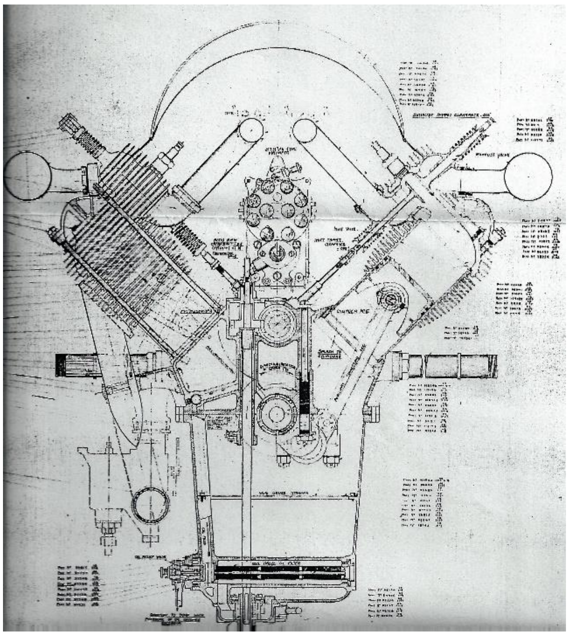
ILLUSTRATIONS for Appendix 8

Fig. 1
PEP 425
1914 Renault 80CV
90V8a/c 105 mm/130 = 0.808 9,005 cc
104 HP @ 1,950 RPM

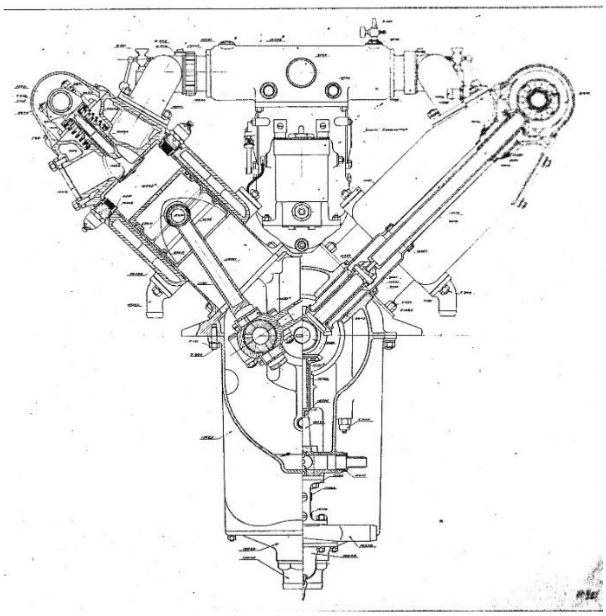


This engine had the unusual layout of side-valve inlet with opposed push-rod operated exhaust valve.
The drawing shows the cowling introduced by the Royal Aircraft Factory (RAF) to guide air to cool the rear cylinders.
Master and-slave (articulated) connecting rods.
Having decided initially NOT to build aircraft engines in WW1, Rolls-Royce were persuaded to build 220 Renault V8s over 1915-1916, followed by 100 of the very-similar derived RAF 1a. They did this while Henry Royce designed and the firm built and developed their own first aero engine (see Fig. 7)

DASO 399

Fig. 2
PEP 424
1917 Hispano-Suiza 220CV
90V8 120 mm/130 = 0.923 11,762 cc
235 HP @ 2,240 RPM

Designed by Marc Birkigt. Cast Al-alloy cylinder blocks with screwed-in steel closed-end liners.
Fork-and-blade connecting rods.
Among other aircraft the Hispano V8 powered the SPAD VII and XIII and the RAF-designed SE5a, three of the most effective fighter ("Scout") aircraft of WW1 .
The Hispano V8 was extremely successful and was built by many firms in all the WW1 Allied nations. All marks of the original size totalled over 41, 500. A further 8.000 were built of a 57% enlarged (140mm/150 = 0.933 18,473 cc) 300CV type, which did not reach the front line before the Armistice.



