1st Pressure-Charged Era (1PC)

Part I
1924 – 1939: 16 Racing Years
Examples 10 to 25

10. 1924 Alfa Romeo P2; 1987cc; 145 HP @ 5,500 RPM See Figs. 10A, 10B

1924 provided Alfa Romeo, who had not competed previously in a Grand Epreuve, with the 1st win by a Pressure-Charged (PC) GP Car-of-the-Year, their type P2 (although as already mentioned the FIAT 805 car had claimed the 1st Grand Prix PC win at Monza in 1923).

The P2 was designed by Vittorio Jano, who had changed firms after being a member of the FIAT racing design team. FIAT in the French Grand Prix had therefore won or influenced directly the winner in 1922, 1923 and 1924, while competing unsuccessfully in the latter two years themselves. After 1924 their major competitive effort was in Schneider Trophy aero engines, see Note 38.

At first glance there was little difference between the FIAT 405 engine and the new Alfa, apart from spur gear rather than shaft-and-bevel-gear drive to the DOHC – Jano, like Bertarione with the 1923 Sunbeam, preferred the lower tooth loading and greater tolerance to clearances of the former. The Mercedes-type upperworks construction was retained together with FIAT's 2-valves-per-cylinder at $102^0$and also the split-race roller bearing bottom-end. Both were IL8 and B/S only slightly higher at 0.72 rather than 0.69. Jano is credited by ref. (25) with having understood better how to prevent coil valve spring surge failures - a FIAT problem – by using fewer turns of thicker wire to raise natural frequency, although this is not apparent in comparing section drawings. This solution raised *normal* spring stress in order to avoid an *abnormal* excess in surge. The MVSP at 2.32 m/s, was no advance over the 1923 Sunbeam. A gain in Roots supercharger efficiency and pressure ratio was claimed (25) by using a smaller geared-up unit – this may have been the largest improvement over the FIAT. The blower still delivered pressurised air to a single carburetter, through a finned manifold which could have cooled the charge somewhat.

Luck once again favoured an FGP winner since the IL6 Sunbeams, now supercharged and sucking a cooling alcohol-base fuel from an upstream carburetter, were faster in practice but lost the high chance of victory by changing all the engines to new magnetos the night before the race – at the maker's (Bosch's) request – which proved to be defective. Racing success is, of course, a matter of management as well as technology and driving skill and *wholesale* last minute changes, for whatever reason, are rarely safe (see the Postscript to this example).

At the end of the season Jano adopted a new fuel – "Elcosina" – with a high alcohol content (53% Benzole, 44% Ethyl alcohol, 2% Ether, 1% Castor Oil), whose evaporative temperature drop cooled the inlet charge and raised power by 8% (322). This was in conjunction with twin pressurised carburetters, adopted late in 1924 (773).

From that date onwards all CoY used this type of fuel until 1957 (excepting 1952-1953), coupled until 1951 with Roots supercharging (as discussed in the previous section). As inlet pressures rose so did the %age of alcohol (ethyl or methyl) in the fuel, as did the richness of the mixture. Appendix 2 Notes gives details of racing fuels followed by Appendix 2 Table.

1924 Postscript on Sunbeam

The 1924 Sunbeam season provided a case history on the soundness of the rule:- whatever the argument, **never fit unproven parts at the last moment to all the machines in a fleet!**

Captain Jack Irving, the Sunbeam Experimental Engineer, had developed the successful 1923 engine with a Roots supercharger sucking a fuel of equal parts petrol/benzole/methanol from the carburetter, a novel system to cool the inlet charge which was kept secret until the French GP weigh-in and which was copied eventually by all Mechanical Supercharger (MSC) makers. At that event in practice the Sunbeams were the fastest cars but a mistake of management on the night before the race cost them the victory.

The magneto was placed directly behind the exhaust manifold (see Fig. 9A), a location which had given no trouble in 1923 but in 1924, probably due to the increased exhaust heat from supercharging, the contact breaker cover were being scorched.

Because of this the Bosch representative, while he was sure the magnetos would last the race, advised a change to a new and, he insisted, better type. Coatalen accepted this advice, all three cars were refitted – and suffered misfiring in the race (one also had a transmission joint failure when 2nd at 60% distance, which might have been caused by the jerky engine running). Plug trouble was suspected but changes made no improvement. Not until afterwards when an engine had its original magneto replaced did it run smoothly again. There had been internal wire fractures in all 3 new units, perhaps due to vibration, perhaps to overheating (4, 24, 201, 763). The fault must have been intermittently "make or break" since Segrave was able to set the fastest lap of the race at 83% distance and he finished 5th.

As some consolation Segrave did win the Spanish GP the following month – presumably with a well-tested magneto.

Fig. 10A

1924 Alfa Romeo P2
IL8 61/85 = 0.718 1,987 cc

Note the finned intercooler between supercharger and pressurised carburetter at bottom left-hand-side.
Steel fabricated 1-piece head + cylinder construction. Finger followers to take cam side thrust.
Triple valve springs. Roller bearing mains and journals.

DASO 184

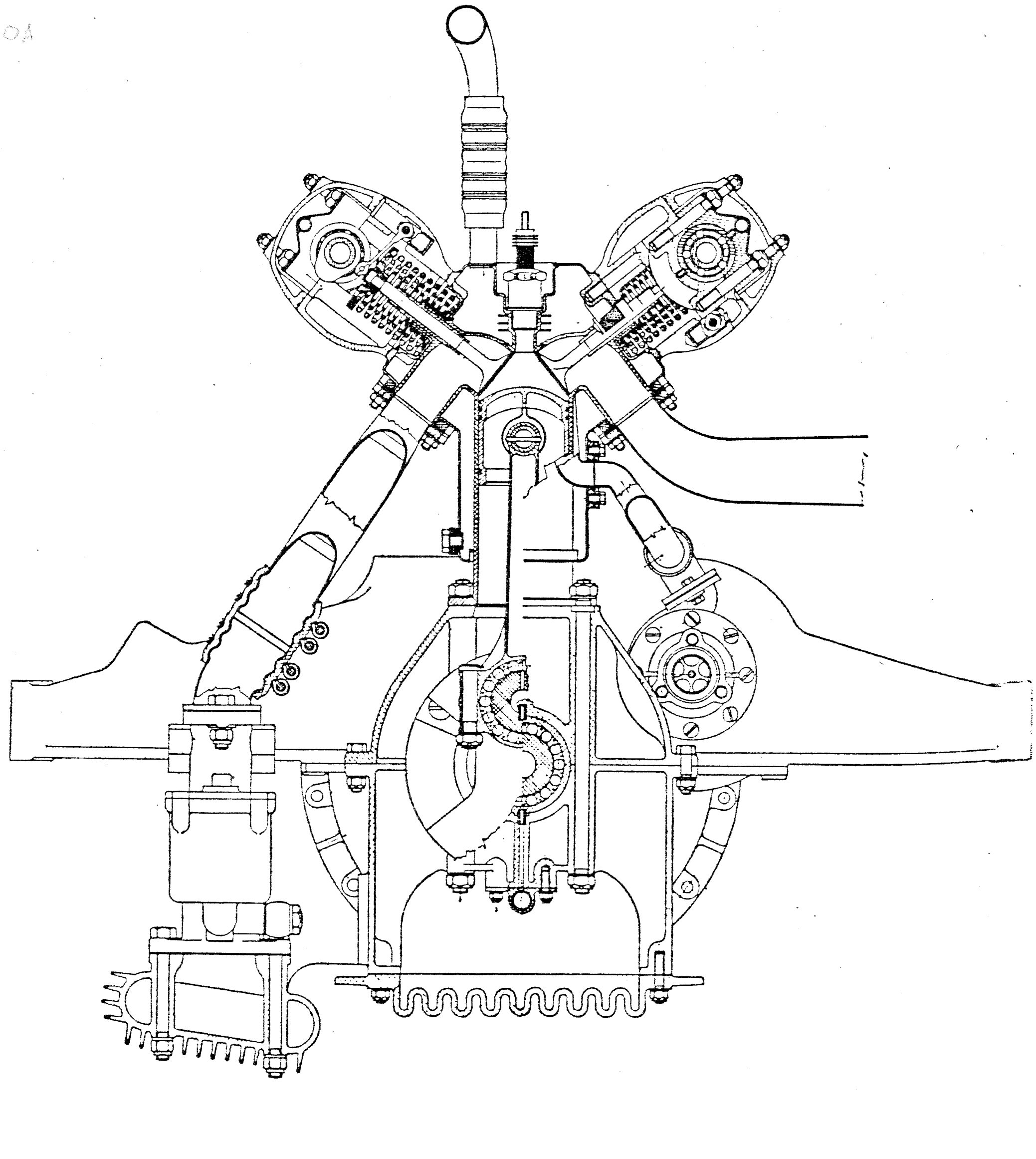
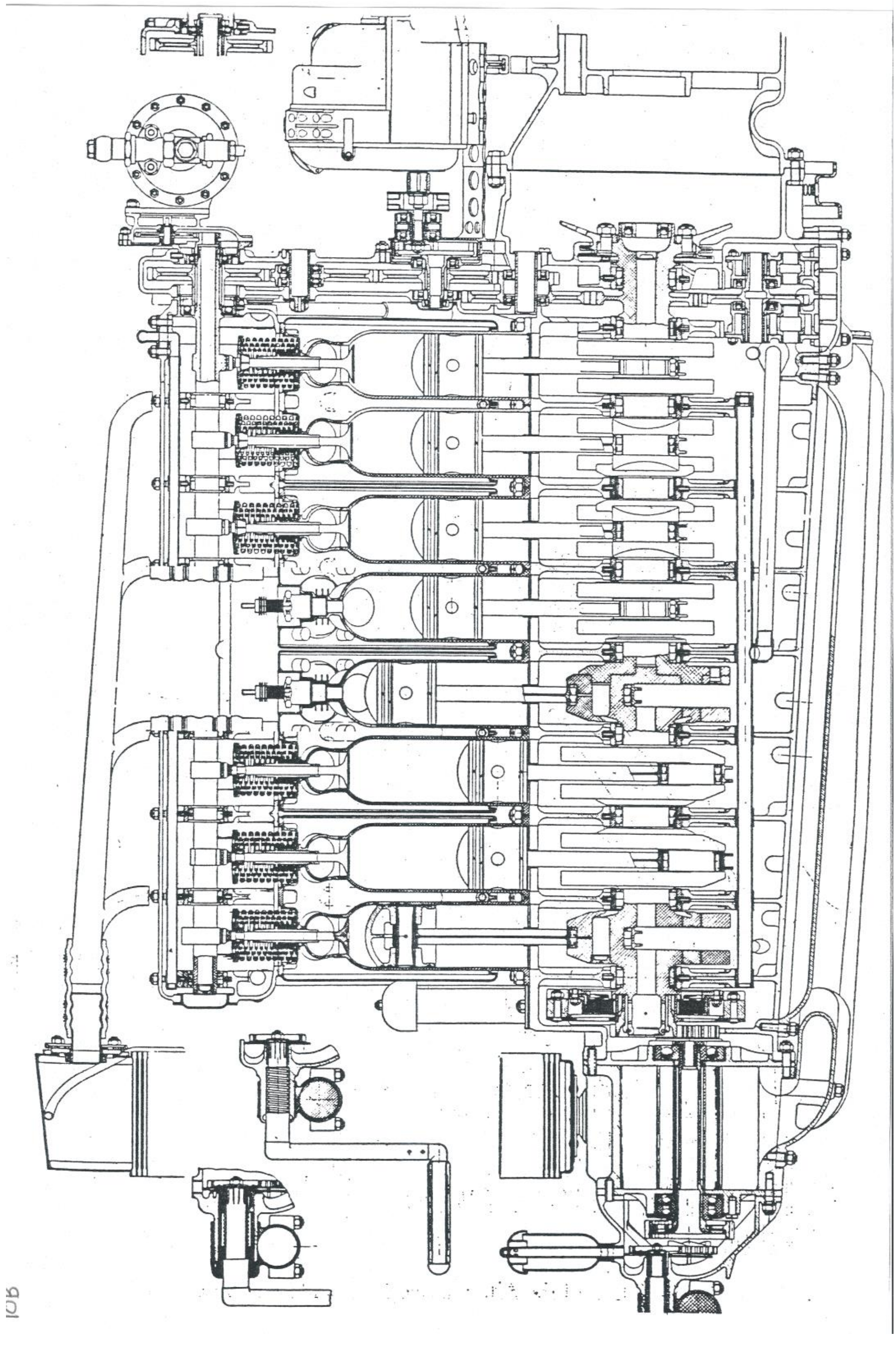


Fig. 10B
1924 Alfa Romeo P2
IL8 61/85 = 0.718 1,987 cc

DASO 184



11. 1925 Delage 2LCV; 1,992 cc; 190 HP @ 7,000 RPM (suspect). See Figs. 11A, 11B.

In 1923 Delage, returning to racing after a break since 1914, had entered a 2 L 60V12 of B/S =51.4/80 = 0.64. This was the first V12 in Grand Prix events. It had perfect balance(732), the Stroke being the shortest up to then in classic GP racing and with the smallest Bore of any CoY up to the present and likely to remain so. This naturally-aspirated design by Charles Planchon followed the reasoning set out earlier in this work as a way of increasing the Power/Swept Volume ratio. When supercharged by Albert Lory for 1925 with a separate Roots unit for each bank it won the 1925 French GP and is therefore the selected CoY but, once again, luck – tragic luck for Alfa Romeo - played a part; Antonio Ascari, leading in a P2, crashed in the rain at Montlhery and was fatally injured. The other Alfa team cars were then withdrawn when another was leading. The Delage 2LCV did set fastest lap, however.

Apart from seeking configuration advance, rolling-contact - often called "anti-friction - roller and ball bearing use was extended in this V12 to every spindle; Pomeroy claimed that there were 100 such bearings (455)! Altogether, the engine may have been the costliest built for GPs until new Mercedes V12s appeared in 1938. However, the expensive Mercedes-type built-up steel-fabricated upperworks of the 1922 -1924 engines were replaced by a 1-piece cast iron head-cum-block for each bank. For some reason the exhaust ports were on the *insides* of the heads so that the dual manifolds and tail pipes had to be carried out of the vee near the top of the bonnet and over to the left-hand side. This may have been to provide room on the outsides originally for the carburettors.

Later in the season a 5 forward speed gearbox with "overdrive" top was tried to reduce the potentially-high RPM.

For the reasons set out in Note 5, concerned particularly with the subsequent IL8 1.5 L Delage , it is considered that the 190 HP quoted for the 2 L engine was only a "flash" brake reading, not sustainable. Ref.(946) says that the normal maximum RPM were 6,200 and from there to 7,000 was a red sector on the tachometer, so the steady power may well have been about 10% below the usually-quoted maximum, say 170 HP @ 6,200 RPM.

Fig. 11A
1925 Delage 2LCV
60V12 51.4/80 = 0.643 1,992 cc

The exhaust ports were on the insides of the cylinder banks
Note the carburetters underneath the superchargers.
The pressure relief valves are missing from the ends of the inlet manifolds.
DASO 4/plate 37

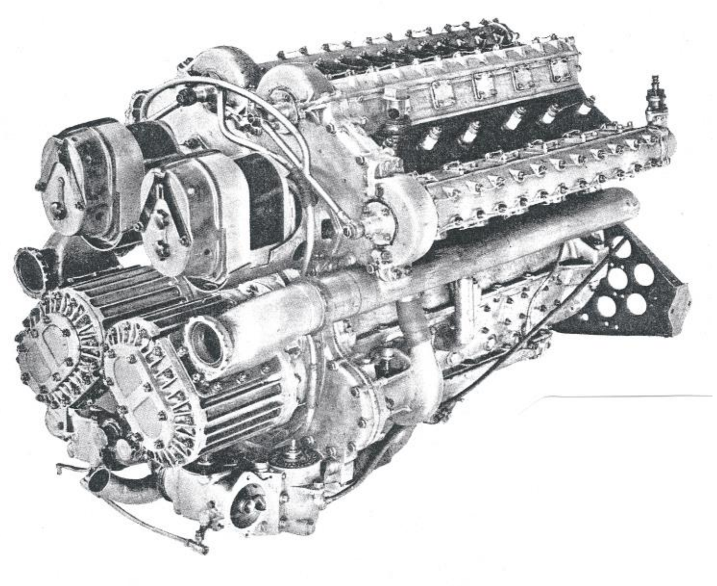


Fig. 11B
1925 Delage 2LCV
60V12 51.4/80 = 0.643 1,992 cc

Short finger cam followers. Triple valve springs.
DASO 455B

11B

<u>12. 1926 Bugatti 39A; 1,495 cc; 126 HP @ 6,200 RPM</u> See Figs 15A, 15B

Having tried IL6, IL8 and 60V12 configurations during 1921 – 1925, CoY designers subsequently chose IL8 in the 12 years until 1938, with the exception of a 45V16 (i.e. a *double-bank* IL8) in 1936. FIAT's bold and promising 2 x IL6 type 406 in 1927 unfortunately raced only once in a minor non-classic event which it won.

