Note 124

Performance of different types of Naturally-Aspirated (NA) 4-stroke 4-cylinder petrol engines Series Production to Full Racing, 1953 - 1979

Performance comparisons for NA 4-stroke 4-cylinder petrol engines ranging from Series Production to Full Racing were published by the Ford engineer C. Brewer in the *Automotive Technology Series* Vol. 2 1968 in a contribution on *Engine Design* (DASO 939). A chart of Brake Mean Effective Pressure (BMEP, psi) v. Crank Speed (N, RPM) was provided for examples from the plainest Side-Valve (SV) Series Production engine, through various Overhead Valve (OHV) Production types [Push-Rod (PROHV), Single Overhead Camshaft (SOHC) and Double Overhead Camshaft (DOHC)], to Full Racing SOHC and DOHC engines. Naturally, most data were for Ford engines or engines with re-designed cylinder heads on Ford bottom ends, but one Coventry Climax engine was included because it had a wedge combustion chamber.

This Note 124:-

(a) reworks the data in the standard format of this website as BMEP (Bar) v. Mean Piston Speed (MPS, m/s) and adds Power (P, HP) v. Crank Speed (N, RPM);

(b) extends the 7 examples given by Brewer with 3 more Racing engines.

The source provided minimum details of each engine and so they have had to be researched for this Note.

The highest value of BMEP reached in this sample, by the BMW M12/7, was 15.4 Bar @ 21.3 m/s in 1979, which has only been exceeded fairly recently.

Engine Examples

The salient features and performance data of the 10 engine examples are given below. The performance curves are shown on P.4.

Tabled data

All NA 4-stroke IL4 petrol* engines

Swept Volume (V) cc	Peak Power (PP) HP @ Crank Speed (NP) RPM	PP/V HP/Litre	BMPP** @ MPSP / BMTP** @ MPST (Bar m/s)

1. **1953 Ford 100E** Production SV with Ricardo-type squish combustion chamber. Cast iron head. 1 carburetter. Same side inlet and exhaust ports. Siamesed inlets. 240^0 inlet cam period (IOD).- 3-bearing crank. A section of the 100E is shown on P.5

2.5''/3 41/64'' = 0.687
(63.5 mm/92.472)

Swept Volume (V) cc	Peak Power (PP) HP @ Crank Speed (NP) RPM	PP/V HP/Litre	BMPP** @ MPSP / BMTP** @ MPST
1,172	36.2 @ 4,500	30.9	6.14 @ 13.88 / 7.72 @ 7.71

The Sales brochure claimed 30 HP, so this must have been a "blue-printed" engine.

Continued on P.2

*Varying grades of petrol. Say, 80 Octane for Production and about 100 for Racing.
**BMPP & MPSP = BMEP & MPS @ Peak Power
BMTP & MPST = " " " Peak Torque

Swept Volume (V) cc	Peak Power (PP) HP @ Crank Speed (N) RPM	PP/V HP/Litre	BMPP @ MPSP BMTP @ MPST Bar m/s

2 **1958 Coventry Climax FWE** Low Production. SOHC with in-line valves inclined in "Wedge" combustion chamber. Al-alloy head (and block). Same side inlet and exhaust ports. Stage III uprating for Lotus L14 *Elite* sports coupe with 2 x 2-choke Weber carbs. IOD =-248^0 . 3-bearing crank.

A section of the FWA, from which the FWE was derived, is given on P.5.

3"/2 5/8" = 1.143
(76.2 mm/66.675)

1,216	89.7 @ 6,000	73.8	11.00 @ 13.34 12.07 @ 10.00

1962 Ford 115E Production PROHV for C*ortina* with vertical in-line valves in a "Bath-tub" combustion chamber. Cast iron head. 1 carb. Same-side inlet and exhaust ports. IOD = 248^0 . -5-bearing crank (1st engine family member, 105E, was 3-bearing).

A section of the 105E, from which the 115E was derived, is shown in Note 81.

3 3/16''/2.29'' = 1.392
(80.9625 mm/58.166)

1,198	50.3 @ 5,000	42	7.52 @ 9.69 9.41 @ 5.23

4. **1962 Cosworth-Ford FJ** Basically a 1959 Ford 105E Production engine (No. 3 in same family. and similar in design). Developed for Formula Junior racing, with IOD = 320^0 and 2 x 2-choke Weber carbs. Bore enlarged in 1962 from 3 3/16'' (80.9625 mm) to 85 mm for alternative weight class. 3-bearing crank.

See also Note 81 for 105E section.

