Allison V-1710

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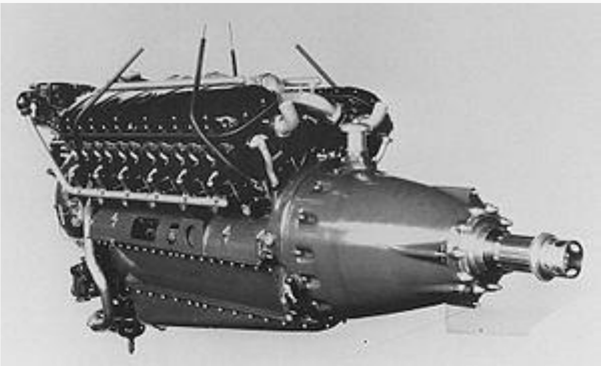	
Allison V-1710	
Type	Liquid-cooled V-12 piston engine
Manufacturer	Allison Engine Company
First run	1930
Major applications	Lockheed P-38 Curtiss P-40 P-51 Mustang
Number built	>70,000

The **Allison V-1710** aircraft engine was the only indigenous US-developed V-12 liquid-cooled engine to see service during World War II. Versions with a turbo-supercharger gave excellent performance at high altitude in the twin-engine Lockheed P-38 Lightning, and turbo-superchargers were fitted to experimental single-engine fighters with similar results. The US Army preference for turbo-superchargers early in the program meant that less effort was spent on developing suitable superchargers, and when smaller or lower-cost versions of the engine were desired, they generally had poor performance at higher altitudes. The V-1710 nevertheless gave excellent service when turbo-supercharged, notably in the P-38 Lightning, which accounted for much of the extensive production run.

The Allison Division of General Motors began developing the ethylene glycol-cooled engine in 1929 to meet a US Army Air Corps need for a modern, 1,000 hp (750 kW), engine to fit into a new generation of streamlined bombers and fighters. To ease production the new design could be equipped with different propeller gearing systems and superchargers, allowing a single production line to build engines for everything from fighters to bombers.

The U.S. Navy purchased the first V-1710s, the B model (the only V-1710 that did not have a gear-driven supercharger) in 1931 and installed them on the airships *Akron* and *Macon*. The U.S. Army Air Corps purchased its first V-1710 in December 1932. The Great Depression slowed development, and it was not until December 14, 1936 that the engine next flew in the Consolidated XA-11A tested. The V-1710-C6 successfully completed the Army *150 hour Type Test* on April 23, 1937 at 1,000 hp (750 kW), the first engine of any type to do so. The engine was then offered to aircraft manufacturers where it powered the Curtiss X/YP-37. All entrants in the new pursuit competition were designed around it, powering the Lockheed P-38, Bell P-39 and Curtiss P-40. When war materiel procurement agents from England asked North American Aviation to build the P-40 under license, NAA instead proposed their own improved aircraft design, using the V-1710 in their P-51A.

The V-1710 has 12 cylinders with a bore and stroke of 5.5 by 6 inches (140 by 150 mm) in 60° V-format, aggregating to 1,710.6 cu in (28.032 L) total displacement, with a compression ratio of 6.65:1. The engine design benefited from the General Motors philosophy to build-in production and installation versatility. The engine was constructed around a basic power section from which different installation requirements could be met by fitting the appropriate Accessories Section at the rear and a tailored reduction gear for power output at the front. This approach allowed easy changes of the supercharger(s) and supercharger drive-gear ratio. That gave different critical altitude ratings ranging from 8,000 to 26,000 feet (2,400 to 7,900 m). It allowed a variety of propeller drives and also remote placement of the reduction gear.

The P-39, P-63, and XB-42 installations used V-1710-E series engines that exchanged the integral reduction gear for an extension shaft that drove a remotely located reduction gear and propeller. Aircraft such as the P-38, P-40, P-51A, and P-82 used close-coupled propeller reduction gears, a feature of the V-1710-F series.

Another feature of the V-1710 design was its ability to turn the output shaft either clockwise or counter-clockwise by assembling the engine with the crankshaft turned end-for-end, by installing an idler gear in the drive train to the supercharger and accessories and by installing a starter turning the proper direction. So, there was no need to re-arrange the ignition wiring and firing order, nor the oil and Glycol circuits to accommodate the direction of rotation.