DASO 399

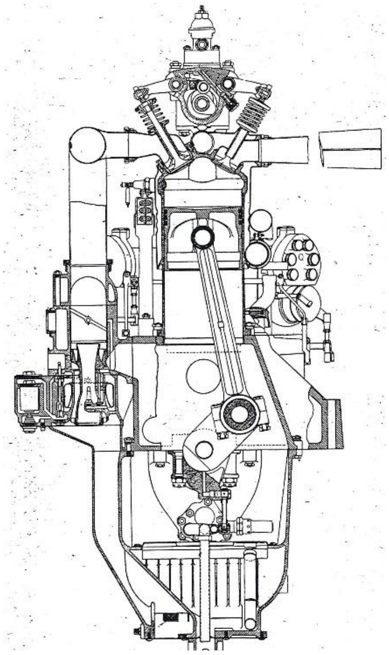


Fig. 3
PEP423
1916 Austro-Daimler 200PS
IL6 135 mm/175 = 0.771 15,030 cc
230 HP @ 1,700 RPM

By WW1 the Austro-Daimler company was no longer connected to the German Daimler firm. The Chief Engineer was Ferdinand Porsche.
German and Austrian engines originally had ferrous pistons but the enemy discovered from engines salvaged from Allied aircraft brought down in their territory that, egs, Hispano-Suiza and Rolls-Royce were fitting Al-alloy pistons. While Daimler (Mercedes) engines continued with ferrous pistons to the end of the war, Austro-Daimler used Al-alloy in the type illustrated. [Benz also changed over. An official analysis ("*Flight*" 4 July 1918) showed that the change of material saved 27% of the mass of a 145 mm piston with rings and gudgeon pin
The official analysis of this A-D engine (DASO 1165) remarked it "*possesses more than the usual amount of originality in design found in enemy aero engines*".

DASO 1165

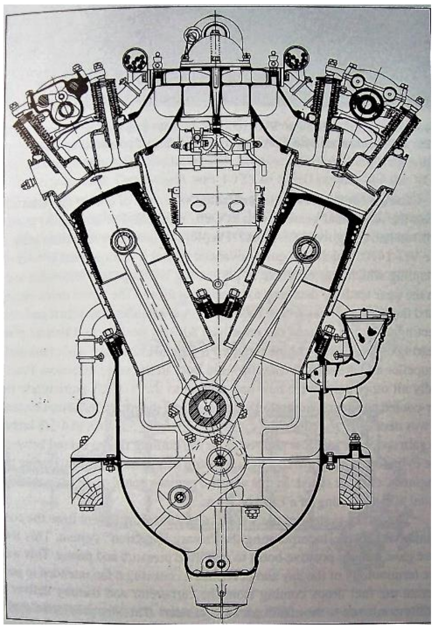
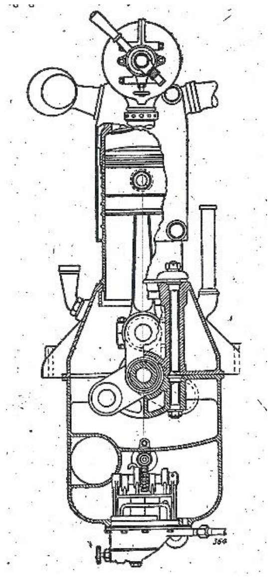


Fig. 4
PEP 373
1917 "Liberty" L12 (US army aero type)
45V12 5''/7'' = 0.714 1,649.3 cid
(127 mm/177.8 27,028 cc)
425 HP @ 1,700 RPM
Fig.. DASO 628

When the USA declared war on Germany in April 1917 its aviation industry was negligible in size. This despite it being the home of the Wright brothers who had made the first powered, controlled, level flights in history in 1903!

To catch up, Jesse Vincent of Packard and Elbert Hall of Hall-Scott were tasked by their government with - and very quickly accomplished.-.the design of a 400 HP aero engine. This was named the "Liberty". It drew heavily on the latest Mercedes design details for its cylinders and valve gear, but with Al-alloy pistons and the novelty of a 45^0 bank angle instead of the "natural" 60^0 for a V12, to reduce frontal area. It was designed from the start for mass production, a process first brought to arms manufacturing in the USA in the mid 19th Century and to automobiles by Henry Ford in the 1908 Model T. In that way it was quite different from the Rolls-Royce Eagle of the same size. With multiple firms engaged 14,000 were made before the Armistice. However, only a few saw action in the 'A' version of the Airco DH9, but it greatly improved that grossly underpowered aircraft. This effort was intended for the 1919 campaign which fortunately was not fought.

The engine was also redesigned more cheaply with cast iron cylinder blocks, instead of welded-up steel, as the power for a new Allied tank for 1919. This type was resurrected as the "Nuffield-Liberty" for British cruiser tanks over 1939 – 1943.



