Packard Merlin Aircraft Engine

The Merlin was considered to be so important to the war effort, negotiations soon started to establish an alternative production line outside the UK. Rolls-Royce had checked out a number of North American automobile manufacturers, in order to select one to build the Merlin in the USA or Canada, and Packard Motor Car Company's attention to high quality and engineering impressed the parent British company so much, Packard was selected to build the Merlin. Agreement was reached 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 (Mark XX). This engine was a (single stage, two speed supercharger). As the Merlin 28, it was used for the Lancaster bomber. The USAAF version of this engine was used in the P-40Fs. The initial Packard modifications were done on this engine by changing the main bearings from a copper lead alloy to a silver lead combination and featured indium plating. This had been developed by 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 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 -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 1,210 horsepower at 25,800 feet. 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 accomplished 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 supercharger cooling 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 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, Rolls-Royce 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 Rolls-Royce 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 Packard V-1650 so outperformed the Allison V-1710 it supplanted the Allison in the North American P-51 Mustang, which then became one of the best fighters of the war. It was also incorporated into some models of the Curtiss P-40, specifically the P-40F and P-40L. 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.

A common misconception is that Packard Merlin engines were used in American PT boats; the engine used was in fact a modified Liberty V-12 engine, totally unrelated to the Merlin. The possibility is that these engines were also used by British MTBs and MGBs.

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. All Merlin engines were "right hand tractor", *i.e.* propeller rotated to the right viewed from rear, unless otherwise noted.

- **Merlin II** or **III** - 1,030 hp at 3,000 rpm at 5,500 ft. *With 100 Octane fuel and increased (+9lb/sq.in) Boost* - 1,160 hp at 3,000 rpm at 12,250 ft.
- **Merlin X** - 1,130 hp at 3,000 rpm at 5,250 ft
- **Merlin XX** - 1,480 hp at 3,000 rpm at 6,000 ft.
- **Merlin 32** - 1,645 hp at 3,000 rpm at 2,500 ft.
- **Merlin 45** - 1,515 hp at 3,000 rpm at 11,000 ft.
- **Merlin 46** - 1,415 hp at 3,000 rpm at 14,000 ft.
- **Merlin 50.M**- 1,585 hp at 3,000 rpm at 2,750 ft Low altitude version with supercharger impeller "cropped" to 9.5 inches in diameter. Permitted boost was +18 lb/sq.in. instead of +16 lb/sq.in. as on a normal Merlin 50 engine.
- **Merlin 61** - fitted with a new two-speed two-stage supercharger providing 1,565 hp at 3,000 rpm at 12,250 ft, and 1,390 hp at 3,000 rpm 23,500 ft.
- **Merlin 76** & **77** - 1,233 hp; Fitted with a two-speed, two-stage supercharger and a Bendix-Stromberg carburetor. The odd-numbered mark drove a blower for pressuring the cockpit.
- **Merlin 130** & **131**. - 2,070 hp; redesigned "slimline" versions made for the de Havilland Hornet. Engine modified to decrease frontal area to minimum and was first Merlin series to use down-draught induction systems. Coolant pump moved from the bottom of the engine to the starboard side. Two -speed, two-stage supercharger and S.U Injection carburetor. Maximum Boost was 25 lb. The Merlin 131 had an additional idler gear in the reduction gear casing allowing "reverse" (left hand tractor) rotation.
- **Merlin 133** & **134** - 2,030 hp; Maximum Boost was lowered to 18 lb.

Specifications (Merlin II/III)

General characteristics

- **Type:** 12-cylinder supercharged liquid-cooled 60° "Vee" piston aircraft engine
- **Bore:** 5.4 in
- **Stroke:** 6 in
- **Displacement:** 1,648.96 in^3
- **Length:** 69 in
- **Width:** 29.8in
- **Height:** 41.2 in
- **Dry weight:** 1,375 lb.

Components

- **Valvetrain:** Overhead camshaft-actuated, two intake and two exhaust valves per cylinder, sodium-cooled exhaust valve stems
- **Supercharger:** Single stage single speed.
- **Fuel system:** Twin-choke updraft carburettor with automatic mixture control
- **Fuel type:** 87 later 100 Octane Aviation fuel
- **Oil system:** Dry sump with one pressure pump and two scavenge pumps.
- **Cooling system:** 100% ethylene glycol, pressurized.

Performance

- **Power output:**
  Note: Maximum boost pressures = 87 Octane +6.25lb; 100 Octane fuel +9 lb boost.
  - 880 at 3,000 rpm at take-off.
  - 1,030 hp at 3,000 rpm at 16,000 ft. (+6.25 lb)
  - 1,160 hp at 3,000 rpm at 12,250 ft. (+9 lb)
- **Specific power:** 0.70 hp/in^3
- **Compression ratio:** 6:1
- **Power-to-weight ratio:** 0.844 hp/lb

Specifications (Merlin 61)

General characteristics

- **Type:** 12-cylinder supercharged liquid-cooled 60° "Vee" piston aircraft engine
- **Bore:** 5.4 in
- **Stroke:** 6 in
- **Displacement:** 1,648.96 in³ (27.04 L)
- **Length:** 88.7 in
- **Width:** 30.8 in
- **Height:** 40 in
- **Dry weight:** 1,640 lb

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
- **Fuel type:** 100 later 150 Octane Aviation fuel
- **Oil system:** Dry sump with one pressure pump and two scavenge pumps.
- **Cooling system:** 70% water and 30% ethylene glycol, pressurized.

Performance

- **Power output:**
  Note: 100 Octane fuel, +12 lb boost.
  - 1,280 hp at 3,000 rpm at take-off.
  - 1,565 hp at 3,000 rpm at 12,250 ft (MS gear)
  - 1,390 hp at 3,000 rpm at 23,500 ft (FS gear)
- **Specific power:** 0.95 hp/in³
- **Compression ratio:** 6:1
- **Power-to-weight ratio:** 0.95 hp/lb