2nd Naturally-Aspirated Era (2NA): 1952 – 1982: 31 years.
Part 3. 1961 – 1965; Egs. 40 to 44

The 1.5L NA Formula; 1961 – 1965

Because of the belief of some delegates to the Commission Sportive Internationale (CSI) that 2.5L NA cars were becoming too fast, that sub-section of the FIA in October 1958 agreed by a majority vote (*excluding* the nations actually *building* Grand Prix cars!) to limit GP engine swept volume to a maximum of 1.5L NA from 1st January 1961 through 1964 (extended later through 1965). They were to run on the best automobile fuel then available commercially (defined later as 102 Research Octane Number (102RON) (see "The Sporting Limits", Table 1, n.8)). This fuel quality limit remained in place *in the letter but not in practice* to the end of the period under review in this work.

In other words, the 1957 Formula 2-size engines were promoted to Grand Prix Formula 1 status, as had happened before (1926; 1946; (from Voiturette rules); 1952 by default when Alfa Romeo withdrew).

A minimum car weight rule of 500kg was also added *with* oil and water but *without* fuel or driver. This was later reduced to 450kg (unballasted) after furious protests by British constructors.

The new formula was contrary to the wishes of all the British *and of* Ferrari, who would have preferred an extension of the 2.5L NA rules. The former then tried for some time to persuade race organisers to adopt a 3L "Intercontinental" formula, hoping for US participation* but with only a slight success in the UK in 1961 as it turned out. Up to September 1960 the British still hoped the CSI would change its mind or postpone the rule change for a year. Neither happened (56). This attitude delayed design of new 1.5L engines by Coventry Climax and BRM to rather late in the 2 years 2 months original lead time. Enzo Ferrari, realistic as always in rule matters, dropped his initial 1.5L opposition and his once-promised "Intercontinental" support and extended his development of his F2 type 156 65V6 which had raced a few times during 1957 – 1960 in competition with Climax, Porsche and Borgward 4-cylinder engines. By mid-1960 the "Cooper Revolution" had persuaded him finally to adopt for this F2 car a mid-engine "Standard Suspension" chassis (double wishbones all round; Note 66).

Carlo Chiti, who had been appointed Ferrari Chief engineer in 1957, also began work on a new 120V6 1.5L engine which became the major power plant for the Ferrari effort of 1961, although the 65V6 was raced sometimes.

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*At that date the US Scarab company, financed by Lance Reventlow (heir to the Woolworth fortune), was just preparing to enter the Grand Prix arena with an IL4 2.5L NA engine based on Mercedes-Benz M196 technology.

40. 1961 Ferrari 156/F1; 1,477 cc; 192 HP @ 9,500 RPM (See Note 70) (See Figs. 40A & 40B) (also Power Curve)

The new Ferrari GP 120V6 engine was B/S = 73/58.8 = 1.24, to which dimensions the previous 65^0 F2 unit was also modified from its original 70/64.5 = 1.09. The re-chosen dimensions went back to the Bore of the 1953 60V12 Sports-Racing engine and the Stroke of the 1948 60V12 2L. Presumably tooling existed for machining this crank throw from solid billets, the preferred Ferrari method.

This was the first step in the 1.5L formula to increase the (Power/Swept Volume) ratio by the classic route of reduced Stroke (see "The General Design of Racing Piston Engines", p.3), which was followed generally in this basically-low car Power/Weight period

The engine design details were conventional along the Lancia-Dino approach. The advantages of the redesigned V6 with the 120^0 bank angle, although not fully-balanced (a contra-rotating engine-speed balance shaft is needed for that (1031)) were:-_

- It had a 3-pin crank, lighter than the 6-pin of the 65^0;
- The Centre-of Gravity was lower for better cornering.

Weight was reduced by 17% (to 120kg from 145kg (711)) not only because of the simplified crank but also by using closer cylinder centres (the original type 156 had been designed for capacity stretch, as described in Note 59). Also dual coil ignition replaced dual magnetos since a battery (not included in the 120kg) had to be carried anyway to power the on-board starter motor now required by the new rules for safety reasons.

An interesting detail was that Weber provided integrated 3-choke carburettors for the new engine (not the first such instrument – they had made a 3-choke unit for the Alfa Romeo 2-stage-supercharged development in 1946).

Trouble was experienced at first with power loss caused by “*barbotage*” – “splashing” – of the oil in the crankcase (22), which called for 2 extra scavenge pumps (422) (see Note 69).

Small-area-ratio megaphones were used on each of the 3 cylinders-into-1 long-pipe exhausts – subsequently shortened (see Fig. 40B).

Specifics were:- BMPP = 12.2 Bar @ MPSP = 18.6 m/s with R = 9.8. The 120^0 engine’s maximum power was 3 to 5% greater than the 65^0 (22, 422). R x VIA was (9.8 x 60^0) = 588^0. ECOM = 53.8%.

The 1961 season was notable for Ferrari’s otherwise clean sweep being interrupted twice by the superlative driving of Stirling Moss with a 1960 Lotus powered by a 1.5L Coventry Climax FPF which had been slightly improved over the original 1957 design but was still giving away some 25 HP (17%) (see Note 70). These wins were on the slower Monaco and Nurburgring circuits and were aided at the latter by a clever choice of Dunlop high-grip “rain” tyres for an initially dry, then wet, race.

Fig. 40A
1961 Ferrari 156/F!
120V6 73/58.8 = 1.241 1,477 cc
Note the 3-choke Weber carburettors and chain drive to the camshafts.

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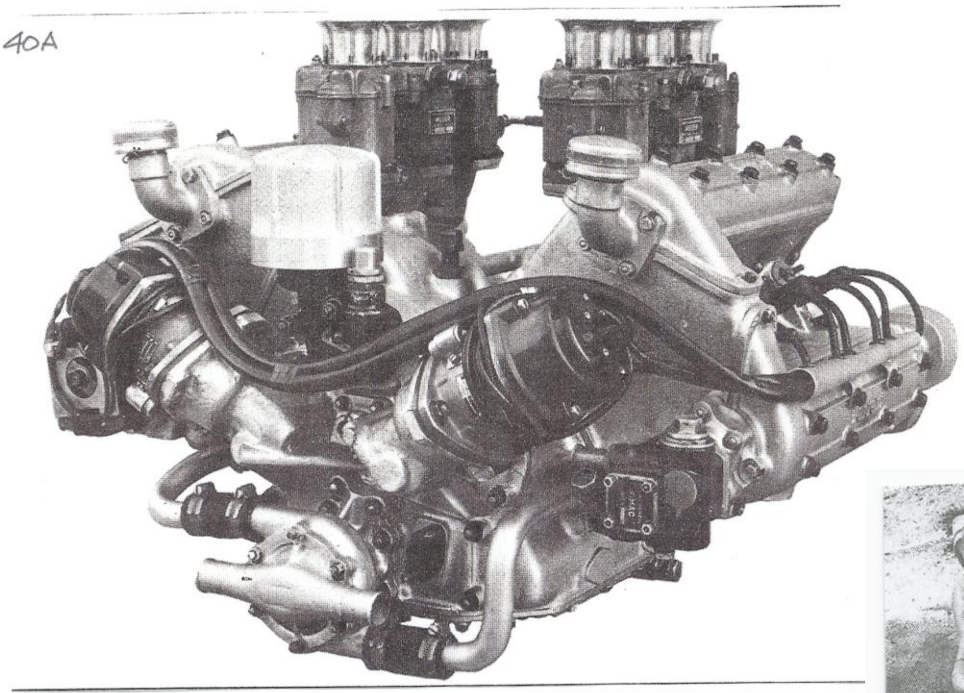
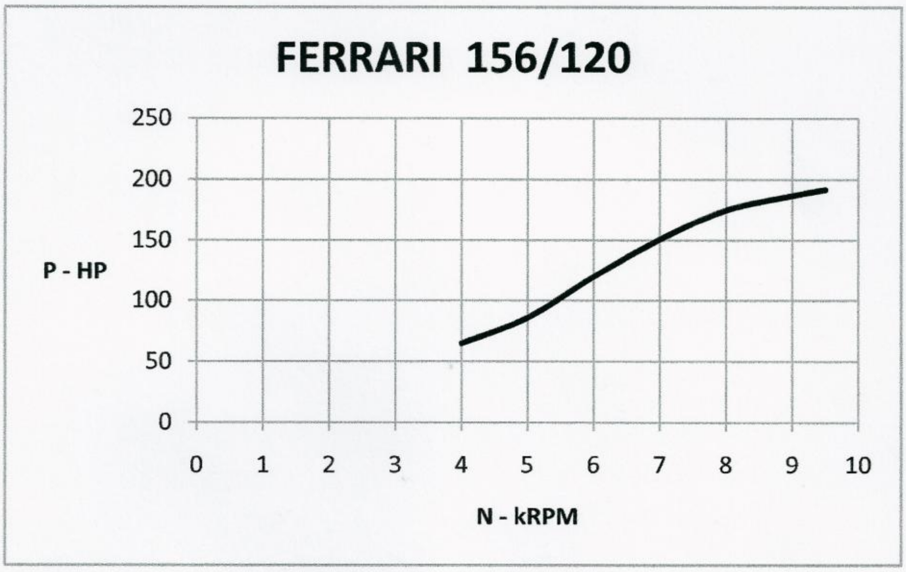


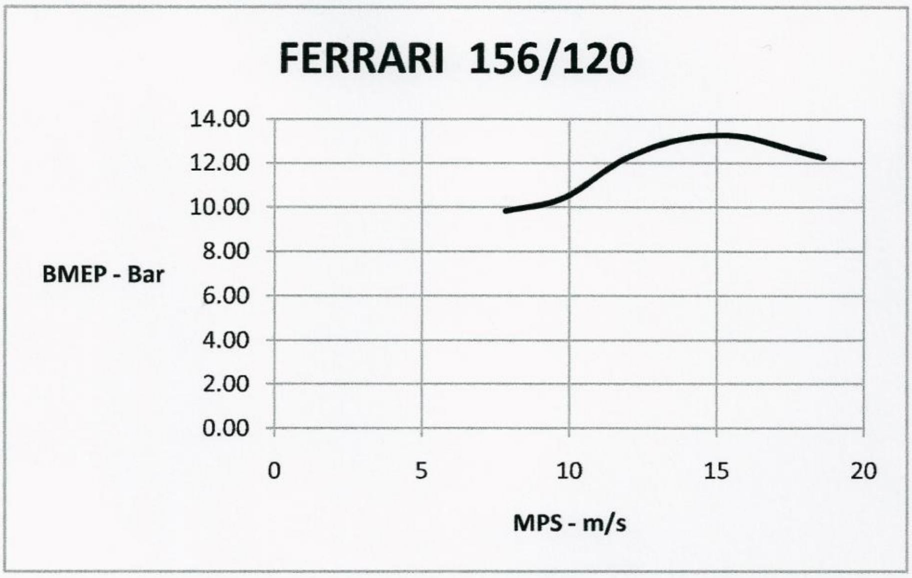
Fig. 40B
The 1962 type 156 was only altered in detail from late 1961 spec. and this view of Guy Mairesse’s unfortunately-inverted car at Spa in that year is probably representative of the previous year’s exhaust system – 3 tuned pipes per bank leading into a short megaphone.
P.S. the driver was not badly hurt!

