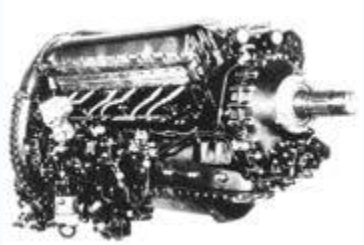
Rolls-Royce Merlin



The **Rolls-Royce Merlin** engines were a series of 12 cylinder, 60° "V", 27 litre, liquid cooled piston aircraft engines built during World War II by Rolls-Royce, and under licence in the United States by Packard. They are widely considered to be among the most successful aero engines produced during World War II, and perhaps the finest piston engines ever built for aviation. Merlins are highly sought-after by aviation enthusiasts even today.

The Merlin name came from the bird (a small falcon also known as "pigeon hawk") rather than King Arthur's legendary magician. However, in the film *The First of the Few*, Sir Henry Royce refers to King Arthur's Merlin, rather than the bird (probably due to some propaganda purposes, or a simple incorrect assumption on the part of the film makers).

History

In the early 1930s, Rolls started planning for the future of its aero engine development programmes, and eventually settled on having two basic designs. The 700 horsepower (500 kW) Rolls-Royce Peregrine was an updated, supercharged development of their existing V-12, 22 L Rolls-Royce Kestrel which had been used with great success in a number of 1930s designs. Two Peregrines bolted together on a common crankshaft into an X-24 layout would create the 1,700 hp (1,300 kW) 44 L Rolls-Royce Vulture, for use in larger planes like bombers. There was also the possibility that the famous 36 L 'R' engine from the Supermarine racing planes could be developed into a 1,500 hp (1,100 kW) class engine of its own, itself a development of the Rolls-Royce Buzzard, a scaled up Kestrel.

However, this plan left a large gap between 700 and 1,500 hp (500 and 1,100 kW). To fill the gap work was started on a new 1,100 hp (820 kW) class design as the *PV-12* – PV for "private venture"

as the company received no government money for work on the project. The PV-12 first flew on the front of a Hawker Hart biplane in 1935, using the new evaporative cooling system then in vogue. The cooling system proved unreliable, and when supplies of ethylene glycol (*Prestone*) from the US became available, the engine was changed to the conventional liquid cooling system instead.

In 1936, the Air Ministry had a requirement for a new fighter aircraft with airspeeds that would eventually have to be over 300 mph (480 km/h). Fortunately, two designs had been developed entirely as private venture exercises: the Hawker Hurricane and Supermarine Spitfire. Both were designed around the PV-12 instead of the Kestrel, and were the only British modern fighters to have been so developed. Production contracts for both aircraft were let in 1936. The PV-12 was instantly catapulted to the top of the supply chain and became the **Merlin**. First widely delivered as the 1,030 hp (770 kW) Merlin II in 1938, production was quickly stepped up. The Merlin I had a 'ramp head' where the inlet valves were at a 45-degree angle to the cylinder. This was not a success and only 172 were made before the conventional flat head arrangement wherein the valves are parallel to the cylinder was adopted for the Merlin II.

Early Merlins were considered to be rather unreliable, but Rolls soon introduced a superb reliability-improvement programme to improve matters. This consisted of taking random engines from the end of assembly line and running them continuously at full power until they failed. Each was then dismantled to find out which part had failed, and that part was redesigned to be stronger. After two years of this, the Merlin had matured into one of the most reliable aero engines in the world, and could be run at full power for eight-hour bombing missions with no problems.

As it turned out, the Peregrine saw use in only two aircraft, the Westland Whirlwind and the Gloster F9/37. Although the Peregrine appeared to be a satisfactory design, it was never allowed to mature; Rolls-Royce's priority was troubleshooting the Merlin. The Vulture was fitted to the Hawker Tornado and Avro Manchester, but proved unreliable owing to big-end failures caused by lubrication problems. With the Merlin itself soon pushing into the 1,500 hp (1,100 kW) range, the Peregrine and Vulture were both cancelled in 1943.

By the end of its production run, over 150,000 Merlin engines were built. It was supplanted in service by the Rolls-Royce Griffon which was a development of the R engine.

Upgrades

Most of the upgrades to the Merlin were the result of ever-increasing octane ratings in the aviation fuel available from the US, and ever more efficient supercharger designs. At the start of the war the engine ran on the then-standard 87 octane aviation spirit and could supply just over 1,000 hp (750 kW) from its 27 L displacement compared to 1,100 hp (820 kW) from the 34 L Daimler-Benz DB 601.

