Butch Mock Motorsports (BMS) Nascar
Big 90V8 NASCAR engines with mandatory 2 valves per cylinder (2 v/c) and Push-Rod-operated Overhead Valves (PROHV) and steel Coil Valve Return System (CVRS) run up to values of Mean Piston Speed at Peak Power (MPSp) which are nowadays quite usual (MPSp = 22.7 m/s in Eg. SO24) but at exceptional values of Mean Valve Speed (MVS*), considering their valve gear.

In SO24 MVS at Peak Power was estimated at MVSP = 4.7 m/s on the assumption that Inlet valve Opening Duration (IOD) was 354°. This is discussed on P.19.

*MVS = \( \frac{12 \times \text{Inlet Valve Lift (mm)} \times \text{RPM/1000}}{\text{IOD}} \) m/s (1st defined in DASO 1139, see below).
A section of the basic Ford Small Block engine from which the racing engine was derived is given RHS.

The IOD of 354° is the timing used by Mario Illien when designing the special 2 v/c PROHV Mercedes-Benz 500I 90V8 3.43 L TC engine for the 1994 Indy 500 race (this unit took great and successful advantage of a rule change which was intended to encourage development of US stock block engines) (468). The valve gear is shown RHS (468).

As on the US engines the valves were Ti-alloy with drilled stems.

The 500I MVSP was 5 m/s at MPSP = 18.37 m/s.

The PROHV gain by using this valve material (and more “scientific” cam profiles) is shown very clearly by the chart below:

PROHV engines with Fe/Cr/Ni-alloy valve material over a wide range of Classes (defined below) are shown to have averaged about 2.5 m/s, i.e. only half of the engine with drilled Ti-alloy valves.

**Class A**:- Plain crankcase-camshaft push-rod-and-rocker gear with Valve Included angle (VIA) between 0 and 40°.
Figure example shown:- BMC A-type used as the basis of the 1963 Formula Junior.
Engine plotted at MPSP = 11.14 m/s and MVSP = 2.92 m/s.
(Figure credit M. Sport May 1964)

**Class B**:- As A with VIA between 41 and 90°.
Example shown:- 1947 JAP 500cc Speedway, Plotted at 19.80, 2.37.
(DASO 73. MOTOR CYCLE ENGINES, 1951)

**Class C**:- “Riley”-type (RHS) with high dual camshafts and VIA = 90°
Eg.1937 ERA C-type, plotted at 23.81, 2.67
(M.Sport March 1959)
**Class D:** “BMW-328”-type with exhaust operated by 2 pushrods, VIA = 80°.
Eg. Bristol 605 representing BS4, plotted at 19.20, 2.45.
(M. Sport March 1959)

**Hollow-head valves?**

It seemed possible that some of the NASCAR engines could be running with Ti-alloy valves which not only had drilled stems but also had hollow heads to further reduce mass. Del West, the specialist manufacturer of Ti-alloy valves, was asked that question in 2014. They replied that, although such valves had been tested, none had been raced because there is a minimum mass rule for these parts.

**Other valve gears for comparison**

<table>
<thead>
<tr>
<th>Engine</th>
<th>Valve operation</th>
<th>Valve Material</th>
<th>Valve Return System</th>
<th>MVSP/MPSP m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938 Norton 500 TT</td>
<td>Double Overhead Camshaft (DOHC) DOHC</td>
<td>Fe/Cr/Ni alloy</td>
<td>Steel Hairpin (HVRS)</td>
<td>3.14/21.22</td>
</tr>
<tr>
<td>1955 Mercedes-Benz M196</td>
<td>DOHC</td>
<td>“</td>
<td>Desmodromic (DVRS)</td>
<td>5.18/19.49</td>
</tr>
<tr>
<td>1982 Cosworth DFV</td>
<td>DOHC</td>
<td>Ti-alloy inlet, Fe/Cr/Ni exhaust</td>
<td>Steel Coil (CVRS)</td>
<td>4.96/24.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[With damping between 2 springs]</td>
<td></td>
</tr>
<tr>
<td>2006 Cosworth CA/6</td>
<td>DOHC</td>
<td>Ti-alloy</td>
<td>Pneumatic (PVRS)</td>
<td>11.6/25.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[Assuming IOD = 320°]</td>
<td></td>
</tr>
</tbody>
</table>

**Reference**

DASO 1139 The Piston Engine; article by S. Tresilian; *Automotive Design Engineering 3 February 1965.*
CORRECTIONS & ADDITIONS

Note 78. The engine Stewart Tresilian designed for Connaught

The engine Stewart Tresilian designed for Connaught

Stewart Tresilian (RHS DASO 1139) was a pre-WW2 advocate of reducing the Stroke(S)/ Bore(B) ratio of Normally-Aspirated (NA) poppet-valve piston engines as a way of increasing the Volume Specific Power (Power/Swept Volume (PP/V)). With a “Bottom-End” limit of [Mean Piston Speed (MPS)]^2 set by the piston material this would allow higher RPM – provided that the “Top-End” limit, characterised by [Mean Valve Speed (MVS)]^2, set by material and gear design could be managed (MVS defined in footnote on P.18). He proposed to do the latter by returning to 4 valves per cylinder (4 v/c) from the 2 v/c which had been general for NA engines since the 1922 FIAT Grand Prix design. With the total valve area the same as required for 2 v/c the individual valve lift would be reduced by a factor of 1/√2 and so, at the same MVS limit, the RPM could be 41% higher. In 1939 he envisaged an S/B ratio of 0.75 (B/S, as now more commonly used, = 1.333) (DASO 1138, see refs. below). The degree of change suggested is shown by comparing this with the B/S of the NA engine with the highest PP/V of the time, the 1938 Norton TT 500 cc 1-cylinder motorcycle, at 0.87. This was 2 v/c. The 2 v/c sports Lagonda 60V12 4.5 litre which Tresilian had just designed under W.O.Bentley had B/S = 0.89.

The Connaught engine design – the size question

It is generally known that Tresilian designed for Connaught in 1952 or thereabouts a 4-cylinder high B/S engine with 4 v/c ((587) and Note 78). The late Brian Lovell reported this as 2 litres. It is now thought that this was a misunderstanding. Although races at the time were being run to the 2 litre NA F2 rules, this was only a temporary situation. Already, in October 1951, rules had been promulgated for a 2.5 litre NA/0.75 litre PC formula to begin in 1954. It is very unlikely that Connaught would have wanted a new 2 L engine which could only have been ready for half of a 1953 season, unproven, at the best. Their desire must have been for 2.5 L.

This view is supported by an article by John Bolster which appeared in Autosport 4 December 1953 describing how Connaught wanted to enter full Grand Prix racing in 1954, if a financial crisis of the moment could be survived. The firm told Bolster that they would first use a new 2.5 litre IL4 Alta engine for the “B”-type car they had in hand (see figure on RHS showing the 1956 engine), the V8 Coventry Climax would take over as soon as it was available and “ in reserve there is a four cylinder of Connaught design which will be developed if necessary”. This is a clear indication that the new IL4 was 2.5 L.