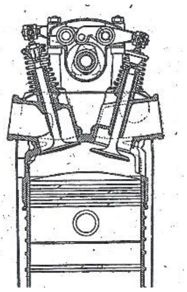
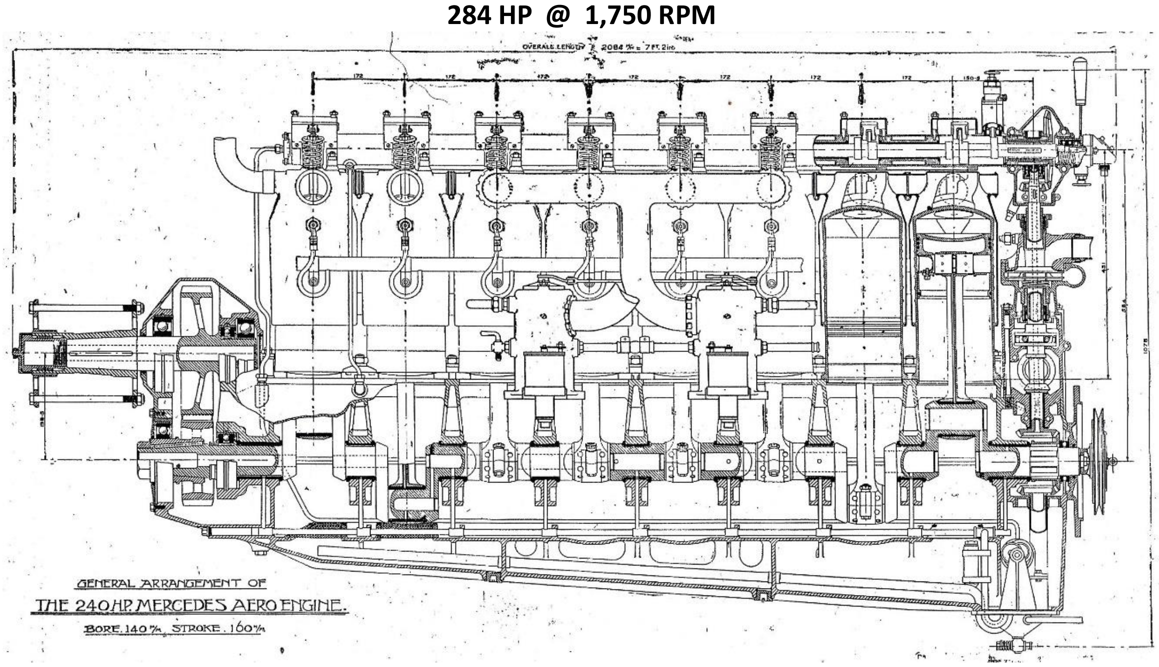


Fig. 5
PEP 421
1917 Daimler "Mercedes" DIVa
IL6 160 mm/180 = 0.889 21,715 cc
268 HP @ 1,600 RPM

This was the first Mercedes aero engine with 4 valves per cylinder.
As mentioned in Fig. 3 Daimler would not change their standard aero ferrous piston construction, which had a steel crown screwed and then welded to a cast iron skirt. In consequence the DIVa piston (with rings and gudgeon pin) weighed 4.86 kg for 160 mm bore! At the Rated 1,400 RPM the MPS was 8.4. This compared with 9.3 for the highest-Rated Hispano at 2,150 RPM and 9.9 for the R-R Eagle VIII at its Rated 1,800 RPM
[Pistons materials are discussed in Note 14.]

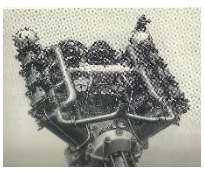
Figs.both DASO 1168.

Fig. 6
1917 Daimler "Mercedes" F1468 [Official DIV]
IL8 140 mm/160 = 0.875 19,704 cc
284 HP @ 1,750 RPM



DASO 1169

(F1468 is the somewhat-obscure Daimler Drawing Office code:-
F = *Flug*; Bore = *14*[0]; Stroke = [1]*6*[0]; *8* Cylinders)
This engine was built up with the complete cylinders of the IL6 DIII (F1466), which was the "workhorse" Mercedes aero engine in WW1, nearly 12,000 being made. Few IL8-cylinder derivatives were made.
Germany and Austria adhered to the IL6 configuration for volume production throughout the war but both Daimler and Benz built a few V8 engines in late 1917 (DASO 637).
The Mercedes was type FV10678 106 mm/170 = 0.624 12,002 cc, Rated 185PS @ 1,800 RPM. It had bearing problems ("*Fighters*" W. Green/G. Swanborough; Salamander 1994), but was flown. Few were made. (See Fig. LHS)