The next major version was the XX which ran on 100 octane fuel. This allowed it to be run at higher manifold pressures, which were achieved by increasing the "boost" from the centrifugal type supercharger. The result was that the otherwise similar engine delivered 1,300 hp (970 kW). The process continued, with later versions running on further-increased octane ratings, delivering higher and higher power ratings. By the end of the war the "little" engine was delivering over 1,600 hp (1,200 kW) in common versions, and as much as 2,070 hp (1,544 kW) in the Merlin 130/131 versions used on the de Havilland Hornet. The Merlin was running on 150 Octane fuel by the time it was used in the Lancaster bomber. This high octane rating was achieved by large quantities of lead anti-knocking agent, so much in fact, that the engine cowlings around the exhaust outlets were usually

heavily stained with it. It had to be regularly removed for aerodynamic, not to mention weight, reasons.

"Miss Shilling's orifice"

The Merlin's lack of direct fuel injection meant that both Spitfires and Hurricanes were, unlike the contemporary Bf-109E, unable to nose down into a deep dive. This meant the Luftwaffe fighters could 'bunt' into a high-power dive to escape attack, leaving the Spitfire spluttering behind as its fuel was forced by negative 'g' out of the carburettor. RAF fighter pilots soon learned to 'half-roll' their aircraft before diving to pursue their opponents. The use of uninjected carburettors was calculated to give a higher specific power output, due to the lower temperature, and hence the greater density, of the fuel/air mixture, compared to injected systems. "Miss Shilling's orifice" (invented by a female engineer named Shilling), a holed diaphragm fitted across the float chambers, went some way towards curing the fuel starvation in a dive in March, 1941. Further improvements were introduced throughout the Merlins, with injection introduced in 1943. Production of the Griffon-engined Spitfire Mk. XII had begun the year before.

Other uses for the engine

A non-supercharged version of the Merlin using more steel and iron components was produced for use in tanks. This engine, the Rolls-Royce Meteor, in turn led to the smaller Rolls-Royce Meteorite.

A Spanish-built version of the Messerschmitt Bf 109 G-2, the Hispano Aviacion Ha 1112 M. 1. L *Buchon*, was built with the Rolls-Royce Merlin 500/45 engine of 1,600 hp, with four-bladed propeller, in the Hispano Aviacion factory in Seville- a fitting powerplant for the last-produced version of the famous Messerschmitt fighter, as the Bf-109 V1 prototype aircraft had been powered by the Rolls-Royce Kestrel V-12 engine in 1935.

Packard's legacy

The Merlin was considered to be so important to the war effort that negotiations soon started to establish an alternative production line outside the UK. Agreement was reached with the Packard company in Detroit in September 1940, and the first Packard-built engine, designated V-1650-1, ran in August 1941.

The first American production of the Merlin was the Packard Merlin 28 or the equivalent of the Rolls Royce Mark XX. This engine was a ((single stage, two speed supercharger)). This engine (Merlin 28) was used for the Lancaster bomber. The USAAF version of this engine was designated the V-1650-1 which were used on the P-40F's. The initial Packard modification on the Merlins were done on this engine by changing the main bearings from a copper lead alloy to a silver lead combination and featured indium plating. Indium plating had been developed by the General Motors (Pontiac Division) to prevent corrosion which was possible with lubricating oils that were used at that time. The bearing coating also improved break-in and load carrying ability of the surface. British engineering staff assigned to Packard were astonished at the suggestion but after tear down inspections on rigidly tested engines they were convinced the new design offered a decided improvement.

The real improvement Packard incorporated into the Merlin was adopting the Wright supercharger drive quill. This modification was designated the V-1650-3 and became known as the "high altitude" Merlin destined for the P-51. The ((two speed, two stage supercharger)) section of the V-1650-3 featured two separate impellers on the same shaft which were normally driven through a gear train at a speed of 6.391:1. A hydraulic gear change arrangement of oil operated clutches could be engaged

by an electric solenoid to increase this ratio to 8.095:1 in high speed blower position. The high speed gear ratio of the impellers was not as great as the ratio used in the Allison but speed of the impeller alone was not the factor that increased the engine performance at altitude. The double staging of the compressed fuel/air mixture provided the boost pressure through a diffuser to the intake manifolds which increased the critical altitude of the power plant.

The ability of the supercharger to maintain a sea level atmosphere in the induction system to the cylinders allowed the Packard Merlin to develop more horse-power at 26,000 feet than the Allison had available for take-off at full power settings. The two stage impeller created extreme heating of the fuel/air mixture during the compression process and in order to prevent detonation of the compressed charge, it was necessary to cool the mixture prior to entry into the cylinders. This cooling was accompplished by the casting of an intercooler passage into the wheelcase housing between the first and second stage impellers.