POWER CURVES

Eg.	40
DASO	422
YEAR	1961
Make	Ferrari
Model	156/120
Vcc	1477
Ind. System	NA
Confign.	120V6
Bmm	73
Smm	58.8

N	P	MPS	BMEP
kRPM	HP	m/s	Bar
4	65	7.84	9.85
5	86	9.8	10.42
6	120	11.76	12.12
7	151	13.72	13.07
8	175	15.68	13.25
9	187	17.64	12.59
9.5	192	18.62	12.24





41. 1962 BRM P56; 1,498 cc; 197 HP @ 11,000 RPM (See Figs. 41A & 41B and Power Curve).

Although BRM had done some preliminary work to decide on a 1.5L NA configuration (4, 8, or 12 cylinders?) before November 1960, it was only then that detailed design began on a new engine by AubreyWoods under Peter Berthon (56).

A 90V8 was chosen, probably to trump the exiting Ferrari V6 without the higher cost of a V12.

High Bore/Stroke ratio

Having in 1955 pioneered the then-largest B/S ratio in Grand Prix racing for the P25 IL4 2.5L NA at 4.05”/2.95” (102.87 mm/74.93) = 1.37 with 2 valves per cylinder, which had led to much “Top-End” trouble because it required MVSP = 4.7 m/s to reach limiting MPSP = 21 m/s, the brave decision was taken to keep that ratio (nearly), at 68.5 mm/2” (50.8) = 1.35. Hairpin valve springs (HVRS) and hollow-head valves had been used in the 2.5L initially in an attempt to keep the valves under control. Welding failures of the discs required to close the valve heads had for a time forced RPM reduction with solid valves. Eventually (mid-1960) coil springs had been fitted (CVRS) after better Swedish spring wire became available. The new 1.5L had the low Valve Lift/Diameter ratio (IVL/IVD) of 0.2 with the Valve Opening Duration (IOD) extended to 320^0 to reduce MVSP to 3.1 m/s and both valve stems and their heads were hollow with resistance welded-in caps. Exhaust *and* inlet were Na-cooled. A new detail by Woods was the extension of the valve stems beyond the spring collars so that the inverted-cup tappets did not shroud the springs from cooling oil. The offset was a little extra reciprocating mass.

Other mechanical details were conventional for the time, including the now-British-standard Dykes’ top piston rings to prevent flutter at MPDP = 3,900 g.

Lucas fuel injection system

Fuel supply system by Lucas was new. It was inlet port injection with the petrol metered by the axial displacement of shuttles within the bore of a rotating-sleeve distributor, mounted in the engine vee and driven by cogged belt off a cam gear train. These shuttles were made to reciprocate by a fuel supply pressure of 100 psi (6.9 Bar) provided from an electrically-driven gear pump (which experience would show needed good air-cooling to prevent fuel vaporisation). This pressure was applied alternately to each end of each shuttle depending upon the sleeve/body port positions so that the opposite end of the shuttle forced out the required cylinder supply. Shuttle stroke was pre-adjusted to give a mixture strength compromise over the RPM range*. This shuttle system was a 1st for a GP engine and Lucas (who had developed it since 1950, provided it in 1956 to Jaguar for Sports-Car racing and fitted it to the winning Jaguar XK120D at Le Mans in 1957) claimed that port injection gave better mixing than the direct-into-cylinder system (of Bosch) (825). On Lucas advice BRM found that *upstream* injection gave more consistent mixture than the original downstream.

This injection system, with many high-precision parts, was costly (although cheaper than the Bosch piston-per-cylinder pump) and when engines were sold to private owners carburettors were fitted instead at a small power loss.

Again on Lucas advice, drawing on Jaguar experience, “sticky” butterfly throttles were replaced by a sliding plate system (which Freddy Dixon had pioneered on his pre-War 2L Riley (447)). This improved power by 6 HP since there was no flow obstruction at full-open (980). Most later engines in this review copied this feature.

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*The original control of shuttle stroke by manifold pressure acting on a linked piston was deleted from the BRM racing unit.

Lucas ignition system

The single plug per cylinder Lucas ignition was the 1st use of a transistorised system to overcome the spark-rate limit of coil or magneto units, which Lucas put at 400 and 500 sparks/min. respectively because of mechanical limits at the contact breakers. The new system could provide 1000/min. at a constant voltage and current proportional to RPM – enough for

15,000 RPM on a V8 (826). The spark-generator also needed good air cooling to preserve reliability.

Low pressure crankshaft

An interesting oil system detail was the 1st use of (what was afterwards called) a “Low Pressure Crankshaft” drilling arrangement to cut bearing oil leakage and reduce crankcase splashing (see Note 71 for a full explanation).

Exhaust system

The exhaust system at first, with a 2-plane (Ford V8-type) crankshaft, was of individual, slightly-megaphoned, “stack pipes” but mechanical and aerodynamic vibration caused failures and there was extra drag ,so a low-level system had to be developed during 1962.

Early problems

The 1st engine run was July 1961, after Rolls-Royce had assisted to correct porous castings. The V8 was available in September 1961 for Italian GP practice and later tests but encountered several troubles:-

- Detonation at the original R of 13;
- Fuel and ignition problems;
- Oil loss;
- Broken con.-rod bolts (the rods had been carried over from the original BRM V16 to reduce cost, although the pistons were heavier.

!962 Performance and results

The P56 produced at the start of 1962 (1085):- 188 HP @ 10,700 RPM with R dropped to11.2. This represented BMPP = 10.5 Bar @ MPSP = 18.1 m/s. ECOM was only 44.6%. The factor R xVIA was (11.2 x 76^0) = 851^0 and MGVP = 53.9 m/s. These latter 2 parameters –too high and too low, respectively, probably accounted for the rather disappointing pressure and speed. The P56 had been *aimed* principally at high power rather than a good torque range, the spread from NP to NT being only 10,700 to 9,400 (12% 0f NP) at the start of 1962. By contrast, Walter Hassan of Climax at this time preferred to sacrifice some power for mid-range torque; his 1962 FWMV Mk 2 had a useful range from 9,000 to 7,000 RPM (22%) (827). To suit the power curve of the BRM a 6-forward-speed Colotti-designed gearbox was used for some 1962 races but oiling problems forced a return to their own 5-speed box.

Tony Rudd realised that the performance of the P56 could be improved and took the advice of Shell to reduce the piston “hump” and improve the Combustion efficiency (EC) (40). The valve timing was also revised. These changes produced 197 HP @ 11,000 RPM for Monza (1088). The scores before that race were:-

Graham Hill BRM 2;
Jim Clark Lotus 25/Climax 2;
Bruce McLaren Cooper/Climax 1;
Dan Gurney Porsche 1.

At Monza Hill had the rare satisfaction of passing Clark’s Lotus “at full chat” (1085) and winning. At Watkins Glen which followed he was able to rev to 11,200 but was 2nd to Clark. Hill then won the final race in South Africa and the Championships when the Climax failed. Final scores:- BRM 4; Lotus 3.

The improved engine Power Curve is shown on P.8.

Later history

After 16 years of nearly-universal failure these Drivers’ and Constructors’ Championships saved the BRM enterprise from being closed by its owner since 1952, Alfred Owen, but they were the first and last CoY obtained in a total 32 years existence.

During the next 3 years of the 1.5L formula the developed BRM V8 was always in with a chance of GP wins and ran close to the Championships in 1964. The engine retained its original B/S. Unsuccessful tests were made in 1964 with 4 valve/cylinder (4 v/c) heads having VIA = 67^0

and axial inlet ports. These led to redesigned 2 v/c heads in late 1964 retaining the axial ports and with VIA = 62^0, the exhausts exiting into a vee-mounted high-level system.
After further advice from Shell's research laboratory had helped Rudd to improve EC again with squish added to the existing axial swirl (see Note 54) the final 1965 output was 220 HP @ 11,600 RPM (545), representing BMPP = 11.3 Bar @ MPSP = 19.6 m/s (ECOM *about* 49%).

1966 Postscript

A happy GP V8 postscript was a win in the 1966 Monaco race by Hill with an engine stretched to nearly 2L (2.825"/2.33" (71.755 mm/59.182) = 1.21, 1.915 cc). This was a stop-gap while awaiting for the new 3L NA formula the Flat-H16 3L double-crank engine which Rudd had chosen as a way of capitalising on the V8 technology – which unfortunately led to 3 years of disappointment after vast expense.

Figs. 41A & 41B are shown on P.7.

Fig. 41A
1962 BRM P56
90V8 68.5 mm/2" = 1.348 1,498 cc
(68.5/50.8)
Showing the new design of inverted-cup tappets introduced by Aubrey Woods
which allowed cooling oil to reach the coil valve springs.
Exhaust valve guides in contact with water.
Inlet ports shown slightly non-orthogonal to valve head *but* this may be due to a section cut through a port shaped to give axial swirl
(it *may* also have provided some "Tumble Swirl).

