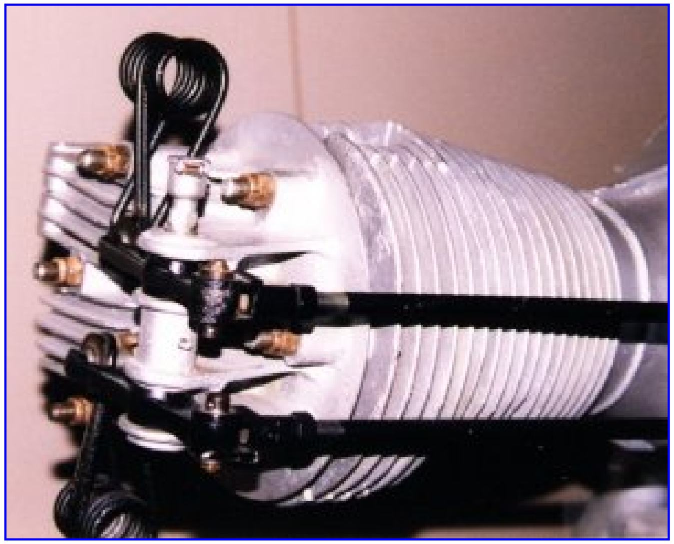
Air-Cooled Aircraft Engine Cylinders

An Evolutionary Odyssey

by George Genevro

Part 2 - Developments in the U.S.

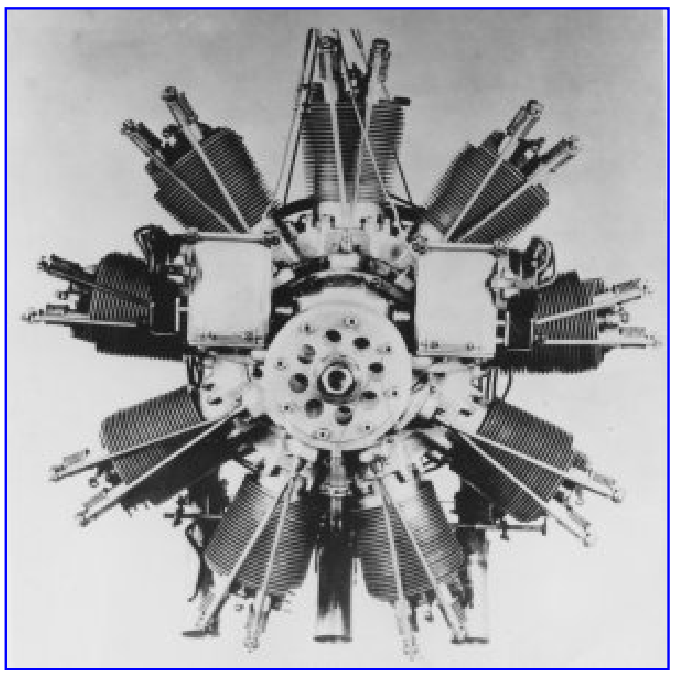
The Lawrance-Wright Era. In the U.S., almost the only proponent of the air-cooled engine during World War I was the Lawrance Aero Engine Company. This small New York City firm had produced the crude opposed twins that powered the Penguin trainers, which were supposed to be the stepping-stone to the Jenny for aspiring military pilots. The Penguins were not intended to fly but apparently could taxi at a speed that would provide some excitement for trainees as they tried to maintain directional control and develop some feel of what flight controls were all about. The Lawrance twins, which can be seen in many museums, had directly opposed air-cooled cylinders and a crankshaft with a single crankpin to which both connecting rods were attached. This arrangement resulted in an engine that shook violently at all speeds and was therefore essentially useless for normal powered flight. After World War I, some attempts were made, generally unsuccessful, to convert the Lawrance twins into usable engines for light aircraft by fitting a two-throw crankshaft and welding an offset section into the connecting rods. This proves that the desire to fly can be very strong indeed in some individuals.



The cast aluminum cylinder head on the Lawrance opposed twin engine used on the World War I “Penguin” trainers was attached to the cylinder with studs. Note the unusual hairpin valve springs and the adjustable length pushrods.