To reduce maximum speeds, considered unsafe at 2 Litre levels with the rigid-axle leaf-sprung chassis of the time, the rules for 1926 – 1927 brought swept volume down to 1.5 Litres.

While several companies intended to compete to this formula only Ettore Bugatti was ready for the French GP and his team had a "drive-over". Obviously this was a "circus" fiasco and totally boring for the spectators at the Miramas banked track but being ready when your rivals are *not* is a tribute to management. The remorseless logic "*To finish 1st, you first must finish*" was applied in this work to the 1925 Delage result as CoY; for the 1926 situation it was amended to "...*you first must start*".*
In any case the seasons's full results justifies the choice of the Bugatti T39A as CoY.

After 2 years refusing to use Pressure-Charging, Bugatti applied it very well to an engine basically the same as the 1924 IL8 2 L T35 but with the Bore reduced from 60 mm to 52 mm – a simple way of being ready first!. The Stroke was unchanged at 88 mm so that the B/S ratio was reduced from 0.68 to 0.59. The usual Roots-type supercharger was improved not only by having 3 lobes instead of 2 so as to reduce loss-making flow pulsation amplitude but also by having flattened rotor tips with 5 integral fins to cut leakage. This contrasts with, eg., Mercedes from 1922 to 1939 who used 2-lobe basically-cylindrical rotors with only line clearance to prevent over-tip leakage; curiously, Irving of Sunbeam stated in ref. (1074) that they had tried 3-lobe rotors and found them less-efficient than 2-lobe but the tip sealing design was not mentioned; Alfa Romeo (Wilfredo Ricart) did eventually adopt the 3-lobe form for the experimental type 162 of 1940 but this also only had single line clearance.

The Bugatti blower was mounted alongside the middle of the cylinder block and required only a short pipe to a symmetrical manifold, unlike other applications with the supercharger at front or back and potentially charge variations along the block.

Unfortunately this good start for the inlet flow fed into tortuous manifold internals and a head designed in 1922 with poorly-shaped passages and siamesed porting to the 2 vertical valves per cylinder (IVA/PA probably 0.4) operated by SOHC.

The sparking plug was at the side opposite the single (drilled and plugged to reduce mass) exhaust valve, which unnecessarily was of 11% large head area than the combined inlets, following Bugatti's belief in easy outflow. This was not the best location for the plug to give best resistance to detonation since it meant that the flame travelled towards the *hottest* end of the charge. However, it was a practical choice to prevent mechanics burning themselves in the change necessary in those days after warm-up from "hot" to "cold" plugs and also when they might have to be changed in a hurry during a race.

The easy-outflow principle was continued in the "bunch-of-bananas" exhaust manifold, 8 individual pipes grouped into 4 and then twinned for the tail pipe.

Cooling of the top end of the cast-iron integral head-block left much to be desired.

The bottom end was good with 5 rolling-contact main bearings (a sufficient number for the IVP and RPM used) and 1-piece con-rods with roller bearings running on a 6-piece built-up crank. This construction permitted a 3rd full-size centre ball-bearing to complement an end pair. As intermediates there were 2 split-race bearings using crowded rollers to avoid split cages. Numbers 2, 3 and 4 bearings were retained by caps bolted up to the block; numbers 1 and 5 were retained by the lower half of the crankcase.

Very-short pistons were used to reduce friction, having Piston Height/Bore = 0.85 where, by contrast, the Alfa P2 ratio was 1.1.

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*The Royal Aero Club enforced that maxim in the 1931 Schneider Trophy when the RAF team was ready and potential competitors were not. By a "flyover" the Trophy was won in perpetuity in accordance with the rules by a 3rd win in succession.

It is worth mentioning that the US organisers did *not* apply the maxim to the 1924 Schneider race. Having won in 1923 easily they could certainly have won the following year's race when they were ready and no one else was but, very sportingly, they refused to do a "flyover. Had they done so their success in 1925 would have given America the trophy for ever. There would then have been no Supermarine seaplanes or Rolls-Royce racing engine to provide the technology from which Reginald Mitchell produced the Spitfire and R-R developed the Merlin. History could have been very different!

13. 1927 Delage 15-S-8; 1,487 cc; 170 HP @ 8,000 RPM (Suspect) See Figs. 13A, 13B.

One reason for Bugatti's 1926 success was a mistake made by Lory, designer of the main rival IL8 Delage. He placed the exhaust on the right, the same side as the driver in a low body still required by the rules to be 2-seater width (although riding mechanics were excluded after 1924) and the manifold ran very close to the pedals. In the additional heat of the car's Spanish GP debut drivers and their necessary reliefs all suffered burnt feet. Consequently the car's superior speed was offset by remedial pitstops. Only one other race was contested by Delage in 1926, in cooler English weather at Brooklands and, one must assume, with added shielding. Using 2 drivers with stops to change over and cool their feet a Delage managed to beat Bugatti on that occasion.

The Delage inlet-and-exhaust ports were reversed in 1927 and the car achieved its full potential in winning all the 4 major races which it contested. These included victory with a single car in the Italian GP.

Like its V12 forebear ball or roller bearings were used in every possible location, allegedly totalling 65 (39). Other features were also similar to the V12; B/S was raised to 55.8/76 = 0.73 and the Stroke was the shortest which would be seen in CoY until 1938. With a 5-forward speed gearbox to reduce RPM on the straight the engine was very reliable as well as fast, hence the confidence to send only one car to Monza.

However, Note 5 deploys several reasons which lead to the conclusion that the *steady* power was probably about 10% below the usually-quoted 170 HP, say 150 HP @ 7,000 RPM. In ref. (660) George Monkhouse (a friend of Dick Seaman) reported that when Guilio Ramponi modified the engine for Seaman in 1936 he fitted better steel adjusting shims in the valve thimbles under the finger cam followers because the originals tended to hammer out. This caused a loss of opening period and lift and resultant power droop with running. The short fingers were also prone to rapid wear with the same result (4).This is a different thing from the short-term drop with rising engine temperature between "flash" and steady brake readings.

The car was stated wrongly in ref. (4) to have a chassis weak in front-end torsional stiffness because, it was said, there was no transverse member between the engine front and gearbox rear-55 inches – and that this affected the steering. In fact the rear engine mounting was just behind the block at 30-odd inches although the Cresswell drawing in (4) does not show it (personal inspection). Clearly the handling was quite satisfactory, although the 3-point engine mounting use to relieve it from 1-wheel road bump twisting did not brace the chassis as did the 4-point Bugatti mounting.

Fig. 13A
1927 Delage 15-S-8
IL8 55.8/76 = 0.734 1,487 cc
DASO 4 p.175

The cylinder/head casting was left open at the bottom and the water-jacket completed with plates, to enable the casting to be cleared of core sand

Triple valve springs.

Note the thimbles over shims on the end of the valves, a particularly tiresome method of clearance adjustment!

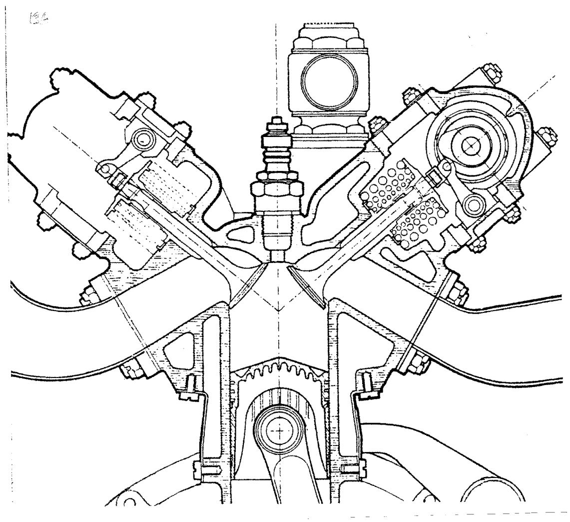
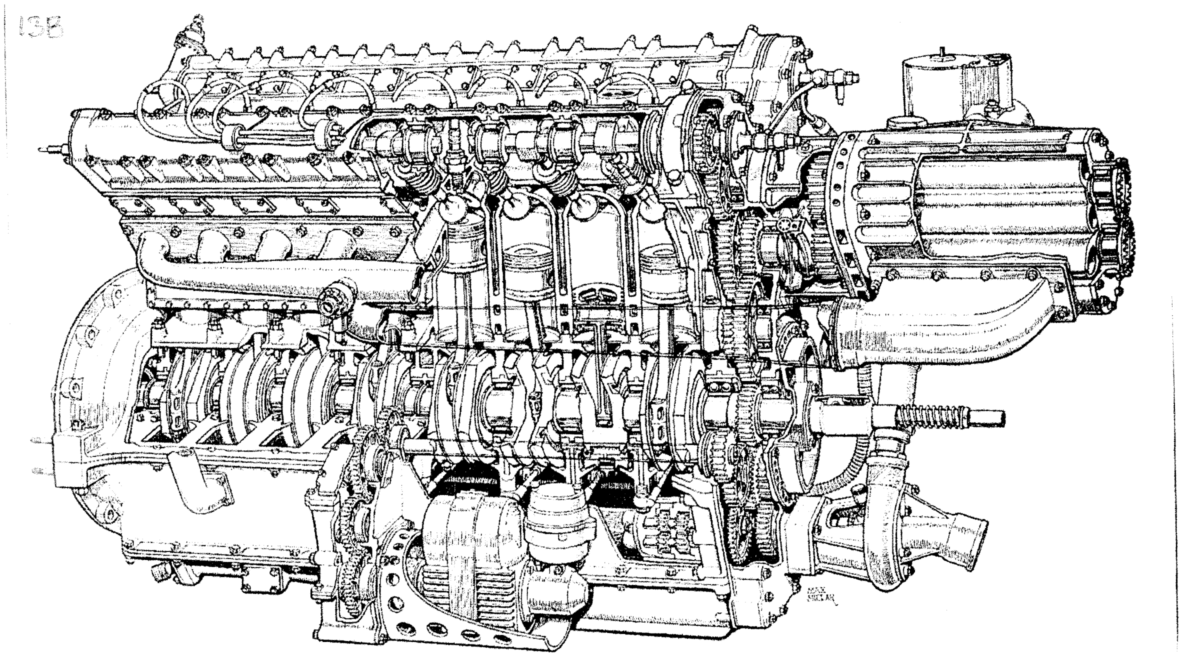


Fig. 13B
1927 Delage 15-S-8
IL8 55.8/76 = 0.734 1,487 cc
DASO 702 p.61

Shows the revised right-hand inlet system,
the exhaust having been moved to the left
away from the driver's feet.
The inlet manifold was tapered in each direction
from the central supercharger delivery pipe
so as to suit the quantity of charge flowing inside.



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14. 1928 Bugatti 35C; 1,991 cc; 158 HP @ 5,500 RPM
15. 1929 Bugatti 35B; 2,262 cc; 147 HP @ 5,200 RPM
16. 1930 Bugatti 35C; as 1928

See Figs. 15A, 15B

In 1928 the sporting rule-makers (the "*Association Internationale des Automobile Clubs Recconu*".- AIACR) instead of a Swept Volume limit chose a Maximum Car Weight of 750 Kg, reasonably as the Bugatti T35B was 770 Kg empty and the official weight definition excluded tyres. However, this rule was unpopular with race organisers and manufacturers so that only 1 classic race out of 3 was run to the formula, the others being unofficially "*Formule Libre*", i.e. no restrictions.

In 1929 and 1930 a fuel consumption limit was revived which equated to about 18 Litres/100 Km (compared with 20 L/100Km in 1913) of petrol, or 70/30 petrol/benzole in the 2nd year, (where alcohol-base fuel had become universal for supercharged racing). These rules also found little favour, only 3 races out of 10 classics following them and the rest being run as *Formule Libre.*

Over these 3 years pre-existing Grand Prix car builders were reluctant to add to the heavy expenses of 1922 -1927 by making new engines and they either retired from the arena or else competed with their existing types, sometimes modified.

One fresh GP engine was produced by Alfieri Maserati in 1930, a relatively-cheap IL8 2.5 L unit with cast iron block and detachable Al-alloy head – the first in this alloy in classic racing and the first detachable head since the 1921 Duesenberg. It was lapped to fit without a gasket (781).

It had 2 valves per cylinder at VIA = 90^0. All bearings were plain white-metal except ball type at the ends of the crankshaft where they could be included easily. Again, plain major bearings had not been seen since the Duesenberg.

Bugatti nevertheless benefitted during 1928, 1929 and 1930 with 2 types introduced in 1926 (T35B IL8 60/100 = 0.6 2.3 L) and 1927 (T35C IL8 60/88 =0.68 2 L), both developed from the 1924 T35 IL8 60/88 2 L and with supercharging. These competed very effectively both in the official formulae and the "*Libre*" races to be CoY in these 3 years. They were the first Grand Prix cars to be supplied for sale new to private customers as well as used by the works team. Presumably they made a profit for Bugatti. Other makers and also Bugatti previously had sold ex-works cars, eg Peugeot even before WW1, although FIAT always scrapped theirs when no longer required. Consequently, besides the classic victories, a vast number of minor races were won over many years by Bugattis driven by their private owners.

The general features of the Bugatti engines have been described already for the 1926 T39A version and are shown on Figures 15A and 15B. The volume-specific power of the T35B Bugatti has been criticised by Pomeroy (4) and the figures for this and the other two types exampled are given below. They are compared with the other three supercharged engines of the 1924 – 1930 period.

Fig. 15A
1929 Bugatti 35B
IL8 60/100 = 0.6 2,262 cc
DASO 28

Note the side-mounted 3-lobed supercharger with 5 tip sealing fins, the short pistons, the drilled and plugged exhaust valve and the air-cooling tubes through the sump.