DASO 36 p.799

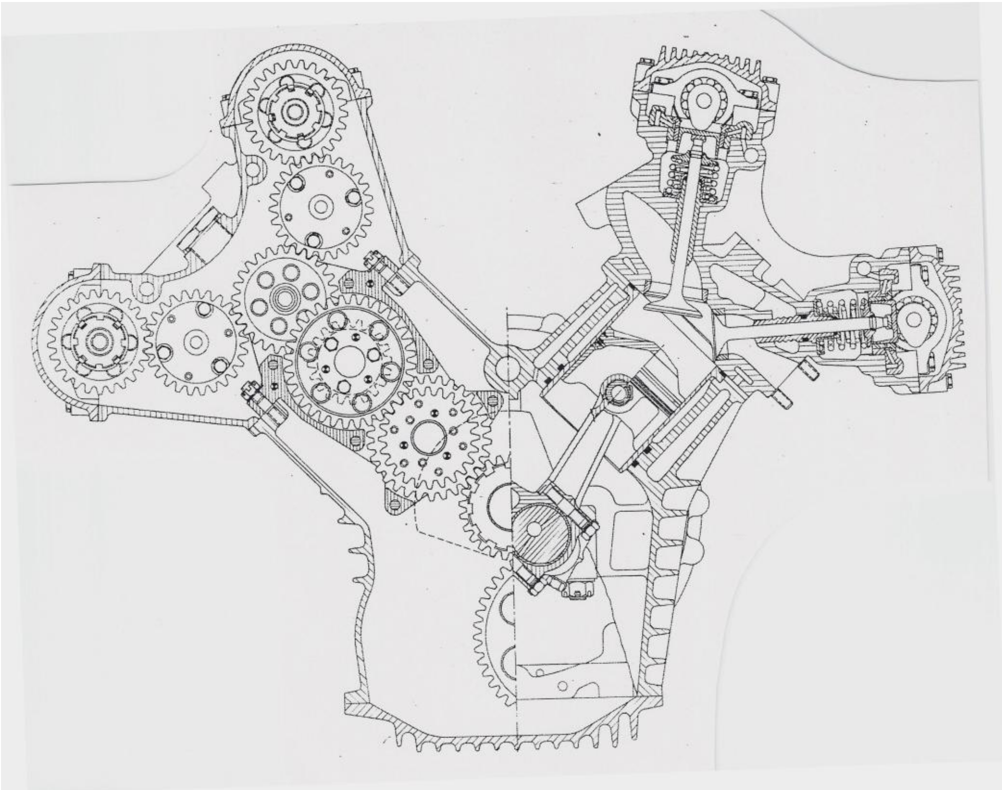
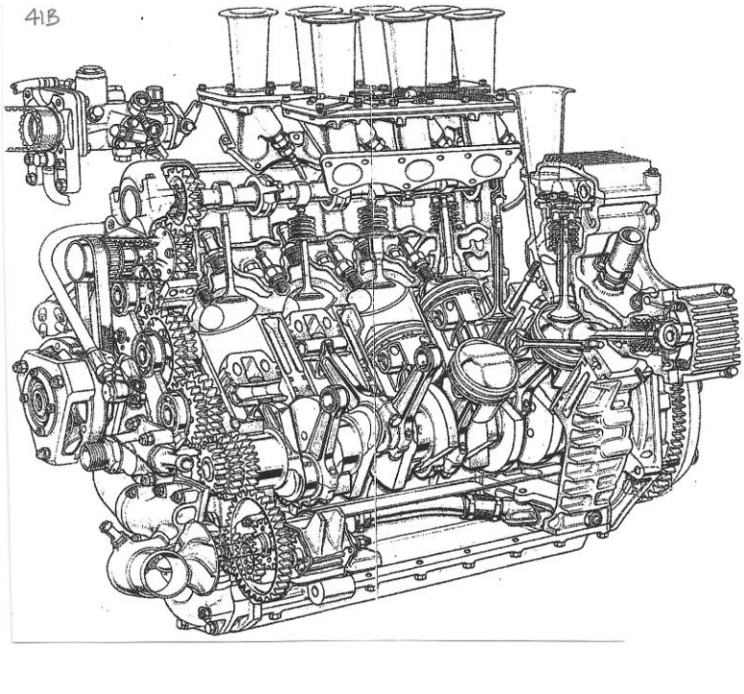


Fig. 41B
This shows the slipper pistons; the 2-plane crank;
the belt drive to the Lucas shuttle-type fuel-injection distributor; and the upstream injection.

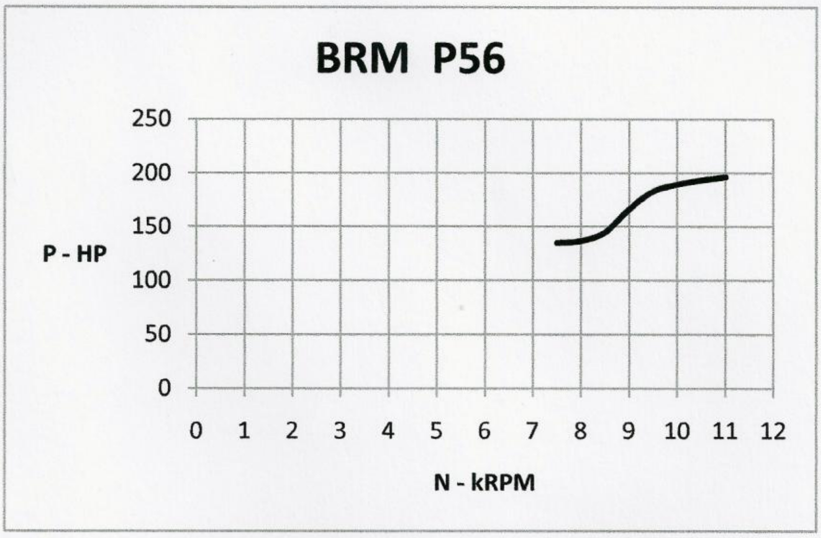


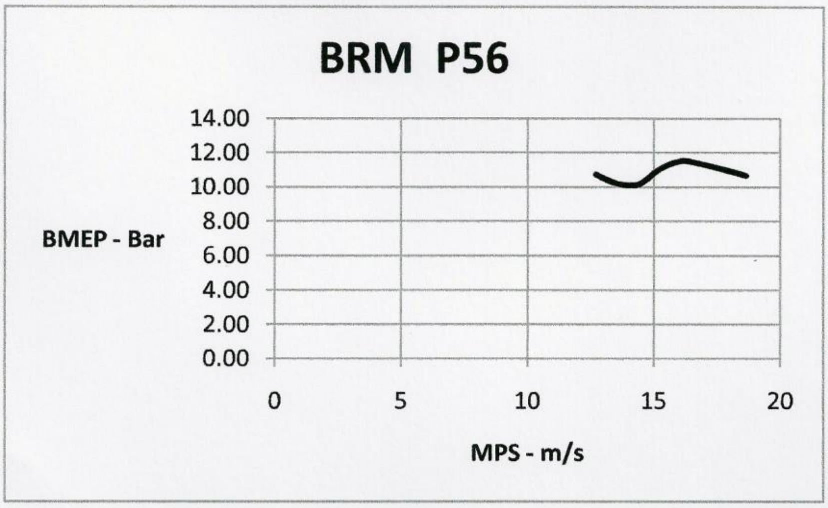
Also the hollow-headed "penny-sealed" exhaust and inlet valves, both with internal Na-cooling.

DASO 36 p.796

POWER CURVES

Eg.	41			
DASO	1088	Revised 14/10/10		
YEAR	1962			
Make	BRM			
Model	P56			
Vcc	1498			
Ind. System	NA			
Confign.	90V8			
Bmm	68.5			
Smm	50.8			
	N kRPM	P HP	MPS m/s	BMEP Bar
	7.5	135	12.70	10.75
	8	137	13.55	10.23
	8.5	145	14.39	10.19
	9	167	15.24	11.08
	9.5	183.5	16.09	11.54
	10	190	16.93	11.35
	10.5	194	17.78	11.04
	11	197	18.63	10.70





42. 1963 Coventry Climax FWMV Mk 3; 1,496 cc; 195 HP @ 9,500 RPM (See Figs. 42A, 42B, & 42C and Power Curve)

44. 1965 Coventry Climax FWMV Mk 6; 1,497 cc; 212 HP @ 10,300 RPM (See Fig. 44A and Power Curve)

Coventry Climax began design of their 90V8 in mid 1960 under the direction of Walter Hassan, a few months ahead of the BRM V8. Consequently they were able to run one engine in the German GP in August 1961 (in a Cooper chassis, Jack Brabham driving). Two engines were available for each of the following 2 races (Rob Walker's modified Lotus 18 receiving the 2nd, Stirling Moss driving).

FWMC base

The new engine had benefited from a DOHC (VIA = 73^0) type FWMC development of the IL4 741 cc Climax 2nd-generation lightweight fire-pump engine, normally SOHC, with B/S = 2.53"/2.25" (64.262 mm/57.15) = 1.12. This produced 82 HP @ 8,200 RPM with R = 10.2 using 4 Amal (motorcycle) carburetters. Therefore around 170 HP for the V8 was expected from the start and actually 174 HP @ 8,500 RPM was achieved after eliminating a late change to the inlet ports recommended by Weslake which had introduced a divergent flow section (34).

The new V8 unit was reduced slightly in B/S to 2.48"/2.36" (62.992 mm/59.944) = 1.05 and VIA was reduced to 60^0. It was conventional, except that the DOHC were chain driven, and kept very simple to reduce costs of very-small-batch manufacture. It was sold for £2,500 (£46,000 in 2013 money).

One simplification to ease cylinder block casting was an *open top*, so that the cast-iron liners were located on a bottom flange and were clamped between that and the head. Previous Climax liners (dry for the fire-pump types, wet for pure racing engines) had been located only by a top flange sandwiched between a *block deck* and the head.

1961 cooling problem and the cure

In the 1961 races cooling water was blown out of the engine. During the winter 1961-62 short-cycle RPM testing was done with a simulated chassis closed-circuit cooling installation. This reproduced the fault, which had not shown up during steady bench running with a constantly-topped cooling tank. The deduction was that repeated differential thermal expansions between the combustion-heated liners and the block at roughly constant water temperature, such as occurred due to throttle open/shut cycling, acting over the 76 mm liner length , was causing variable clamping loads and resulting in fatigue failure of the "Vanwall"-type cylinder sealing ring.

The cure was to adapt the blocks back to a top-flange location by means of an Al-alloy "muff" surrounding a thinner C.I. liner to transfer the lower block location upwards. Effectively the liner was then dry. A "deck" was added back to the block at the same time to ensure that the liners remained square to the head. Altogether the simplified block had been an expensive blind alley (see Note 71B).

