ILLUSTRATIONS for Appendix 8

Fig, 13
PEP 276
1931 Rolls-Royce R "Sprint"
60V12 6''/6.6'' + 0.909 2,239 cid
(152.4 mm/167.64 36,696 cc)
2,783 HP @ 3,400 RPM

After the government-financed and RAF-organised 1927 Schneider Trophy victory, the British had to organise the September 1929 event (it had become bi-annual by an F.A.I. decision in January 1928). The government were ready to repeat the effort and overrode objections by the Chief of the Air staff, Trenchard.

There had been an exponential rise in engine power to win since 1919 – the Napier *Lion* had doubled from 450 HP to 900 in 1927.Much more would be needed.

One route was to supercharge the *Lion*, although, having an integral steel-liner closure this could give cooling problems. The *Lion* 7D was the result giving 1,350 HP @ 3,600 RPM. Henry Folland chose it for his Gloster VI monoplane. Incurable fuel feed problems in race-practice turns led to these aircraft becoming non-starters.

It seems that Reginald Mitchell of Supermarine thought more power would be needed than Napier could supply. He talked to the engineers at Rolls-Royce and they were keen to make a racing engine. Their Managing Director, Basil Johnson, was not. He had to be ordered by the Air Ministry to do the job (DASO 1176).

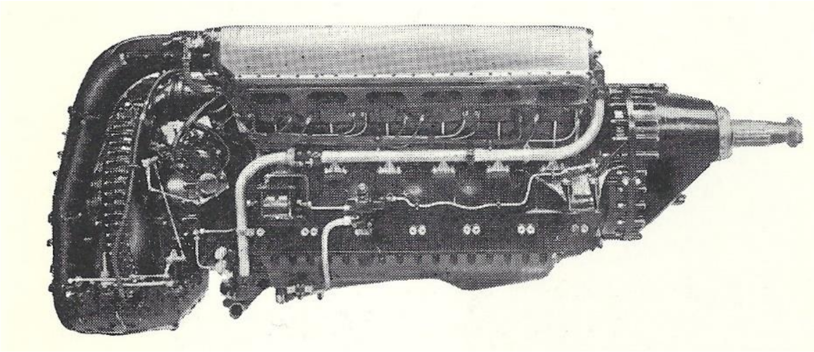
Rolls-Royce had already scaled-up the 'F' type by 6''/5'' = 1.2 to the 'H' (later named *Buzzard*) to 2,239 cid (36,696 cc), expected to have a 1st run in July 1928 at around 900 HP, mildly supercharged. Henry Royce favoured uprating this for racing. Arthur Rowledge proposed instead a 45V16 based on the 'F' cylinder of 5'' x 5.5'' which would give 1,728 cid (28,312 cc) and could provide higher power with less frontal area. Royce, no doubt concerned at a new 8-throw crank and wondering about the subsequent market for such an engine, decided on the 'H' as the basis for the 'R' type in January 1928.

For the race R-R eventually provided 1,900 HP @ 3,000 RPM by higher supercharge with higher-Octane Number-and-airflow-cooling fuel (see Appendix 2 at (11)). In the S6 piloted by Flg. Off. Richard Waghorn this won the race, after a last-minute partial piston seizure had necessitated an overnight block change.

After some considerable hesitation over finance a defence of the Trophy in September 1931 *was* authorised. Further uprated 'R' engines for S6B seaplanes were ordered and delivered at 2,350 HP @ 3,200 RPM. This followed the same path of improved fuel, higher supercharge and then making the machine stand the increased loads for the required life. This would become the usual process during the later *Merlin* years. No other country being ready – and the British preparations had been under exceptional pressure of time – an S6B piloted by Flt. Lt. John Boothman gained the trophy in perpetuity for Great Britain on 13th September.

Attention was turned after the Trophy to achieving a world speed record over 400 MPH. Money was again the problem – the UK went off the Gold Standard on 21 September 1931. For a shorter-life engine Rolls-Royce had gone further up the power-process (see Appendix 2 at (13)) to the specification given in Appendix 8, i.e. 2,783 HP @ 3,400 RPM. This had unacceptable acceleration and was really too much for the airframe*. Therefore a record engine was supplied at 2,530 HP @ 3,200 RPM (see Appendix 2 at (14)) and Flt. Lt. George Stainforth used this to raise the record to 407.5 MPH.