DASO 637

Fig. 7
PEP 427
1917 Rolls-Royce *Eagle* Series VIII
60V12 4.5''/6.5'' = 0.692 1,240.5 cid
(114.3mm/165.1 20,329 cc)
360 HP @ 2,035 RPM

Designed by Henry Royce from 1 September 1914, his first aero engine, with the assistance of Albert Elliott and Maurice Olley. Nominal design point 200 HP, steadily developed through the 8 series to 360 HP, delivered in September 1917. The true power peak shown was improved by the removal of the crank balance weights in November 1917 to provide 360 HP @ the Rated !,800 RPM by reduction of windage.
A total of over 3,000 *Eagles* of all series was delivered by the end of 1918, totalling over 1 million HP.

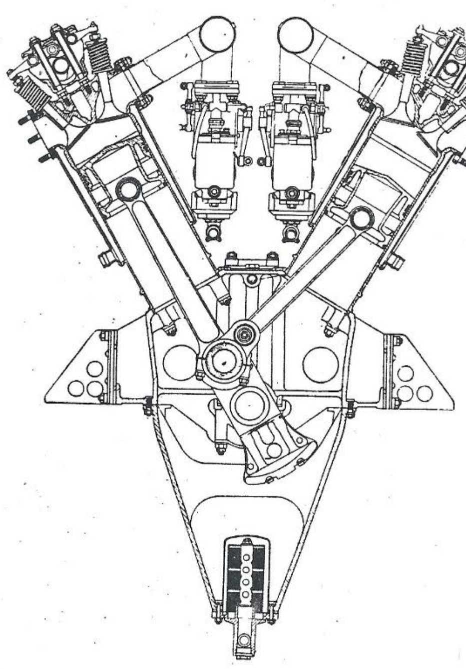
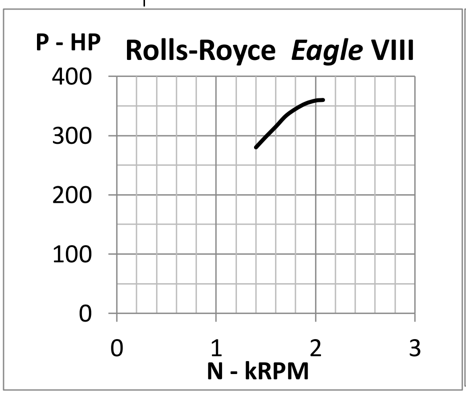
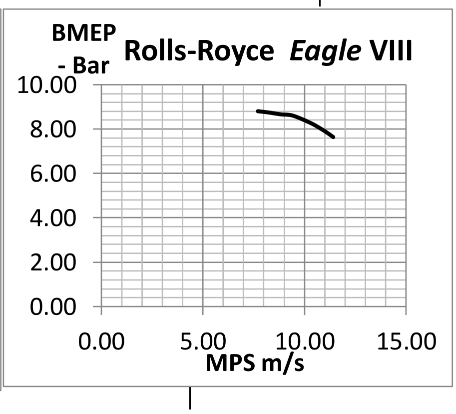


Fig.(DASO 1053) is of a Series II. The Series VIII had more streamlined inlet manifolds, revised rocker pivots to give higher valve lift and no crank balance weights after Nov. 1917.

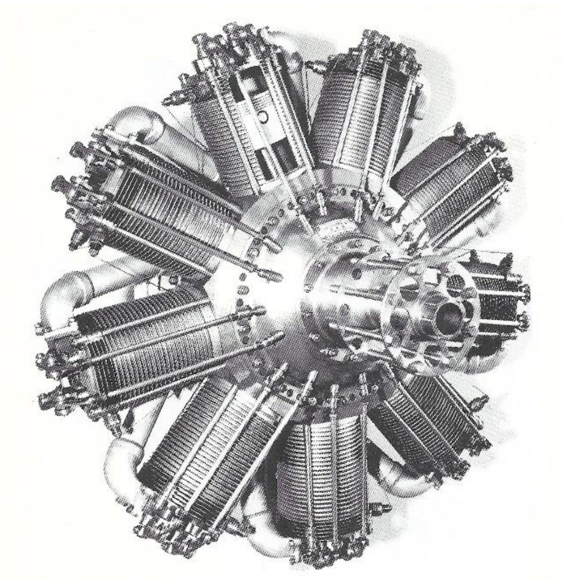
POWER CURVES

PEP	427	N	P	MPS	BMEP
DASO	399	kRPM	HP	m/s	Bar
YEAR	1917	1.4	280	7.70	8.80
Make	1.6 Eagle	1.5	298	8.26	8.75
Model	VIII	1.6	315	8.81	8.67
		1.7	333	9.36	8.62
Vcc	20329	1.8	345	9.91	8.44
Ind. System	NA	1.9	354	10.46	8.20
Confign.	60V12	2	359	11.01	7.90
Bmm	114.3	2.075	360	11.42	7.64
Smm	165.1				