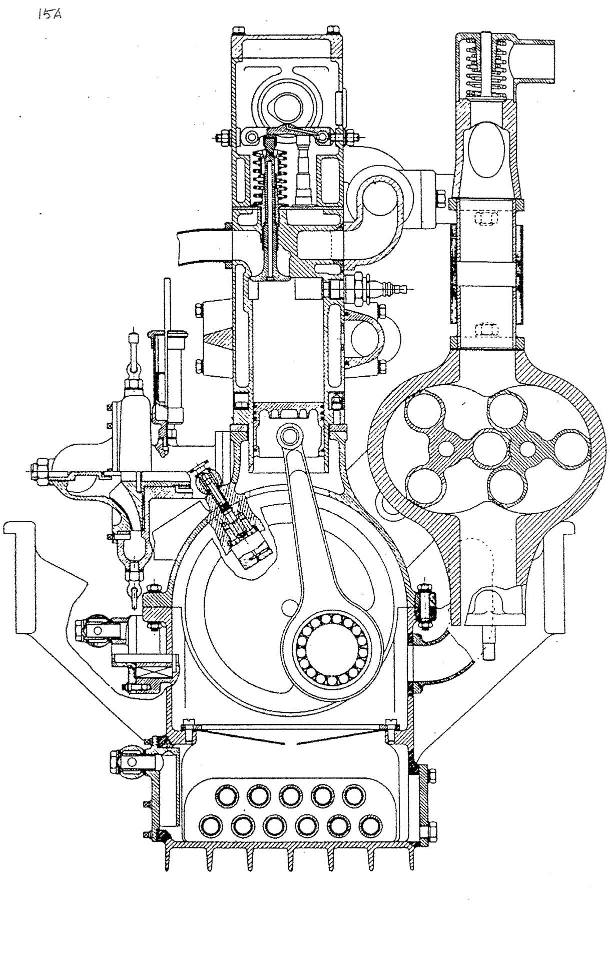
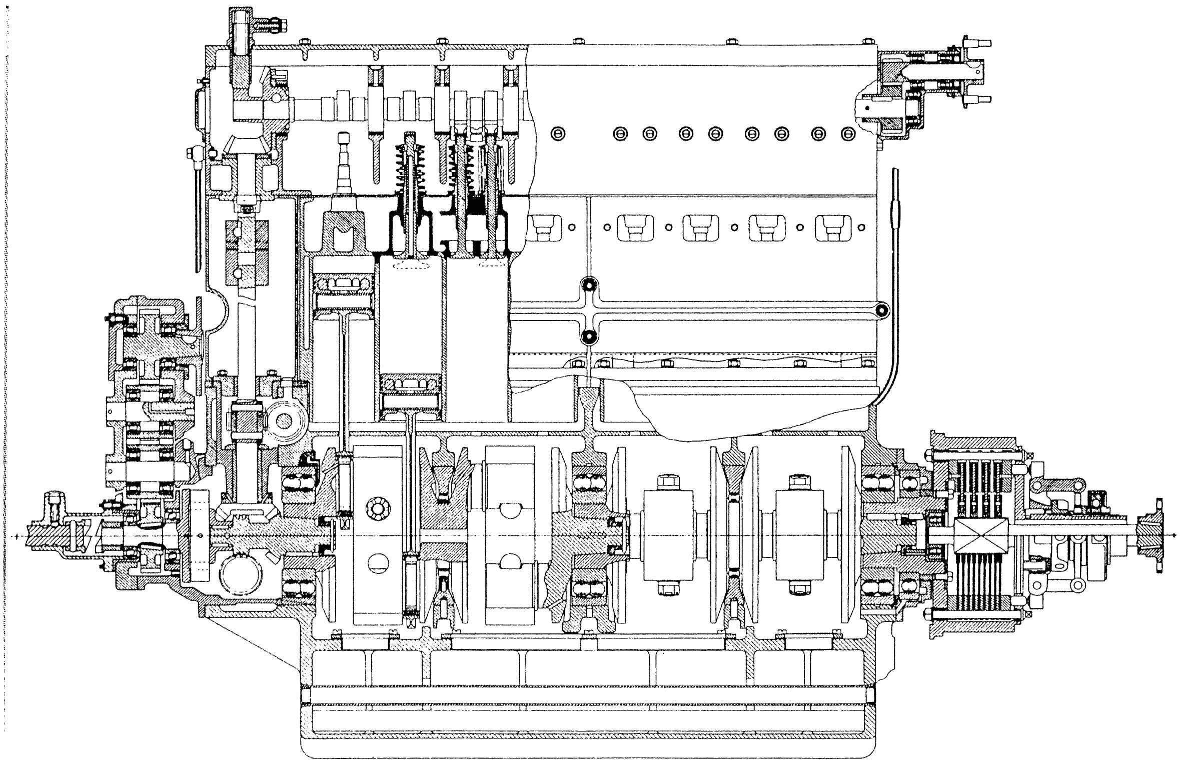


Fig. 15B
1929 Bugatti 35B
IL8 60/100 = 0.6
DASO 711

This shows the centrally-jointed crank as well as the bolted-up webs.
It also shows the oil feeds to the big-ends from the web catcher grooves.



These Figures can also represent Examples 12 (Type 39A), 14 and 16 (Type 35C). The differences in Bore and Stroke within the same block and basically-similar crank were:-

Type 39A	52/88 = 0.591	1,495 cc
Type 35C	60/88 = 0.682	1,991 cc

Engine comparisons, 1924 – 1930

	1924	1925	1926	1927	1928	1929	1930
Eg.	10	11	12	13	14	15	16
Type	P2	2LCV	39A	15-S-8	35C	35B	35C
				HP/Litre			
PP/V	73.0	85.3*	84.3	100.9**	79.4	65.0	79.4

*Adjusted to 170 HP @ 6,200 RPM
** " " 150 " 7,000 "

(As described in the Examples and Note 5.)

The PP/V for the T39A and the T35C is not as poor as the T35B which led to Pomeroy's stricture but the average value of this Bugatti parameter at 76.2 HP/Litre is 12% less than the average of the other 3 engines at 86.4.

Taking the other measure, the combined efficiencies, these are:-

[EV x EC x EM] %

43.3	43.6*	41.1	44.4**	43.7	37.8	43.7

The average combined efficiency of the Bugatti types is 40.9, 7% points less than the average 44.1 of the other 3.

It would be helpful to understanding the undoubted success of the Bugattis if their engine Power/Weight ratios could be compared with the others. This has not been possible because the Weight data could not be obtained. The SOHC Bugattis would have been lighter than the DOHC engines.

It has been considered generally that the Bugatti chassis, being particularly stiff in torsion and with a rear spring-base equal to the front, would have neutral –steering handling rather than the over-steering characteristic of the period. This may have become a significant advantage after country circuit road surfaces in the mid '20s were made more durable with tarmac or asphalt and so provided good grip. Previously roads tended to break up during a race and it is doubtful if steering subtleties then had any effect.

Bugatti T35B in sound and motion;- see Note 116

Mechanically-Supercharged versus Naturally-Aspirated engines

The combined efficiency average for the 6 Mechanically-Supercharged types listed above is 42.3. This is 4.1 % points lower than the 46.4 average of the 3 Naturally-Aspirated types which were Coy for 1921 -1923. This is because Mechanical Efficiency (EM) dropped due to the net* HP subtracted to drive the supercharger.

> *Net because some of the gross HP taken from the crank to drive the supercharger is recover pneumatically in the cylinders on the inlet stroke with the inlet pressure above ambient.

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17. 1931 Bugatti 51; 2,262 cc; 185 HP @ 5,500 RPM (See Fig. 17A)

Formule Libre was promulgated officially in 1931, though coupled with a 10 hour race duration (which would need 2 drivers per car). As had become usual regarding the popularity of AIACR rules, only 3 races out of 6 classics followed this latter requirement.

Bugatti was CoY with a new T51 IL8 2.3 L with a major technical change which provided a very interesting comparison with his previous designs. Late in 1929 he had bought from an American, "Leon Duray" (the *nom-de-course* of George Stewart) two Miller FWD IL8 1.5 L centrifugally-supercharged track-racing cars. Duray had driven each in turn in heats of the Monza GP but both broke down after showing high straight-line speed. The owner then had not enough money to take them back to the USA. Bugatti tested one of these engines to compressor destruction, showing 208 HP (141 HP/Litre)(28), probably on the usual Elcosina fuel used by Bugatti. This test persuaded him for the first time in his life to adopt the ideas of another designer. The first results were new DOHC inclined 2-valves per cylinder heads for the production T50 and a new racing T51. It may be remarked that he could have done that after the example of the 1922 2 L FIAT racing and winning the French GP just down the road from his Molsheim factory, even after ignoring the 1921 FIAT 3 L which started the inclined 2-valve hemi-head approach at Monza. Certainly Harry Miller had not neglected the advantage from that architecture in mid-1922, apparently from a suggestion by Colonel Hall (6) who may have studied the FIAT initiative.

The T51 had finger-cam-followers, unlike Miller's use of inverted cups. Its iron head was still integral with the cylinder block which was fitted on the T35B bottom-end. The much-cheaper and lighter plain bearings of the Miller – and also of the MaseratI and sports Alfa Romeo engines – had yet to be appreciated by Bugatti, although the advantage of rolling-bearings in an oil-starved situation is valuable as Note 39 reminds us.

A detailed comparison between the T35B and the T51 is given on Note 40. A power gain of 26% resulted, mostly from higher BMEP, not only from easier charge inflow through the inclined valves but also from higher combustion efficiency – the MGVP having been pushed up to 86% of the optimum 75 m/s (from 64%), the maximum flame travel reduced 25% and the exhaust valve opening cut by 23^0 (from 250^0 to 227^0, very like the Miller).

The T51 combined efficiency (designated from here as 'ECOM') was 45%, which was 7.2% points higher than the T35B. More generally it was 4.1% points above the average of the T35B, T35C and T39A and rather better than the 44.1% average of the P2, 2LCV and 15-S-8.

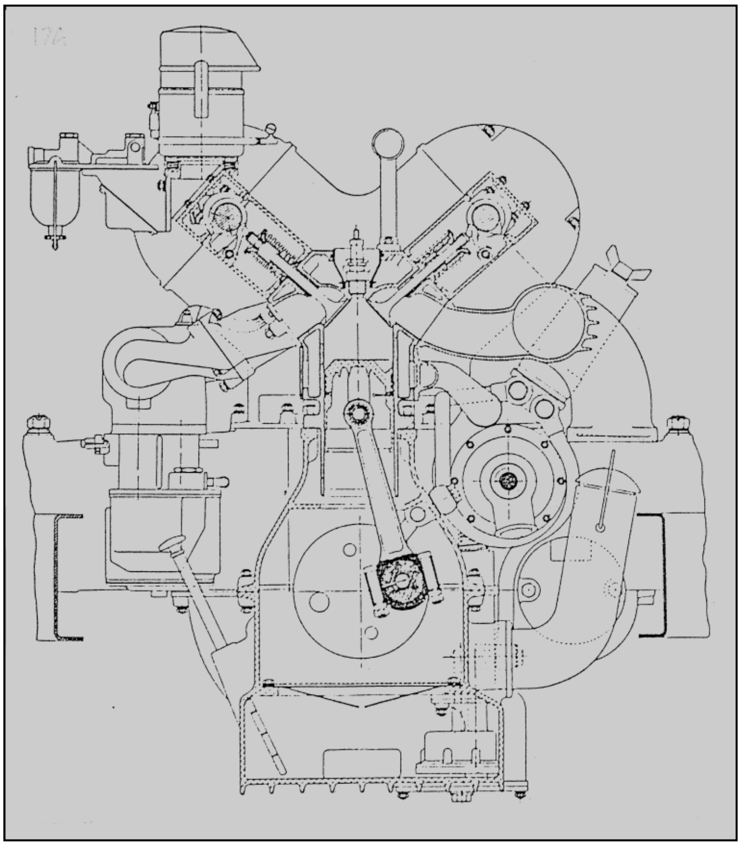
From 1931 all CoY engines were DOHC, excepting only 1936, 1966 and 1967. If not otherwise mentioned for those years this valve operating system may be taken as the case.

It has to be recorded that the Bugatti T51 was the last of this famous marque to be CoY.

Fig. 17A
1931 Bugatti T51
IL8 60/100 = 0.6 2,262 cc

The section given here is actually a T57 naturally-aspirated sports engine
, for which B/S = 72/100 = 0.72 and 3,257 cc, but the top-end architecture is the same as the T51.
The T51 bottom-end was the same as the T35B shown on Figs. 15A and 15B.

DASO 26



18. 1932 Alfa Romeo B (P3*); 2,655 cc; 215 HP @ 5,600 RPM (See Figs. 20A, 20B)

For 1932 the AIACR permitted *Formule Libre*, provided that the race duration was at least 5 hours, and 2 out of 5 classic GPs were organised to those rules.

Alfa Romeo produced in mid-season their Type B "*Monoposto*" (also known unofficially as the "P3"*), IL8 2.65 L with B/S = 65/100 = 0.65, designed by Jano. This was CoY.

The *Monoposto* was:-

- The 1st GP racing car *built* as a single-seater (it had about 5% less frontal area than the Bugatti T51 (4);
- The engine was the 1st to have all-light-alloy cast static structure. Block and head were integral in Al-alloy with dry steel liners, while the crankcase and sump were Mg-alloy (25) (the car, with other lightweight features, was about 7% lighter than the T51 (700 Kg v. 750) (25,28)
- The 1st *re-use* throughout of plain white-metal bearings since the 1914 Mercedes.

Another CoY novelty was a split 8-cylinder crank with central drive to the DOHC and also to twin parallel-flow Roots superchargers

Jano had used previously these features successfully in his 1931 Type 8C-2300 IL8 2.3 L 65/88 = 0.74 sports-cum-racing car (named "*Monza*" when in short-chassis form after it had a major win there), except that this predecessor had a detachable head and a single supercharger. Jano acknowledged the originator of the central camshaft and blower drive to be Emile Petit with his 1928 Salmson IL8 1,100 cc car (25). This feature gave a torsionally "quiet" point for these subsidiary power offtakes but no other CoY IL8 designer adopted this method until the 1954 Mercedes-Benz M196 at a much higher B/S ratio (the M196 also took the primary power from the crank centre).

White-metal bearings actually had been included by Jano since 1926 in his IL6 1.5 L and 1.75 L sports Alfas, with a satisfactory performance history (the 1.5 L mounted the 1928 Mille Miglia winner and the 1.75 L provided the same service in the 1929 and 1930 Mille Miglias). They were not only lighter but also much cheaper than ball or roller bearings both in first cost and by having a longer life, *provided* that they were kept within known temperature limits and not abused by oil shortage. Cost had become an important factor, even in racing, in those years of economic slump following the October 1929 Wall street stock market crash. The MPSP at 18.7 m/s of this new Alfa was as high as any sustainable speed achieved by a rolling-contact-bearing engine. Friction loss at design speed (i.e. at an appropriate value of the ratio

$$\left(\frac{\text{Viscosity x RPM}}{\text{Bearing Pressure}}\right)$$

where the lubricant film has been formed (625) (see Note 18)) was not *necessarily* much higher, only at start-up (594) (the Alfa sports-car team took care to fill their engines with warmed oil before a race began). However, combined efficiency (ECOM) at 41.7% was 3.3% points below the T51 so perhaps the plain bearings *did* affect performance. Note 39 tells a tale about oil shortage effect in a *Monza*.

The *Monoposto*, as outstanding as the P2 had been (3 classic races entered, all won) was built by a firm which had money trouble as early as 1922 and only survived by the aid of various Italian government financial bodies *plus* the interest in racing of the dictator Mussolini (who chose an Alfa for his official car in 1925 (25)). This support was for Fascist prestige as well as personal reasons. Nevertheless, to satisfy the official accountants, withdrawals from racing were announced from time to time. After one of these, at the end of 1929, the *Scuderia Ferrari* was organised by that ex-works driver with an off-factory base in Modena to manage the marque racing (8). The team was supported by wealthy customers competing with their own Alfas. [This background has been included because of the importance of Ferrari to the continuing history of motor racing up to the present day.]

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*It seems that "*Tipo B*" was the factory designation but, after its successful debut, Alfa's publicity department called it "P3" although it was not in direct chronological sequence from the famous "P2".

19. 1933 Maserati 8C-3000 (8CM); 2,991 cc; 230 HP @ 5,500 RPM (See Fig. 19A)

With *Formule Libre* retained for 1933 but now with 500 km maximum race distance, the French GP winner and CoY was a new IL8 3 L type 8C-3000 Maserati. Designed by Ernesto of that family of brothers (Alfieri having succumbed to an old accident injury in 1932), this was basically an enlargement of a 1931 unit of 2.8 L, which was itself an over-bored version of the 2.5 L of 1930. It retained the features already described for the 2.5 under Eg. 14.

The 3 L Maserati followed the general increase in swept volume which had occurred in CoY during the 1928 -1933 *Formule Libre* events after the 1.5 L formula ended. The new objective, freed from AIACR capacity rules, was to obtain the highest possible power which could be deployed usefully with the current chassis layout on road courses. A table shows this growth for CoY engines.

1928	1929	1930	1931	1932	1933
Bugatti	Bugatti	Bugatti	Bugatti	Alfa Romeo	Maserati
		V cc			
1,991	2,262	1,991	2,262	2,655	2,991

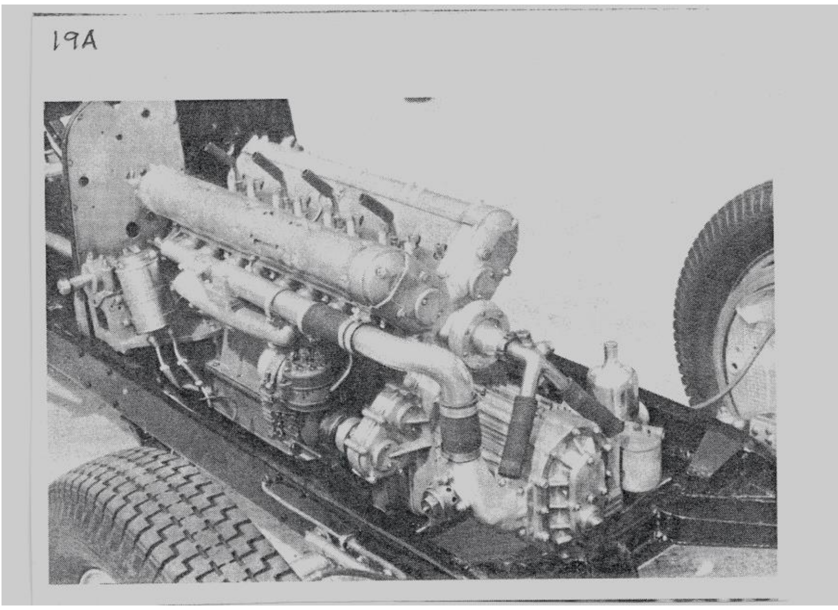
[Substantially more powerful cars were built for *Formule Libre* racing in a limited number of events but none became CoY. Note 41 gives some details of these.]