The 1931 Rolls-Royce ‘R; engine



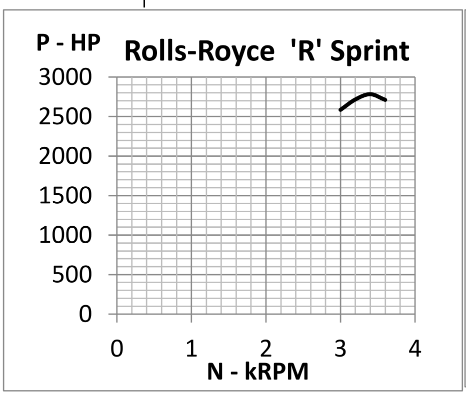
[Note that the powers quoted for the ‘R’ were taken on a test-bed to which air was supplied at speeds up to 400 MPH into a diffusing intake, as fitted on the aircraft (R-R Patent). This would have provided about 5% of the 2.37 ATA IVP given.]

A Power curve is shown below

***Rod Banks, in the discussion after DASO 686, said that the cylinder head bolts pulled. This would have been a simple matter to correct. The spec. was afterwards supplied to Campbell.**

POWER CURVES

PEP	276	N	P	MPS	BMEP
DASO	186	kRPM	HP	m/s	Bar
YEAR	1931	3	2585	16.76	21.01
Make	Rolls-Royce	3.2	2717	17.88	20.71
Model	R' sprint	3.4	2783	19.00	19.96
		3.6	2711	20.12	18.36
Vcc	36696				
Ind. System	PC				
Confign.	60V12	9 Sept 1931 s/n R15 s/c gear 7.94			
Bmm	152.4	With 400 MPH intake			
Smm	167.64				



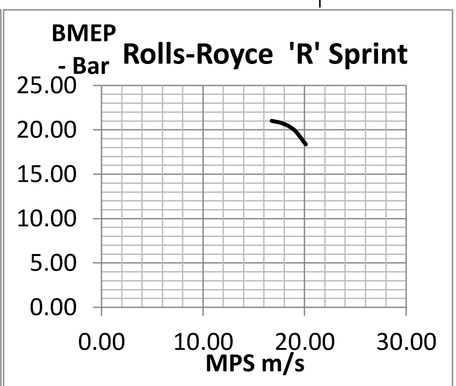
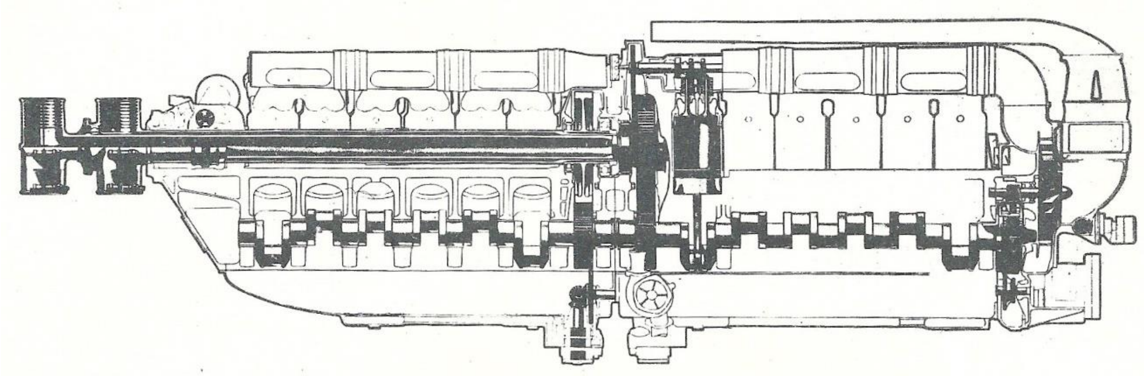
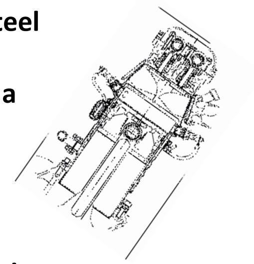


Fig. 14
1934 Fiat AS6
60V24 138 mm/140 = 0.986 50,256 cc
2,959 HP @ 3,300 RPM



DASO 686

The 1926 – 1934 Fiat series of racing aero engines is tabled in Note 38, all designed under the leadership of Tranquillo Zerbi. The 1926 AS2 was inspired by the Curtiss D-12 of 1923, although 67% larger in size (31.34 litres v. 18.76), and the following engines retained the same general design features. A major difference was that the Al-alloy Monobloc was rejected in favour of retaining the (originally Mercedes-inspired) separate steel cylinders with steel water jackets welded-on; see the scrap section at RHS.