85 mm/1 29/32'' = 1.755
(48.419 mm)

1,099	98.4 @ 7,500	89.5	10.68 @ 18.10 11.50 @ 8.88

5. **1962 Lotus-Ford "L26"** Low Production Al-alloy DOHC re-designed head on a Ford 116E bottom end.- Valves at 54^0 included angle (VIA). 2 x 2-choke Weber carbs.
Tuned for Lotus L26 *Elan* sports car, with IOD = 248^0.

A section of the engine is shown in "ILLUSTRATIONS for Appendix 6" at P.17.

3 3/16''/72.75 mm = 1.113
(80.9625 mm)

1,498	91.1 @ 5,500	60.8	9.39 '@ 13.34 11.58 @ 9.94

6. **1964 Cosworth SCA** Al-alloy SOHC re-designed head on a Ford 116E bottom-end but with 105E-size special crank throw for Formula 2 racing. Vertical in-line valves in flat head with combustion chamber in the piston. Same side inlet and exhaust ports. 50^0downdraft inlet ports. 2 x 2-choke Weber carbs. IOD = 324^0 . 5-bearing crank.

A section of the cylinder head is given in Note 73.

.3 3/16''/1 29/32'' = 1.872
(80.9625/48.419)

997	122.7 @ 8,500	123.1	12.96 @ 13.72 13.69 @ 12.27

Continued on P.3

Swept Volume (V) cc	Peak Power (PP) HP @ Crank Speed (N) RPM	PP/V HP/Litre	BMPP @ MPSP BMTP @ MPST Bar m/s

7. **1965? Lotus-Ford "L23"** As no. 5 but fully-tuned for racing, probably by Cosworth. No details are known for the engine whose BMEP was given by Brewer, but it would have had larger valves (possibly +6% area – Wikipedia), higher lift and a longer IOD cam (possibly as much as 320^0).

The power curve carries on from the mildly-tuned engine.

The designation as "L23" is arbitrary, assuming it would have been raced in that Lotus.

3 3/16''/72.75 mm= 1.113
(80.9625 mm)

1,498	146.6 @ 7,300	97.9	12.00 @ 17.70 13.00 @ 15.28

8. **1966 Cosworth FVA** Al-alloy DOHC 4 valves per cylinder re-designed head on a Ford 120E bottom-end for a new Formula 2. VIA 40^0. Inlet ports shaped by Keith Duckworth to give "Barrel Turbulence" (also known later as "Tumble Swirl", although the concept was kept secret for many years). IOD = 320^0 . Port fuel injection. 5-bearing crank.

(See "The Unique Cosworth Story" and Note 26).

3.3/8''/2.722'' = 1.24
(85.725 mm/69.139)

1,596	222 @ 9,000	139.1	13.83 @ 20.74 14.50 @ 16.13

9. **1967 Ford "Cross-Flow"** Production PROHV for C*ortina* with vertical in-line valves in a flat head with the combustion chamber mostly in a bowl in the piston top. Cast iron head. Exhaust ports on opposite side to the inlets. 1 carb. IOD = 248^0 . 5-bearing crank.

A section of the 1,600 cc version of this engine is shown on P. 5.

3 3/16''/72.75 mm = 1.113
(80.9625 mm)

1,498	72.1 @ 5,000	48.1	8.62 @ 12.12 10.62 @ 6.55

10. **1979 BMW M12/7** Al-alloy DOHC 4 valves per cylinder re-designed head on a Production cast iron block bottom-end for a new Formula 2. VIA 40^0. IOD = probably 320^0 . Port fuel injection.

See "Significant Other" at Fig. SO19A for an illustration of this engine.