The value of ECOM for the 8C-3000 was 41.2%, a drop of 0.5% point from the Alfa P3 (which did not race for most of the 1933 season due to the firm's money troubles).

The first two 3 L Maseratis, of which the French GP winner was one, were built (as before with this firm) as nominal 2-seaters. Later cars were *Monoposto* and designated as 8CM. The 1933 French race was therefore the last of the classic series to be won with that type of body, although in 1936 - 1937 the French ran their major race for 2-seater sports cars so as to prevent the Germans winning!

[When developed with higher supercharge pressure and an integral head + block as the 8CTF (TF = *Testa Fissa*, "Fixed head") the 3 L Maserati achieved fame as the first European car to power the Indianapolis 500 winner since 1919, which it did in both 1939 and 1940 driven by Wilbur Shaw.]

Fig. 19A
1933 Maserati 8CM
IL8 69/100 = 0.69 2,991 cc
The SU carburetter shown was fitted on serial no. 3011 in 1934,
in place of the original Weber, when the car was bought by Whitney Straight.
The water-pump to radiator pipes are shown disconnected.
DASO 977 p.86



20. 1934 Alfa Romeo "P3B"; 2,905 cc; 255 HP @ 5,400 RPM (See Figs. 20A, 20B)

In October 1932 the AIACR published the rules to apply to 1934 – 1936 which consisted principally of a maximum empty car weight of 750 Kg (dry and excluding wheels and tyres - there seems to have been no *reason* for the latter two exclusions, it was just their *policy*!). This limit they believed would peg speeds to those obtained in 1932 with engines some way under 3 L.

Alfa Romeo were able to meet the weight fairly easily with a *Monoposto* type B, whose engine had been enlarged to 2.9 L, the Scuderia Ferrari-run-team figures at the official French GP weigh-in being 720 to 730 Kg (2.7% margin)(940). In this race they defeated 3 new Mercedes-Benz type W25 and 2 new Auto Union type A, as well as Maserati 8CMs and the new 3.3 L Bugatti T59s.

The Germans were competing in the premier French race for the first time since 1914. With their new and duplicated technical approaches much was expected of them. Their novelties included especially:-

- 4-wheel independent suspension in place of rigid axles, to eliminate steering shimmy, to improve traction by eliminating torque reaction and, by reducing unsprung weight, to aid roadholding;
- Mid-chassis-engine location for the Auto Union, to reduce simultaneously frontal area, weight and change of weight distribution with fuel usage.

Yet Alfa Romeo took the 1st *, 2nd and 3rd places, together with the Fastest Lap by the winner, and no German machine finished!

Although the full season showed a very different pattern as the new German designs were brought *au point* nevertheless using the French Grand Prix as a criterion for the last time in this review Alfa are accepted as CoY.

As in 1923, the old technology beat off the new at the first major encounter.

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*Admittedly, the Monogasque Louis Chiron, who won, jumped the start from the 3rd row drawn by lot and, being an"honorary Frenchman", was allowed to get away with it. It did not actually affect the result.

Fig. 20A
1934 Alfa Romeo Type "P3B"
IL8 68/100 = 0.68 2,905 cc

Note the dry liners (steel) in the cast Al-alloy integral block and head, the plain bearings and the side-mounted 2-lobe Roots supercharger section (actually one blower for each 4-cylinder block).

DASO 184

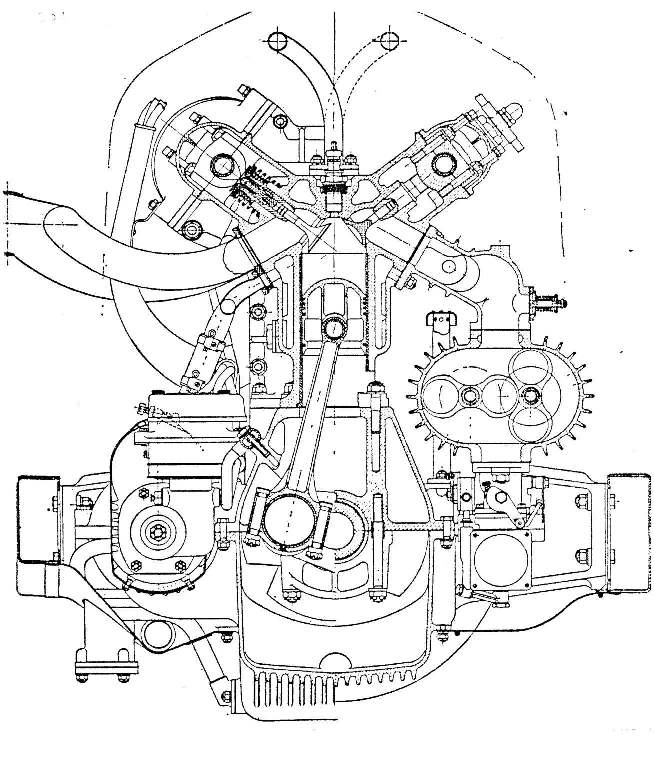
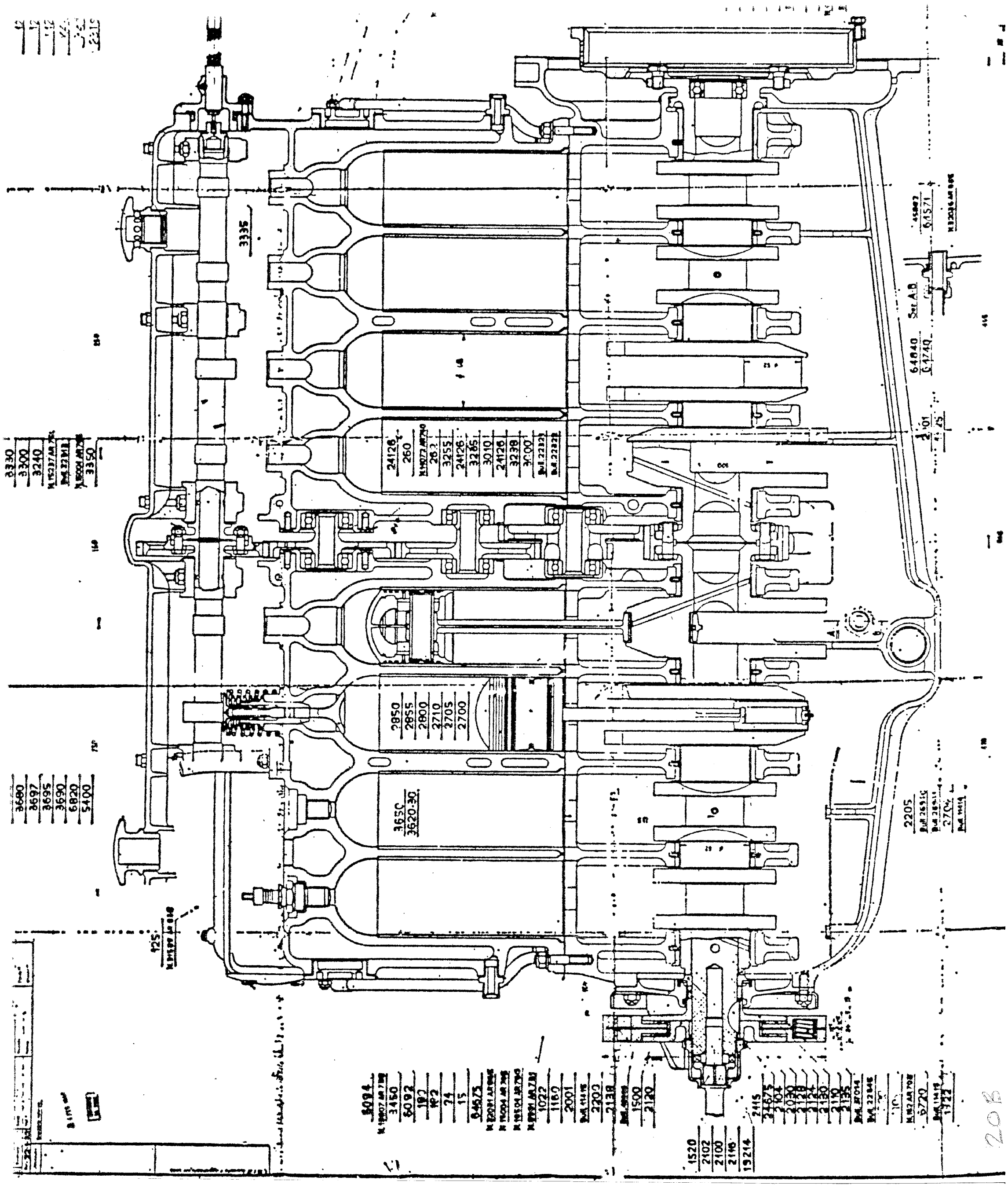


Fig. 20B
1934 Alfa Romeo Type “P3B”
IL8 68/100 = 0.68 2,905 cc
Note the central gear train driving the camshafts
and also the 2 superchargers from the 2-piece bolted-up crank.
DASO 184



Although captioned in DASO 184 as a 1932 Type B (P3), which was 65/100 = 0.65 2,655 cc, this drawing is marked in No. 6 cylinder as the 68 mm Bore of the “P3B”.

However, both of these Figures can represent the original Eg. 18.

<u>21. 1935 Mercedes-Benz M25C; 4,309 cc; 397 BHP @ 5,500 RPM</u> (See Fig. 21A)

<u>23. 1937 Mercedes-Benz M125; 5,663 cc; 548 BHP @ 5,800 RPM</u> (See Figs. 23A, 23B)

The original period for the 750 Kg formula of 1934 -1936 was extended later to include 1937.

It is logical to treat the years 1934 -1937 in one block where the Mercedes-Benz CoY for 1935 and 1937 are concerned, since there was a steady development of one general engine design.

Similarly the rival Auto Union engines can be considered together over that period, being CoY in 1936 (see Eg. 22).

It is also convenient to say immediately that the reason for the unprecedented spend on racing by these two German teams was very much Adolf Hitler's stated intention in February 1933, when opening the Berlin Motor show (607) to use motor-racing successes to promote Nazi technical prestige (4). It followed the precedent set by Benito Mussolini with Alfa Romeo. This was apart from the companies' own desires for advertising, in particular by the newly-formed Auto Union group, and also the Daimler-Benz long-term policy of racing to improve their technical knowledge. The teams' racing programmes had to be approved by the Nazi motor sport organisation (NSKK)(468). While Hitler arranged for small direct subsidies to be paid to Daimler-Benz and Auto Union these (at 0.225M RM p.a. each (468)) were *negligible* compared to their outgoings as they strived by might and main to beat each other. In later years these expenditures were financed by the profits of rearmament contracts retained under a 6% company dividend limit imposed by the state in September 1936 (772). Daimler spent twice the amount allocated by Auto Union (10M RM p.a. versus 5M, according to von Eberhorst)(607) and secured greater success.

After mid 1934, until their country precipitated World War Two, when the Germans entered a race all other contenders, with a very few occasional exceptions, can be summed up as "Also Ran".

Over 1934 -1937 both companies had new engine objectives which were different:- for Mercedes, to obtain the highest Power/Weight ratio; for Auto Union, to obtain the highest Torque/Weight ratio. Both worked towards their objectives by increasing Swept Volume (V) at more-or-less constant RPM and supercharger pressure within the cylinder centres first chosen (until that dimension was increased in 1937 for the Mercedes M125).

The powers increased far beyond the level which the 1932 rule-makers had supposed possible.

<u>Mercedes-Benz M25</u>

When designing the new Mercedes M25 engine Hans Nibel and his team drew particularly on the last Grand Prix unit from the company, the 1924 M218, designed by Ferdinand Porsche. They also had available a new IL8 3.3 L independently-sprung car design which Porsche had done before leaving the firm in 1928 (according to his son in ref. (607)).Mercedes-Benz also built in 1933 a 1-cylinder research engine (M25 *Versuchs*) – almost certainly a 1^{st} in motor-racing (468) although aero engineers had used such experimental tools for some years to reduce the cost of full-configuration tests.

The M25 retained the following M218 features:-

- IL8 configuration;
- Built-up steel integral head + block, used by Daimler since the 1912 *Kaiserpreis* aero engine;
- 4-valves-per-cylinder at 60^0 (an angle which was the maximum set by the need to insert the valves from the cylinder);
- Sodium-cooled exhaust valves (later engines used mercury which they found more effective (311);
- DOHC with finger cam followers;
- FIAT-type split-race roller bearings for mains and big-ends – only 5 mains to reduce friction. Although Alfa Romeo and Maserati had shown that cheaper and lighter plain bearings could be satisfactory for Grand Prix racing, Mercedes probably retained rolling-contact bearings because they could withstand an interruption of oil supply for some time and the company philosophy was always "Reliability regardless of cost".

The B/S ratio was pushed up on the M25A in 1934 to 78/88 = 0.89 from the 0.75 of the M218.

A major change from the M218 was a vertical front-mounted Roots supercharger (for better cooling versus the previous horizontal rear-mounting) feeding 2 *pressurised* double-choke carburettors rather than sucking mixture. The latter M218 arrangement, both theoretically and practically, was more powerful because of the better fuel evaporative cooling but Mercedes were dissatisfied with the suction system. It had a poor throttle response due to a larger gas volume between throttle and inlet valves. The pressurised carburetter system, used on all their other supercharged engines, had to have a valve after the blower which opened to let air overboard on the over-run when the downstream throttles were shut – this escaping air produced the shrill whistle characteristic of these Mercs. Another valve *could* have been linked-up *ahead* of the blower to shut off the entry on the over-run but perhaps Mercedes preferred the extra braking effort of the scheme used. A choice of inlet manifolds of different diameters was provided (carefully-branched to each cylinder) so that on twisty circuits a quicker pick-up could be obtained by a smaller gas volume at the cost of some extra pressure drop and power loss.

A detailed comparison between M218 and M25A is given in Note 42 (so far as available for the M218). The parameter nearest to being the same between the two designs is:-

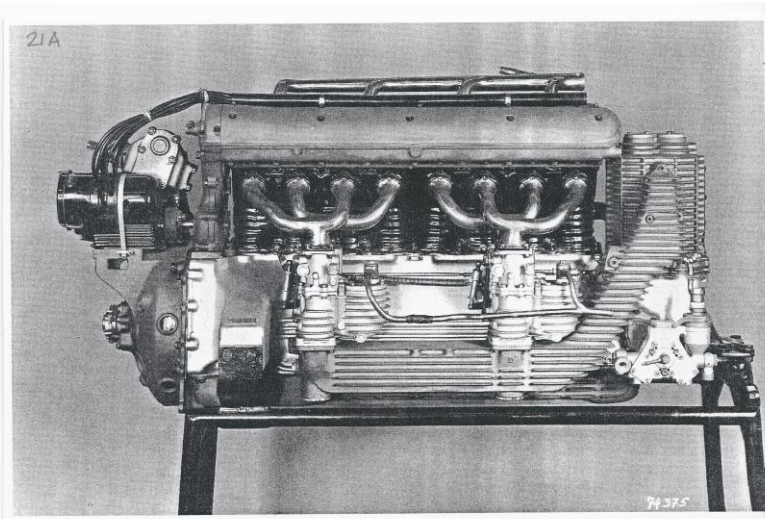
[(PPA/V)/MDR] at about 75 Adjusted HP per Litre per unit Manifold Density Ratio.

The ECOM comparison was:- M218 40.1%;
M25A 48.6%, a remarkable apparent gain of 8.5% points.
The Alfa Romeo P3B ECOM had been 48.2%, the P3 41.7% and the previous best supercharged engine the T51 at 45%. Perhaps both the P3B and the M25A should be regarded with some suspicion!

Eg. 21 1935 M25C

Attention has been given up to here to the initial new Mercedes-Benz engine for the 750 Kg formula, the M25A of 3.36 L. During the first season there was a lot of rapid capacity development and engines M25AB of 3.72 L and M25B of 3.99 L were raced in 1934. For 1935 the M25C of 4.31 L was available and it powered the W25 to 5 victories out of 8 races contested. Shifting the criterion for CoY to the most successful unit in a year, the M25C was CoY engine. The year is famous in motor racing history for the defeat of the home teams at the, by-now all-important, German Grand Prix by Tazio Nuvolari driving an Alfa Romeo P3B with an engine enlarged to 3.2 L and fitted with independent front suspension.