Unfortunately, although money was found to race the Alta-engined B-types until it ran out in May 1957, obtaining as the high point the October 1955 Syracuse victory, the Climax engine was not suitable and was dropped by its builders anyway ( as described on P.16 ). Some work was done on the alternative IL4, as will be described.

The new IL4 engine parts offered for sale

When Connaught Engineering had to close all the assets were put up for auction in September 1957. The sales catalogue included the following:-

| LOT 270 | Quantity of components and patterns for 4-Cylinder Connaught Racing Engine, including 3-5 Bearing Laystall Crankshafts 8-100 m.m. Bore Liners, Crankcases and Bearing Caps, and 4 Part Machined Con rods |

It is not known if this Lot was sold or, if sold, who bought it.
Probable engine dimensions

Given the Bore was 100 mm, a 79.5 mm Stroke would give 2,497.6 cc and B/S = 1,258. This compares with the 1.333 which Tresilian might have wanted ideally. Perhaps the specialist liner makers (Laystall ‘Cromard’?) could only supply at 100 mm?

If the engine had been originally designed for 2 litres (and then a stretched 79.5 mm stroke crank made or contemplated for the new formula) the possible Stroke dimension would have been 63.6 mm for 1,998 cc and B/S would have been 1.572. This seems unlikely at that date.

The conclusion is that the Tresilian engine was a 2.5 litre.

Design considerations

The Alta which Tresilian’s design might replace was B/S = 93.5/90 mm = 1.039. Originally, with sand-cast Al-alloy pistons, it was limited to 6,700 RPM to give a life for a race finish, which did not give enough power to win classic GPs. Mike Oliver fitted forged pistons in mid-1956 and it could then run to 7,500 (MPS = 22.5 m/s) reliably (701), but still not enough to defeat the opposition.

Tresilian knew in 1952 that Ferrari had already built an IL4 2.5 litre with 2 v/c of 94/90 mm = 1.044. Even, perhaps, limited to a Bore of 100 mm by liner supply he could anticipate beating that. The expected return of Mercedes-Benz in 1954 was something else! Nevertheless, Ferrari did succeed in beating the German car twice in that year, but by using redesigned 2 v/c engines of 100/79.5 mm (see figure at LHS (DASO 790)), the very B/S ratio which Tresilian had adopted for his 2.5 litres! These new Ferrari engines had VIA of 100° and history tells us that such a wide VIA with high compression ratio was generally disappointing in BMEP because the “humped” piston gave an “orange-peel-shaped” combustion chamber. What VIA Tresilian used is not known. He went on to BRM in 1953 or 1954 to design a high B/S ratio 4 v/c engine for them of B/S = 4.05”/102.87 mm)/2.95”(74.93) = 1.373, just about the ratio which he had proposed in 1939. The finally-resulting IL4 had VIA = 79°, still too wide for high Combustion Efficiency, but this may have been a Berthon choice when he rejected the Tresilian 4 v/c in favour of 2 v/c with hollow lightweight valves. This was a good idea in theory but in practice it was bedevilled for 2 years by inability to weld soundly the necessary head closures (1141).

Some other deductions on the Connaught design

- It would, of course, have been DOHC to operate its 4 v/c. The engine built by BRM had hairpin valve springs (HVRS, until 1960) but again this may have been a Berthon choice;
- The crank is known from Lot 270 to have had 5-bearings. Tresilian changed his mind when he designed the BRM unit because that was only 4-bearings with a massive counter-weight in the centre (this is shown in DASO 1140). His reasoning for this was given later in DASO 1139:- “Counterweights should be situated where main bearing loads would be high, and bearings where the loads are low” Another Berthon alteration, in 1958, was to use 5-bearings because it was thought that the crank was deflecting at the back and causing cam driving gear failures (DASO 1141); Tresilian is known to have been unhappy about that (1138). It is hard to see how a shaft 2 3/8”/2 1/2” in diameter supported by 2 bearing at the back could deflect enough to damage a spur gear. There seems to be no specific report that the cam gear problem was solved. Cam-gear-train resonance with torque excitation is well known to have caused failures with the Cosworth DFV of 1967, the Ilmor-Chevrolet of 1985 and long before that with the first Rolls-Royce aero engine in 1915. Certainly the 5-bearing crank engine still vibrated and caused car problems in 1959 – sheet-metal failures (see Note 118 Part 2) and a tremendous crash when a front brake pipe fractured (DASO 56).

Tony Rudd in DASO 40 states the 1958 5-bearing crank cost nearly 19 HP compared to the 1957 4-bearing, as measured by heat-to-oil.
• The BRM engine had 4-bolt con-rods (also shown in DASO 1140) and it is probable that the Connaught was the same;
• Since Tresilian wanted a top-flange-located cylinder liner for the BRM (following Rolls-Royce Merlin 100 Series with which he was familiar) (DASO 1137), he would have chosen the same for the earlier engine. Once again Berthon selected something else - liners screwed into the head like the contemporary Ferrari. Tresilian noted in DASO 1137 that this led to trouble in obtaining liners parallel with each other.

The ultimate success of high B/S and 4 v/c – with additional ideas
The Berthon modified P25/P48 IL4 BRM with B/S = 1.373, having numerous problems and, perhaps, not the best team management, only achieved one classic Grand Prix victory in 6 years. With the now-reliable hollow 2 v/c layout and B/S = 68.5 mm/2” (50.8 mm) = 1.348 in the new P56 V8 for the 1.5 litre formula of 1961 the concept finally came good in winning the 1962 Championships. Sadly, Stewart Tresilian died in May 1962 at the age of 58 and did not see that. But the final success of high B/S and 4 v/c came in 1967 when two additional features were added to Tresilian’s 1939 idea in Keith Duckworth’s Cosworth DFV, having B/S = 3.373” (85.67 mm)/2.55” (64.8 mm) = 1.322 :-
• Narrow VIA (32°) to give a flat-top piston – developed by Weslake in a 1964 research unit;
• “Barrel turbulence” (aka “Tumble swirl”) – developed by Duckworth in the Cosworth FVA of 1966.

In 1989 the advance of higher B/S ratio would be furthered by the use of all-Ti-alloy valves and, from 1990, by the Pneumatic Valve Return System, so that by 2005 B/S had reached nearly 2.5. This will now never be exceeded as the FIA in 2014 introduced more prescriptive rules limiting B/S to about 1.5.

References
DASO 1139 The Piston Engine; article by S. Tresilian; Automotive Design Engineering 3 February 1965.
DASO 1140. www.ianmacfarlane.co.uk

CORRECTIONS & ADDITIONS
19 February 2016

ADDITION

Note 12. Speed Correlation Function (SCF)
The SCF provided a good prediction for NP for most CoY engines:-
• For an 18 engine sample of the T group (Tortuous Inlets and Simple Exhausts) the mean deviation from \( NP = 38.6 \times SCF \) is 5.7%;
• For a 15 engine sample of the I group (Individual and Tuned Inlets and Exhausts) the mean deviation from \( NP = 47.4 \times SCF \) is 3.6%.