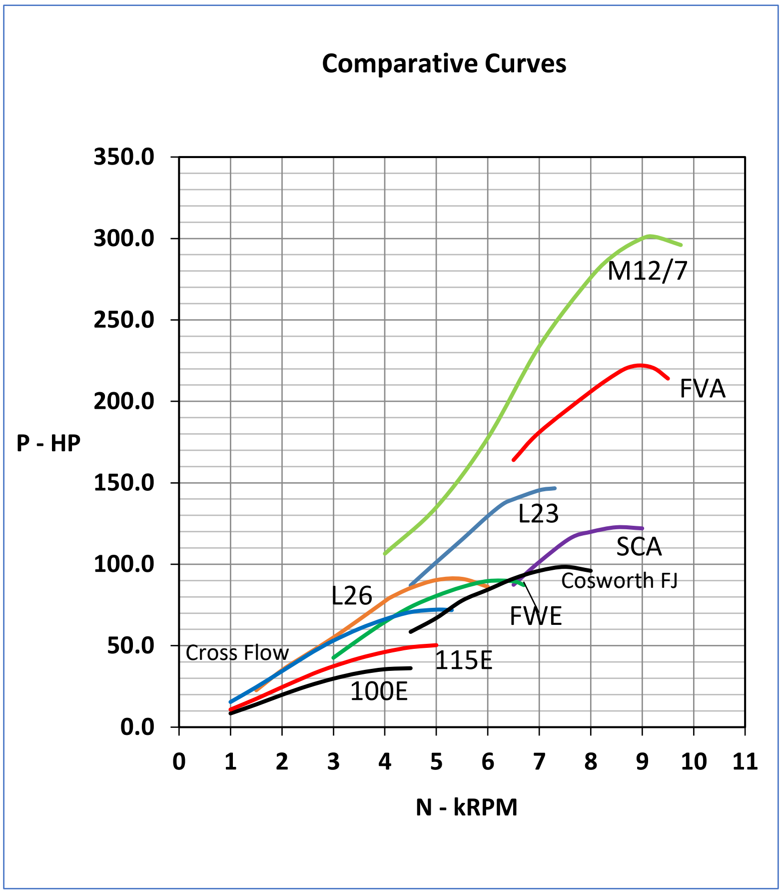
Influenced by Duckworth architecture and replaced the unsatisfactory Apfelbeck radial-valve design (see "How many valves per cylinder" at p.11).

89.2 mm/80 = 1.115

1,999.7	301 @ 9,250	150.5	14.56 @ 24.67 15.44 @ 21.33

Performance curves for engines nos. 1 to 10 are shown on P. 4.

Analysis of the Flexibility (FY) of the engines is continued on P. 6.


Comparative Curves
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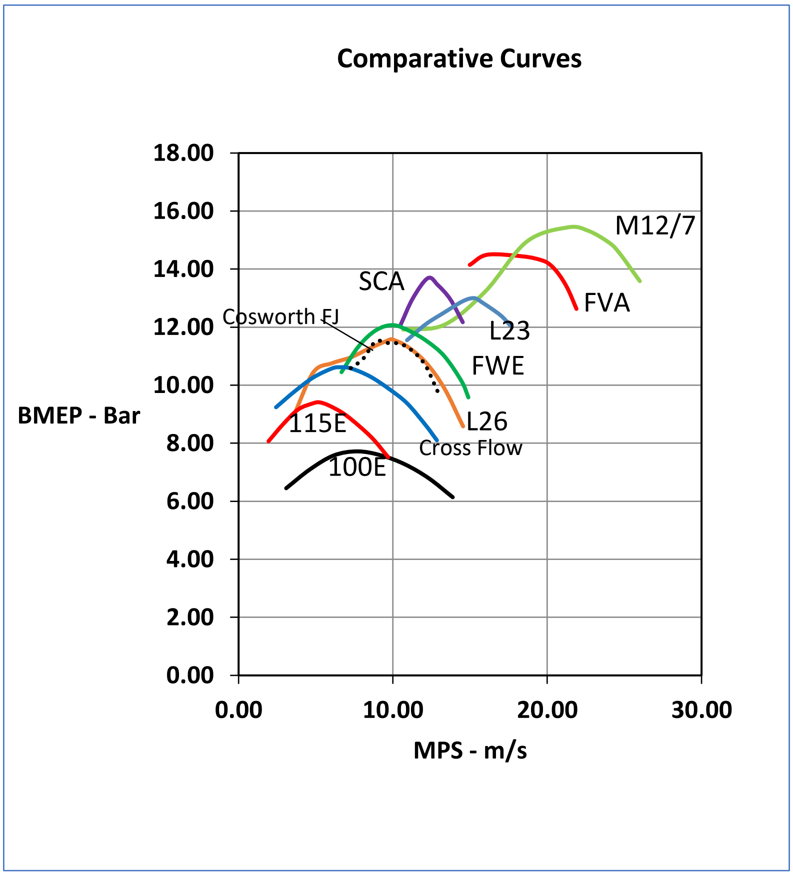
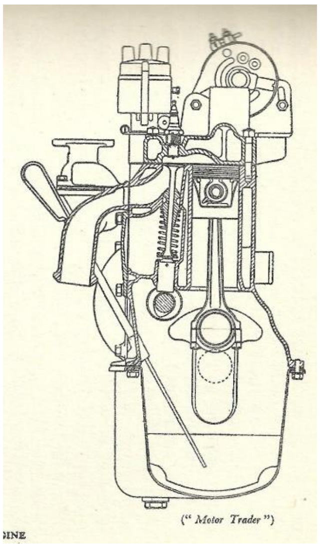
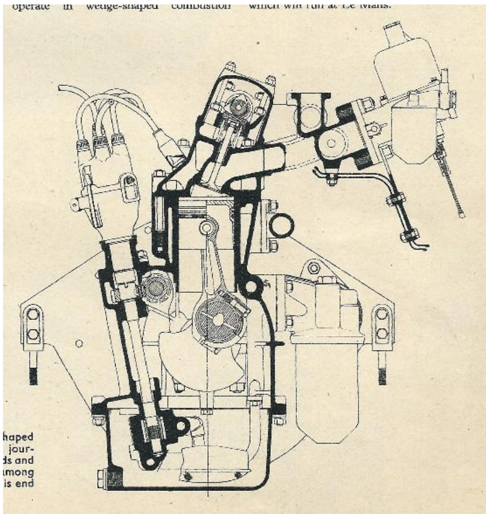
300.0
250.0
200.0
150.0
100.0
50.0
0.0
P - HP
0
1
2
3
4
5
6
7
8
9
10
11
N - kRPM
M12/7
FVA
L23
SCA
Cosworth FJ
FWE
L26
Cross Flow
115E
100E