The V-1710 has often been criticized for not having a "high-altitude" supercharger. The comparison is usually to the later, two-stage, versions of the Rolls-Royce Merlin built by Packard as the V-1650 and used in the P-51B Mustang and subsequent variants. The US Army had specified that the V-1710 was to be a single-stage supercharged engine and, if a higher altitude capability was desired, the aircraft could use their newly developed turbo-supercharger as was featured in the P-37, P-38, and XP-39.

The benefits of a two-stage supercharger eventually became so clear that Allison did make some efforts in this direction. Allison attached an auxiliary supercharger in various configurations to the existing engine-mounted supercharger and carburetor. Early versions of these two-stage supercharger engines were used on the P-63. No intercooler, after-cooler, or backfire screen were incorporated into these two-stage V-1710 engines (except for the V-1710-119 used on the experimental P-51J, which had an after-cooler). The two-stage Merlin engines had all of these features, which were designed to prevent detonation from charge heating and backfire into the supercharger. The G-series V-1710s installed on the F-82 E/F/G models had only anti-detonation injection to deal with these problems, and not surprisingly had severe reliability and maintenance problems. In one record, it was stated that the F-82 required 33 hours of maintenance for one hour of flight. Although the early V-1710 powered P-39, P-40 and P-51A airplanes were limited to combat operations at a maximum of about 15,000 feet (4,600 m) they were available in comparatively large numbers and were the mainstay of some Allied Air Forces in all but the European theater of war. The engines proved to be robust and little affected by machine-gun fire. In total, over 60 percent of the US Army Pursuit aircraft operated during WWII were powered by the V-1710.

Allison continuously improved the engine during the war. The initial rating of 1,000 hp (750 kW) was incrementally increased; the final V-1710-143/145(G6R/L) was rated for 2,300 hp (1,700 kW). By 1944, the War Emergency Power rating on the P-38L was 1,600 hp (1,200 kW). The most powerful factory variant was the V-1710-127, designed to produce 2,900 hp (2,200 kW) at low altitude and 1,550 hp (1,160 kW) at 29,000 feet (8,800 m). This engine was static tested at 2,800 hp (2,100 kW) and was planned for installation in an XP-63H aircraft. The end of the war ended this development, so this promising experiment never flew. The extra power of this version was derived from using exhaust turbines, not to drive a turbo-supercharger, but to return that energy to turning the crankshaft. This was called a "turbo-compound" arrangement.

Improvements in manufacturing brought the cost to produce each engine from $25,000 down to $8,500 and allowed the installed lifetime of the engine to be increased from 300 hours to as much as 1,000 hours for the less stressed power plants. Weight increases needed to accomplish this were minimal, with the result that all models were able to produce more than 1 hp/lb. (1.6 kW/kg) at their takeoff rating. Comparisons between Allison engine and the Rolls-Royce Merlin engine are inevitable. What can be said for the Allison is that it made more power at less boost with a longer time between overhauls and the part count was nearly half that of the Merlin engine which facilitated mass production greatly. The British-made Merlin engines were still reliant upon hand-crafted and fitted parts from skilled craftsmen, something which was corrected by the redesign and success of the Packard V-1650 license-produced version of it in the United States, built with American production-line techniques. There also was a high degree of commonality of parts throughout the series. The individual parts of the Allison series were produced to a high degree of standardization and reliability, using the best technology available at the time. Even after the War, racing Merlins used Allison connecting rods! Allison employed a modular design, so that it was capable of being mated to many different styles of turbo-superchargers and various other accessories, although the variety of turbo-superchargers available for installation was limited due to the constraints of single-engine fighter design. Since it was produced in large numbers and was highly standardized, the engine has been used in many postwar racing designs. Its reliability and well-mannered operation allowed it to operate at high rpm for extended periods.

Following the war, North American built 250 P-82E/F for air defense roles into the early 1950s. This was the final military role for the V-1710.

The Army had earlier decided to concentrate on turbo-superchargers for high altitude boost, believing that further development of turbochargers would allow their engines to outperform European rivals using superchargers. Turbo-superchargers are powered by the engine exhaust and so do not draw power from the engine crankshaft, whereas superchargers are connected directly by gears to the engine crankshaft. Turbo-superchargers do increase the exhaust back-pressure and thus do cause a decrease in engine power, but the power increase due to increased induction pressures more than make up for that decrease. Crankshaft-driven superchargers require an increasing percentage of engine power as altitude increases (the two-stage supercharger of the Merlin 60 series engines consumed some 230-280 horsepower at 30,000 ft.). General Electric was the sole source for research and production of American turbo-superchargers during this period. Turbo-superchargers were indeed highly successful in U.S. bombers, which were exclusively powered by radial engines. The P-47 fighter had the same combination of radial engine (R-2800) and turbo-supercharger and was also successful, apart from its large bulk, which was caused by the need for the ductwork for the aft-mounted turbo-supercharger.