However, Eg. 85, the 2000 Ferrari 049, was 22% above the predicted NP. In Note 12 it was suggested that this might have resulted from the IVL/IVD ratio of 0.384, significantly higher than earlier engines.

Two later engines have extended the data:-
• SO29 2005 Honda RA005E;
• SO25 2006 Cosworth CA/6 (The IOD for this engine is assumed to be 320°).

These are shown on the Figure on P.24. They are also well above the prediction:-
While the CA/6 at 28% above prediction had IVL/IVD = 0.387, the RA005E at 31% had only 0.325. This seems to disprove the earlier suggested effect of high IVL/IVD causing the extra speed. **Other possible causes of NP >> 47.4 x SCF**

Efforts were made in the later years of the 3rd Normally-Aspirated Era (3NA) to reduce friction which had been increasing as NP was pushed up. Better lubricants were produced and the new surface coating treatment Diamond-Like Carbon(DLC) was introduced from 1994 (see Note 103). The application of DLC was steadily extended. These anti-friction actions may have produced the extra speed above prediction. **Higher Efficiency**

If friction was much reduced from about 1994 onwards, this should show in higher values of Combined Efficiency (ECOM = EV x EC x EM). The Figure below shows that this was the case:

The hypothesis of reduced friction leading to NP up to 30% higher than SCF derived from earlier engines seems to be valid. It may be disproved when complete data is available for the engines of 1989 to 2006. It is hard to know when that much-to-be desired situation might arise, considering that Renault have never released officially even the Bore and Stroke of their RS series from 1989 to 1997. Neither have Mercedes for their 1998 – 1999 engines. **P.S., on current RPM**

The age of ever-rising Grand Prix engine RPM is now over for ever. The “Red Line” reached 20,000 in the first year of the 2.4L V8 formula in 2006, a maximum of 26.5 m/s.
The FIA decreed a reduction to 19,000 in 2007 and then to 18,000 in 2009 – these lower speeds helped to achieve the longer engine lives also mandated.

The 2014 1.6L V6 TC formula imposed a maximum fuel flow rate of 100 kg/hr at 10,500 RPM so that there was no point in going far beyond that at a weakening Fuel/Air ratio. TV telemetry seems to show flicks up to 12,000. The rule limit of 15,000 RPM was always going to be a dead letter, and it is surprising that it was ever specified. With the also-prescribed cylinder dimension of 80 mm Bore leading to 53 mm Stroke a maximum in practice of 12,000 RPM represents 21.2 m/s.

CORRECTIONS & ADDITIONS

3rd Naturally-Aspirated Era (3NA)

Eg. 75 1992 Renault RS4

It was recorded in Eg.75 that Renault would not supply significant data on any of their engines in the 3rd NA Era, even 18 years after their retirement in 1997.

This policy changed in 2016 when Haynes were given some internal details of the RS3C and RS4 of 1992 for their book on the Williams FW14B (DASO 1184; see References below). This provided Bore (B) and Stroke (S) for these two engines and also the Valve Head Diameter for their Inlet and Exhaust Valves (IVD & EVD). A reproduced works drawing enabled the Maximum Valve Lift (VL) to be scaled and also confirmed the 20° non-orthogonality of the inlet port giving Tumble Swirl.

Difference in B/S from Appendix 1

<table>
<thead>
<tr>
<th>Appendix 1, Eg. 75</th>
<th>Actual</th>
</tr>
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<tbody>
<tr>
<td>RS3C -</td>
<td>93 mm/51.5 = 1.806</td>
</tr>
<tr>
<td>RS4 93 mm/51.5 = 1.806</td>
<td>96 mm/48.3 = 1.988</td>
</tr>
</tbody>
</table>

Therefore Appendix 1 actually gave the correct figures for the RS3C which was raced very successfully in 1992 up to and including Round 10 (Germany), securing 8 wins with the FW14B. After that the RS4 took over as the race engine. As described in Eg. 75 the simultaneous imposition by the FIA at very short notice of “real petrol” as fuel then caused a loss of reliability. The Win/Race ratio dropped from 8/10 to 2/6.

The increase in B/S for the RS4 over the RS3C was much greater than suspected at the time. Consequently the 1993/94 RS5/RS6 were probably the same as the RS4. The 3 litre engines from 1995 to 1997 shown in Appendix 1 may or may not be correct in B/S ratio.

1992 Renault RS4

Valve data

For the first time values of Valve Diameter have been given in DASO 1184. It is interesting that these correspond to the general non-dimensional ratios in Note 107 for Narrow VIA/4 v/c engines, as shown below:-

Contd. on P.26
Contd. from P. 25

<table>
<thead>
<tr>
<th>VIA</th>
<th>RS3C</th>
<th>RS4</th>
<th>Note 107 trend</th>
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<tr>
<td>IVD/B</td>
<td>38.4 mm/93 = 0.413</td>
<td>39.6 mm/96 = 0.413</td>
<td>0.411</td>
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<tr>
<td>EVD/IVD</td>
<td>32/38.4 = 0.83</td>
<td>33/39.6 = 0.83</td>
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</tr>
<tr>
<td>Valve actuation</td>
<td>DOHC; PVRS; finger followers</td>
<td>DOHC; PVRS;</td>
<td></td>
</tr>
<tr>
<td>IVL/IVD</td>
<td>10.75/39.6 = 0.271</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVL/EVD</td>
<td>13.6/33 = 0.412</td>
<td>The value of EVL/EVD</td>
<td></td>
</tr>
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</table>

It is not possible to measure the Inlet Valve Opening Duration (IOD) from the drawing, but it is clear from the cam shape that it must have been of the same order as the “classic” Cosworth valve timing of 58/82//82/58 giving IOD = 320°. This value is assumed in the standard performance analysis shown at Col. B in Appendix 9. Renault did not give the RS4 value of Peak Power for DASO 1184 but the good sources DASO 563 and 589 agreed on 760 HP @ 14,200 RPM and this has been retained.

**Speed Correlation Function (SCF)**

At +16% the value of GS shown at Row 119 in Appendix 9 is disappointingly higher than the SCF trend of 47.4 (disappointing for this analyst – but gratifying for Renault, whose V10 produced as much power as its rival V12 Honda RA122E/B which gave 764 HP @ 14,400 RPM on “real petrol” (DASO 69)). Following the argument in C & A at p.23 19 February 2016 it is possible that Renault in 1992 were already making use of the ultra-low-friction surface treatment Diamond-Like Coating (DLC). **Note 103** speculated that this might not have been used until 1994, but there is no firm data on this.

**World Championships**

In the active-suspension Williams FW14B the 1992 Renault engines powered the Drivers’ Championship (Nigel Mansell) and the Constructors’ Championship, gaining at last the honours which had eluded them for 15 years.