Comparative Curves
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
BMEP - Bar
0.00
10.00
20.00
30.00
MPS - m/s
M12/7
FVA
SCA
Cosworth FJ
L23
FWE
L26
Cross Flow
115E
100E

Ford 100E

DASO 337

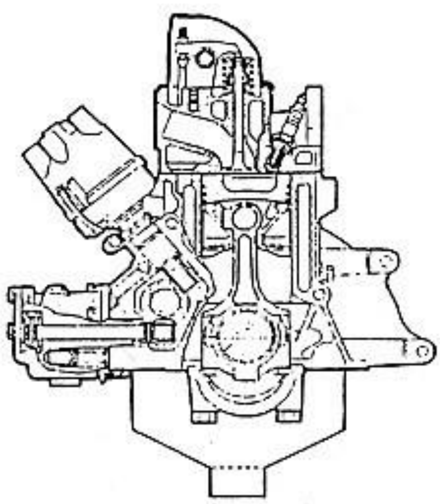




Coventry Climax
FWA
This engine, B/S = 2.85’’/2 5/8” = 1.086
72.39 mm/66.675 1,098 cc,
was the original automotive application.
The FWE was derived from it with enlarged bore:-
B/S = 3’’/2 5/8” = 1.143,
76.2 mm/66.675 1,216 cc.
DASO 135

Ford Crossflow
This is the 1971 version ``
enlarged to
B/S =3.188’’/3.056’’ = 1.043
80.975 mm/77.622 1,599 cc.

thekentlives.com



Flexibility

Flexibility (FY) is defined here for piston engines as the drop of RPM between Peak Power speed and Peak Torque speed as a ratio of the former. Expressed in Mean Piston Speed, as tabled:-

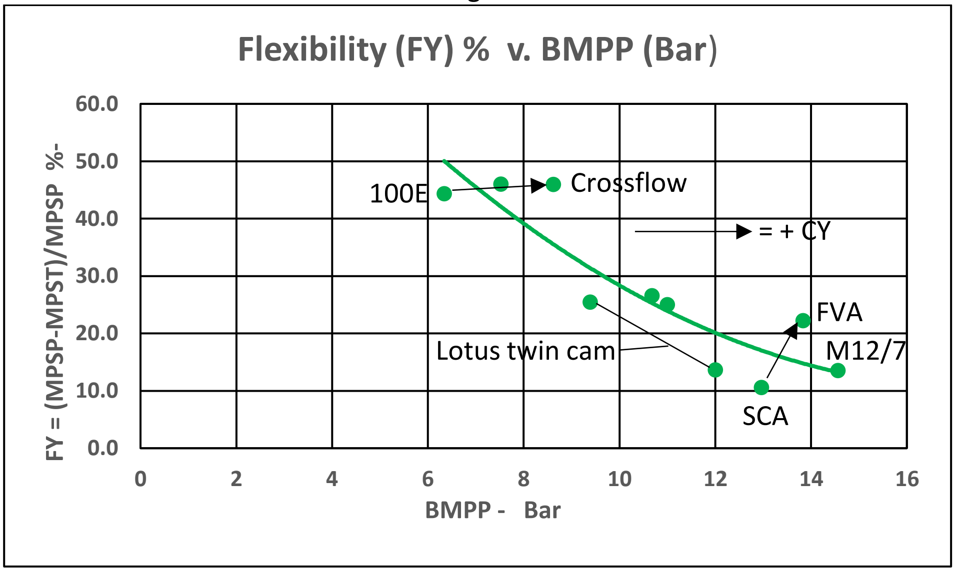
$$FY\ \% = \frac{MPSP - MPST}{MPSP} \times 100$$