Fig. 21A
Representing
1935 Mercedes-Benz M25C
IL8 82/102 = 0.804 4,309 cc
This photograph is actually of an M25B engine raced towards the end of 1934, being 82/94.5 = 0.868, 3,992 cc, but the externals were identical on the M25C
Note the pressurised carburettors.
DASO 468 p.146.



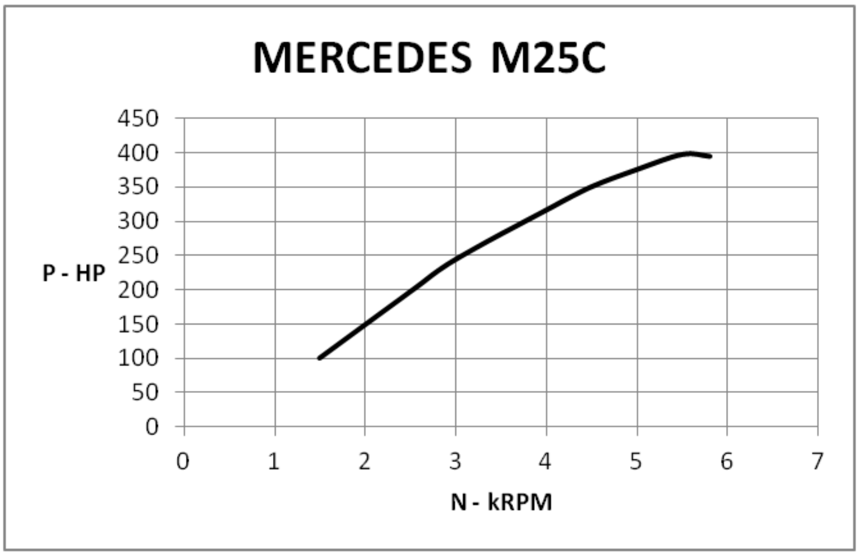
A power curve is given on P.19.

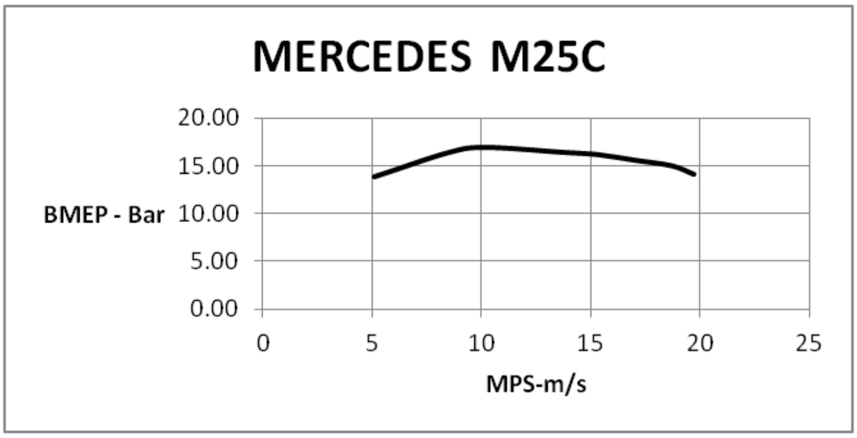
POWER CURVES

Eg.	21
DASO	468
YEAR	1935
Make	Mercedes
Model	M25C
Vcc	4309
Ind. System	MSC
Confign.	IL8
Bmm	82
Smm	102

N	P	MPS	BMEP
kRPM	HP	m/s	Bar
1.5	100	5.1	13.84
2.5	197	8.5	16.36
3	244	10.2	16.89
4	316	13.6	16.41
4.5	350	15.3	16.15
5	375	17	15.58
5.5	397	18.7	14.99
5.8	394	19.72	14.11

Powers as published were German PS and have been divided by 1.014 to convert to HP.





Eg. 23 1937 M125

During their successful 1935 season Mercedes-Benz decided to go for substantially higher power in 1936 by designing a 60V12 engine of 5.58 L. The estimated extra weight of this was to be offset by shortening the (rather weak girder) chassis from a wheelbase of 2723 mm to 2464 (-9.5%). When completed in September 1935 the power increase of the new type DAB engine over the M25C was 33%, a little over pro rata to the capacity increase of 29% but at 295 Kg it was 80 Kg heavier than the M25C. Although this *could* still be accommodated within the 750 Kg formula* it placed too much weight on the front wheels for reasonable agility (468).

Therefore, a further enlargement of the IL8 was built, the ME25 of 4.74 L. This engine was unreliable in 1936 and the car's handling was bad**, despite moving to a de Dion rear suspension in place of the former swing axle.

Mercedes withdrew the team from races after August 1936.

Just before this drastic step was taken – and there had been earlier abandoned race entries (468) - a significant change had been made in the firm's organisation. A "*Renn Abteilung*" to do development work was added to the Experimental Department which built the cars and tested the engines. This was headed by a new young engineer, Rudolf Uhlenhaut. His tests and subsequent recommendations would henceforth be a major factor in all future Mercedes-Benz successes.

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*The W25 with ME25 engine had a specification weight of 712 Kg (468). Deducting the 211 Kg of that unit and adding the 295 Kg of the DAB gave 796 Kg. The non-counted wheels and tyres of the formula would have subtracted 53 Kg (figure from W125 data), so giving a formula weight of 743 Kg.

This V12 K*urz* (short*)* was entered in the 1937 AVUS race, which was actually *Formule Libre*, but had engine trouble in practice and did not compete (468).

**The W25 *Kurz*/ME25 badly caught out two good drivers:- Louis Chiron crashed one in the 1936 German GP; and Dick Seaman crashed another while training at Monza in early 1937.

Serendipitously, the 1934 – 1936 750 Kg formula was extended in September 1936 to run for a further year because agreement could not be reached on the next rule. This provided an opportunity for Mercedes-Benz to recover their prestige in the formula with a completely new car for 1937, the W125 with M125 engine. This was built in 5 months.

The chassis was longer than previously used, at 2797 mm (2.7% above the W25C), much stiffer and with long-travel front and rear suspension, the latter being an improved de Dion.

All previous M25/IL8 engines had been enlargements on a constant cylinder spacing of 95 mm – and had clearly gone too far in the ME25. The M125 was given 104 mm spacing to provide 5.66 L, other details being similar to the earlier engines *except* that by mid-season the inlet system had been converted from pressure carburation to suction (see details below).

The expense of all this for just one extra year was something Auto Union could not match and the new car became CoY with 5 wins out of 7 classic races. The disgrace of 1936 was expunged – but, just to keep the company on its toes, the last 1937 race was won by their German rivals!

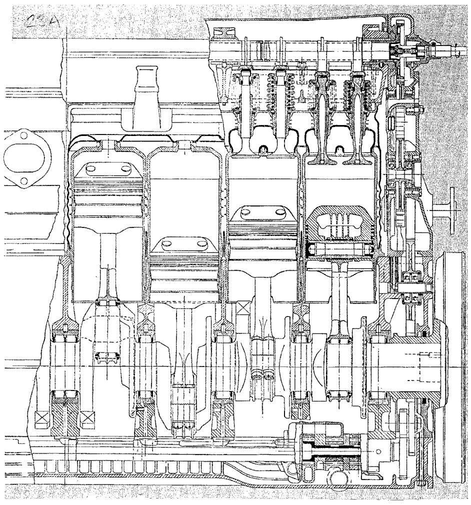
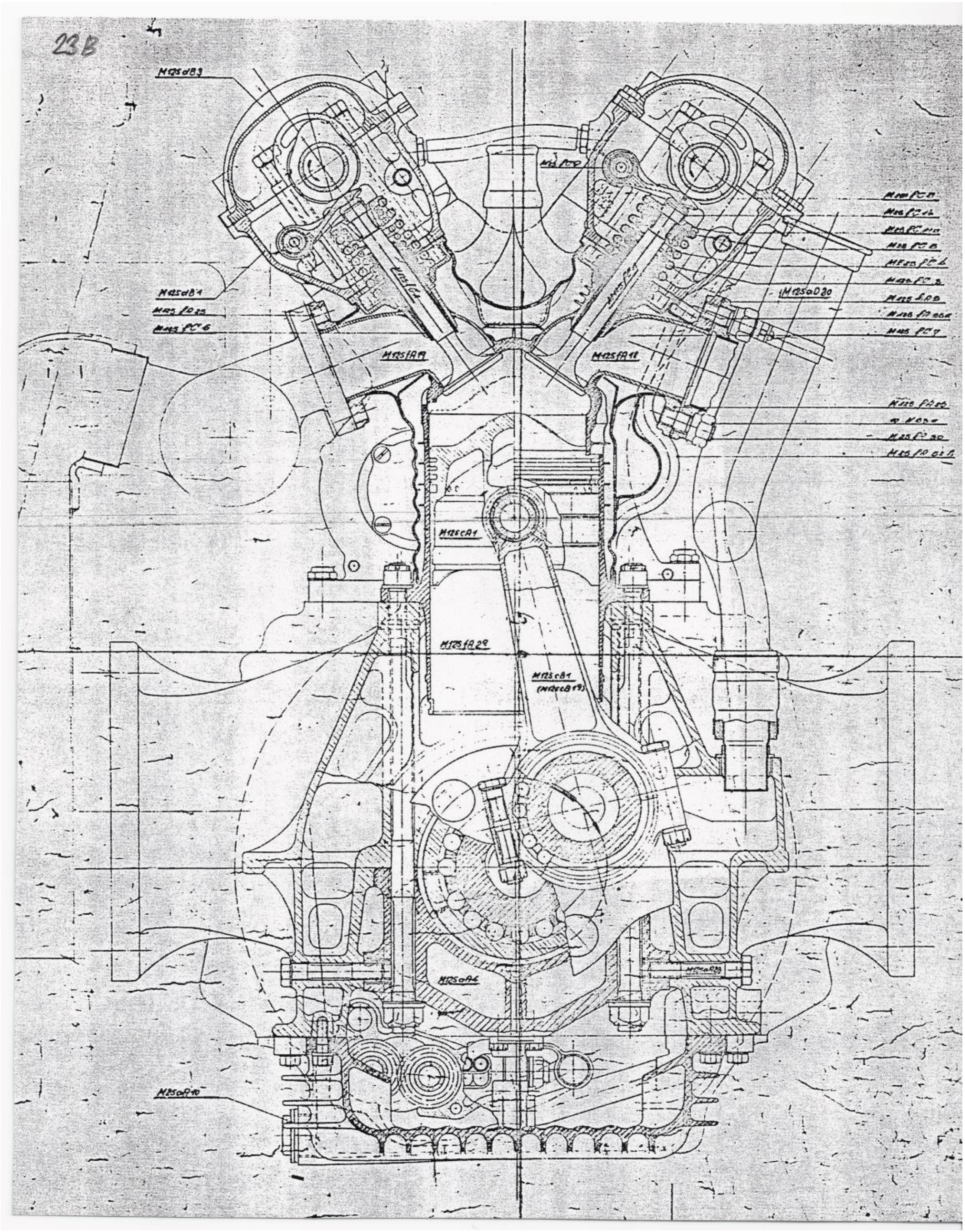


Fig. 23A
!937 Mercedes-Benz M125
IL8 94/102 = 0.922 5,663 cc
Showing the hollow exhaust valves
and 4-bolt connecting-rods.
DASO 4 p.230

Fig. 23B
1937 Mercedes-Benz M125
IL8 94/102 = 0.922 5,663 cc
Note the cross-bolting of the main bearing caps.
DASO 468 p.166

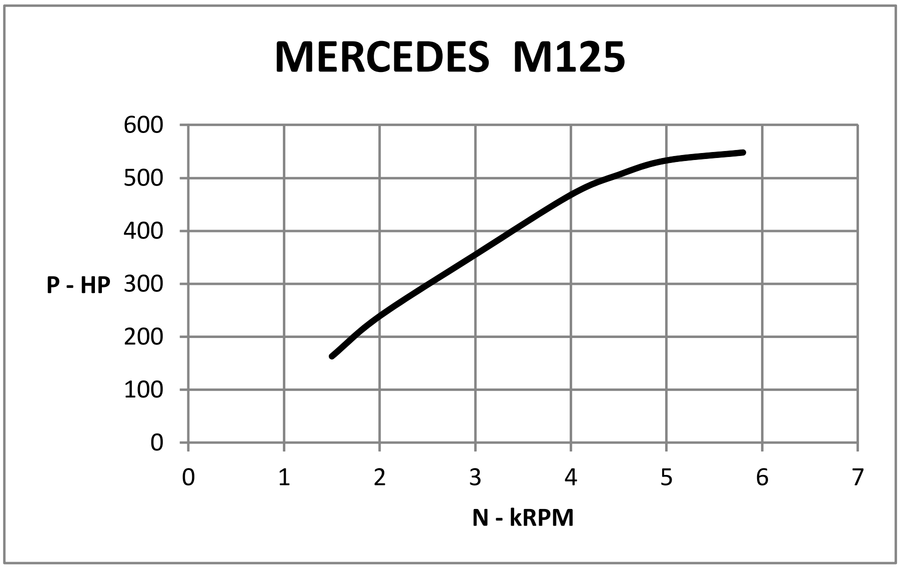


A Power Curve for the M125 is given on P.22, and details of the 1934 – 1937 development are given on Fig. 23C, P.23.

POWER CURVES

Eg.	23			
DASO	468			
YEAR	1937			
Make	Mercedes			
Model	M125			
Vcc	5663			
Ind. System	MSC	Suction carbn.		
Confign.	IL8			
Bmm	94			
Smm	102			
	N	P	MPS	BMEP
	kRPM	HP	m/s	Bar
	1.5	163	5.1	17.17
	2	239	6.8	18.88
	3	355	10.2	18.70
	4	468	13.6	18.49
	4.5	506	15.3	17.77
	5	533	17	16.84
	5.8	548	19.72	14.93

Powers as published were German PS and have been divided by 1.014 to convert to HP.



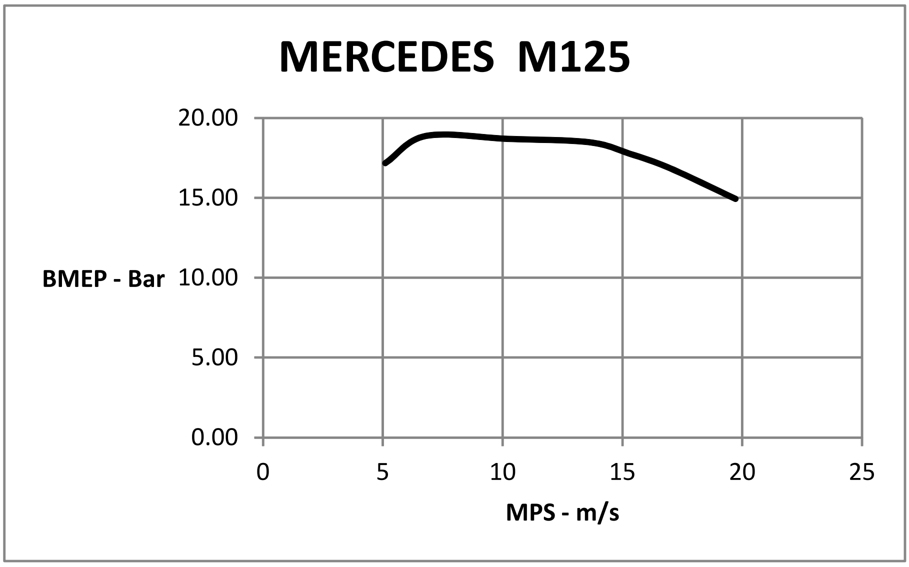
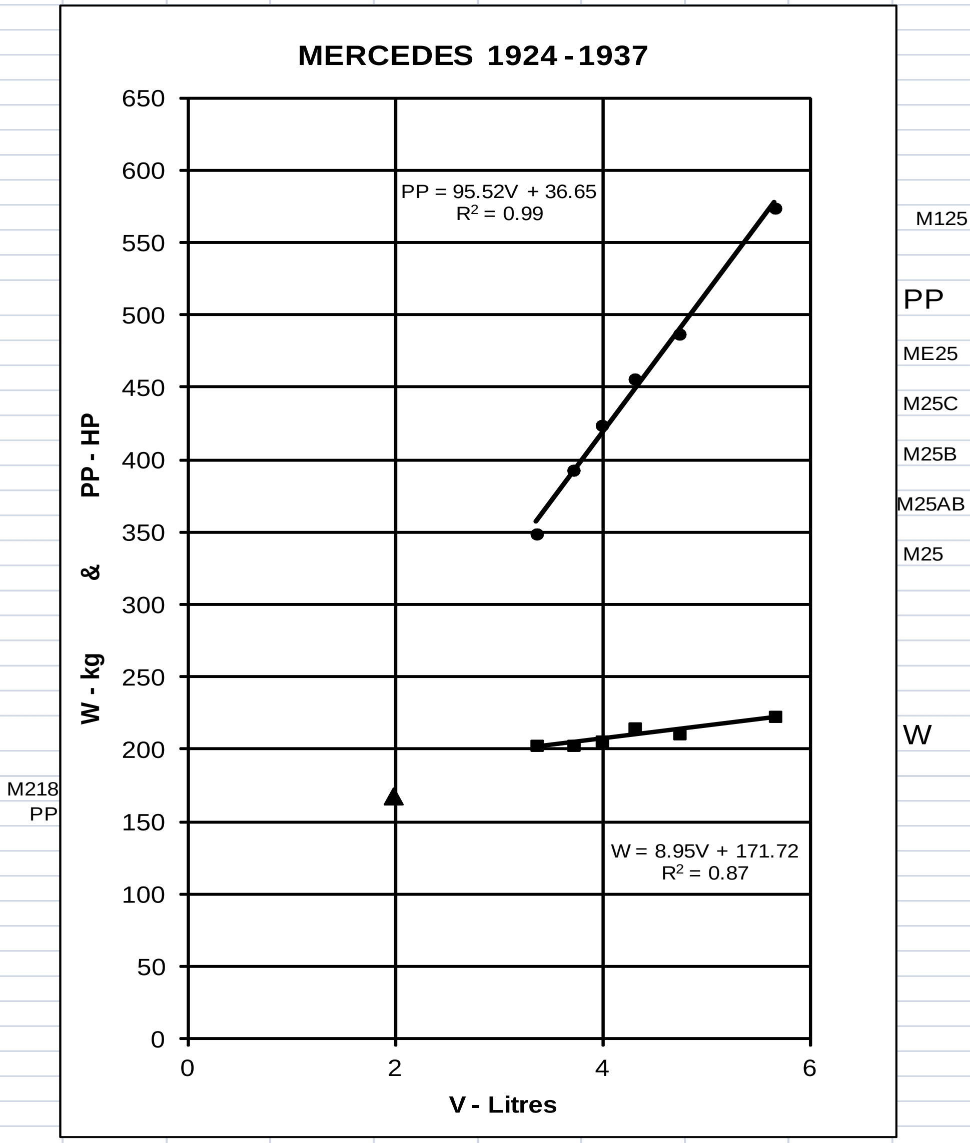