**References**

DASO 69. JSAE 9301494

**CORRECTIONS & ADDITIONS**

29 September 2016

**2nd Naturally-Aspirated Era (2NA)**

**Eg. 35 1957 Maserati 250F**

DASO 1185 (Referenced below, advised by Ron Rex) gave some details of the 1957 Maserati 250F.

The main difference from Eg. 35 is that it shows the Inlet Valve Head Diameter (IVD) was increased from the initial 46 mm to 48. DASO 27, referring to the “large port” engine but without quoting the size, dates it to April 1955. The associated carburetter change was from 42DCO3 to 45DCO3 (Carb. Bore area/Valve area change from 42²/46² = 83.4% to 45²/48² = 87.9%).

Both the Maserati works and Stirling Moss privately experimented with fuel injection into the inlet ports in place of Weber carburetters. **Note 118** Part 1 (p. 7) and **Note 118** Part 2 (p. 2) give illustrations of the systems used and the resultant effects. These were considered to be unsatisfactory and neither persisted with the change.

There were small differences in IVL and IOD from the figures used from 1954 Maserati build records. **Contd. on p. 27**
The power output was confirmed at 271 HP @ 7,500 RPM. Eg. 35 expressed a 10% doubt on the power because of a known tendency for Maserati to exaggerate (see Note 6). There is no mention by Alfieri of Nitromethane in the fuel.

The new figures are incorporated in the standard performance analysis in Appendix 9. A Power curve is shown below.

Regarding the re-calculated Speed Correlation Function (SCF), this is still close in GS to the trend value of 47.4

### POWER CURVES

<table>
<thead>
<tr>
<th>Eg.</th>
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<tr>
<td>DASO</td>
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<tr>
<td>YEAR</td>
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<tr>
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</tr>
<tr>
<td>Model</td>
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<tr>
<td>Vcc</td>
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<td>Smm</td>
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<td>6.2</td>
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<td>15.5</td>
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<td>6.4</td>
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<td>7</td>
<td>266</td>
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<td>13.64</td>
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<tr>
<td>7.2</td>
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<td>18.75</td>
<td>12.97</td>
</tr>
<tr>
<td>7.7</td>
<td>268</td>
<td>19.25</td>
<td>12.49</td>
</tr>
</tbody>
</table>

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

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**Fangio at the Nurburgring**

The most famous race of the Maserati 250F was that won by Juan Fangio in 1957 at the old 22.80 km (14.167 mile) Nurburgring. During this race he drove a record lap about which he admitted "I never drove quite like that before and I never drove quite like that ever again!" (DASO 1083). It is interesting to put this into perspective with other fastest laps on that circuit with 2.5 litre Naturally-Aspirated formula cars over 1954 – 1958, as follows:-

Contd. on p. 28
<table>
<thead>
<tr>
<th>Date</th>
<th>Car</th>
<th>Driver</th>
<th>Nurburgring lap time</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Practice (P) or Race (R)</td>
<td>Min.</td>
<td>Sec.</td>
</tr>
<tr>
<td>1954</td>
<td>Mercedes-Benz W196</td>
<td>Fangio</td>
<td>P</td>
<td>9.</td>
</tr>
<tr>
<td>1955*</td>
<td>''</td>
<td>''</td>
<td>P</td>
<td>9.</td>
</tr>
<tr>
<td>1956</td>
<td>Ferrari-Lancia D50</td>
<td>''</td>
<td>R</td>
<td>9.</td>
</tr>
<tr>
<td>1957</td>
<td>Re-surfaced (DASO 1083)</td>
<td>Maserati 250F</td>
<td>R</td>
<td>9.</td>
</tr>
</tbody>
</table>

*No 1955 German GP. Time set in Mercedes works test with short-wheelbase W196 (215 cm, 8.5% less than 1954 235 cm chassis). DASO 32.
No 1959 or 1960 GP at the Nurburgring.

Fangio in 1957 at the age of 46 brought Maserati their only F1 Championships and only the 2nd “GP Car-of-the-Year” in their 33 year participation in Grand Prix racing (the 1st was the 8C3000 in 1933). However, unlike their rivals, they had always built GP cars for sale, carrying on from Bugatti in that way. Maserati no. 2508 is famous as the car which enabled Stirling Moss to show his ability.

**References**
DASO 27. MASERATI. A. Pritchard. ARCO. 1976.

**CORRECTIONS & ADDITIONS**

**Gilera 1957 500 cc and 1939 Rondine 500 cc**

Through the courtesy of Mitchell Kay of MV Meccanica Verghera Ltd, who have replicated 1957 Gilera 500 cc racing motorcycles from an original, detailed data has become available on this engine (DASO 1187. See References below). During the career of the machines there were practically no internal details ever released. A standard performance analysis is given in Appendix 9.

The power of the replicas was given as 56 HP @ 10,000 RPM. It is believed this is a back-wheel rolling-road figure and so 10% has been allowed for tyre and chain losses to assume 62 HP at the crank, as for other engines analysed. This is still about 10% less than Gilera claimed and which was repeated in Appendix 4 (not an unusual situation with Italian power outputs, quite apart from the 1.4% smaller Cavallino Vapori!).

A cross-section of the engine by Mark Kay is shown.

1957 Gilera Grand Prix

Transverse IL4a/c 52 mm/58.8* = 0.884 499.5 cc
62 HP @ 10,000 RPM

*58 mm 1948 – 1953.
The 1948 engine was claimed to give 45 HP @ 8,500 RPM. Claims for later developments are tabled in Appendix 4.

Contd. on P. 29
Gilera Rondine
The post-WW2 Normally-Aspirated (NA) Gilera transverse 4-cylinder aircooled (a/c) 500 cc engines, designed under the direction of Piero Remor and raced from 1948 to 1957, were strongly influenced by the pre-War Pressure-Charged transverse 4-cylinder watercooled Gilera. This was developed from the Compagnia Nazionale Aeronautica (CNA) Rondine (Swallow) engine designed in 1933 by Carlo Gianini, which was itself an outcome of a transverse 4-cylinder aircooled 500 cc conceived and built in various forms by Gianini and Remor from as early as 1923 – the full history is given in DASO 1188. The work of Piero Taruffi as development engineer, rider and team manager at various times over the history of these machines up to 1955 is also very important.

It is clear that the Rondine “top-end” was modelled on the Alfa Romeo “P3/P3B” of design dates 1931 - 1933. This can be seen by comparing the engine sections below.

1933 (Design) Alfa Romeo P3B
Bore 68 mm
DASO 184

1933 (Design) CNA Rondine
Transverse IL4 w/c
52 mm/58 = 0.896  493 cc

The item at the top of the inlet camshaft is a water pump.
The vertical item on the RHS is the magneto.

The following features were common between the P3B and the Rondine:-
* DOHC*  • Wide VIA (100°)**  • IVD/B = 0.6 (31 mm/52 = 41/68)***  • Mid-camshaft-drive*
* "Mushroom" tappets*  • Updraft inlet ports*  • Masked sparking plugs*
* Integral head and block  • Al-alloy static structure with Fe-alloy dry cylinder liners*
* Water-cooled
* Roots supercharger (but Bugatti-type 3-lobe rotors with labyrinth tip seals, not plain 2-lobe).