The hairpin valve springs pictured to the left were possibly pioneered by Salmson in 1911, and later used not only on British single-cylinder racing motorcycle engines, but also by Ferrari and others into the 1950s. This use was a response to the same problem that led to desmodromic valves at Ducati, Norton (test only) and Mercedes - namely the fatigue of coil springs from "ringing". Hairpin springs ran cool because they were exposed, and they were less subject to fatigue. They could also be changed without engine disassembly. Around 1964 cleaner steels produced by vacuum remelting became available in quantity, making possible the manufacture of highly fatigue-resistant spring wire. Previous wire was made from electric furnace steel - then the cleanest available. Vacuum remelted steel wire made desmo and hairpins redundant. Today Ducati engineers respond to the question "Why still desmo?" much as Bosch engineers did to the 1945 question "why direct injection when carbs were so much simpler?". They said that once they'd started down that road, it was simpler to continue rather than start over with another technology.

Kevin Cameron



After the end of World War I, the Lawrance engineers worked with both the Army and the Navy in developing a nine-cylinder radial engine, the Model J-1. It was the best American air-cooled engine at the time and passed its 50-hour test in 1922. A unique feature of the engine was the use of exhaust valves with hollow stems that were partly filled with mercury as a means of carrying heat from the head of the valve through the stem to the valve guide. Heron and Gibson had experimented with hollow stemmed valves for a number of years using water or mercury as heat transfer agents. The use of mercury was not really satisfactory since it would not wet the surface of the inside of the valve stem and therefore did not transfer heat well. Water had been found to be wholly unsuitable.

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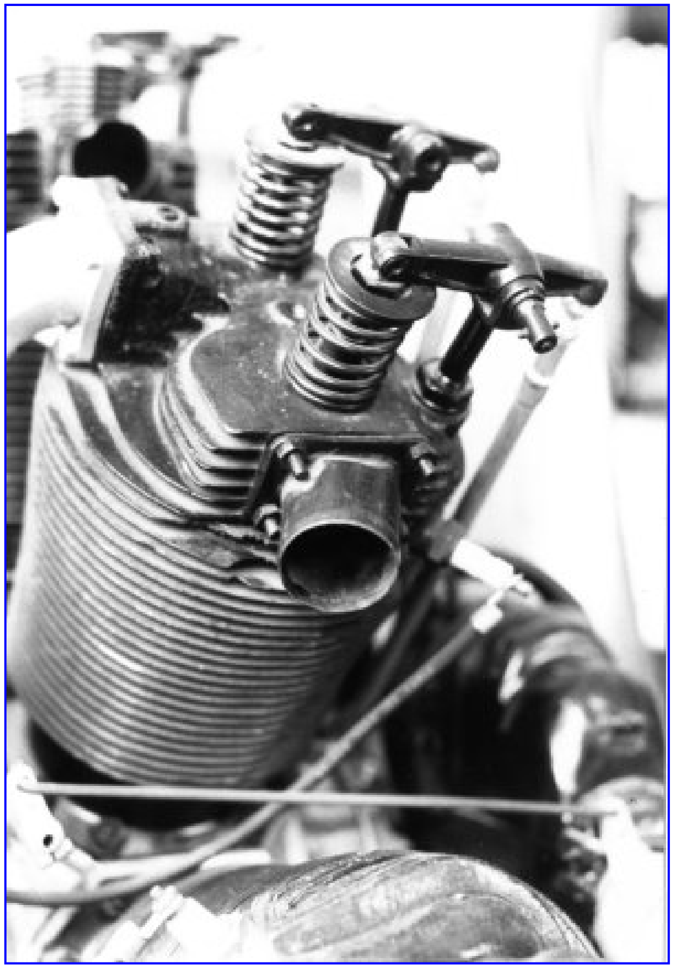
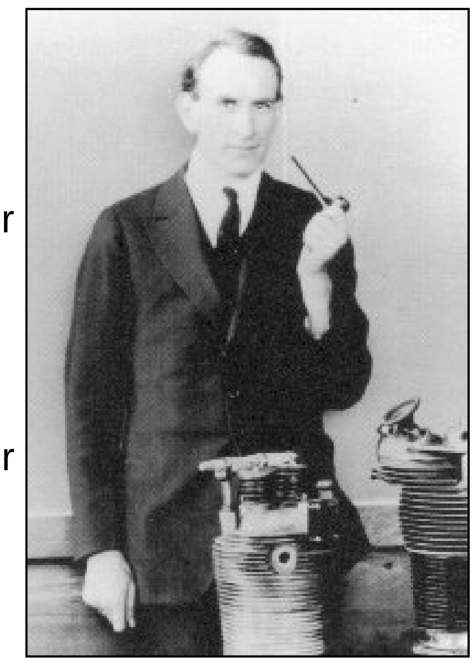