The *Eagle* was scaled by the ratio 4''/4.5'' to produce the *Falcon,* at 867 cid (14,209 cc). This was developed in a similar way to the *Eagle* to reach a Series III in 1917 giving 270 HP @ 2,000 RPM. It powered the Bristol F2B "*Fighter*", a very successful aircraft. Over 1,600 *Falcons* were delivered by the end of 1918, 75% built under licence by Brazii Straker in Bristol.



DASO 285

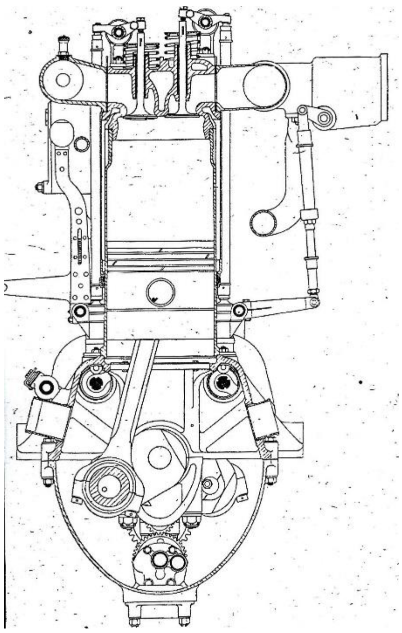
Fig. 8
PEP 339
1918 Bentley BR2
Rotary9a/c 140 mm/180 = 0.778 24,938 cc
238 HP @ 1,300 RPM

Designed by Walter Bentley, while serving in the Royal Navy, after experience with unreliable French Clerget rotary engines licence-built by Gwynne.
In his new engine "WO" introduced Al-alloy cylinders with shrunk-in cast iron liners, which cured the steel-finned thermal distortion of earlier French rotary engines, and also Al-alloy pistons. He had pioneered the latter before WW1 in the DFP car and had introduced them to Rolls-Royce and Sunbeam in 1915 (see Note 14).
This was the most powerful rotary engine in service.

Fig. 9
PEP 383
1918 Maybach 300PS
IL6 165 mm/180 = 0.917 23,093 cc
305 HP @ 1,520 RPM

Wilhelm Maybach was the designer of Daimler engines from the earliest up to 1907. He then left to form a company to make engines for Graf Zeppelin's airships. All these were powered by Maybach engines up to the end of WW1. The type described, however, was for a Rumpler aircraft. It was noted in DASO 1167 as "*a great improvement in general design and efficiency*" with "*workmanship…exceptionally good*" compared to the standard 240PS Zeppelin-Maybach engine.

Unusally for a WW1 aero engine the test curve in DASO 1167, shown below, was taken over the peak power.

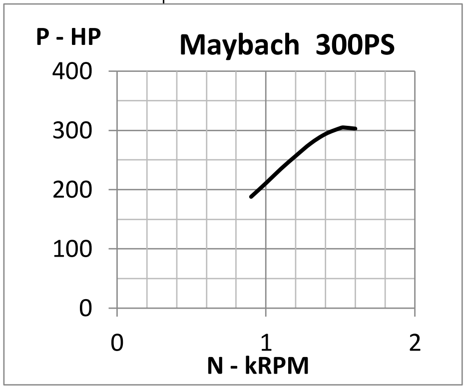


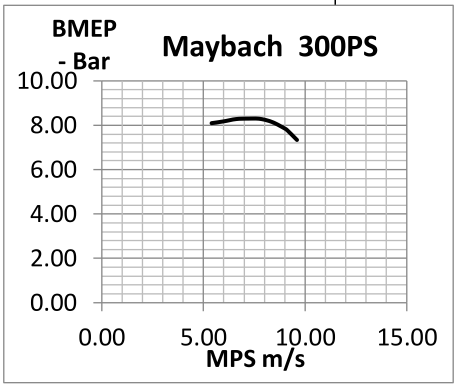
DASO 1167

POWER CURVES

		N kRPM	P HP	MPS m/s	BMEP Bar
PEP	382				
DASO	1167				
YEAR	1918	0.9	188	5.40	8.09
Make	Maybach	1	211	6.00	8.18
Model	300PS	1.1	235	6.60	8.28
		1.2	257	7.20	8.30
Vcc	23093	1.3	278	7.80	8.29
Ind. System	NA	1.4	294	8.40	8.14
Confign.	IL6	1.5	304	9.00	7.85
Bmm	165	1.52	305	9.12	7.78
Smm	180	1.6	303	9.60	7.34