There were two features where Gianini did not follow Vittorio Jano’s P3B:-
1. The B/S ratio was much higher: 52 mm/58 = 0.896, not 0.68.
The original Gianini/Remor 4-cylinder of 1923 had been 51/60 = 0.85. [Carlo Guzzi had been resurrecting high B/S since his 1919 prototype 500 cc had 88 mm/82 = 1.073, although in 1926 he settled on 68 mm/68 = 1 for a new 250 cc.]
2. The “bottom-end” bearings were roller (and presumably ball), where Jano had used plain bearings (Note 18 discusses the features of each type).

The cross-section of the Rondine is almost certainly of the 1933 design, since the supercharger delivery is direct to the inlet ports. When the motorcycle was sold to Gilera in 1935, Taruffi inserted a plenum chamber-cum-intercooler. This is shown on the drawing on P. 30.

*Carried over to the post-War NA a/c engine.  **Although VIA of 80°, then 90° and finally 100° have been published for the post-War engines, photos show that it was always 100°.
*** Increased finally in 1957 to 34 mm/52 = 0.65.
1939 Gilera Rondine

75 HP @ 9,000 RPM (see comment below)

NB! No source gives the supercharger pressure. It is assumed in the analysis to be the same as the P3B at 1.7 ATA.

Note the camshaft drive in the middle.

Showing the intercooler.

The original design had a water pump driven off the inlet camshaft, which is not seen on this drawing. Possibly it was found that thermostatic cooling was sufficient.

DASO 1190

The great days of the Gilera Rondine were in 1939, when Dorino Serafini beat Georg Meier’s supercharged BMW to the 500 cc European Championship (much to Adolf Hitler’s disgust!).

A comment on power. DASO 1188 records the opinion of Harold Willis, the development engineer for Velocette, that the Gilera gave no more than 50 HP! It is suggested that he was judging from the speed relative to his 500 cc single-cylinder but not taking into account the greater frontal area and weight of the Italian bike which sapped driving power. It is known that the BMW had 55 HP (DASO 30 reporting works data). It was a 14% lighter motorcycle (302 lb v. 350; DASO 1188), although also hampered by its frontal area, and the Gilera beat it.

References

CORRECTIONS & ADDITIONS

2nd Naturally-Aspirated Era (2NA)

Eg. 47 The Unique Cosworth Story

When “The Unique Cosworth Story” was written no full cross section of the DFV engine was known to this author. A, perhaps belated, search of the Internet has now found the drawing shown at RHS.

Credit: - March 701.Formule1constructorsf1.com

This section enables a correction of a detail on Fig. 47D of Eg. 47 – the oil scavenge offtake in the crankcase. The original figure was known to be wrong by the advice of Michael Costin; the new illustration shows how the oil was swept horizontally into the cast-in scavenge channel by the windage from the rotating crank.

As a March 701 installation the section is of a 1970 DFV. The curved inlet horns may not have been used in practice.
ILLUSTRATIONS for Appendix 5 Part 1

Fig. 19  1939 Auto Union D-type

This 60V12 engine continued the Auto Union 45V16 economy on camshafts to some extent (it had only one) by operating 4 rows of valves with three camshafts. The way this was done is illustrated in the figure at LHS. Although the figure is diagrammatic, it is probably to scale.

Addendum to Maserati 250F

Power absorbed in oil supply

Guilio Alfieri included in DASO 1185 an interesting note on the power absorbed by the oil pumps in the 2.5 Litre 250F. With a plain bearing surface total of 156 square centimetres fed at 6 kg/square centimetre (85 psi) these required 18CV representing 6% of the power before deducting the pump loss.

CORRECTIONS & ADDITIONS

How many valves per cylinder?

This article described engines with 0, 1, 2, 3, 4, 5 and 8 valves per cylinder (v/c), with a P.S. on 6. A correspondent has now kindly supplied data on a 1980 Yamaha experimental Grand Prix engine with 7 v/c (DASO 1192; see references below)! The “missing link” therefore existed and the series from 0 to 8 is complete.

Background to the Yamaha experiment

Yamaha racing motor-cycle engines were 2-stroke from their start in 1957 with the smaller classes. They gradually built larger engines until, in 1974, they won the Manufacturers’ Championship in the premier 500 cc class. Yamaha improved this in 1975 when Giacomo Agostini won the Riders’ Championship as well, the first 2-stroke-mounted rider to do this on a 500.

During the following years, all won on 2-strokes, Yamaha gained both Championships in 1978, 1979, and 1980.

Honda’s 4-stroke attempt to beat the 2-strokes

Meanwhile, Honda, who had retired from a very-successful participation with 4-stroke engines in all classes of Grand Prix motorcycle racing in 1967 (although they had never won the premier Riders’ Championship) had returned to 500 cc competition. They believed that a 4-stroke could still win, although their previous method of raising Volume-Specific Power by increasing the number of cylinders was now denied by a FIM rule introduced in 1970 limiting 500 cc engines to 4 cylinders. The 2-strokes were developing 120 – 125 HP (see Appendix 4). Honda’s last 500 cc 4 cylinder engine in 1967, the RC181, produced 95 HP @ 14,500 RPM (11.8 Bar @ 21.7 m/s)(DASO 354)(see Note 92). If BMEP could be maintained at the RC181 level then to get, say, 130 HP would require 14,500 x (130/95) = about 20,000 RPM. If the MPSP was still limited by piston material to 21.7 m/s then the Stroke (S) would have to be 32.6 mm. Actually, Honda chose 36 mm (DASO 1193). A circular Bore (B) would then be 66.5 mm and B/S 1.85.

Continued on P. 32
Continued from P. 31

To retain the same breathing as the RC181 the IVA/PA ratio would have to be the same (0.326). If this was done with 4 valves per cylinder (2 inlet), as used in all the earlier Honda engines, it would mean IVD = 27 mm. But the MVSP would be beyond the limit set by the valve gear technology of the time, using steel-alloy valves with steel Coil-spring Valve Return System (CVRS); assuming IVL = 0.3 x IVD and IOD = 300° it would be 6.5 m/s, where (with the same assumptions) the RC181 was 4.2 m/s. More smaller valves with less lift were therefore needed and Honda chose 8; (4 inlets with IVD = 19.5 mm). How then to accommodate 8 v/c? Thinking “Outside the circle” gave the answer:- a “race-track” section! The dimensions were:- length 93.4 mm and width 41 mm, the ends being semi-circular, and PA = 138.75 cm². The IVA/PA ratio was 0.344. The 4 inlets in a row were opposed by 4 exhausts.

Honda raced the NR500 for 3 years but never looked like beating the 2-strokes in Grands Prix. Development had taken the power up to a competitive level – 134 HP @ 19,250 RPM (12.47 Bar @ 23.10 m/s)(DASO 354) – but weight was against it. Four overhead camshafts with their driving gears and 32 valves with 64 springs were all extra to the 2-strokes.