Intended for the 1931 Schneider Trophy in a Macchi Castoldi 72, the AS6 used a unique configuration. Essentially it was two of the 1929 AS5 engines (with some modifications) *in tandem*, so as to double the power with the same frontal area.

The rear engine drove through the vee of the front to one of a pair of contra-rotating propellers; the front engine had a hollow shaft in the vee to drive the rear propeller (the Figure will make this clear).

This latter feature cured a basic problem with high-powered float-planes – on take-off the propeller torque forced one float down so then the offset drag made the plane turn through a large angle which had to be laid-off at the start.

There was no mechanical connection between the two units, only a common carburetter, supercharger, and long induction manifold – which latter proved its Achilles' heel.

The engine suffered from back-fires during bench tests but this was thought to have been cured (DASO 1177). However, during flight trials on 2 August 1931 an MC72 suddenly plunged into Lake Garda, killing its pilot Lt. Giovanni Monti. At first this was put down to a propeller bearing failure allowing the two airscrews to touch (DASO 1178 p. 224). It was clear that the machine was not going to be ready to race on the scheduled date of September 12th and the Italian team withdrew. They then tried to beat the World Speed Record (WSR) of 357.7 MPH set by a S6 in 1929. There was another crash on 10 September, fatal to Lt. Stanislao Bellini. This time there was evidence of a massive explosion in the induction manifold. It is disputed (DASO 1178 p.248) whether Fiat realised that the ram air pressure at speed, not simulated on the test-bed as it had been by Rolls-Royce with the 'R', was causing a weak mixture and a backfire setting off the charge in the induction manifold and then the fuel gravity tank behind the engine; or whether Rod Banks, the Ethyl specialist who had specified the 'R' fuels and had had been called by the Italian Air Ministry to help after the last Schneider race, identified the problem. At any rate, a ram air simulation was set up on the Fiat test-bed and tappings made from the aircraft-type intake to ensure the carburetter received the right pressure difference. The flight problem was solved. The fuel used, recommended by Banks, is given in Appendix 2 at (17). There must have been other problems, because it was not until April 1933 that the MC72 piloted by Warrant Officer Francesco Agello raised the WSR to 423.8 MPH with a 2,400 CV engine rating.

With a further18 months improvement to 3,000 CV Agello finally passed the mark aimed at by the Italians of 700 KPH, achieving 709 – 440.6 MPH - in October 1934. This is a figure for seaplanes which has not been beaten since- and probably never will be.

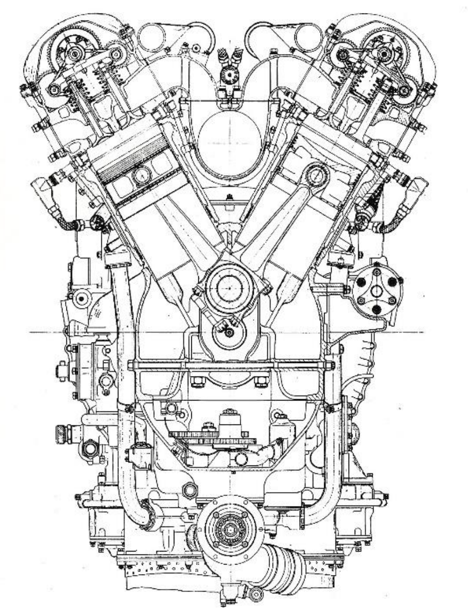


Fig. 15
PEP 365
1938 Rolls-Royce High-Speed Merlin
60V12 5.4''/6'' = 0.900 1,640 cid
(137.16 mm/152.4 27,022 cc
2,160 HP @ 3,200 RPM
Fig. Rolls-Royce

Basically a *Merlin* II (as shown) with stronger reciprocating parts run unthrottled at sea level on special fuel (see Appendix 2 at (24)). Installed in a specially-painted high-gloss Spitfire (K9834, N17) with reduced wing span and a streamlined cockpit. This aircraft reached 408 MPH (SPITFIRE. J. Quill. Arrow ed. 1985) by March 1939, the World Air Speed Record being then the 440.6 MPH attained by the MC72 in 1934. This was put up to 463.8 by a Heinkel He100 in March 1939 and then to 469.2 by a Messerschmitt 209 (called a 'Bf109R' for German propaganda purposes) in April. Both German aircraft used evaporative cooling to reduce drag.