Exhaust system

With a conventional "Ford-type" 2-plane crank for this V8, to eliminate secondary vibration, Climax decided to couple the exhausts from opposite cylinder banks so as to improve extraction. Nos. 1 and 4 from one side were carried round behind the engine and upwards to meet the pipes from Nos. 2 and 3 of the other side, the 4 pipes thence joining into a common low-area-ratio megaphone. This layout was repeated as a mirror image for the other 4 cylinders (i.e.2 &3 meeting 1 and 4) (see Fig.GR7A in "Review of Salient Design Features"). The whole system was a fine example of the pipe-benders art which, from henceforward with mid-mounted multi-cylinder engines needing equal-length pipes in a short space, would become much in demand! Hassan noted that his sharp bends did not lose any power (34).

Valve timing

Because Hassan believed in a (relatively) broad torque curve for racing, saving time on gear-changing and reducing the work-load on the driver, his valve timing was moderate at Inlet Open Duration (IOD) = 290^0 and Overlap (OL) = 90^0. The BMEP curve on P.   for the Mk 3 shows how this avoided the sharp dip seen on the 1962 BRM curve on P.8.

Piston Rings

Curiously, throughout his FPF and FWMV series, Hassan adhered to the principle put forward by J. Hepworth in June 1953 (745) that Maximum Piston Deceleration (MPDP) should not exceed 100,000 ft/sec^2 (3,100 g) (33) and he chose valve timing and valve sizes to prevent this. In fact, as discussed fully in Note 13 Part II, the Hepworth “limit” set by piston-ring flutter only applied when plain iron rings could not be made thinner than 3/64” (1.2 mm) axial width. It had already been by-passed when Hepworth wrote by the invention of the Dykes’ ring in the late ‘40s – which Hassan was using!

Ignition and carburation

Lucas transistorised ignition was fitted for the 1 plug/cylinder system but Weber carburettors were used and retained for1962, unlike BRM.

1962 results

Some further teething troubles were cured in 1962 (tappet cracking and a con.-rod failure) and the FWMV Mk 2 had a 3.8% increase in inlet valve diameter (to 34.3 mm). Colin Chapman’s new semi-monocoque Lotus 25, with frontal area reduced by an extremely-laid-back driving position, powered by the Climax and driven by Jimmy Clark, came close to defeating the BRM for the Championships. It failed to do so in the last few miles of the season when a scavenge pump drive broke (832).

The late-1962 Coventry Climax hiatus

In October 1962 Leonard Lee, Chairman and Managing Director of Coventry Climax, announced that his firm would not continue to supply racing engines after the year end since their original purposes of extending and promoting the firm’s engineering ability had been achieved over 1959 – 1962. He also said i*nformally* that the successful engine maker was no longer being credited sufficiently in the Press.

This statement stimulated action in the British motor industry to increase support to the chassis-makers so that they in turn could pay higher prices for their Climax engines. Mr Lee was then persuaded in December 1962 to reverse his decision.

Coventry Climax was bought by Jaguar Cars Ltd in April 1963 and maybe this was triggered by the late 1962 industry discussions. It was a big change from the industry cold-shouldering of Vanwall in late 1958!

1963 Coy

The 1963 Climax FWMV Mk 3 which powered the Lotus 25 CoY was revised very substantially; B/S was raised to 2.675”/2.03” (67.945 mm/51.562(= 1.32; a longer con.-rod was adopted to give CRL/S = 2.51 instead of 1.78, which would have reduced friction from side-thrust; there was an increase of 6% in R; and Lucas *downstream* port injection was fitted (in an enlarged tract to offset the injector blockage), which gave 5% more power and cleaner acceleration*.

Conversions of the 1962 engines were sold for £3,000 (£55.000 in 2013 money), a figure arising from the late-1962 support agreement.

With improved reliability the Championships were secured by the Chapman-Clark-Climax combination after the 7th race of the 10 event series.

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*See top of P.11.

*With the simplified racing injection system the preset mixture compromise referred to under Eg. 41 BRM meant that the best mixture at Peak Torque, as preferred by Climax, gave too rich a mixture at Peak Power and actually lost 3% of HP (34). A cockpit re-setter was provided later in the Lotus to lean the mixture at high RPM but drivers rarely had time to use it (754).

<u>1963 Performance</u>

The FWMV Mk 3 had BMPP = 12.3 Bar @ MPSP = 16.3 m/s with R = 11. ECOM was 52.4%. The ratio R x VIA = 11 x 60^0 = 660^0 and MGVP = 64.1 m/s. There was no squish but some inlet axial swirl.

At Monza the car fuel consumption was 23L/100km, equivalent on average load to 2.5 Tonne.Km/Litre while averaging 206 kph (833).

Although MVSP = 3.5 m/s was normal for DOHC of the time, the character of the valve gear was such that Chapman thought it worthwhile to have the cam covers off before *every* start in order to oil the tappet faces (833). This minimised the combined (friction + contact) forces on the cam nose at max. lift when cranking –over, where they are highest because there is negligible inertial “fling” of the valve to reduce spring load.

Fig. 42A
Representing
1963 Coventry Climax FWMV Mk 3
90V8 2.675”/2.03” (67.945 mm/51.562) = 1.318 1,496 cc
This is a section of the FWMV Mk 2 of 1962, which was
2.48”/2.36” (62.992 mm/59.944) = 1.051 1,495 cc,
As modified in late 1961 with an Al-alloy “muff” around the cylinder liner to support a top retaining flange.
It is shown with the Lucas port fuel-injection system fitted for the last event of 1962 but not raced. This became standard for the Mk 3.
Note the electric starter motor on the RHS of the drawing – this accessory had been made compulsory for safety reasons in 1961.
DASO 34

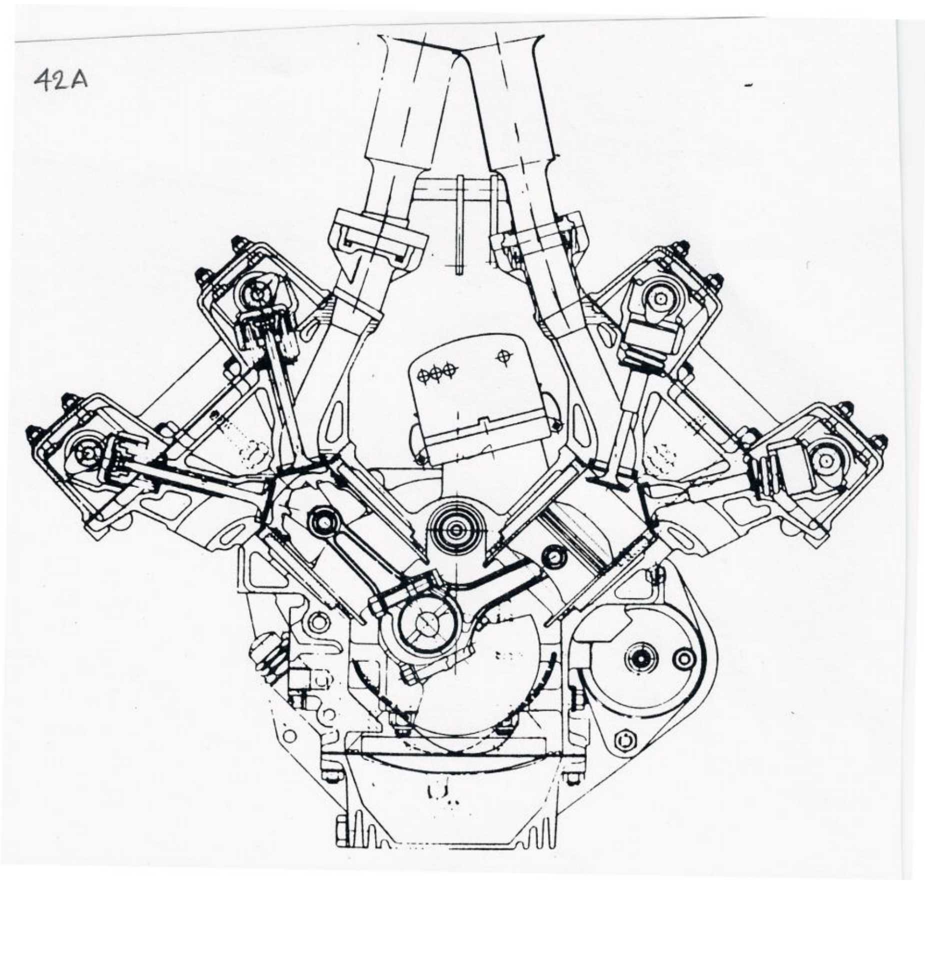


Fig. 42B
On the fuel injection engine the water-pump was moved forward to provide room for a cogged-belt drive to the distributor.