Fig.23C

DASO	468	4,468	4,468	4,468	4,468	4,468	4,468	4,468	4,468
YEAR	1924	1934	1934	1934.6	1934.7	1935	1936	1937	1937.5
Make	MERC.	MERC.	MERC.	MERC.	MERC.	MERC.	MERC.	MERC.	MERC.
Model	M218	M25A	M25A	M25AB	M25B	M25C	ME25	M125	M125
V Litres	1.981	3.364	3.364	3.718	3.992	4.309	4.740	5.663	5.663
Induction System	PC/Suctn	PC/Press	PC/Press	PC/Press	PC/Press	PC/Press	PC/Press	PC/Press	PC/Suctn
Fuel Type	P/B	P/B	A/WW	A/WW	A/WW	A/WW	A/WW	A/WW	A/WW
PP HP	168	310	349	393	424	456	487	574	580
PP/V HP/Litre	84.8	92.2	103.7	105.7	106.2	105.8	102.7	101.4	102.4
W kg		203	203	203	206	215	211	223	223
PP/W HP/kg		1.53	1.72	1.94	2.06	2.12	2.31	2.57	2.61
Relative PP/W			Datum	x1.13	x1.2	x1.23	x1.34	x1.49	x1.52



DASO	468	468
YEAR	1936	1937
Make	MERC.	MERC.
Model	DAB	DAB
V Litres	5.58	5.58
Induction System	PC/Press	PC/Suctn
Fuel Type	A/WW	A/WW
PP HP	608	726
PP/V HP/Litre	109	130
W kg	295	295
PP/W HP/kg	2.06	2.46
Relative PP/W	Datum	x1.19

A general review of Mercedes-Benz engine development, 1934 - 1937

Fig.23C gives data and a chart illustrating the development of the IL8 series of engines built for the 750 Kg formula and also data for the DAB 60V12 engine which was intended for 1936 but was too heavy and afterwards was developed for record-breaking. The 2 L M218 of 1924 is included as the last Mercedes Grand Prix engine before the “New Era”. Details and analyses are given in Note 43.

Fuel

These comparative figures are all given as bench tested on Standard Oil “WW2 fuel containing 86% Methyl Alcohol. This was used for short-distance record breaking. For circuit racing the fuel used to give adequate range varied in 1934 from 50% Petrol + 50% Benzole (S.O. “2B”) (which dropped power by 11% from all-WW), to 64% mixed alcohol (S.O. “XM”) in 1935 and then settled on a 50/50 blend of “XM” and “WW” plus additives in 1936 -1937 (a HP drop of 6%). Appendix 2 Notes & Appendix 2 Table give full fuel details and Appendix 1 for CoY data gives powers on the relevant racing fuel.   The plotted points are also all for pressurised carburetion.

Original Specific Weight

As already stated, the original M25A design of 3.36 L in 1934 had a cylinder spacing of 95 mm. It weighed 60.3 Kg per Litre. This was only 2% better than the 1933 Maserati 8CM 3 L at 61.5 Kg/L, i.e. the Mercedes had little advantage for the 750Kg formula in engine constructional method over a representative competitor of the “old school”. The actual difference of 203 – 184 Kg = 19 Kg had to be made up by a lighter Mercedes chassis (it is known that the W25 in 1934 was on the weight limit (468))

Enlargement

The basic engine was then enlarged in 4 further steps, as given on Fig.23C, to reach 4.74 L for 1936, which proved to be too much. Stimulated by their 1936 defeats Mercedes took advantage of the 750 Kg formula extension to 1937 to design a new engine at 104 mm cylinder spacing to obtain 5.66 L, the M125, which with its greatly-improved W125 chassis, restored the firm’s successes.

RPM limit

The maximum crank speed of all 6 engines was “placarded” at the odd figure of 5,800 RPM, regardless of increasing Stroke, so that Mean Piston Speed at max Power (MPSP) rose from 17 m/s to nearly 20, i.e. +16%,meaning +34% in piston stress.

This RPM limit was probably a Mean Valve Speed (MVSP) limit. This parameter was in the range of 2.37 to 2.5 m/s (which was only 5.5%) for all these 4 valve-per-cylinder DOHC units, because Inlet Valve Lift (IVL) was held at 8.5 mm and Inlet Valve Open Duration (IOD) was similar. For comparison, the average MVSP of DOHC engines from 1922 to 1932 was 2.4 m/s.

An interesting post-WW2 comment by Uhlenhauut (607), following a test-bed memo of 1937 (468), was that Mercedes drivers could if necessary over-rev their engines *briefly* to pass a 1934 – 1937 Auto Union near the end of a race, where the rival engines could not accept the same treatment because they had push-rod operated exhaust valves. The inference is that this emergency procedure would result in valve-spring failures and power loss if held too long. *Instantaneous* RPM of 6,500 *could* be reached in the M125 without the valves touching the pistons (468). It is concluded that 5,800 RPM was a race-life coil spring limit. Another interesting sidelight on the subject is that because von Brauchitsch was a notorious over-revver the works sought to protect his engines by exaggerating his tachometer scale to induce him to back off!

Supercharging

Supercharger pressure was at a mixed level over the 1934 – 1937 development. Inlet Valve Pressure (IVP) ran between 1.7 ATA and 2.1 and back to 1.8, so that the bulk of the 64% power gain (with the same carburetion) was from the 68% increase in Swept Volume (V), as shown on the chart of Fig. 23C, where the best-fit line nearly runs through the origin.

Change to carburetion

Regarding carburetion, a major change in mid-1937 was to replace the pressurised carburettors with a suction system. This brought Mercedes in the “New Era” at last in line with the layout initiated by Irving at Sunbeam in 1924 – actually also used on the 1924 M218 by Porsche, possibly an independent idea – and adopted by every other maker subsequently. However, as Mercedes had feared, a sluggish throttle response had then to be overcome with a variable venturi (double-choke) carburetter at blower entry and reduced manifold volume. The increase in power at maximum permitted RPM was very small, a tribute to their previous pressurised development, but the gain in torque at 52% speed was 14% and at 34% speed was 33%. This was attributed to the fuel-cooling of the supercharger rotors. The pressure system had to have an air-cooled Al-alloy casing clearance sufficient to prevent its more-rapid contraction on an RPM "chop" from fouling the still-hot steel rotors.

By inspection the suction system may have been a little lighter than the original M125 layout for which weight was quoted.

Gain in Specific Weight

Over the 4 years of development the overall engine weight increase was only 10% so that Specific Weight rose by 49%. Clearly, the original design at 60.3% Kg/L was just a "sighting shot" and had a very high safety factor, although this was exhausted on the ME25 which had some cylinder block failures (468). The non-scalar characteristic of complex machinery with size certainly came to the aid of the later engines, particularly the M125. This was only 39.4 Kg/L, despite having to go to 9 main bearings (from 5). This was offset at first by a lighter crank but an early failure called for substantial thickening. The resultant weight increase may have been offset later by the lighter carburetion system.

These 750 Kg formula engines in their later form were so minimal in material that they were not capable of being run for prolonged tests at high power without damage (311).This limited the amount of fundamental internal data which could be obtained.

Combined Efficiencies (ECOM)

The values of ECOM were as follows:-

M25A	`M25AB	M25B	M25C	ME25	M125	M125
			ECOM%			
	All on WW fuel and with pressurised carburetion except the final M125					
45.9	46.7	47.3	36.0	36.6	37.1	40.3

The drastic drop of ECOM at the M25C may have been due to a loss of Volumetric Efficiency (EV) as Mean Gas Speed (MGVP) rose:-

			MGVP m/s			
44.8	45.4	48.7	52.6	53.3	57.3	57.3

If this *was* the case there can have been no offset by improved fuel/air mixing to raise Combustion Efficiency (EC). In the suction-system M125 there would have been "mashing" of the mixture in the supercharger. The subject of "Optimum Gas Velocity at Inlet" is discussed in Note 34.

Mercedes-Benz W125 in sound and motion:- see Note 114

22. 1936 Auto Union C; 6,008 cc; 520 HP @ 5,000 RPM (See Figs. 22A, 22B)

Note 44 provides details and analyses of the Auto Union development from 1934 to 1937. The data is less complete than for Mercedes since the works and records fell into Russian hands in 1945 and the racing activities have not since received the full research such as Karl Ludvigsen devoted to Mercedes with that firm's full support in ref. (468).

The Ferdinand Porsche mid-engined "P-Wagen" design of 1932 – 1933, prepared by that very-experienced (although technically unqualified) engineer in his independent bureau and then sold to the new Auto Union group to build and race, was a complete break with his previous work. The chassis novelties have been described already (see Eg. 20). The engine, designed by Joseph Kales (711) was 12% more lightly constructed than the 1934 Mercedes M25, at approximately 53 Kg/L versus 60, which within the 750 Kg formula allowed it to be 30% larger in Swept Volume (V) than its rival, at 4.36 L. It was a 45V16, the only 16 cylinder car ever to become CoY which it did in 1936. A Vee-configuration was unavoidable for a mid-mounted large-capacity engine and 16 cylinders may have been chosen because it retained a crank like the many well-known IL8s. Balance is perfect. It had Al-alloy crankcase-plus-block with wet steel liners – another 1st in Grand Prix racing but Harry Ricardo had used that construction for his 1922 TT Vauxhall engine. Cylinder heads were detachable Al-alloy, which Maserati had pioneered in 1930.

Bore/Stroke ratio was 68/75 = 0.91 initially, a trifle higher than the M25A.

The "natural" 45^0 bank angle allowed an ingenious use of only one camshaft for the 2-valves-per-cylinder layout with VIA = 90^0. The camshaft operated the inlet valves through short levers and the exhaust valves by transverse push-rods and levers (see Fig. 22A).While lighter than 2 additional overhead camshafts the exhaust gear certainly imposed a limit on RPM. MVSP on that valve was 2.1 m/s initially, which was pushed up to 2.3 in the final development. This must have been extremely close to the maximum then possible with steel-coil-spring push-rod OHV. It can be compared to Mercedes reaching 2.5 m/s with direct cam operation. The 1937 rev-counter had a red sector which started at only 4,500 RPM representing MVS of 2.1 m/s (660). Uhlenhaut's comment on the Auto Union inability to over-rev has already been quoted.

Three more 1sts for the "P-Wagen", aka Auto Union type A, were:-

- Copper-lead for plain main and big-end bearings, which permitted very narrow bearings by accepting higher pressure than white-metal.
- An air/oil cooler in the lubrication system;
- Gudgeon pins running on needle-roller bearings.

Within the same block casting at the same cylinder spacing of about 85 mm the engine was enlarged in 4 steps to 6.33 L for record attempts (ref. 711 says it may have been raced in 1937).

Both Bore and Stroke were increased in mid-1935, with a new bolted-up long-stroke crankshaft on the Hirth principle having face dogs – another 1st – so as to permit one-piece con rods with roller bearings. Copper-lead bearings would have been overloaded after the enlargement, the Length/Diameter ratio being very restricted.

As Compression Ratio (R) and MDR were also raised substantially (the former equivalent to + 9% on Air Standard Efficiency (ASE), the latter by about +25%), plus 11% on RPM, the power increase for this type B at 27% greatly exceeded the capacity increase of 14%. Caution is needed with these figures since the fuel formulae are unknown. Probably the 1934 engine ran on 50% petrol/ 50% Benzole but the later units certainly had an alcohol-rich fuel. Since Standard Oil supplied both German companies it was probably similar to Mercedes' racing blends (311).

Weight is only known for certain for the 1936 6 L C-type which was CoY and also was raced generally in 1937. It represented 41 Kg/L, a little more than the 1937 M125 of totally-different design but similar capacity. Note 44B compares the ways in which the rival firms enlarged their Bores by reducing inter-cylinder spacing.

The values of ECOM for the Auto Unions are as follows:-

	1934	1935	1935.5	1936	1937
Type	A	B	*B/C*	C	R
			ECOM%		
	48.2	39.0	n.a.	40.7	40.5

The average at 42.1 is near enough the same as the Mercedes-Benz average of 41.4 over the same period and they both show a drop with enlargement.

Fig. 22A
Representing
1936 Auto Union C-type
45V16 75/85 = 0.882 6,008 cc

This section is actually a *B/C*-type with B/S = 72.5/85 = 0.853 and 5,614 cc which had the preceding B-type Bore but a new 85 mm Stroke crank built-up by the Hirth method to permit 1-piece con rods with roller bearings. Although the section seems to show crowded cage-less rollers there was in fact an Al-alloy cage (DASO 4). This interim type was raced in/after the 1935 French GP (DASO 381).
The C-type for 1936 then had an enlarged Bore.
Note the unusual mixture of SOHC and PROHV.