A power curve is given below.

POWER CURVES

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Make</th>
<th>Model</th>
<th>Vcc</th>
<th>Ind.</th>
<th>Confign.</th>
<th>Bmm</th>
<th>Smm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>Honda</td>
<td>NR500</td>
<td>499.5</td>
<td>NA</td>
<td>90V4</td>
<td>&quot;66.5&quot;</td>
<td>36</td>
</tr>
</tbody>
</table>

Powers as published were kW and have been multiplied by 1.34 to convert to HP

Yamaha 001A 4-stroke

Yamaha, the 2-stroke Champions during the inception and building of the Honda NR500, undoubtedly got to hear about it. They seem to have decided to hedge their bets for future wins by producing their own 4-stroke 90V4. All the considerations listed above for the Honda would have applied to the Yamaha design, but, although they probably knew about the “Race-track” cylinder, they did not hesitate to use a circular cylinder with B/S = 70 mm/32.4 = 2.160.
However, they could not get 8 valves into the bore but only 7. Their arrangement is shown below (DASO 1192), with 4 inlets and 3 exhausts, and 2 x 8 mm spark plugs. IVD (by scaling) was 19 mm and IVA/PA = 0.295. The photo shows that the inlet valves are inclined at about 20° to the cylinder axis and the exhaust valves were parallel to it.

DASO 1192 states that the 1980 001A engine produced 123 HP @ 18,000 RPM (12.28 Bar @ 19.44 m/s). No doubt this could have been improved with development. Yamaha 2-strokes were supplanted in the Championships by Suzuki in 1981 and 1982, but they never tried to race their 4-stroke. They had the same weight problem as Honda and saw that company could not win races with the NR500. The project was dropped. More analysis is given in Note 92.

Yamaha 5 v/c and 6 v/c engines

Yamaha’s description of the 001A engine suggested that they increased the v/c in order “to improve intake/exhaust/combustion efficiency”. The above reasoning shows that it was forced on them by valve gear design and material in the late ‘70s if they wished to run at high B/S..

Yamaha did experiment with a 6 v/c engine according to DASO 1192. They stated that their experience did lead them to the 5 v/c introduced in the 1985 FZ750 motorcycle, and this was in the belief that higher efficiencies could be obtained (see the basic article “How many valves per cylinder” for more on 5 v/c configurations). They persisted with this v/c into the MotoGP era but finally gave in to the more-or-less standard 4 v/c in 2004.

Increased B/S from the ‘80s to the ‘00s

The Honda and Yamaha engine designs with higher-than-typical B/S in the late ‘70s/early ‘80s were governed by valve gear, as shown. The advance to ever-higher B/S and higher RPM became possible with efficient 4 v/c when all-Ti-alloy valves became available, followed by the Pneumatic Valve Return System (PVRS), and then Diamond-Like Carbon (DLC) anti-friction coating (see Note 15). Finally B/S reached 2.465 in the 2005 BMW P85 prototype (see Note 112 and Appendix 1 at SO27). “Finally”, because the FIA then ruled out any further increases.

References

DASO 1193. www.motorcyclespecs.co.xa

P.S.
The theories for Mean Piston Speed (MPS; at Peak Power this is MPSP) and Mean Valve Speed (MVS; at Peak Power MVSP) are given in Note 13 Part I and Part III, respectively.

CORRECTIONS & ADDITIONS

23 May 2017

ADDITION

A tribute to Geoffrey Taylor of Alta

Geoffry Taylor (1903 – 1966) founded the Alta Car and Engineering Co. in 1931, having already built himself a prototype of a car which he intended to market. The name “Alta” he obtained from a Canadian abbreviation for Alberta and he liked the sound of it. There is actually an “Alta Lake” in British Columbia and it is derived from the Spanish for “High up”. Very appropriate.
For over a quarter of a century Alta cars and engines played a significant part in English motor-racing and they all sprang from the mind of Geoffrey Taylor. From 1945 to 1957 he was the only supplier of pure-bred racing engines in the UK (the Bristol engine from 1952, although very effective, was a tuned-up BMW-basis sports car unit).

**Pre-WW2.**
Following his 1929 prototype, the first Taylor car offered for sale was with an engine of IL4 60 mm/95 = 0.632 1,074 cc. It could be bought either Naturally-Aspirated (NA) or Mechanically-Supercharged (MSC). It had an Al-alloy block and head, as did all later Altas. All Alta engines built were 4-cylinder, DOHC and 2 v/c, with finger cam followers.

In the 8 years before WW2 there followed larger engines: an IL4 69 mm/100 = 0.69 1,496 cc and an IL4 79 mm/100 = 0.79 1,961 cc. The latter two units were basically the same with different wet liners in the Al-alloy block.

The most successful pre-War Alta was a 2 litre, later converted to 1½ litre, rebuilt in 1937 from a crash and sold to George Abecassis at a figure only a quarter of a new B-type ERA price. His greatest achievement was to beat “B. Bira” driving his famous B-type ERA “Romulus” in the 1938 Imperial Trophy at Crystal Palace, a particular stamping-ground for the highly-talented Siamese.

The Final was run in heavy rain and Abecassis had ingeniously fitted twin rear wheels, a “first” for circuit racing, though seen before in hill-climbs. See Figs. 1 and 2 below.

![Fig. 1](image1)

George Abecassis driving his 1½ litre Alta. Note the twin rear wheels. Suspension was all-independent to the Sizaire/Lancia pattern, with all-4 wheels sliding on fixed pillars, the roll axis being at ground level. The driver is apparently wiping his goggles.

![Fig. 2](image2)

A pre-WW2 supercharged Alta engine, not known whether 1½ or 2 litre. Note the twin SU carburetters feeding the low front-mounted Roots-type blower, made by Alta. True 1½ litre output 140 BHP (DASO 737) @ 5,800 RPM.

**Post-WW2.**
Post-WW2 Taylor was quickly off the mark in late 1945 to design a new 1½ litre MSC car, the engine being IL4 78 mm/78 = 1 1,491 cc. Post-War difficulties delayed the debut to 1948. This car also had all-independent-suspension (see Note 66B). Sold to low-budget drivers this GP car and a 1952 F2 2 litre NA adaption did not obtain success.

However, Taylor’s close neighbours at HW Motors saw the way in 1950 to build and campaign a F2 car with his new 2 litre engine:- IL4 83.5 mm/90 = 0.928 1,971 cc (this is also covered in Note 66B). The power output of this engine in various 1950 and 1951 tunes is shown at Fig. 3 on P.35.

The engines were raced on 80% alcohol-base fuel (DASO 147). Development for the 1951 HWM was carried out with the help of HWM’s Chief Mechanic, Alf Francis.

In both the 1950 and 1951 seasons, the former with 2-seater-width bodies and the following year with true monopostos, the overall performance of the HWM team on the smallest of budgets was truly remarkable. The highlight of 1950 was Stirling Moss’ 3rd place at Bari behind two 159 Alfa Romeos. In 1951 it was Moss’ 3rd place at Monza in a F2 race behind Ascari and Villoresi on two works V12 Ferraris.
The Taylor designed-and-built Alta engines made the HWM team possible. In particular the unit stood up to lengthy slipstreaming by Moss of Villoresi’s Ferrari at Monza.