DASO 34

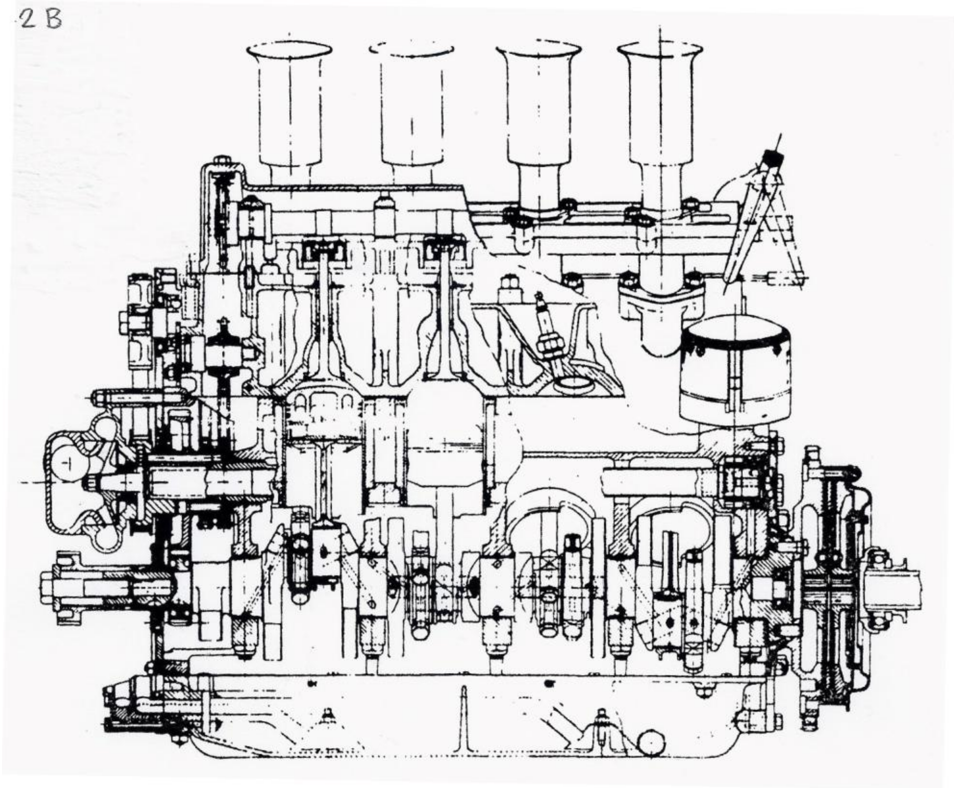
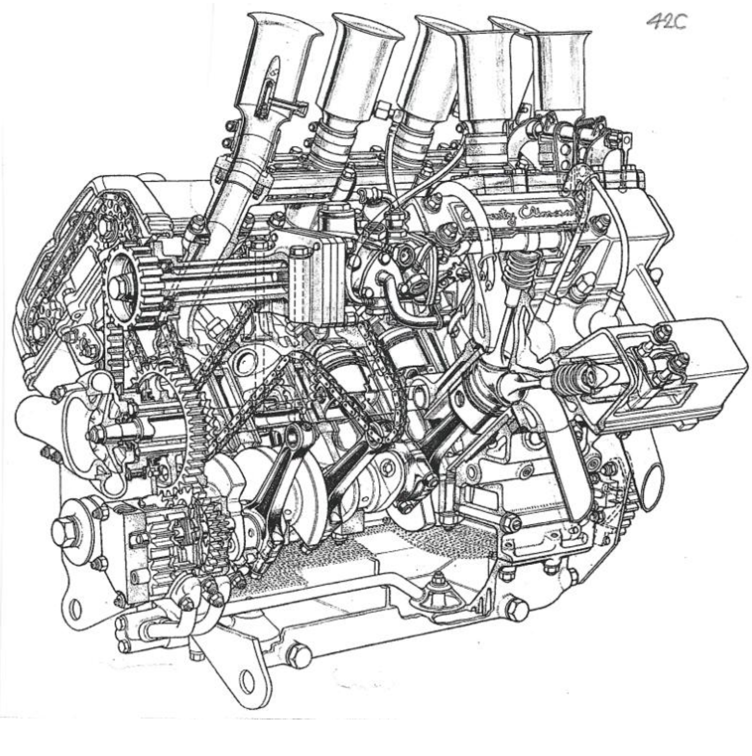


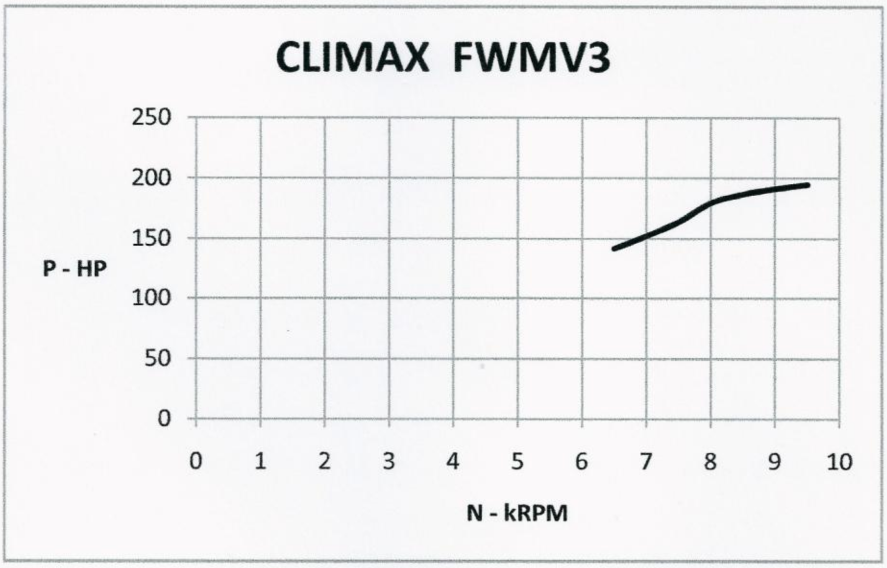
Fig. 42C
The 1963 FWMV Mk 3, showing the downstream fuel injection.
The cylinder "muff" is shown clearly.
Pistons are still solid-skirted.
Chain-driven camshafts.
2-plane crankshaft.

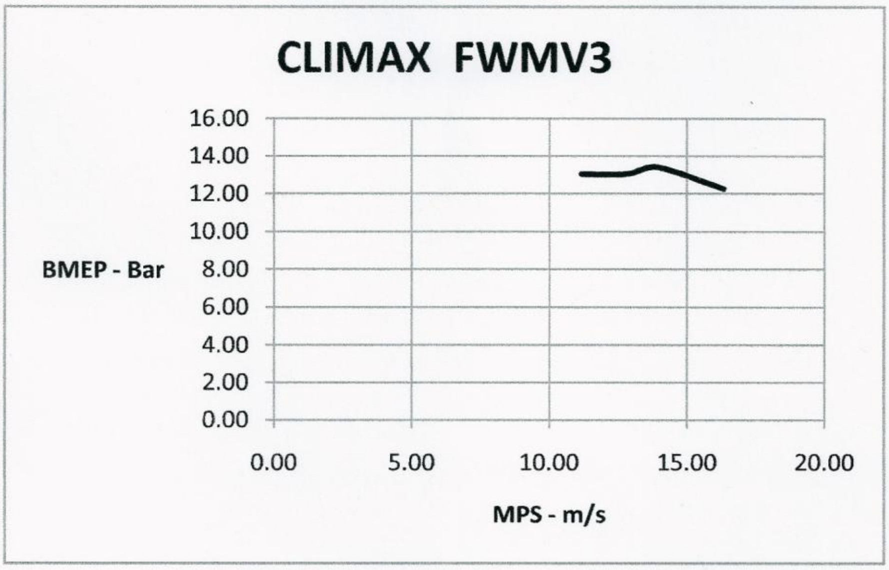
DASO 1079



POWER CURVES

Eg.	42			
DASO	34			
YEAR	1963			
Make	Climax			
Model	FWMV3			
Vcc	1496			
Ind. System	NA			
Confign.	90V8			
Bmm	67.945	(2.675")		
Smm	51.562	(2.03")		
	N	P	MPS	BMEP
	kRPM	HP	m/s	Bar
	6.5	142	11.17	13.07
	7	152.5	12.03	13.03
	7.5	164	12.89	13.08
	8	179.7	13.75	13.44
	8.5	187	14.61	13.16
	9	191.5	15.47	12.73
	9.5	195	16.33	12.28





1964 Development

The 1964 CoY was the Ferrari type 158 but for continuity the Climax development series through 1964 – 1965 will be described first.

Hassan and his Chief Designer, now Peter Windsor-Smith (previously development engineer on the V8) intended to field a 4 valves/cylinder (4 v/c) variant in 1964. To take full advantage of this "faster Top-End" (i.e. with MVSP = $\left(\frac{IVL_{mm} \times NP_{RPM}}{83.333 \times IOD^0}\right)$ m/s the lower lift of the smaller valves gave increased RPM at the same MVSP set by the same type of DOHC valve operation; (see Note 13 Part III) they raised B/S again so that piston speed (MPSP) would remain moderate. The new figures were: 2.85"/1.79" (72.39 mm/45.466) = 1.59. This ratio was by far the highest yet seen in Grand Prix racing, with the shortest stroke which would be used in CoY until the mid-'90s. With this configuration CRL/S = 2.35 was obtained with the original con.-rod in a shorter block. Compression ratio was raised again, by 9%.

The 4 v/c head, still with VIA = 60^0, had IVA/PA = 0.27, effectively the same as the Mk 3 (Hassan still "under-valving" his engines). Development work began in 1963 but the new head gave less power than the 2 v/c!

As a stopgap the Mk 3 head was fitted to the higher B/S "Bottom-End" (designated Mk4) and one engine for Clark was given inlet valves enlarged by 4% (to 35.6 mm). This latter unit, designated Mk5, had 4% power advantage over the 1963 Mk3.

Efficiencies

Ref. (34) reports that Mechanical Efficiency (EM) was 76% for the 2 v/c engine at (apparently) 9,000 RPM. It can be estimated that this would have fallen to 72% at NP = 9,750 RPM for the Mk 5. Since Specific fuel Consumption (SFC) was 0.504 lb/BHP. Hr on 102RON Petrol, which gives Brake Thermal Efficiency (BThE) of 26% and Volumetric Efficiency (EV) of 124% (see Note 37), this leaves the estimated balancing item of Combustion Efficiency (EC) as 58%. This is a rather low figure, probably associated with the fairly small bore of 73.29 mm and R.VIA of 720^0. There was axial, but no deliberate tumble, swirl and no squish.

Revised crank and exhaust system

At the last race of 1964 a 1-plane "flat" crank was introduced which (without noticeably greater vibration of the small-capacity engine) permitted a simpler low-level exhaust system. This *might* have improved installed power slightly since heat was kept away from the rear inlet manifolds (754). BRM had adopted a flat crank in 1963 (1048) but the Climax version was actually done originally to suit mounting in the Ferguson front-engined (4WD) car (34) which could not have the coupled exhausts.

1964 result

The Clark-driven Lotus 33 (an up-dated 25 using wider tyres) only just failed to win the 1964 Championships, losing them to Surtees and Ferrari in the last race on the last-but-two laps when a rubber oil pipe split.

The 1965 "32-valve" engines

It was discovered in August 1964 by Hassan and Windsor-Smith personally that the 4 v/c head required 10^0 greater ignition advance than the 2 v/c, 48^0 in fact (34), because it was such a slow burner despite having some squish in its design (34). Having thus obtained more power and after having had to cure camshaft timing-chain failures by "cobbling-up" gear drives to handle a 6% higher combined spring load (34), just two 32-valve V8s were released to Lotus and Brabham in June 1965. It is believed that they were to have been priced at £5,000 (£84,000 in 2013 money), according to statements made when first designed but, in practice, the engines were lent to the teams (871).