Charts on P.6





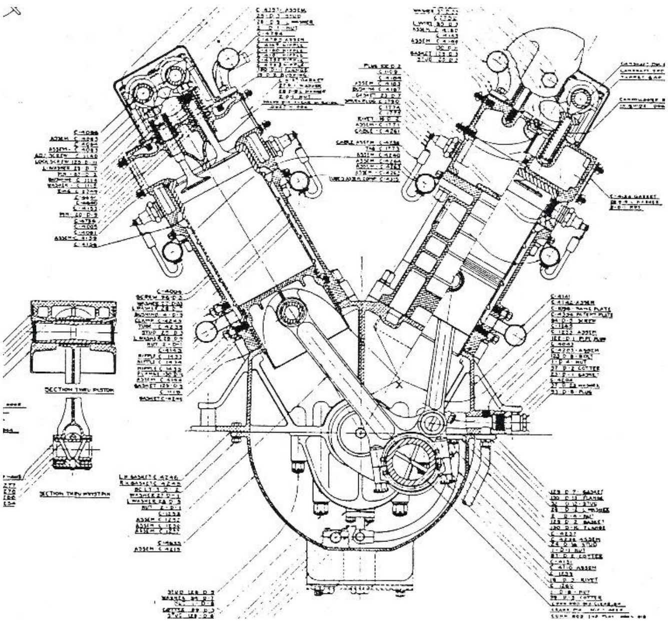
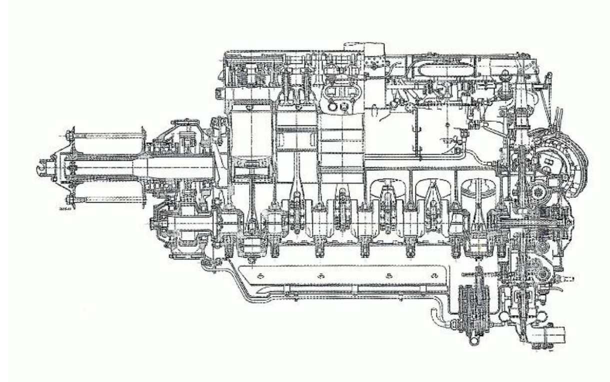


Fig. 10
1923 Curtiss D12
60V12 4.5''/6'' = 0.75 1,145 cid
(114.3 mm/152.4 18,765 cc)
470 HP @ 2,350 RPM

Designed by Arthur Nutt as a development (via the Finlay Porter-designed C12) of Charles Kirkham's innovative 1917 K12. That engine had been inspired by the Hispano-Suiza V8 but with only the top of the closed-end steel liner screwed into the Al-alloy block, the rest of the liner in direct contact with the surrounding water.
In 1923 the D12 powered the Curtiss CR-3 biplane seaplane, piloted by Lt. David Rittenhouse USN, to win the Schneider Trophy. It raised the average speed by nearly 22% over the figure set by a biplane flying-boat in 1922.

The D12 inspired improvement in British engines. A D12 was examined by Rolls-Royce before they began design in July 1925 of a 60V12 21 litre "*Falcon-Experimental*" ('*FX*', then "*F*") engine (DASO 328). Initially this had dry liners but piston seizures led to a redesign to wet *open-ended* liners sealed by the Al-alloy cylinder head (DASO 900). This was cheaper than the D12 construction and better cooled, which helped when it was later supercharged. The liners had their own problem – see Note 71B. SOHC (with rockers) may have also reduced cost from the DOHC (with tappets) D12.

1927 Rolls-Royce "*F*" type, later named "*Kestrel*"
60V12 5''/5.5'' = 0.91 1,296 cid
(127 mm/139.7 21,236 cc)
480 HP @ 3,000 RPM
Designed by Arthur Rowledge.
The "*F*", by scaling-up 6''/5'', led to the 36,696 cc "*H*" ("*Buzzard*"), in turn uprated to the racing "*R*" (see Fig. 13), and later to the 5.4''/6'' 27,022 cc "*Merlin II*" (see Fig. 15). The rest is history!