**Fig. 3**
In 1951 Taylor was one of the first to fit the new Weber double-choke carburetters.
Fuel was 80% methanol (DASO 147)

Alta and HWM parted company in 1952 and the internals were redesigned by R.R. Jackson. However, the following year after Moss decided to rebuild his season around a standard Cooper chassis with his well-tuned Alta engine (dropping a special chassis which did not fulfil its theoretical promise), a combination of SU port fuel injection and Shell nitro-methane additive produced 186 BHP (DASO 1) (Francis reported 200 was seen (147)). The %age of the oxygen-bearing constituent has not been reported.
In the 1953 Italian Grand Prix Moss was able to hold a works Maserati for speed, although far behind in laps from pitstops (see Fig. 4).

**Fig. 4**
1953 Italian Grand Prix.
Stirling Moss slipstreaming a works Maserati driven by Felice Bonetto.
Apart from refuelling stops, with the car doing only 4 MPG on the nitro-methane mix (147) the rear tyres could not stand the speed and lost treads.
With bolt-on wheels much time was lost in changing.

Although not a direct Alta development, this performance again showed the strength of the engine.

Re-tracking a little in time, the FIA in October 1951 had published rules to be effective in 1954 for Grand Prix cars with 2½ litre NA engines (an option at 750 cc PC was generally ignored). Geoffrey Taylor immediately began to design a 90° V8 75 mm/70 = 1.071 2,474 cc. This was his first “over-square” project. The result was published in “Autocar” 26 December 1952 (see Fig. 5 on P.36). It was stated in the article that a prototype was under construction and “it is hoped that it will be...ready for test in approximately four months’ time”. In fact, the V8 never appeared, for reasons unknown, probably due to lack of development money but also considering what customers could afford to pay for the units.

Continued on P.36
1952 Alta V8 project

An interesting detail is that the wet cylinder liners were to be held in compression, a basically bad feature (see Note 71B) but the top sealing was to be by Wills rings. These have resilience in compression and so could have accommodated differential expansion.

Instead of the V8 Taylor produced for Connaught in 1954 a new 4-cylinder engine: IL4 93.5 mm/90 = 1.039 2,472 cc. It first appeared – in a demonstration of the prototype all-enveloping car – in August 1954, but not in a race until 1955. This engine is included in Illustrations for Appendix 5 at P.14. It had a new feature (presumably in the preceding 2 litre) in that the 4 cylinders were cast as a 1-piece iron block bolted into the Al-alloy crankcase cum water jacket.

Over the next 2 years Michael Oliver and the late Brian Lovell of Connaught developed this basic Alta engine, enlarging the 2” inlet valves by ¾” (+13% area) and replacing the sand-cast Al-alloy pistons with forged to permit +500 RPM to 7,500 reliably (22.5 m/s MPS instead of 21). Somewhat ironically Connaught’s moment of glory came as early as October 1955, when the “rookie” Tony Brooks thrashed the works Maserati team at the non-Championship Syracuse GP (see Fig. 6). Small British races provided firsts, but Connaught’s severely-cash-limited team could not obtain Championship wins. It was forced to close half-way through the 1957 season.

With his customer gone, Geoffrey Taylor called it a day in building racing engines and Alta ceased to exist. His post-War engines had provided much of the basic power to scale the foothills in the climb of British teams to the summit of Grand Prix racing.
### 2nd Pressure-Charged Era (2PC): Egs. 66 - 68: Porsche P01

My regular correspondent, Ron Rex, has advised me that the long-time Porsche engineer Hans Mezger in his autobiography (DASO 1197) published full power data on the P01 TC engines of 1983—1987 (badged as “TAG” after the group which financed them for McLaren).

Mezger’s data not only gave the Race power for all the years raced but also the Qualification figures. This is unusually comprehensive. Figures are given below, adjusted to the usual website units. Note that the power figures are rated maxima but not peak as Porsche did not test the P01 to that condition.

#### 80V6 82 mm/47.3 = 1.734 \ V = 1,499 cc

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel</th>
<th>R</th>
<th>Race Rating</th>
<th>Max Power BHP</th>
<th>@ RPM</th>
<th>MPS m/s</th>
<th>BMEP Bar</th>
<th>ECOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>102RON</td>
<td>7</td>
<td>2.94</td>
<td>769</td>
<td>11,400</td>
<td>17.97</td>
<td>40.29</td>
<td>66.7%</td>
</tr>
<tr>
<td>1984</td>
<td>Same</td>
<td>7.6</td>
<td>2.94</td>
<td>799</td>
<td>11,600</td>
<td>18.29</td>
<td>41.12</td>
<td>66.2%</td>
</tr>
<tr>
<td>1985</td>
<td>Same (from mid year, Toluene based)</td>
<td>7.8</td>
<td>3.04</td>
<td>838</td>
<td>11,800</td>
<td>18.60</td>
<td>42.42</td>
<td>65.5%</td>
</tr>
<tr>
<td>1986</td>
<td>Same</td>
<td>8.5</td>
<td>3.13</td>
<td>888</td>
<td>12,000</td>
<td>18.92</td>
<td>44.17</td>
<td>64.6%</td>
</tr>
<tr>
<td>1987</td>
<td>Same*</td>
<td>8.9</td>
<td>3.31</td>
<td>937</td>
<td>12,300</td>
<td>19.39</td>
<td>45.48</td>
<td>62.0%</td>
</tr>
</tbody>
</table>

#### Difference from published Power

<table>
<thead>
<tr>
<th>Year</th>
<th>+6.5%</th>
<th>+4.8%</th>
<th>+4.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>+6.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
<td>+0.8%</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td></td>
<td></td>
<td>+0.5%</td>
</tr>
<tr>
<td>1987</td>
<td>+4.5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 1 has been updated to the Mezger data.

#### Qualification rating

<table>
<thead>
<tr>
<th>Year</th>
<th>MDR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>3.0</td>
</tr>
<tr>
<td>1984</td>
<td>3.17</td>
</tr>
<tr>
<td>1985</td>
<td>3.36</td>
</tr>
<tr>
<td>1986</td>
<td>3.45</td>
</tr>
<tr>
<td>1987</td>
<td>3.54</td>
</tr>
</tbody>
</table>

*Assuming that the TC intercoolers reduce $T_2$ to 40°C as described in Note 10B.

Fig. 1 below shows the right-hand intercooler installation for the P01.

Note that the wastegate position differs from Fig. 66A.