This Mk6 version in the Lotus 33 was used by Clark in 3 wins of the 6 which gave him and Chapman their 2nd Championships just past mid-season after the first 6 races in which they competed. The other 3 wins were with Mk 5 and notably a *Mk2* victory in the French GP, the second occasion when the 32-valver failed in practice. It was somewhat fragile and lubrication was a problem at the higher RPMs, apparently due to piston blow-by despite the Dykes' rings – the British GP was very nearly lost by oil loss from this cause (754). The 4 v/c engine built for Brabham had 13% more inlet valve area (it was designated Mk7) but very little extra power. It never started a race after troubles in every practice.

Mk 6 Performance and Efficiency

The Climax Mk 6 produced BMPP = 12.3 Bar @ MPSP = 15.8 m/s with R = 12. ECOM = 51.4%. MVSP was 3.6 m/s. R x VIA = 12 x 60^0 = 720^0 and MGVP = 58.7 m/s. Neither of the latter two parameters can be seen as best in the light of later information. Hassan certainly believed in late 1966 that VIA should have been less than 60^0 (34) – probably after seeing the Cosworth FVA with 4 v/c and VIA = 40^0 (see "The Unique Cosworth Story" and linked Note79).

With SFC = 0.554 lb/BHP.Hr on 102RON Petrol, BThE was 24%, 2 points lower than the Mk 5 but EV = 135% was 11 points higher.

In the 1965 season, Climax-engined cars were doing about 30L/100km (840).

A detailed performance analysis of all Coventry Climax DOHC racing engines is given in Note 20, showing in particular the diminishing gains in Power/Swept Volume (PP/V) as Stroke (S) was reduced.

No new Climax engine for 3L Formula

The Coventry Climax participation in Grand Prix racing came to an end in 1966 after an announcement early in 1965 that they would not build an engine for the new3L NA/1.5L PC Formula which had been announced late in 1963. It was stated that, depending on how it was costed the company had spent between £500,000 and £1,000,000 making racing engines (834) (one must express some surprise that the accountants could not do better than that!). Say £750,000 (nearly £13M in 2013 money) of costs not recovered by sales. Since the firm was now owned by Jaguar the decision was not Leonard Lee's alone.

It is probable that a contributory cause to there being no 1966 Formula engine, apart from the stated desire to return all their technical effort to commercial engines, was that Climax had spent a small fortune by late 1964 in building an F16 1.5L engine, type FWMW, which never produced the power expected and was never raced, although both Lotus and Brabham built suitable chassis. The place of this engine in Climax technology is illustrated in Note 20.

!966 Appendix: type FWMV Mks 9 & 10

There *was* a 1966 "appendix" to Climax racing with a V8 2L engine made by combining the biggest Bore of the FWMV series with the longest Stroke crank – Mks 9 & 10, depending on whether middle or large inlet valves were fitted:- B/S = 2.85"/2.36" (72.39 mm/59.944) = 1.21. These were supplied to Lotus for a few races under the 3L formula but no Championship wins were secured.

Coventry Climax contribution to Grand Prix racing

Thus the contribution of Coventry Climax to Grand Prix racing concluded after powering 37 classic race victories in 8 years which secured 4 Drivers' World Championships (two each to Jack Brabham and Jimmy Clark and 4 Constructors' (two each to Cooper and Lotus).

Coventry Climax probably gave more Grand Prix success per constant-money £ spent on engines than in any previous era.

Liaison failures over installations

There could have been more wins if liaison on engine installations had been better. During the space frame era Lotus had run oil from rear engines to front radiators through the frame tubes. Despite static flushing scale flaked off the tubes as the frame twisted while racing and the engine vibrated had sometimes fouled the lubricant. Not cleaning the system adequately after an engine failure could then cause a repeat (831).

Lotus adopted Esso oil for their V8s without telling Climax, who had developed the engine on another oil and this caused early tappet failures (515).

Teams also failed to ensure that their fuelling churns and funnels were clean and dirt clogged the Lucas fuel injection system's built-in (inaccessible) distributor filters – several races were lost as a result (34). A separate filter had to be added.

On the other hand, a piston-ring change by Climax, which raised oil consumption above the Lotus tank capacity, nearly lost the 1965 British GP, as already noted.

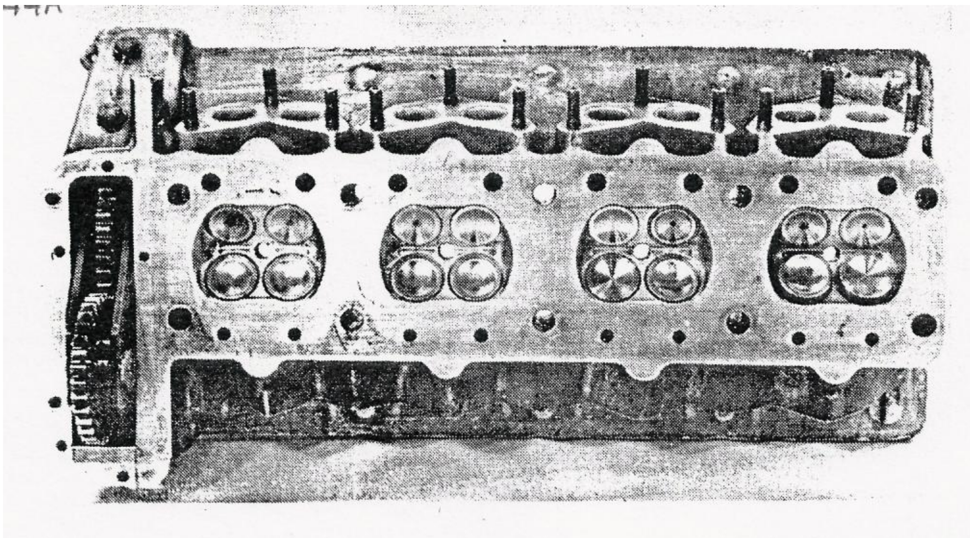
It is not known whether Lotus or Climax were responsible for the standard of rubber oil pipe which split and lost them the 1964 Championships.

All the things mentioned would in the past have been under the control of *one* Chief Engineer. Their occurrence when chassis and engine makers were separate firms was, no doubt, an inevitable "learning-to-live-together" experience (especially with the strong individualism of Colin Chapman).

<u>The influence of Jimmy Clark</u>

There is little doubt that the Climax engine successes of the 1.5L formula were influenced heavily by the chassis design brilliance of Chapman and the superior driving of Clark. This was illustrated also by their joint success with Ford power in the 1965 Indianapolis, after a narrow and controversial defeat in 1963, which revolutionised American racing cars. Clark alone could probably have achieved as much as he did for Lotus if he had driven for BRM or Ferrari. However, history has to deal with facts, not speculation!

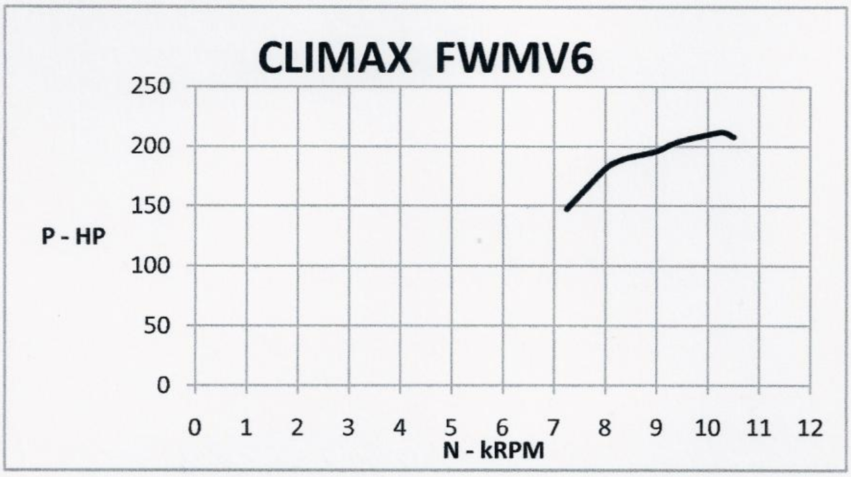
Fig.44A
1965 Coventry Climax FWMV Mk 6
90V8 2.85"/1.79" (72.39 mm/45.466) = 1.592 1,497 cc
Inlet ports for this 4 v/c engine were direct, without offset to create axial swirl.
There were small squish plateaux.
Note the gear drive to the camshafts.
The inter-cylinder spacing, at ½ Bore (36 mm),was very large by current standards.
DASO 34

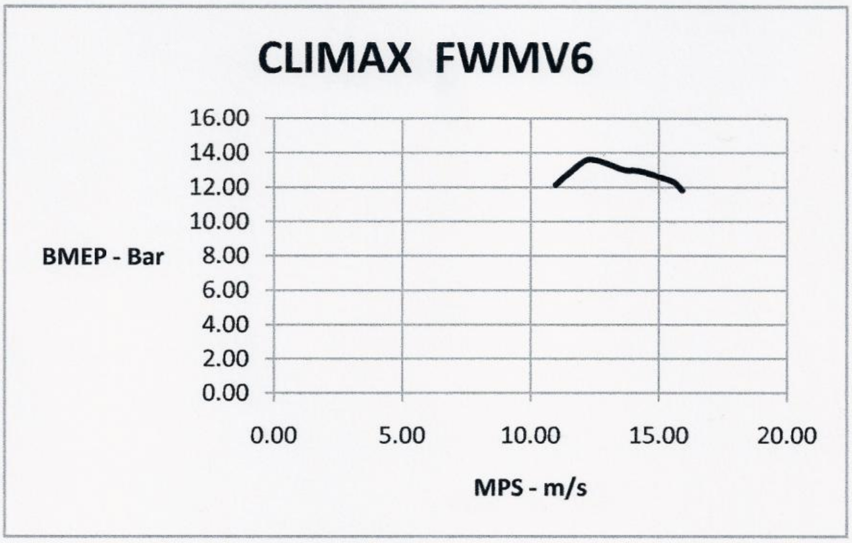


POWER CURVES

Eg.	44
DASO	34
YEAR	1965
Make	Climax
Model	FWMV6
Vcc	1497
Ind. System	NA
Confign.	90V8
Bmm	72.39 (2.85")
Smm	45.466 (1.79")

N kRPM	P HP	MPS m/s	BMEP Bar
7.25	147.5	10.99	12.16
7.5	159	11.37	12.67
8	181.3	12.12	13.55
8.25	187.5	12.50	13.59
8.5	191	12.88	13.43
9	196	13.64	13.02
9.25	201	14.02	12.99
9.5	205	14.40	12.90
10	210	15.16	12.55
10.3	212	15.61	12.30
10.5	208	15.91	11.84





43. 1964 Ferrari 158; 1,489 cc; 210 HP @ 11,000 RPM (See Figs. 43A & 43B)

The Ferrari type 158, built in very similar fashion to the Lotus 25 with “monocoque” chassis and “standard” suspension, running on “standard” Dunlop R6 tyres, braked by Dunlop discs, driven by an Englishman (John Surtees) became Constructors’ World Champion and CoY on the last lap of the last race of 1964. Surtees, a former multiple World Motorcycle Champion on MV Agusta machines, had raced consistently through the season but had scored only 2 wins.