The author has investigated a "Natural Rule of Thumb" (which can be accessed) expressed by:-

$$\frac{\text{Effectivity (EY)} \times \text{Flexibility (FY)}}{\text{Complexity (CY)}} = \text{Constant.}$$

The 10 engine data sample, taking EY = BMPP, enables this relation to be examined. The result is shown on Fig. 1

Fig. 1

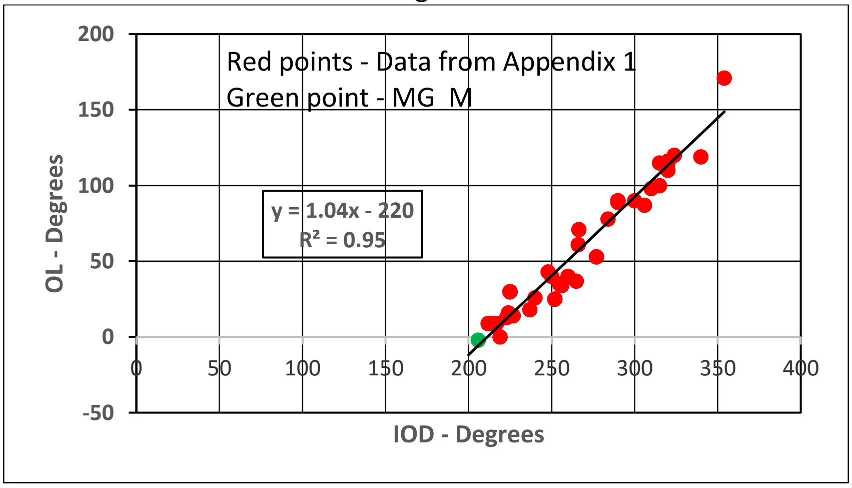


Since the data is the result of designers with different methods, there is scatter but the general relation does follow the "Rule". In particular the Lotus Twin Cam at two different states of tune shows it well. Some scatter is actually the result of different CY; egs., the Ford SV 100E relative to the Ford Crossflow; also the Cosworth SCA versus the Cosworth FVA. These increases in CY enabled higher BMPP to be obtained at the same or higher FY.

Other ways in which increased CY can raise the (BMPP x FY) product are:- Variable Valve Timing; and Variable Inlet Length; but these were not available to the sample engines.

A major cause of decreased FY as BMPP is raised is the increasing inlet and exhaust valve overlap (OL). This is an inevitable but not determinate result of increasing Inlet Open Duration (IOD), as shown on Fig. 2.

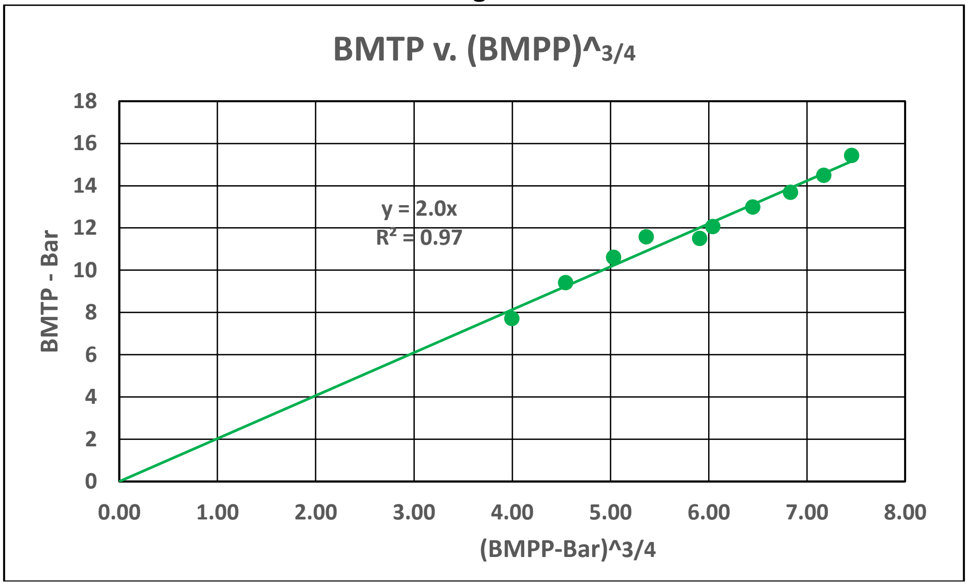
Fig. 2



Relation between BMPP and BMTP

The relation between BMPP and BMTP was also examined with the 10 engine sample. The result is shown on Fig.3.

Fig. 3



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