However, mating the turbocharger with the Allison V-1710 proved to be problematic. As a result, designers of the fighter planes that utilized the V-1710 were invariably forced to choose between the poor high-altitude performance of the V-1710 versus the increased problems brought on by addition of the turbo-supercharger. The fates of all of the V-1710 powered fighters of World War II would thus hinge on that choice.

The original XP-39 was built with a V-1710 augmented by a Type B-5 turbo-supercharger as specified by Fighter Projects Officer Lieutenant Benjamin S. Kelsey and his colleague Gordon P. Saville. Numerous changes were made to the design during a period of time when Kelsey's attention was focused elsewhere, and Bell engineers, NACA aerodynamicists and the substitute fighter project officer determined that dropping the turbocharger would be among the drag reduction measures indicated by borderline wind tunnel test results; an unnecessary step, according to aviation engineer and historian Warren

M. Bodie. The production P-39 was thus stuck with poor high-altitude performance and proved unsuitable for the air war in Western Europe which was largely conducted at high altitudes. The P-39 was rejected by the British, but used by the U.S. in the Mediterranean and the early Pacific air war, as well as shipped to the Soviet Union in large numbers under the Lend Lease program. The Soviets were able to make good use of P-39s because of its excellent maneuverability and because the air war on the Eastern Front in Europe was primarily short ranged, tactical, and conducted at lower altitudes. In the P-39, Soviet pilots scored the highest number of individual kills made on *any* American, or British fighter type.

The P-40, which also had only the single-stage, single-speed-supercharged V-1710, had similar problems with high-altitude performance.

The P-38 was the only fighter to make it into combat during World War II with turbo-supercharged V-1710s. The operating conditions of the Western European air war – flying for long hours in intensely cold weather at 30,000 feet (9,100 m) – revealed several problems with the turbo-supercharged V-1710. These had a poor manifold fuel-air distribution and poor temperature regulation of the turbo-supercharger air, which resulted in frequent engine failures (detonation occurred in certain cylinders as the result of persistent uneven fuel-air mixture across the cylinders caused by the poor manifold design). The turbo-supercharger had additional problems with getting stuck in the freezing air in either high or low boost mode; the high boost mode could cause detonation in the engine, while the low boost mode would be manifested as power loss in one engine, resulting in sudden fishtailing in flight. These problems were aggravated by suboptimal engine management techniques taught to many pilots during the first part of WWII, including a cruise setting that involves running the engine at a high RPM and low manifold pressure with a rich mixture. These settings can contribute to overcooling of the engine, fuel condensation problems, accelerated mechanical wear, and the likelihood of components binding or "freezing up." Details of the failure patterns were described in a report by General Doolittle to General Spatz in January 1944. In March 1944, the first Allison engines appearing over Berlin belonged to a group of P-38H pilots of 55FG, engine troubles contributing to a reduction of the force to half strength over the target. It was too late to correct these problems in the production lines of Allison or GE, and so the P-38s were steadily withdrawn from Europe until they were no longer used for bomber escort duty with the Eighth Air Force by October 1944. A few P-38s would remain in the European theater as the F-5 for photo reconnaissance.

The P-38 had fewer engine failures in the Pacific Theater, where operating techniques were better developed (such as those recommended by Charles Lindbergh during his P-38 flight testing in the PTO,) the fuel quality was consistently superior and the Japanese did not operate at such high altitudes. Using the same P-38Gs which were proving difficult to maintain in England, Pacific-based pilots were able to use the aircraft to good advantage including, in April 1943, Operation Vengeance, the interception and downing of the Japanese bomber that was carrying Admiral Isoroku Yamamoto. New P-38 models with ever-increasing power from more advanced Allisons were eagerly accepted by Pacific air groups.

When Packard started building Merlin V-1650 engines in America, certain American fighter designs using the Allison V-1710 were changed to use the Merlin. The P-40F, a Lend Lease export to Britain, was one of the first American fighters to be converted to a Packard-Merlin engine. However, the installed engine was the V-1650-1 with a slightly improved single-stage, two-speed supercharger, yielding only modest gains in performance.