Ethylene glycol coolant was circulated by a pump through this passage to carry off the excess heat generated by the impellers. Without the intercooler the temperature of the charge could be as high as 400 °F. The intercooler in itself was not adequate to deal with the high temperature and an additional cooling fin and tube core was placed between the outlet of the blower and the induction manifold to the cylinders. This radiator was known as an aftercooler and served as a reservoir for the system. The glycol mixture used for the superchargercooling was independent of the main engine cooling system and used a centrifugal pump driven by the engine to circulate the coolant through an aircraft radiator system at a rate of 30 gallons per minute.

This combined system reduced the charge temperature to suitable levels. The throttle valves in the updraft carburetor throat were controlled by an automatic boost control through the pilot's linkage to maintain the selected manifold pressure during changes in altitude. These valves were only partially open during ground and low level operation to prevent overboosting of the engine. As air density decreased with an increase in altitude, the throttle valves were moved to an open position by boost pressure corresponding to aircraft altitude. This system provided full power within engine boost limitations up to the critical altitude of 26,000 feet. This was the improvement Packard brought to the Merlin.

When the first of the Packard-built Merlins arrived in Britain, the engineers at Rolls-Royce stripped it down and were amazed to find that the production-line built Packard engine, far from being as bad as they expected it to be for component tolerances, was actually better. Up until then, R-R Merlins were hand built, every face being finished off by hand, and this time-consuming process placed great strain on the production capability of the skilled workforce involved in the manufacture of these engines. The Packard engine changed many minds, although there were still some at R-R who remained unconvinced of the quality of the American engine, produced as it was by a largely unskilled and semi-skilled female workforce. In the end, the engine's performance removed any doubts about its quality and workmanship.

The V-1650 performed so much better than its US counterpart, the Allison V-1710, that it went on eventually to replace it in the Curtiss P-40 and later the North American P-51 Mustang, which then became viewed as one of the best fighters of the war. Packard Merlins powered Canadian-built Hurricane, Lancaster and Mosquito aircraft, as well as UK-built Spitfires in the shape of the Mark XVI, otherwise the same as the Mark IX with its British-built Merlin.

Although it is not commonly known, Packard greatly improved the maintainability of the engine (by allowing easier use of interchangeable parts, rather than custom finished ones), and their changes were also incorporated in subsequent British production.

Civilian uses

Automotive

Michael Wilcock of Sussex, England built the Swandean Spitfire Special, using a Merlin XXV engined acquired from a a scrap yard for fifty pounds. The engine was installed in a home-brewed chassis confected from two Daimler Dingo scout car chassis. The car was run in the Brighton Speed Trials in 1953, and was sold to James Duffy of St. Louis, Missouri in 1956. As of 2005, the vehicle is still in St. Louis, where it is undergoing restoration.

In the 1960s, Paul Jameson put a Merlin engine (some say it actually was a Rover-built Rolls-Royce Meteor, which was a de-tuned Merlin without superchargers and with steel components replacing some aluminium ones) into a chassis he had built himself. He did not get around to building a body, and sold the car to Epsom automatic transmission specialist John Dodd, who fitted a fibreglass body based on the shape of the Ford Capri and named the machine "The Beast". Originally it had a grille from a Rolls-Royce, but after complaints from R-R themselves he had to change it. According to Dodd's account, he once drove past a Porsche driver on the autobahn who then called Rolls Royce asking about their "new model". The Beast was once listed in the Guinness Book of Records as the world's most powerful road car. The engine came from a Boulton Paul Balliol training aircraft which would give 1,262 hp (941 kW) at 8,500 feet (2,600 m). No supercharger was fitted to the engine in car so it "only" delivered about 850 hp (630 kW). The car used a General Motors TH400 automatic transmission. The Beast is alive and well in Marbella, Spain and is still owned by Dodd. It is still taxed in the UK; a DVLA search shows the engine capacity as 27000 cc.

In the mid-1970s, Jameson designed a second Merlin-powered car. This one had six wheels - two in front and four driven at the rear - and a mid-engined layout. The vehicle was featured by the British weekly motoring magazine "Motor"), and is said currently to reside in a museum in Sweden.

Around 1990, Jameson began work on a third Merlin-powered car, using a genuine 1930s Rolls-Royce chassis, but this vehicle remained uncompleted at the time of his death.