The 158 engine, designed under Mauro Forghieri (after the late-1962 departure of Carlo Chiti in protest at interference at races by Signora Ferrari), followed the English 1.5L units in being a 90V8, B/S = 67/52.8 =1.27 (having been originally 64/57.8 = 1.11 (22)). It differed in many details:-

- “Jano” tappets;
- Axial (or “downdraught”) inlet ports – the prototype was side-ported
- Direct-into-cylinder Bosch fuel injection at 50 Bar (a system first applied by Michael May to the 1963 version of the Ferrari 120V6 engine);
- 2 plugs per cylinder.

BMPP = 11.5 Bar at MPSP = 19.4 m/s with R = 9.8. ECOM = 50.4%. R x VIA = 9.8 x 70^0 = 686^0.

Internal details are not known but Fig.43B gives an educated guess at them.

Fig. 43A
1964 Ferrari Type 158
90V8 67/52.8 = 1.269 1,489 cc
Showing the downdraught inlet ports and the Bosch pump for the direct fuel injection system.
DASO 22 p.11

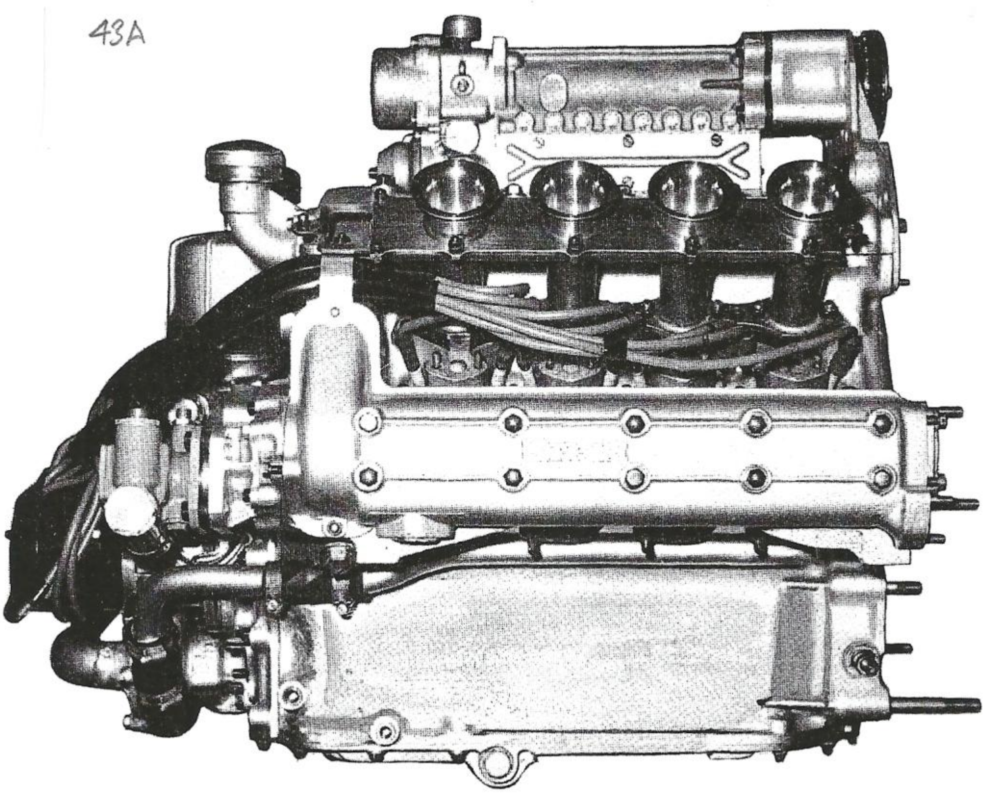
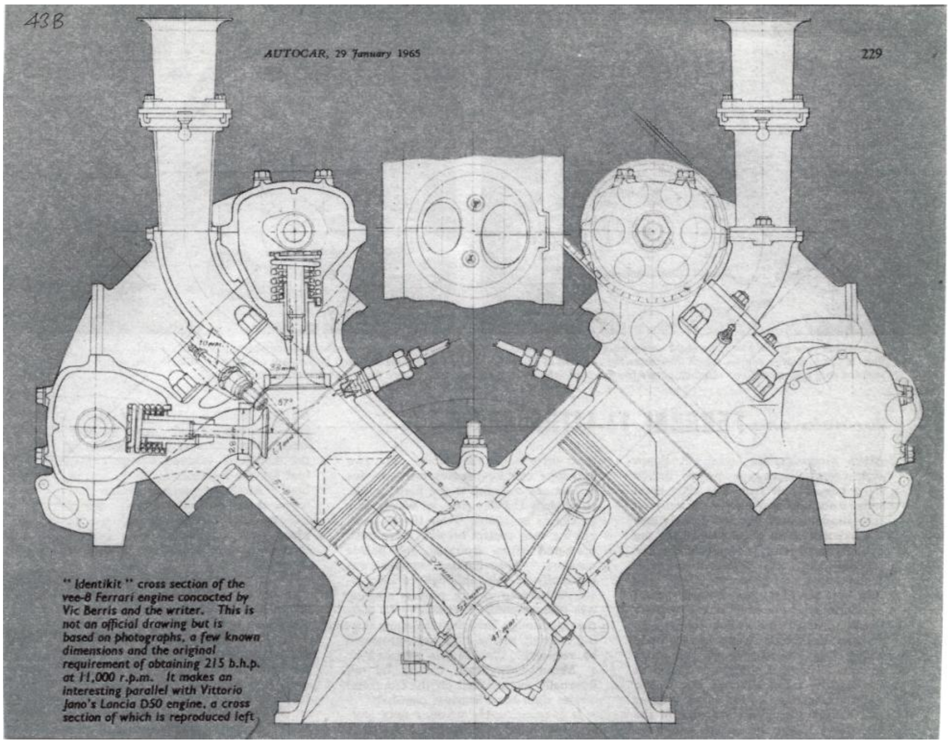
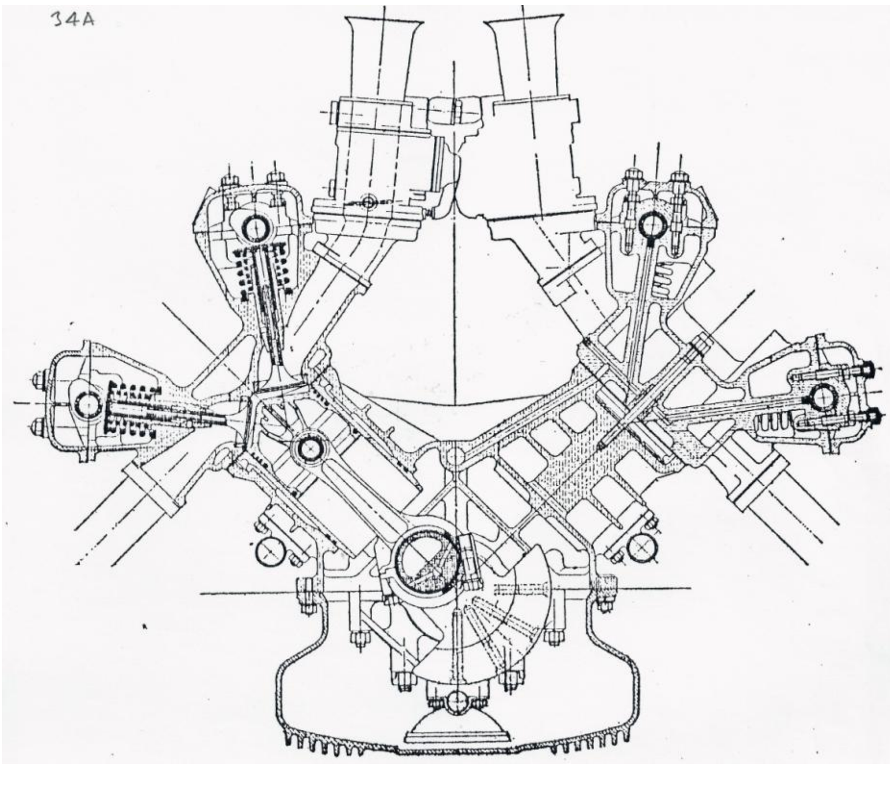


Fig. 43B
Representing the Ferrari Type 158
An interesting attempt by Edward Eves and Vic Berris to “reverse engineer” the internals of the Type 158.
The comparison with the Lancia D50 mentioned is provided below (Fig. 34A).

DASO 955 p.229



Repeat Fig. 34A
1953 Lancia D50
90V8 73.6/73.1 = 1.007 2,488 cc



Summary for the 1.5 Litre Normally-Aspirated (NA) Grand Prix Formula

The 5 years of the 1.5L NA GP Formula, following 4 years of the same-sized Formula 2 engines, provided a good illustration of the influence on design of the fundamental relation governing the Power/Swept Volume ratio (see "The General Design of Racing Piston Engines") since *Power* was desired before anything else – there could never be so much power from so small an engine as to be more of a hindrance than a help. This was especially true with tyre design improved in tread compound and contact area shape so as to give more grip.

Consequently the Stroke was reduced fairly steadily, both in CoY units and the many others whose results were not what their makers had hoped-for, or were not developed in time. The table on P.22 and the charts on P.23 illustrate the trend (showing just those engines whose dimensions were different).

The search fpr 1.5Litre power

The search for 1.5L power had led, across 9 years of F2 and GP, to the production of:-

- 11 designs from Coventry Climax (adding to the table on P.22 the un-raced late-1960 IL4 shortened-Stroke variant of the 2.5L FPF, which was 3.7"/2.125" (93.98 mm/53.975) = 1.741) and 7 Marks of the FWMV V8;
- 10 designs from Ferrari (adding the un-raced 1962 4 v/c version of the V6 and also the direct-injection V6 of 1963);

These two firms competed throughout the F2 + GP period.