N17 was modified to that system but apparently never flew with it. Production Spitfire work then took precedence over any further flights

In Jeffery Quill's opinion, although the High-Speed or "*Schneiderised*" *Merlin* did not fulfil its purpose "*It demonstrated…to Joe Smith at Supermarine* (their Chief Designer) *the enormous power growth potential of the Merlin engine*"…"*from thenceforward the full Supermarine design effort should be directed towards the continued development of the Spitfire rather than dabbling with new designs.*".

Of course, Rolls-Royce *did* continue the military power development of the *Merlin*. The ultimate result was the RM17SM, Fig. 18.

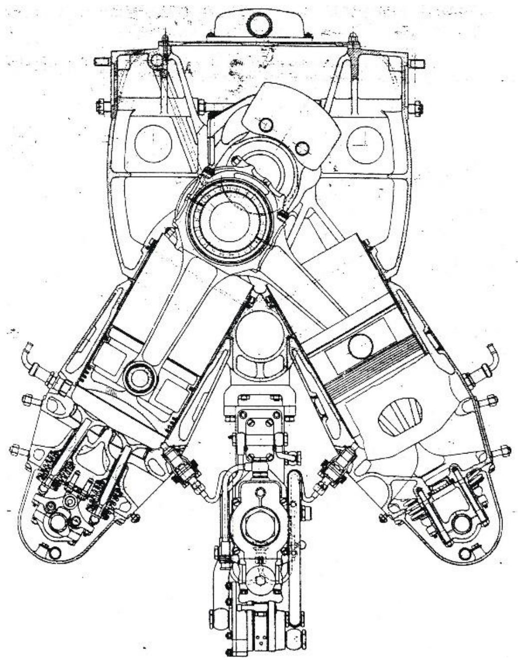


Fig. 16
1940 Daimler-Benz DB601E
60IV12 150 mm/160 = 0.938 33,929 cc
1,332 HP @ 2,700 RPM

The DB601 (and later its 5.3% enlargement DB605) versus the *Merlin* were the mechanical expressions of the hostilities between Germany and Great Britain, both in service throughout WW2 in Messerschmitt Bf109 and Spitfire respectively.

Regarding the inverted V12 layout, an interesting point is made in DASO 901:- at Rolls-Royce a design investigation in early 1933 had produced an inverted V12, claiming an improved pilot's view and possibly a thermo-syphon gain to head cooling. "*A wooden mock-up of this engine …was on display…when an important mission of German engineers…including Daimler-Benz and Junkers, visited Derby. They displayed more than ordinary interest in the design…*". The *Merlin* was built subsequently as a normal V12 – Daimler-Benz and Junkers produced IV12s.

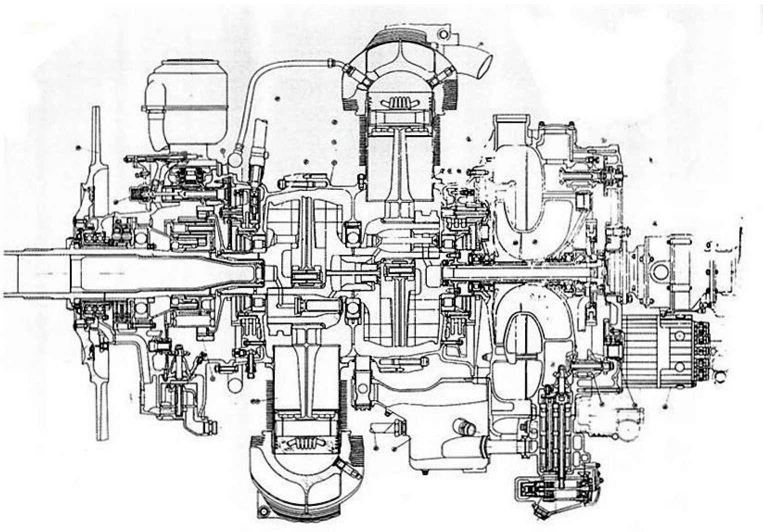
A feature of the DB601 was direct petrol injection . This avoided negative-g problems during manoeuvres (but provided no inlet charge cooling, worth 25^{0}C, from petrol evaporation). Negative-g affected the *Merlin* with a conventional float carburetter if a sudden dive was begun from level flight; first the fuel and the float were flung to the top of the float chamber, causing a weak-mixture hesitation; then the needle, no longer under float control, was forced open by fuel pressure and a rich-mixture engine cut-out followed. The effect on dog-fighting has perhaps been somewhat exaggerated. A retired ex-Battle of Britain Squadron-Leader wrote in 1965 "*I cannot recollect any serious trouble from this cause…the absolutely instinctive action when following a Messerschmitt into a sudden dive was to quickly apply full bank and then bottom rudder…and, of course, the Merlin never shed a rev*."(DASO 1179). Steps were taken nevertheless, under the charge of a Miss Shilling of the RAE, to prevent over-fuelling and then develop an anti-g SU carburetter (DASO 753).