DASO 4 p.220

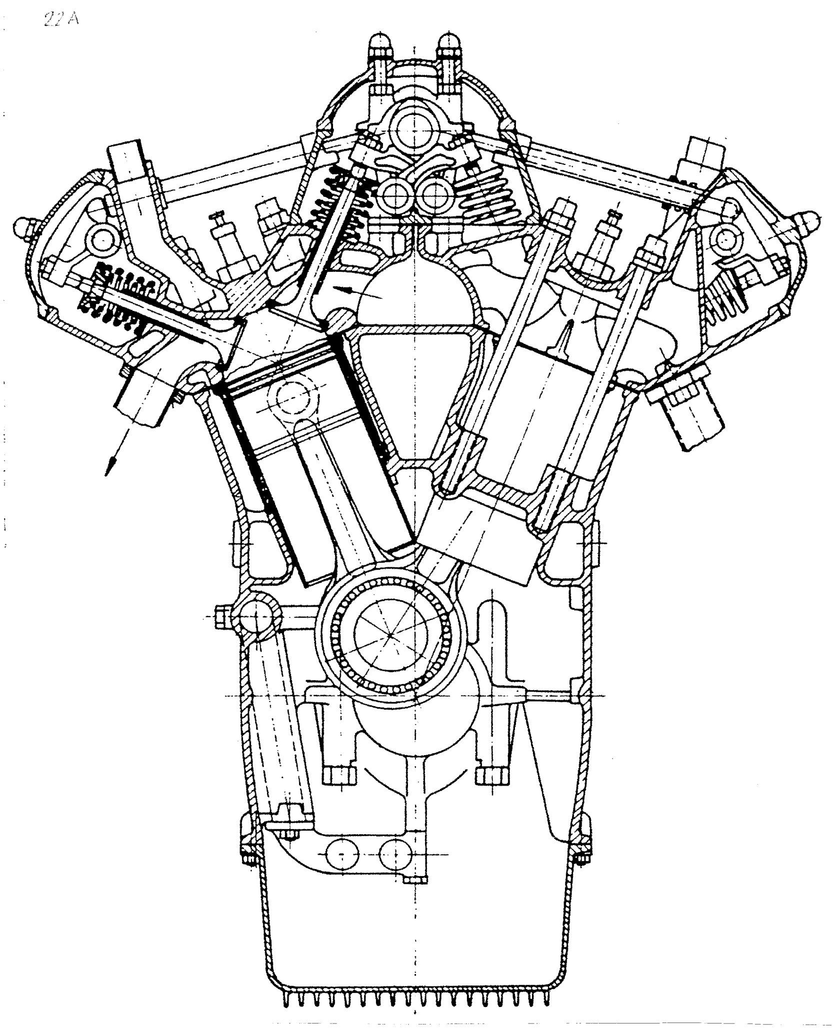
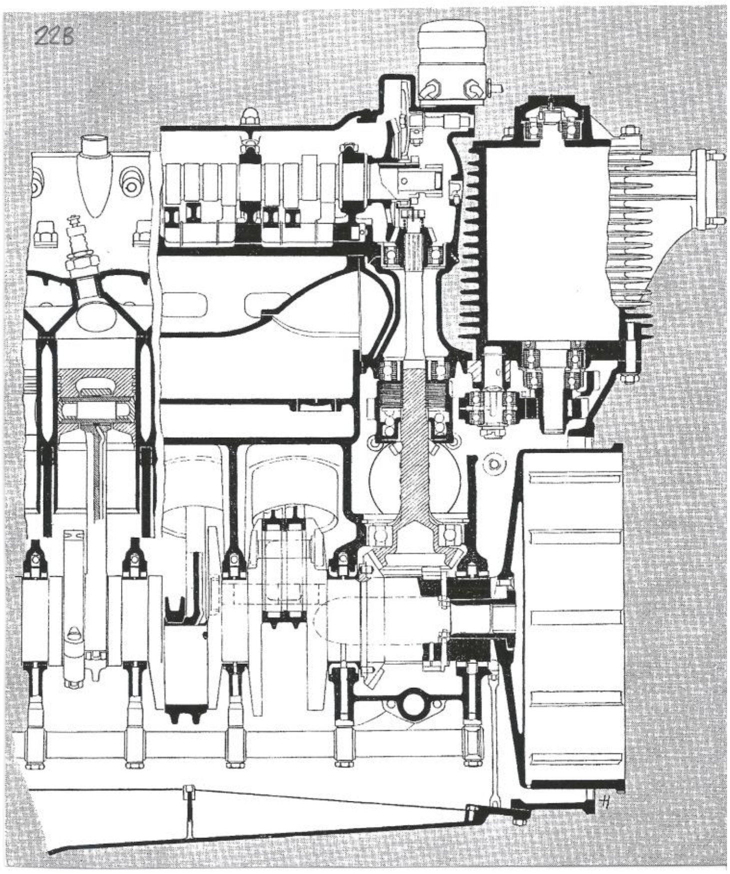


Fig. 22B

Showing the very-narrow plain copper-lead main bearings and the needle-roller little ends

DASO 4 p.219



Grand Prix 16-cylinder engines

The author is going to allow himself here to digress a little on the history of racing 16-cylinder engines!

The Porsche/Auto Union of 1934 – 1937 was the 1st Grand Prix engine with that cylinder number and the only one of several 16-cylinder attempts to win classic races and CoY, *bar* one BRM win (see below).

Alfa Romeo in 1938 built a 16 from 2 type 158 engines geared together in a common crankcase and two took creditable 2nd and 4th places in that year's Italian GP. Their 1939 type 620 3 L of Wilfredo Ricart's design was a true 135V16 but it was overtaken firstly by WW2 and then by the post-War capacity rule reduction to 1.5 L.

In 1949 BRM completed a 135V16 whose unfortunate history is too well-known to need repetition.

Coventry Climax built a F16 1.5 L in 1965 in the 2nd Naturally-Aspirated Era without bettering the power of their best 90V8.

These last two engines were simply too ambitious for the development resources available. Also, no doubt, they were hampered in efficiency by their small cylinders (see Note 20).

Another BRM 16-cylinder engine was built in 1966, a Flat-H 3 L NA with top and bottom 8-cylinder engines geared together. This was not short of development money – BRM even tried a 64-valve version - but it powered only one classic race win.

Regarding the necessary restriction of complexity by available talent, time and money, which is a matter calling for the highest technical judgement, it is interesting to recall a decision made in 1928 by Rolls-Royce when they accepted the Air Ministry's request to produce a racing aero engine for the 1929 Schneider Trophy. The Assistant Chief Designer Arthur Rowledge, a man with an impeccable CV in the field, proposed a new 45V16. Compared to a development of the large 60V12 H-type in production this would have allowed higher RPM and have a smaller frontal area (1065). Henry Royce, running the main off-site design office, chose the former route. The resultant R-type powered the 1929 win and was capable of improvement at short notice in 1931 to enable Great Britain to take the Trophy in perpetuity.

Comparison between Mercedes-Benz and Auto Union engine development, 1934 – 1937

A table below compares the parallel Power and Torque developments of the rival German firms over 1934 – 1937.

Mercedes were seeking the highest power where Auto Union preferred to improve maximum torque to minimise gear-changing. As an example of this, Bernd Rosemeyer proved that it was possible with the C-type to lap the twisty Nurburgring in top gear only, although unfortunately the time is not known (607).

		1934		1935	1936	1937	1937
				Maximum Power (PP) HP			
Mercedes	M25A	M25AB	M25B	M25C	ME25	M125	
						Pressure	Suction
						Carburation	
	310	342	365	397	447	542	548
			All figures on road-racing fuel				
Auto Union		A		B	C	C	(R)
		295		375	520	520	(545)
				Maximum Torque (TP) lb.ft.			
Mercedes	305	n.a.	363	432	459	553	629
Auto Union		380		477	627	727	(650)

So far as the engine contributed to victories (where chassis, tyres, drivers, organisation and *luck* were also significant, of course), the comparison of race wins where both teams competed shows:-

1934 Mercedes had more power, Auto Union more torque and the former were more successful (4 : 3 wins);

1935 The same power v. torque situation and an overwhelmingly Mercedes season (6 : 1);

1936 Auto Union had more power *and* more torque and well beat their rivals (AU 4 : 2 Merc, who scratched from 3 races);

1937 Mercedes once again had more power but mostly regained the upper hand in road-racing after obtaining much more low-RPM torque with suction carburetion (7 : 5).

The Mercedes approach – backed by much higher spend – was therefore more successful (overall 19 : 13).

Regarding chassis contribution, it is considered generally that the 1934 – 1937 Auto Union's extremely forward-mounted seat, combined with the type of suspension, hampered its drivers. When an ex-AU driver (Hans Stuck) was invited by the Mercedes team manager to try a W125 at the end of practice at Brno in 1937 he lapped 0.4% faster than the speed at which Hermann Lang (Mercedes) and Rosemeyer (AU) had tied for best lap (151 kph), saying afterwards that he had taken no more risks than he considered normal in the Auto Union (777).

24. 1938 Mercedes-Benz M154; 2,962 cc; 468 BHP @ 8,000 RPM (See Figs. 24A, 24B)

The AIACR settled the rules for 1938 – 1940 finally in September 1936, producing two scales of Minimum Car Weight related to Maximum Swept Volume (V), one scale for Pressure-Charged (PC) engines up to 3 L and another 50% higher in V, i.e. 4.5 L, for Natural Aspiration (NA). The intention, once again, was to reduce speeds from those of the 750 Kg cars. This was the first time PC had been recognised officially for Grand Prix racing (excluding a ban on PC in 1914) since the FIAT type 805 raced 13 years earlier. From 1937 onwards V would once again be the basic engine control rule, with a PC/NA ratio (sometimes with PC = 0, sometimes PC limited and on one occasion NA = 0), with or without a fuel quality or quantity limit – see Table 1 in The Sporting Limits earlier in this review.

The non-scalar weight content of cars v. V and associated power (see Note 8), which was not recognised in the new rules, soon showed that the largest permissible V should be chosen, whether 3 L PC or 4.5 L NA. ERA did consider briefly entering in Grands Prix with their 2 L PC engine in a new chassis at the relevant formula weight but soon reverted to 1.5 L PC Voiturette racing.

Both Mercedes and Auto Union chose the 3 L PC option, although the former had some precautionary W24 (!) design and 1-cylinder test work done on the 4.5 L NA alternative which showed insufficient power (468). The French Delahaye and Talbot concerns did build 4.5 L competitors but, with one notable exception (Pau 1938, a win for Delahaye's 60 V12), were "also rans", as were Alfa Romeo with various 3 L PC cars. Maserati's type 8CTF IL8 3 L PC did provide a few frights to the Germans but generally the firm was too poorly-financed to enter a strong, reliable team. Their great days with that type came at Indianapolis with 1938 and 1939 victories by Wilbur Shaw with an American-prepared car.

Mercedes-Benz were CoY for 1938 after much development work and partly due to the tragic bad luck – or bad team management – of Auto Union in losing their "ace" driver, Rosemeyer, in early 1938. He was killed during an ill-advised record attempt with a non-GP car in windy conditions which had the car off the road. His eventual replacement as No.1 driver was Tazio Nuvolari but he only joined the team in mid-season after becoming disillusioned with Alfa Romeo. He then took some time to master the A U D-type mid-engined car, although its handling had been improved greatly over the C-type. What might-have-been was shown by Nuvolari's victories in the last two classic races of 1938.

The design objective for the 1938 Mercedes-Benz 3 Litre

Because of the new rules the engine design objective had reverted to "Maximum Power/Swept Volume".

Recapping from the section in this review on "General Design **of** Racing Piston engines":-

" The basic power equation can be re-arranged as:-

$$\frac{\mathbf{P}}{\mathbf{V}} \propto \frac{\mathbf{(BMEP) \times (MPS)}}{\mathbf{S}}$$

With MPS limited at a particular date by design convention and available materials and with BMEP at the best attainable level at that date (taking into account any rule limits on inlet charge pressure or on fuel quality), then, **if V is limited by regulation:-**

$$\mathbf{P} \propto \frac{\mathbf{1}}{\mathbf{S}}$$

Volume-Specific Power (Power/Swept Volume) has therefore been sought in such conditions by either **increasing the number of cylinders** (CN) to reduce S, or by **raising B/S ratio** or by a combination of the two methods".

Regarding B/S ratio, Mercedes over the previous 2 years built these 3 engines:-

- 60V12 DAB 82/88 = 0.932;
- IL8 ME25 86/102 = 0.843
- IL8 M125 94/102 = 0.922

They were prepared to push the ratio up to a little over 0.93 at 0.96.

Regarding the incentive to increase CN it must have seemed logical to go to 12 cylinders by drawing on the knowledge gained with the DAB and this was done, retaining the “natural” Vee angle of 60^0. While the DAB had been too heavy on the front wheels of a 750 Kg car the 3 L V12 would of course be lighter. Mercedes did consider a back-up IL8 but did not proceed with it (468).

As it happened Auto Union also chose a 60V12 with B/S = 65/75 = 0.867, pulling back from their 45V16. This was probably to shorten the engine so that the driver’s seat could be further back from the front wheels to give better control.

Given 12 cylinders and B/S around 0.96 the actual dimensions of the new Mercedes M154 engine were B = 67 mm; S = 70 mm, precise B/S = 0.957. Apart from side-by-side con rods instead of fork-and-blade in the DAB all other major features of the M154 were like the DAB and in keeping with standard Daimler racing engine constructional practice.

Supercharging and fuel supply

Two Roots superchargers in parallel were carried over from the DAB but horizontally-mounted instead of bevel-gear-driven vertical. The extreme Inlet Valve Pressure (IVP) of 2.4 ATA was chosen, where the efficiency of compression had actually dropped off to only 35% (calculated from ref. 468 data). In consequence, even after standardising on “WW” 86% methyl alcohol fuel for high evaporative cooling, the charge heating before cylinder entry reduced Manifold Density Ratio (MDR) to only 2. A special carburetter element developed for the DAB as a record engine was also fitted to the M154 (the “*Zusatz Schieber Vergaser”, ZSV, “*Supplementary Slide Carburetter*”)* where a 3rd throat whose throttle only opened at maximum boost gave a super-rich mixture, effective in extra power production with alcohol fuel. Some of this mixture – the 9% acetone content – went into the cylinders still liquid with the object of cooling the piston crowns and exhaust valves (30). Necessary because these parts now had to provide a specific output of 158 HP/L compared to the M125’s road-racing level of 97. The resulting fuel consumption at the Nurburgring rose 40% from 100 L/100 km in 1937 to 140 in 1938 (607).

Direct fuel injection into the cylinders had been planned at first, taking up experimental work with petrol on Daimler-Benz aero engines, and Fig. 24A shows this on the engine section. This was tried in a 1-cylinder rig but the favourable alcohol evaporative cooling effect on the superchargers and on inflow density was lost and the project was dropped.

RPM problems with valve gear and piston rings

At a race-finishing limit to MPS of about 19 m/s with 70 mm Stroke the maximum RPM adopted was therefore 8,000 (precisely 18.67 m/s). With a “peaky” power curve a 5-forward-speed gearbox was now required.

A very necessary improvement for the 8,000 RPM required was better valve gear to achieve a Mean Valve Speed at Peak RPM (MVSP) of 3 m/s, a 20% rise on the M125 figure. This took much development work and, in fact, valve bounce was still occurring at maximum speed (468). It is interesting to note that the M154 proved to have the optimum B/S ratio for the materials and technology of its time, since this “Top-end” limit on MVSP was combined with a “Bottom-end” MPSP limit on pistons, con rods and big-end bearings! These subjects are discussed in detail in Note 13 Parts I and III and Note 21.

There was another limit because the M154 also passed the plain iron piston ring flutter boundary (see Note 13 Part II). It therefore suffered excessive blow-by and high oil consumption. While cured sufficiently in normal conditions with extra rings and more scavenging, in hot weather it was necessary at pit-stops for tyres and fuel also to add oil.

Weight

Because of the non-scalar effect the M154 weighed 86% 0f the DAB figure (254 Kg v. 295) although only 53% of its Swept Volume (V). It is estimated that an IL8 3 L PC to Mercedes design standards would have weighed 78% of the M154 at 198 Kg (working from Fig. 23C). The difference in the V12 v. the IL8 was attributable to :- 4 extra cylinders; extra camshaft drives; twin superchargers v.one. With a rule now requiring a 3 L PC car to exceed 850 Kg (now including oil, wheels and tyres) this was not significant.

The V12 configuration lowered the Centre-of Gravity v. an IL8 and this reduced cornering roll with the softer springs introduced by Mercedes in the 1937 W125 so as to improve adhesion on the relatively-rough road circuits of the day (in contrast to the current very-smooth specialised tracks).

Driver over-heating

Note 45 describes an installational defect of the W154 which caused injuries to their drivers' feet and possibly the chances of winning the last two races of the 1938 season.

ECOM

The value of ECOM for the M154 was 45.2%, compared to the M125 at 38.1%.

The 1938 score card

Mercedes 4 : Auto Union 2.

Fig. 24A
1938 Mercedes-Benz M154
60V12 67/70 = 0.957 2,962 cc

This section shows the original design for Bosch direct fuel injection into the cylinders; pumps were to be mounted each side and the nozzles fitted in bosses under the exhaust ports. The system did not reach the racing units but the injection pump drives provided were used for additional oil scavenging pumps.