The relation between Race and Qualification ratings is shown on Fig. 2 on P. 38.
Comparisons with engines in their final development

It is interesting to compare certain parameters in the P01 with two other engines in their final developments:

<table>
<thead>
<tr>
<th>Engine</th>
<th>Year</th>
<th>Model</th>
<th>IVD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosworth DFV</td>
<td>1982</td>
<td>NA</td>
<td>30.5</td>
</tr>
<tr>
<td>Porsche P01</td>
<td>1987</td>
<td>PC (TC)</td>
<td>32</td>
</tr>
<tr>
<td>Honda RA168E</td>
<td>1988</td>
<td>PC (TC)</td>
<td>32</td>
</tr>
</tbody>
</table>

Mezger unfortunately did not give any new internal data for the P01. As shown in Note 107 there is doubt over the IVD of 30.5 mm which has been published. A recent search through the internet discovered the picture shown at Fig. 3 below. From an enlargement it was possible to scale IVD relative to B, the ratio being 0.39 so that IVD = 32 mm. With this dimension the values of MGV for the above 3 engines are given below.

<table>
<thead>
<tr>
<th>Engine</th>
<th>MGV (m/s)</th>
<th>BNP (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosworth DFV</td>
<td>75.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Porsche P01</td>
<td>63.7</td>
<td>16.8</td>
</tr>
<tr>
<td>Honda RA168E</td>
<td>68.7</td>
<td>16.5</td>
</tr>
</tbody>
</table>

This corrects the remark previously published that the P01 valve gear was “doing well”, as it is seen to be in the same ball-park as the others, all being CVRS.

Some P01 parts

No cross-section of the P01 is available but Fig.4 shows some of the critical parts.

The piston shows 4 rings, which is extremely unusual. It is not known which standard of engine is illustrated.
**CORRECTIONS & ADDITIONS**

6 September 2017

**2nd Naturally-Aspirated Era (2NA)  Egs. 54, 56, 57, 59 Ferrari 312B (chassis T1 to T4)**

Thanks again to my correspondent Ron Rex, who has passed to me information from the chapter in "Ferrari Monoposto 1948–1997" (DASO 1198, see ref. below) written by the designer of the Ferrari 312B, Mauro Forghieri, some updates can now be provided for that series of engines.

<table>
<thead>
<tr>
<th>1975</th>
<th>1977</th>
<th>1979</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers’ and Constructors’ Champions (CoY)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chassis</td>
<td>PP</td>
<td>BHP</td>
</tr>
<tr>
<td>T</td>
<td>493</td>
<td>496</td>
</tr>
<tr>
<td>12,200</td>
<td>12,500</td>
<td>12,800</td>
</tr>
</tbody>
</table>

These powers differ from those previously published by:

-0.4%  -2.7%  -0.4%

<table>
<thead>
<tr>
<th>BMPP</th>
<th>Bar</th>
<th>@MPSP</th>
<th>m/s</th>
<th>20.17</th>
<th>20.67</th>
<th>21.16</th>
</tr>
</thead>
<tbody>
<tr>
<td>W kg</td>
<td>145</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-9.4%</td>
</tr>
</tbody>
</table>

Appendix 1 has been updated to the DASO 1198 figures.

**Typical Power Curve**

A Power Curve is available for the 1975 engine and is shown below to the standard website format.

**POWER CURVES**

<table>
<thead>
<tr>
<th>PEP</th>
<th>DASO</th>
<th>YEAR</th>
<th>Make</th>
<th>Model</th>
<th>Vcc</th>
<th>Ind.</th>
<th>System</th>
<th>Config.</th>
<th>Bmm</th>
<th>Smm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1198</td>
<td>1975</td>
<td>Ferrari 312B (T)</td>
<td>2992</td>
<td>NA</td>
<td>180</td>
<td></td>
<td>V12</td>
<td>80</td>
<td>49.6</td>
</tr>
<tr>
<td>N</td>
<td>P</td>
<td>MPS</td>
<td>BMEP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kRPM</td>
<td>HP</td>
<td>m/s</td>
<td>Bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>242</td>
<td>10.75</td>
<td>11.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>283</td>
<td>11.57</td>
<td>12.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>321</td>
<td>12.40</td>
<td>12.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>350</td>
<td>13.23</td>
<td>13.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

---

**Diagram**

![Power Curve for Ferrari 312B(T)](image-url)
Efficiencies

Data is given in DASO 1198 for the 1978 312B(T3) engine (not CoY) which includes the Specific Fuel Consumption (SFC). It enables the Brake Thermal Efficiency (BThE) and Volumetric Efficiency (EV) to be determined by the methods given in Note 37.

PP 500 BHP @ NP 12,500 RPM (11.96 Bar @ MPSP 20.67 m/s)
SFC 250 g/CV.Hr (0.558 lb/BHP.Hr)

BThE = 23.8%
EV = 132%

312B compared with the DFV
The 1979 312B comparison with the contemporary Ford-Cosworth DFV can be updated to DASO1198 figures, as follows:-

<table>
<thead>
<tr>
<th>Engine</th>
<th>312B</th>
<th>DFV</th>
<th>312B v. DFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>B/S</td>
<td>80/49.6 = 1.613</td>
<td>85.674/64.77 = 1.323</td>
<td>+ 6.9%</td>
</tr>
<tr>
<td>PP HP</td>
<td>513</td>
<td>480</td>
<td>+ 18.5%</td>
</tr>
<tr>
<td>@ NP RPM</td>
<td>12,800</td>
<td>10,800</td>
<td></td>
</tr>
<tr>
<td>Typical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMPP Bar</td>
<td>11.99</td>
<td>13.31</td>
<td>- 9.9%</td>
</tr>
<tr>
<td>@ MPSP m/s</td>
<td>21.16</td>
<td>23.32</td>
<td>- 9.3%</td>
</tr>
<tr>
<td>ECOM</td>
<td>50.5%</td>
<td>55.6%</td>
<td>- 5.1 points</td>
</tr>
<tr>
<td>BNP m/s</td>
<td>17.07</td>
<td>15.4</td>
<td>+10.8%</td>
</tr>
<tr>
<td>W kg</td>
<td>145</td>
<td>≈ 160</td>
<td>- 9.4%</td>
</tr>
<tr>
<td>PP/W HP/kg</td>
<td>3.54</td>
<td>≈ 3</td>
<td>+ 18%</td>
</tr>
<tr>
<td>IVA/PA</td>
<td>0.272</td>
<td>0.324</td>
<td>-16%</td>
</tr>
<tr>
<td>IVL/IVD</td>
<td>0.341</td>
<td>0.301</td>
<td>+13.3%</td>
</tr>
<tr>
<td>Crank Factor</td>
<td>14.6</td>
<td>19.3</td>
<td>-24.3%</td>
</tr>
</tbody>
</table>

The Crank Factor is surprisingly small. It is based on a given CP of 30 mm, which was a reduction of the figure given for the original 312 design of 38 mm. It may be a misprint. If it was really 38 the factor would be 18.5.

The performance improvement of the 312B from 1969 to 1979 was from 454 HP (DASO 1198) to 513 (same in 1980), a 13% rise in 11 seasons. This compares with the DFV achieving 405 HP to 535 (Judd-tuned) = +32% in 16½ seasons (see Note 84).

Reference