The development of the 'E' version of the DB601 from the 'A' in 1940 is described in an article by Jerry Wells in DASO 1172, including an increase of RPM from 2,400 to 2,700 (12.5%), of IVP from 1.3 to 1.42 (9.2%) and of OL from 42^0 to 105^0, to obtain 35% power increase.

In general, Daimler-Benz preferred to obtain more power by increasing swept volume at low supercharge using petrol of fairly-low Octane number (33.9L DB601; 35.7L DB605; 44.5L DB603) rather than using ever higher supercharge with fuel of improving anti-detonation quality as did Rolls-Royce with the *Merlin* (see Note 58-2).

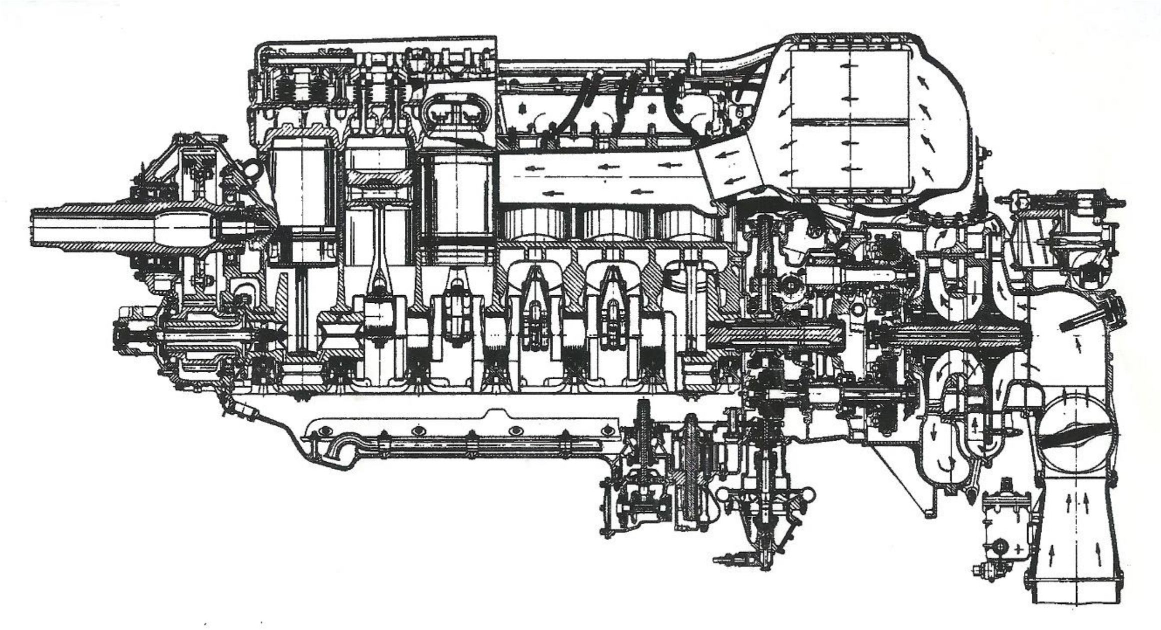
Fig. 17
1942 BMW 801C
R14a/c 156 mm/156 = 1
41,744 cc
1539 HP @ 2,700 RPM