DASO 468 p.219

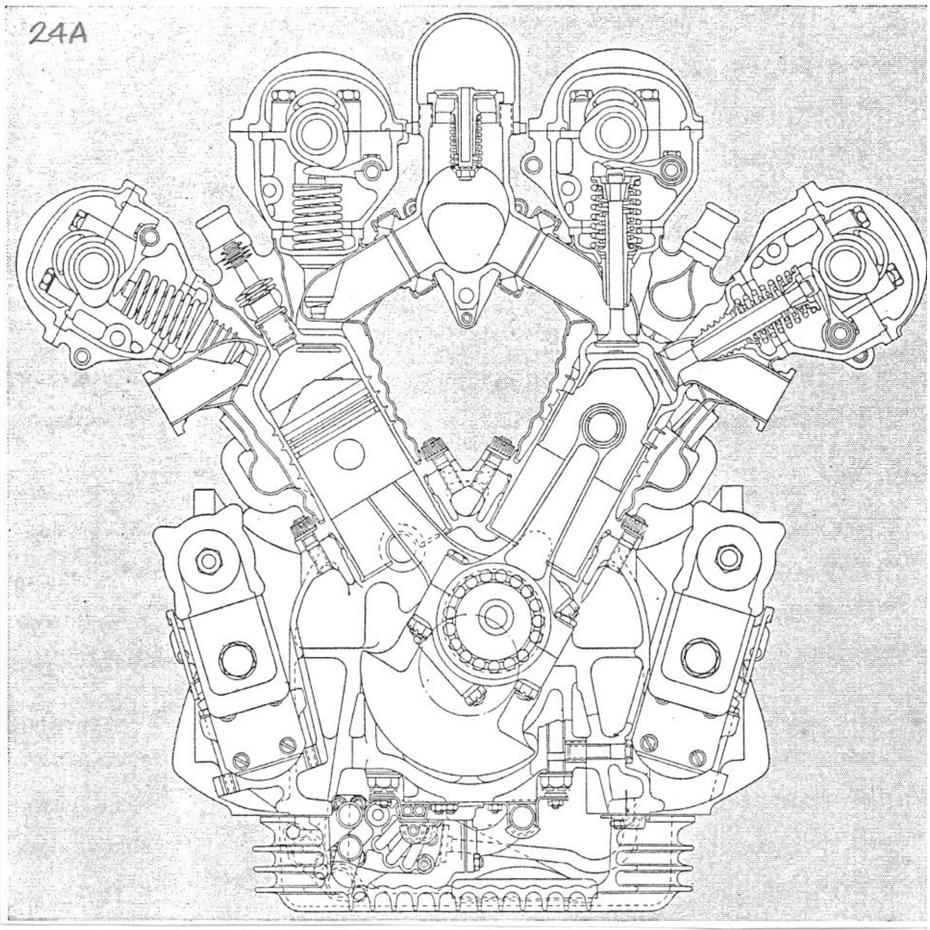
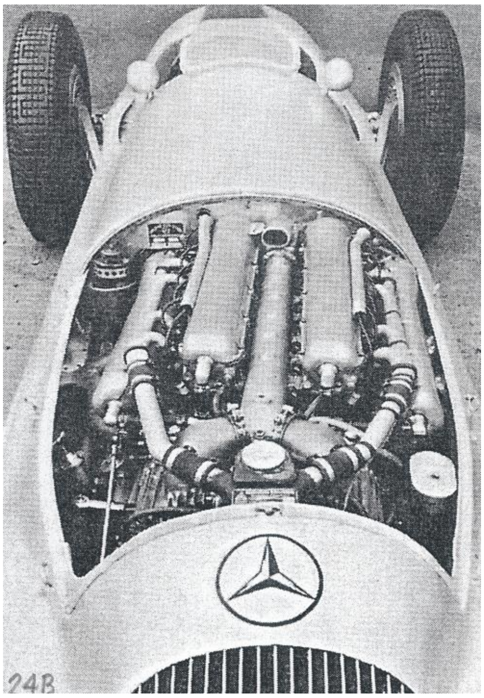


Fig.24B
1938 Mercedes-Benz M154
60V12 67/70 = 0.957 2,962 cc
Showing the supercharging system of 2 Roots blowers in parallel.
DASO 468 p.218



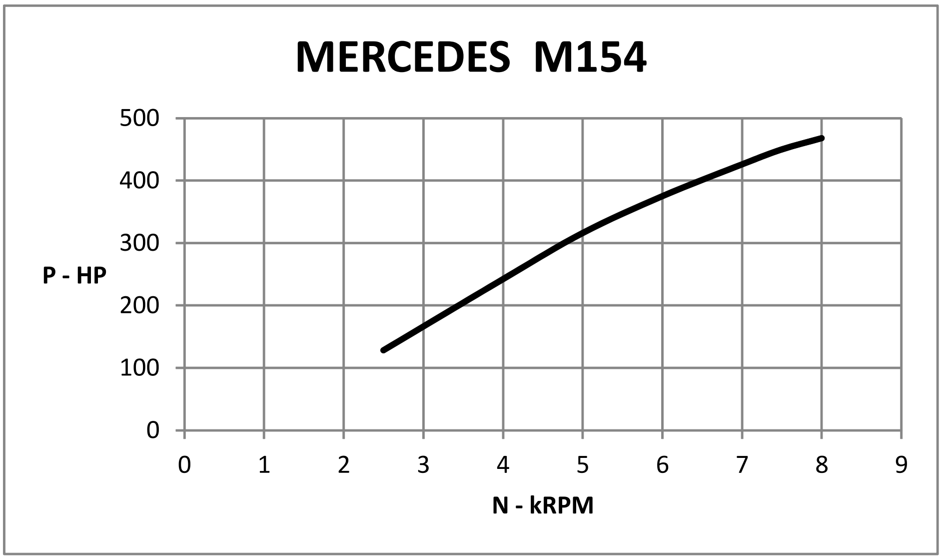
A Power Curve for the M154 is given on P.35

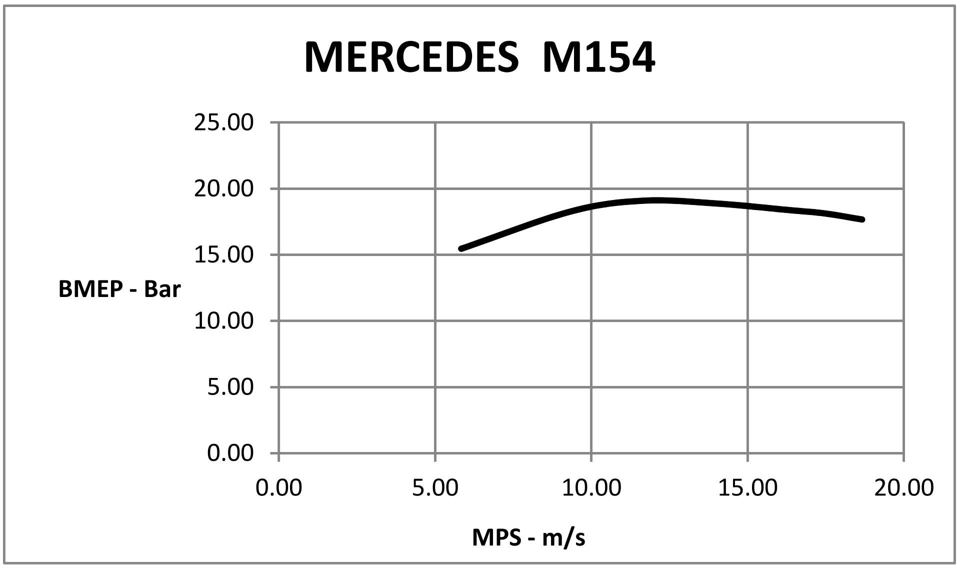
POWER CURVES

Eg.	24
DASO	468
YEAR	1938
Make	Mercedes
Model	M154
Vcc	2962
Ind. System	MSC
Confign.	60V12
Bmm	67
Smm	70

N	P	MPS	BMEP
kRPM	HP	m/s	Bar
2.5	128	5.83	15.47
4	242	9.33	18.28
5	316	11.67	19.09
6	375	14.00	18.88
7	426	16.33	18.39
7.5	450	17.50	18.13
8	468	18.67	17.67

Powers as published were German PS and have been divided by 1.014 to convert to HP.





25. 1939 Mercedes-Benz M163; 2,962 cc; 464 BHP @ 7,200 RPM (See Fig. 25A)

In 1939 the tally of wins, in a season cut short by war, was again: Mercedes 4 : 2 Auto Union and Mercedes were CoY. They had carried out much further development work over the winter to strengthen their engine and to fit a new supercharging layout. In this type M163 engine, by splitting the pressure rise across 2 blowers in series each unit was enabled to operate at rather over 50% efficiency where the 2 blowers in parallel of the M154 had been down to 35%. This new 2-stage system reduced the net power required from the engine for a given MDR (net = gross mechanical power taken from the crank *less* pneumatic power recovered in the cylinders by a proportion of the boost pressure acting during the inlet stroke). The M163 2-stage set operated at 1.82 x 1.26 = 2.29 ATA and MDR was also 2.29 after evaporative charge cooling by the "WW" fuel.

The overall result was essentially the same power as the best M154 but at 10% lower RPM – 7,200 instead of 8,000– and with maximum torque up 6% at 76% of the new peak speed.

The effect of the various changes was to increase the engine weight by 8% to 274 Kg.

This was a winning performance at *generally* greater reliability because of the 19% margin on stresses from the levels reached in 1938. This was valuable as even Mercedes-Benz, with all their resources, could only provide a few of the strengthened engines (works code "K-series") and otherwise had to race 1938 units ("H-series") overhauled and fitted with 2-stage superchargers (468).

Engine failures

There were 2 occasions when reliability disappeared. In the French and German GPs several engines suffered partial or complete piston seizures. The actuating piston of the butterfly valve in the supplementary carburetter throat (the "Zusatz-Vergaser" designed to open at full power and provide a super-rich mixture for maximum power with extra cooling) seized first. Then, at lower RPM this allowed excessive fuel into the engine, wetting the plugs and, unburned in consequence, washing oil off the cylinder walls and causing ring wear and piston pick-up. When it was realised that the need for the supplemental system was marginal at the new 7,200 RPM limit its fuel flow was reduced or eliminated to bypass the trouble.

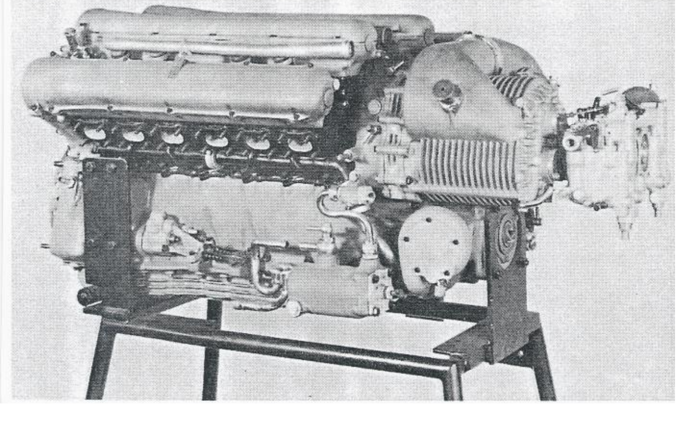
3 Litre PC v. 4.5 Litre NA

It will be noted that, whereas the rules supposed that MDR for a supercharged 3 L would be 1.5 (i.e. 1.5 MDR x 3 L = 4.5 L) in practice the level of MDR was 2 to 2.3. Therefore, with one exception in the 1st (non-classic) race at Pau in 1938 where the Mercedes W154s were not "*au point*" and were defeated by a 4.5 L Delahaye, the 4.5 L NA cars never bettered one 3rd place. This was despite their ability to run non-stop against one or even two fuel and tyre stops by the 3 L PC cars.

ECOM

The value of ECOM for the M163 was 41.6% compared to 45.2% for the M154. Bearing in mind possible comparison inaccuracies it is probably safer to say that the Mercedes 3 L average was 43.4%.

Fig. 25A
1939 Mercedes-Benz M163
60V12 67/70 = 0.957 2,962 cc
Showing the M163 supercharging system of 2 Roots blowers in series.
The large carburetter at the front contained a supplementary throat
which opened for maximum power.



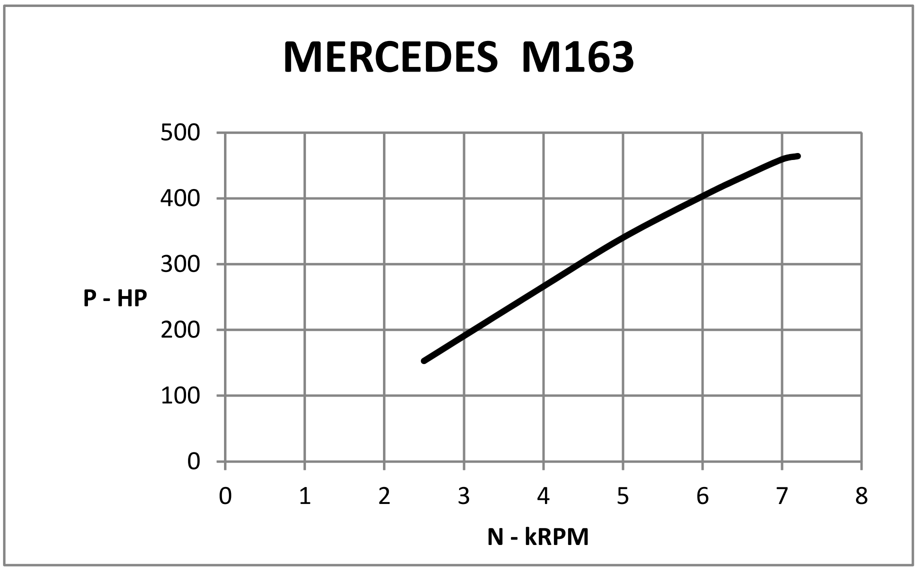
A Power Curve
Is given on p.37.

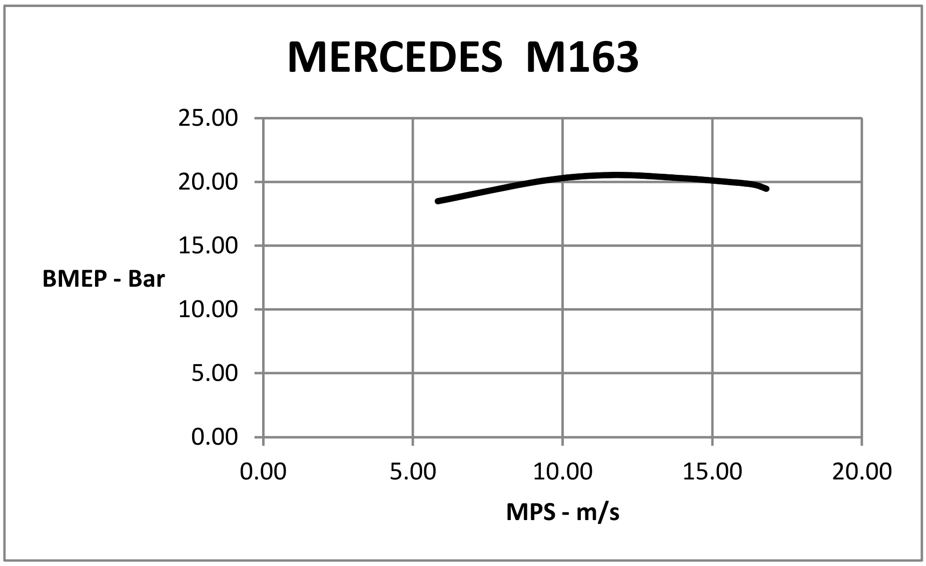
POWER CURVES

Eg.	25
DASO	468
YEAR	1939
Make	Mercedes
Model	M163
Vcc	2962
Ind. System	MSC
Confign.	60V12
Bmm	67
Smm	70

N	P	MPS	BMEP
kRPM	HP	m/s	Bar
2.5	153	5.83	18.49
4	266	9.33	20.09
5	340	11.67	20.54
6	403	14.00	20.29
6.5	432	15.17	20.08
7	459	16.33	19.81
7.2	464	16.80	19.47

Powers as published were German PS and have been divided by 1.014 to convert to HP.





Summing-up the "Teutonic Era"

With the German invasion of Poland and hence World War Two in September 1939 a hugely expensive 6 year period of Grand Prix motor racing came to an end. The final score of this "Teutonic Era" 1934 – 1939, counting those races where Mercedes-Benz and Auto Union both competed, was:-

Mercedes-Benz	27 wins	56.3%	1.6
Auto Union	17 wins	35.4%	1
Alfa Romeo	4 wins	8.3%	
	48		

So the results in the ratio of 1.6 : 1 were well below the 2 : 1 Mercedes : Auto Union expenditure (607).

This was very creditable to Auto Union and to Ferdinand Porsche, since the Saxon team had begun racing from nothing in 1934 in competition with the vast experience of the Swabian firm.

1st Pressure-Charged Era (1PC)

Part II

1948 – 1951: 4 racing years

Examples 26 to 29

Will be added to this web-site shortly.