Rolls-Royce

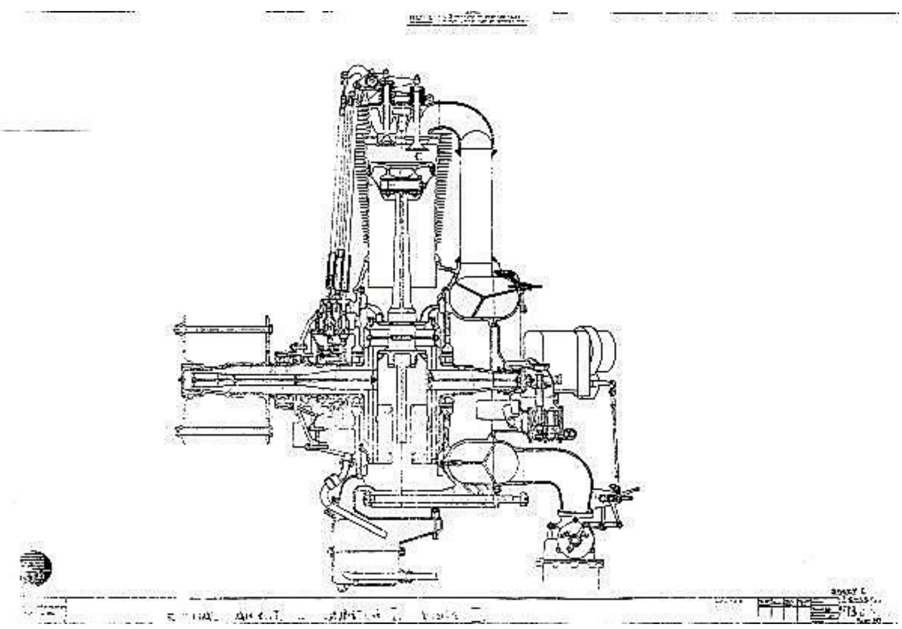


Fig. 11
1924 Bristol Jupiter V
R9a/c 5.75''/7.5'' = 0.767
1,753 cid
(146.05 mm/190.5 28,723 cc)
500 HP @ 1,900 RPM

Designed by Roy Fedden with the assistance of Leonard Butler. Henry Royce foresaw trouble with the master crank-pin bearing, which occurred. That initially prevented the engine from reaching its intended RPM and 500 HP.

DASO 1175

Harry Ricardo solved the bearing problem with a 1-piece floating bush, which required a built-up crankshaft. The Mark V Jupiter with these features then achieved 500 HP.
The engine went on to be a great success. It was developed later with supercharging (MSC). Many foreign countries took licences to build the Jupiter, including France, Italy, Germany and Japan. The Soviet Union also built the French version (whether licence fees were paid is uncertain). Initially it powered the Polikarpov I-16, described in Wikipedia as "*the world's first low-wing cantilever monoplane fighter with retractable landing gear to have attained operational status*" in 1934.
Jupiters powered the RAF biplane fighters Gloster *Gamecock (NA, 1926, 155 MPH, 6 squadrons) followed by the* Bristol *Bulldog* (1929, MSC, 178 MPH, 10 squadrons).
The engine in NA and MSC versions powered the Imperial Airways Handley Page HP42 4-engined biplane airliner. This type flew for 8 years in civil service up to WW1 without a fatal accident.