The first production P-51A had the Allison V-1710 without turbo-supercharger and thus, poor high altitude performance. At low altitudes, the P-51A was substantially faster than the Spitfire, which very much impressed the British when they first received the plane; they quickly realized the P-51 had an outstanding low-drag airframe and the airplane could become one of the best of the war if the Allison V-1710 engine were replaced by the two-stage-supercharged Merlin. Conversion proceeded on both sides of the Atlantic, with North American Aviation engineers making the definitive changes to the airframe to fully integrate the Packard-Merlin V-1650-3 into the P-51B. Ironically, because the P-51 was not originally developed for the USAAF, this was allowed to proceed rapidly with no Army input (or interference). A similar attempt to cure the problems of the P-38 by replacing its Allisons with Merlins was quashed by the USAAF, after protests from Allison.

Cutaway of Allison V-1710

Starting with the V-1710-45 around 1943, Allison attached an auxiliary supercharger to some of its engines in an effort to improve high-altitude performance, with limited success. Although described as a two-stage supercharger, it was essentially an afterthought and did not have the full refinements of the two-stage Merlin, such as the pressure-altitude governed two-speed gearbox and the intercooling system. Various configurations of this auxiliary supercharger were used in production versions of the V-1710 that powered aircraft such as the Bell P-63 and North American P-82E/F/G series. In addition, it was tried or studied as the power plant for many experimental and test aircraft such as variants of the Boeing XB-38, Republic XP-47A, both with turbo-superchargers (AP-10), Curtiss XP-55 Ascender, and Douglas XB-42 Mixmaster. The F-82 did see brief action in the Korean War, but the type was completely withdrawn from Korea by the end of 1950. It had a short service life that was probably due to a combination of factors: poor reliability from the G-series V-1710 engines, low numbers of F-82s produced, and the arrival of jet fighters. The initial production P-82B had Merlin engines, but North American was forced to use the Allison V-1710 for the E/F/G models.

In total, over 70,000 V-1710s were built by Allison during the war, all in Indianapolis, Indiana.

The V-1710's useful life continued, as thousands were available on the surplus market. In the 1950s, many drag racers and land speed racers, attracted by its reliability and good power output, adopted the V-1710; Art Arfons and brother Walt in particular used one, in *Green Monster*. It proved unsuccessful as a drag racing engine, being unable to accelerate rapidly, but "could taxi all day at 150". Unlimited hydroplane racing also became a big sport across the U.S. at this time and V-1710s were often tuned for racing at up to 4,000 hp (3,000 kW)—power levels that were beyond design criteria and significantly reduced durability.

Later, as purpose-built V8 engines became available for drag racing and unlimited boats shifted to turboshaft power, tractor pullers began using the Allison engine, again developing unimagined power. Finally, the warbird movement began to restore and return to the air examples of the classic fighters of the war and many V-1710-powered pursuit airplanes began to fly again, with freshly overhauled engines. The reliability, maintainability, and availability of the engine has led others to use it to power flying examples of aircraft whose original engines are unobtainable. This includes newly manufactured Russian Yak-3 and Yak-9 airplanes, originally powered by Klimov V-12s in World War II, as well as ambitious projects such as a replica Douglas World Cruiser and Focke-Wulf Fw 190D by Flug Werk of Germany.

General characteristics

- **Type:** 12-cylinder supercharged liquid-cooled 60° "Vee" piston aircraft engine
- **Bore:** 5.5 in (139.7 mm)
- **Stroke:** 6.0 in (152.4 mm)
- **Displacement:** 1,710 cu in (28 L)
- **Length:** 85.81 in (2,180 mm)
- **Width:** 29.28 in (744 mm)
- **Height:** 37.65 in (958 mm)
- **Dry weight:** 1,395 lb. (633.5 kg)

Components

- **Valve train:** Two intake and two exhaust valves per cylinder with sodium-cooled exhaust valves, operated by a single gear-driven overhead camshaft per each bank of cylinders
- **Supercharger:** Centrifugal-type, single-stage, 15-vane impeller, 10.25 in (260 mm) diameter
- **Fuel system:** Bendix Stromberg carburetor with automatic mixture control
- **Fuel type:** 100 octane
- **Oil system:** Dry sump with one pressure and two scavenge pumps.
- **Cooling system:** Liquid-cooled with a mixture of 70% water and 30% ethylene glycol, pressurized.

Performance

- **Power output:** 1,475 hp (1,100 kW) at 3,000 rpm
- **Specific power:** 0.86 hp/cu in (39.3 kW/L)
- **Compression ratio:** 6.65:1
- **Power-to-weight ratio:** 1.05 hp/lb. (1.76 kW/kg)