- 3 designs from BRM (including the un-raced 4 v/c version and the 1965 variant with axial inlet ports). This firm had chosen a very short stroke for 1961 and found no reason to reduce it further;
- 2 designs each from Porsche and Maserati (one un-raced);
- 1 design each from Borgward, ATS, OSCA, de Tomaso and Honda (not counting the latter's rumoured research units).

The almost incredible total was therefore 32 racing-engine designs in 9 years. Of these, 15 were successful in securing 1 or more F2 or GP wins.

Side ports and axial ports had been tried, without a definite conclusion as to which was superior; 2 v/c and 4 v/c had also been tried and, with wide VIA, the latter had not shown to advantage generally.

Fuel injection replaced carburettors for good durimg the 1.5L formula, at a large cost increase; into the inlet tract for British engines, into the cylinder by the Bosch (Mercedes-developed) system for Ferrari initially but then changing to Lucas for the type 1512. The 1959 F2 Borgward had also used direct injection.

All cars were, of course, mid-engined and with the "standard suspension" described in Note 66. The search for speed led Chapman in 1961 to adopt a 45^0-reclined driving position to reduce frontal area and this feature and his 1962 semi-monocoque hull became the new chassis standard.

Overall result

The overall result of design and development can be seen in the best Climax-powered lap speeds at an unaltered Silverstone, which rose from 111.39 MPH in 1960 to 116.05 in 1965, a gain of 4.2% compared to the last year of the 2.5L Formula. This was despite a drop to only 60% of the swept volume but this was largely offset by a 51% increase in RPM, with a slight fall of 3% in BMPP, so that the drop in power was only 12%. Engine weights were similar because the new Formula required the addition of an electric starter.

The actual *increase* in speed was probably due to Dunlop tyre improvement from R5 toR7, which had a high-hysteresis tread compound with a contact patch of higher span/ chord ratio yielding a higher coefficient of friction in the lateral plane partly offset by higher rolling resistance - straight-line speed of the Lotus 25/33 fell by 10 MPH over 1962 – 1965 (754, 821, 822, 823).

Conclusion for the 1.5Litre Formula

A Formula which had been resented bitterly by the British constructors in 1958 – it was actually greeted by their *boos* at the announcement meeting! – led nevertheless to the re-establishment of their supremacy by its end. The order in the 1965 Constructors' Championship was:-

1st Lotus-Climax;
2nd BRM;
3rd Brabham-Climax;
4th Ferrari.

However, with the effective departure of Coventry Climax from the Grand Prix arena, Lotus did not have a fully-competitive engine ready for the succeeding 3L Formula and neither did BRM as they worked on their complex FlatH16. Jack Brabham, who had launched his own team in 1962 after 6 years with Cooper, *was* ready.

Page 22 continues below

1.5 Litre engines, 1957 -1965

	Make	Type	Confign.	Bore B mm	Stroke S mm	B/S	100/Smm
F2							
1957							
	Ferrari	156	65V6	70	64.5	1.085	1.55
	Climax	FPF	IL4	81.28	71.12	1.143	1.41
	Porsche	547/3	F4	85	66	1.288	1.52
	Borgward	RS	IL4	80	74	1.081	1.35
Grand Prix							
1961							
CoY	**Ferrari**	**156/F1**	**120V6**	**73**	**58.8**	**1.241**	**1.70**
	Ferrari (1 win)	156	65V6	73	58.8	1.241	1.70
	Ferrari	156	65V6	81	48.2	1.680	2.07
	Ferrari (1 win)	156 Note 1	65V6	67	70	0.957	1.43
	Climax (3 wins)	FPF Mk2	IL4	81.788	71.12	1.150	1.41
	Climax (4 wins)	FWMV 1 Note2	90V8	62.992	59.944	1.051	1.67
	OSCA	Note 3	IL4	78	78	1.000	1.28
	Maserati	150 Note 4	IL4	81	72	1.125	1.39

Note 1: win was in 1963 when mod. with Direct Fuel Injection
Note 2: wins were in 1962 as Mk 2; 3 Lotus, 1 Cooper
Note 3: modified sports-car engine with desmodromic valve-gear
Note 4: modified sports-car engine

1962							
CoY	**BRM**	**P56**	**90V8**	**68.5**	**50.8**	**1.348**	**1.97**
	Porsche (1 win)	804	F8	66	54.6	1.209	1.83
	deTomaso		F8	68	51	1.333	1.96
1963							
CoY	**Climax**	**FWMV 3**	**90V8**	**67.945**	**51.562**	**1.318**	**1.94**
	ATS	T100	90V8	66	54.6	1.209	1.83
	Maserati	T8/F1 Note 5	60V12	55.2	52	1.062	1.92
	Ferrari	158	90V8	64	57.8	1.107	1.73

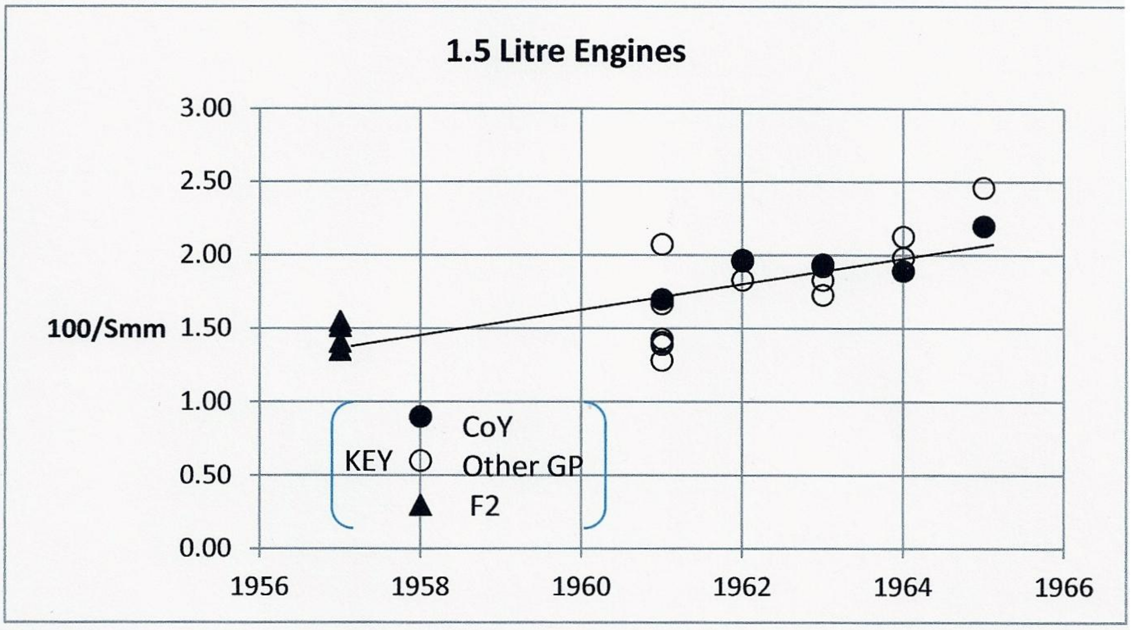
Note 5: transverse installation designed, but not raced

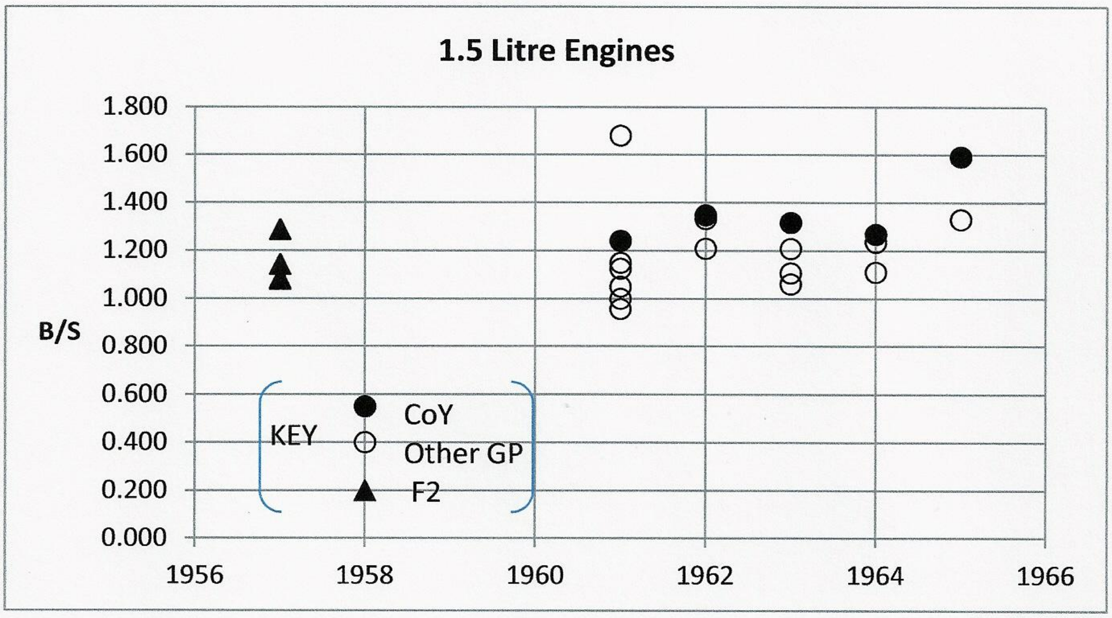
1964							
CoY	**Ferrari**	**158**	**90V8**	**67**	**52.8**	**1.269**	**1.89**
	Ferrari	1512	F12	56	50.4	1.111	1.98
	Honda	RA271E (1 win)	60V12 Note 6	58.1	47	1.236	2.13

Note 6: win was in 1965 as RA272E. Transverse installation.
Honda were reported in 1962 to have tested IL8 and V8 engines before adopting V12, but no details have ever been released (820).

1965							
CoY	**Climax**	**FWMV 6**	**90V8**	**72.39**	**45.466**	**1.592**	**2.20**
	Climax	FWMW Note 7	F16	54.102	40.64	1.331	2.46

Note 7: not raced


1.5 Litre Engines
100/Smm
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1956
1958
1960
1962
1964
1966
KEY
CoY
Other GP
F2


1.5 Litre Engines
B/S
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
1956
1958
1960
1962
1964
1966
KEY
CoY
Other GP
F2