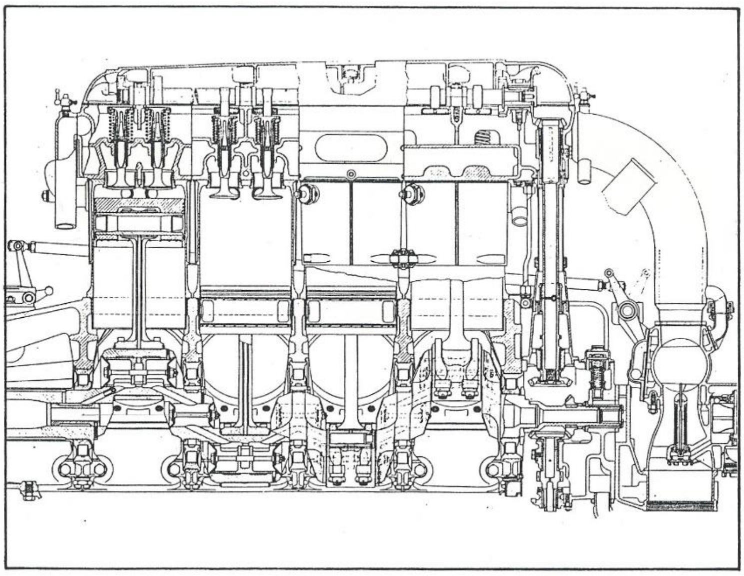


Fig. 12
PEP 307
1927 Napier Lion VIIA
60W12 5½''/5 ⅛'' =1.073
1,461 cid
139.7 mm/130.175 23,944 cc)
970 HP @ 3,600 RPM

The first *Lion* was designed by Arthur Rowledge in 1917 and produced 450 HP @ 1,950 RPM. It did not reach WW1 service but post-War it found many applications. A racing version powered the biplane flying boat Supermarine *Sea Lion* II piloted by Henri Biard to win the 1922 SchneiderTrophy, at a rating of 525 HP.

DASO 226

***Lion*s of 680 HP powered the unsuccessful Gloster GIII biplane and Supermarine S4 cantilever monoplane seaplanes in 1925 (the S4 crashed because of wing flutter).**
***"The British government went mad"* in 1926 and ordered 3 types of seaplane (Supermarine wire-braced monoplane; Gloster biplane; Short monoplane) and 2 types of engine (an improved Lion; a new Bristol *Mercury* radial air-cooled) aimed at a 1927 race.** **[Contd. on P.8].**

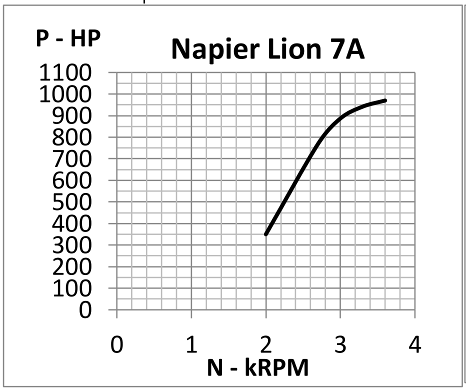
Contd. from P.7

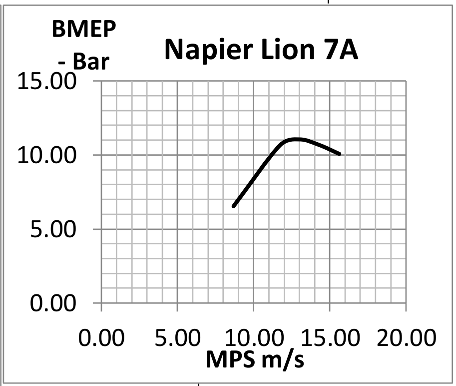
As well as using higher-lift camshafts and a higher-Octane No. fuel (see Appendix 2 at (10)) with R = 10, a very high figure for the time, the engine was redesigned to reduce frontal area. The con.-rods were shortened by 1'' and camshafts lowered, to give a total height reduction of 2''. Magnetos were tucked into the cross-section. Compared to a standard *Lion* the area was reduced by 23%. Supermarine played their part by drawing the S5 fuselage section to just fit a seated pilot.

The use of gearing to reduce propeller speed by 23% and raise propulsive efficiency at some cost in power (4.7% loss was measured) and weight increase was decided late in the development programme. This was justified in the 1927 race, when the 7B geared engine powered the S5 piloted by Flt. Lt Sidney Webster to win at a speed 3% higher than the direct-drive 7A-powered S5 , piloted by Flt. Lt. O. E. Worsley, which finished 2nd.

POWER CURVES

		N	P	MPS	BMEP
PEP	307				
DASO	225	kRPM	HP	m/s	Bar
YEAR	1927	2	350	8.68	6.54
Make	Napier	2.7	769	11.72	10.64
Model	Lion 7A	3	887	13.02	11.05
		3.3	942	14.32	10.67
Vcc	23944	3.6	970	15.62	10.07
Ind. System	NA				
Confign.	60W12				
Bmm	139.7				
Smm	130.175				





Amazing as it is to modern students of racing machinery, the government published full details of the whole aircraft and engine programme in R & M 1300 (DASO 225) – but not until 1931 after Great Britain had won the Trophy in perpetuity! No doubt it was read with interest in Germany and Japan….