The BMW 801 radial had 2 novelties:- a fan to give adequate air-cooling in a close cowl, running at 3.2 x propeller RPM; and a control unit which set low or high supercharger speed, fuel mixture, ignition advance and propeller pitch, all linked to the throttle lever.
The 801's most famous installation was the Focke-Wulf 190, which gave the RAF a hard time in 1942.



automoto.it

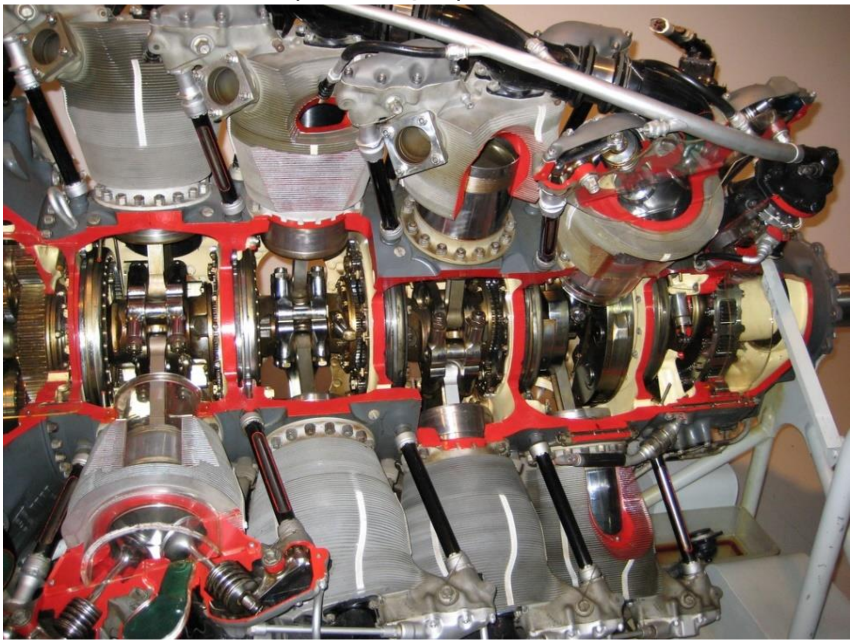
Fig. 18
PEP 364
1944 Rolls-Royce Merlin RM17SM
60V12 5.4''/6'' = 0.900 1,640 cid
(137.16 mm/152.4 27,022 cc
2,620 HP @ 3,150 RPM



Rolls-Royce

After the re-design of the *Merlin* to *Kestrel*-type cylinders was Type-tested in the *Merlin* II the Max. Take-Off rating at Sea-Level in 1937 was 890 HP. By late-1944 the RM17SM had been Type-tested at a maximum of 2,200 HP, but this rating did not go into production. The highest rating used in service was the Mk 66 at 2,050 HP in mid-1944 on 150 grade fuel, a power development needed for Spitfires and Mustangs to catch the German V1s (DASO 753).
A special 15 minute test was run on the RM17SM in December 1944 with 150 grade fuel + 16% water injection (by volume) and this achieved the 2,620 HP given in Appendix 8. An interesting detail is that the Mechanical Efficiency was 72.7% (DASO 326).
This 2,620 HP was the highest power ever produced by the *Merlin*. The cylinders had been changed to top-flange location in the 1st Packard-built engine in August 1941. Only two crank designs had been required, the 2nd being for double end-oil feed in February 1944.
Two-stage supercharging had been introduced in 1942. This required an intercooler before the engine inlet manifold, but this was restricted to 40% temperature drop by considering the offsetting drag of the extra radiator needed for the water cooling – a true systems approach to the engineering. In theory that drag could have been eliminated by making full use of the "Meredith effect" but it would seem that the Spitfire installation was not long enough to do that. The Mustang *should* have been able to do it. Intercooler bulk and its weight with its associated radiator must also have affected the optimum cooling.
If the jet engine had not come to fruition in 1944 it is probable that the *Merlin* would have been developed further by using Triptane fuel, which without TEL had a Performance No. of 200 (see Note 58-2).