Recently in Australia, Rod Hadfield, of the Castlemaine Rod Shop, used the Merlin engine in a 1955 Chevrolet BelAir Sports Coupe, which was named "Final Objective."[1]

Boat racing

In the mid-forties and early fifties, aviation engines gained in popularity as powerplants of choice for hydroplane racing, given their relatively high power-to-weight ratio, reliability and availability. Starting with the MISS WINDSOR raceboat at Detroit in 1946, several ever-more-powerful variants of the Merlin were so used, over the next decades, in a heated battle against the equally popular Allison V-1710. In unlimited hydroplane racing, both were eventually supplanted by gas turbine engines, which exhibit even more favourable power-to-size and power-to-weight ratios.

Variants

This is an incomplete list of representative Merlin variants. Engines of the same power output were typically assigned different model numbers based on supercharger or propeller gear ratios, differences in cooling system or carburetors, engine block construction, or arrangement of engine controls.

- **Merlin II** or **III** - 1,040 hp (775 kW) at 3,000 rpm at 5,500 ft (1,680 m); used in Spitfire Mk.I and Hurricane Mk.I fighters.
- **Merlin X** - 1,130 hp (840 kW) at 3,000 rpm at 5,250 ft (1,525 m); used in Halifax Mk.I, Wellington Mk.II, and Whitley Mk.V bombers.
- **Merlin XX** - 1,480 hp (1,105 kW) at 3,000 rpm at 6,000 ft (1,830 m); used in Hurricane Mk.II and Beaufighter Mk.II fighters, Halifax Mk.II and Lancaster Mk.I bombers. Also in the P-51 Mustang fighter.
- **Merlin 32** - 1,645 hp (1,230 kW) at 3,000 rpm at 2,500 ft (760 m); used in Barracuda Mk.II bomber.
- **Merlin 45** - 1,470 hp (1,100 kW) at 3,000 rpm at 9,250 ft (2,820 m); used in Spitfire Mk.V
- **Merlin 46** - 1,415 hp (1,055 kW) at 3,000 rpm at 14,000 ft (4,270 m); high-altitude version used in Spitfire PR.Mk.IV and PR.Mk.VII
- **Merlin 61** - fitted with a new two-speed two-stage supercharger providing 1,565 hp (1,170 kW) at 3,000 rpm at 12,250 ft (3,740 m), and 1,390 hp (1,035 kW) at 3,000 rpm 23,500 ft (7,170 m); high-altitude version used in Spitfire Mk.VII, Mk.VIII, Mk.IX, and PR.Mk.XI
- **Merlin 76** & **77** - 1,233 hp (920 kW); used in the Westland Welkin high-altitude fighter and some later Spitfire and Mosquito variants. Fitted with a two-speed, two-stage supercharger and a Bendix-Stromberg carburettor. The odd-numbered mark drove a blower for pressurising the cockpit.

Specifications (Merlin 61)

Rolls-Royce Merlin with some components labeled. *Click image for a larger version.*

General characteristics

- **Type:** 12-cylinder supercharged liquid-cooled 60° "Vee" piston aircraft engine
- **Bore:** 5.4 in (137.2 mm)
- **Stroke:** 6 in (152.4 mm)
- **Displacement:** 1,648.96 in³ (27.04 L)
- **Dry weight:** 1,640 lb (745 kg)

Components

- **Valvetrain:** Overhead camshaft-actuated, two intake and two exhaust valves per cylinder, sodium-cooled exhaust valve stems
- **Supercharger:** Two-speed two-stage, boost pressure automatically linked to the throttle, water-air aftercooler installed between the second stage and the engine.
- **Fuel system:** Twin-choke updraft carburetor with automatic mixture control
- **Oil system:** Dry sump with one pressure pump and two scavenge pumps.
- **Cooling system:** 70% water and 30% ethylene glycol coolant mixture, pressurized.

Performance

- **Power output:**
  - 1,565 hp (1,170 kW) at 3,000 rpm at 12,250 ft (3,740 m)
  - 1,390 hp (1,035 kW) at 3,000 rpm at 23,500 ft (7,170 m)
- **Specific power:** 0.95 hp/in³ (43.3 kW/L)
- **Compression ratio:** 6:1
- **Power-to-weight ratio:** 0.95 hp/lb (1.57 kW/kg)

Related content

Similar engines

- Rolls-Royce Griffon
- Daimler-Benz DB 605
- Klimov VK-107
- Allison V-1710
- Junkers Jumo 213

See also

- Rolls-Royce Meteor tank engine developed from the Merlin
- Napier Sabre