Fig. 19
1945 Pratt & Whitney R-4360
R28a/c 5.75''/6'' = 0.958 4,362 cid
(146.05 mm/152.4 71,488 cc)
3,250 HP @ 2,700 RPM



Wikipedia

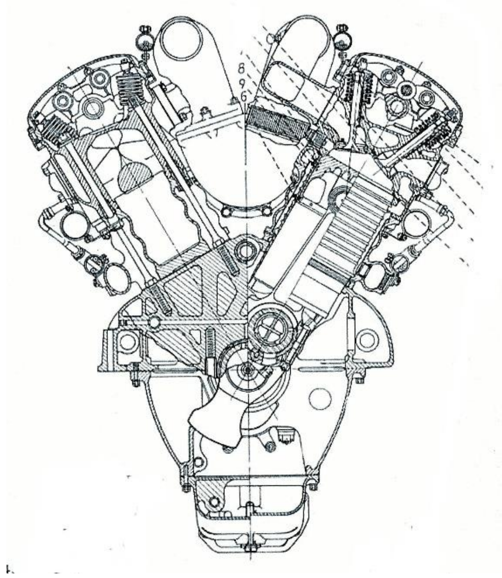
As shown, a 4-row air-cooled radial which in principle was a doubling-up of P & W's R-2180 14-cylinder engine Type-tested in 1938 so as to give twice the power at the same frontal area. To cool all the cylinders the engine had the rows at different stagger angles.

The inlet Valve head Diameter (IVD) of 3 3/16'' (80.963 mm) has been obtained by scaling from a photograph of a sectioned engine and may not be accurate, but at 55.4% of the Bore (B) it can be compared with the known IVD of the Wright R-3350 at 3 5/16'' which is 54.1% of B. These figures must be about the largest valve sizes ever flown!

A comment about the R-4360 was that a false start which wetted the plugs meant a long delay to change the 56 involved. An anecdote; in the winter of 1950-51 a fault developed in some of the Boeing Stratocruiser R-4360s of BOAC in the system used to inject some petrol into the lubricating oil to ease starting friction and this ran the bearings. A major strip and rework programme was caused, not made cheaper because the units had to be trucked to the engine overhaul base at Treforest in Wales, 150 miles away!

Fig. 20
1945 Allison V-1710
60V12 5.5''/6'' = 0.917 1,711 cid
(139.7 mm/152.4 28,032 cc)
2,250 HP @ 3,200 RPM

The *Merlin* and the DB601 were enemies; the V-1710 and the *Merlin* were allies – but this did not stop arguments later about which was the better engine! "*Vee's for Victory*" (DASO 628), a detailed account of the Allison engine, devoted a chapter to a comparison between the two similar-sized engines.
The discussion originated because the *Merlin* displaced the V-1710 from the P-51 Mustang in 1943 and that combination became the standard fighter of the US 8th Army Air Force, escorting their bomber offensive over Germany.



DASO 1170

The *Merlin*-Mustang had displaced the Allison V-1710-engined P-38 Lightning and the Pratt & Whitney R-2800-engined P-47 Thunderbolt from the 8th AAF, although not before that combination had done most to write-down much of the Luftwaffe fighter force in the February 1944 'Big Week' battles.
DASO 628 makes clear that the V-1710 was always intended by the pre-WW2 US Army Air Corps to obtain high-altitude performance by using the Turbocharger then being developed by General Electric. With an engine-integral mechanical supercharger this was the specification which powered the Lightning. Without the Turbocharger the Mustangs very-good low-level performance, obtained by its excellent aerodynamics, could not be maintained higher up. The latest *Merlin* 2-stage mechanical supercharger provided the necessary power there. Ironically, both the P-38 and the P-47 *were* Turbocharged, but they did not have the range or agility of the P-51.
Allison *did* develop 2-stage mechanically-supercharged versions of the V-1710, and the highest rated is given in Appendix 8. Their design had the first stage as an add-on separate item, unlike the integrated *Merlin* layout. Also, although they tried an intercooler, they preferred to take out compressor delivery temperature with water-methanol injection (ADI = Anti Detonation Injection) as a lighter mission solution.
Allison tested an engine with Triptane (2,2,3,-tri methyl butane, C_7H_{16}) fuel and obtained 430 psi (29.6 Bar) IMEP (DASO 628 p.374). If a Mechanical Efficiency of 72.7% applied, as for the *Merlin* RM17SM (see Fig. 17) it would mean a BMEP of 21.6 Bar. As this is below the pressure obtained on 145 grade fuel of 22.4 Bar, it suggests the tests were supercharger-limited.