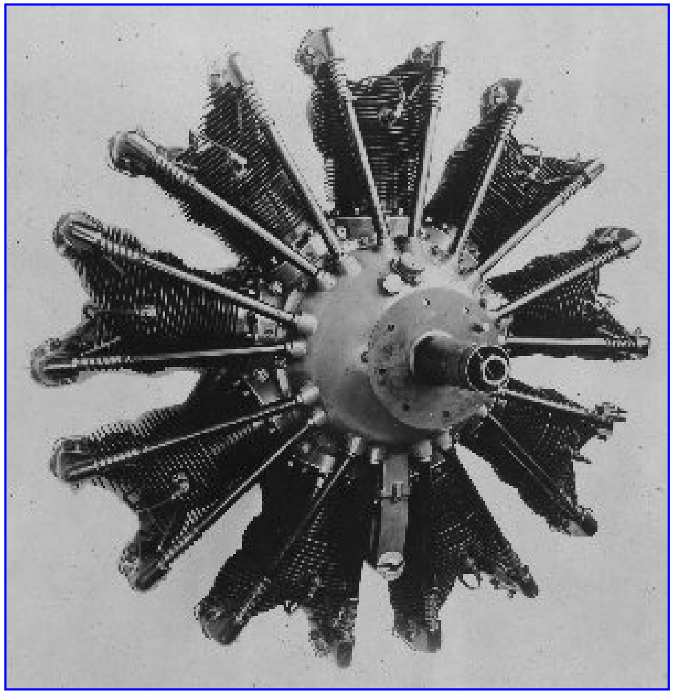
The early 1920s Wright-Lawrance radial engine had exposed overhead valves. Note the roller tips on the rocker arms, adjustable pushrods, and Alemite grease fittings on the rocker arm pivots.

The U.S. Navy had decided to build aircraft carriers and since it badly needed light, reliable engines it gave a contract to Lawrance for the J-1 radial and ceased buying the liquid-cooled Hispano-Suiza engines manufactured by Wright under license as a means of pressuring Wright and other companies into developing radial engines. The Wright Aeronautical Corporation bought the Lawrance Company, largely at the urging of the Army and Navy, and the later engines were known as Wrights. These engines, known as the J series, were dominant in the 1920s and the J-5, which was the first American production engine to use salt-cooled exhaust valves, achieved everlasting fame as the powerplant that carried Charles Lindbergh across the Atlantic.



Samuel Heron, ever on the move, had emigrated to the U.S. in 1921 after a disagreement with his employer, J.D. Siddeley of the Siddeley Deasy Company, over Siddeley's efforts to alter one of Heron's cylinder designs. It has been said that Heron did not suffer those he considered fools gladly-or at all-and apparently he did not make exceptions for employers or company owners. After his arrival in the U.S. he went to work for the U.S. Army Air Service at McCook Field (now Wright-Patterson AFB) in Dayton, Ohio as a development engineer. In 1926, he joined the Wright Company, of which Lawrance was now vice-president, and his work in cylinder development was largely responsible for the success of the Wright J-5 engine. The Lawrance cylinder design had evolved from an all-aluminum cylinder with a steel liner that suffered from breakage of the aluminum mounting flange to the J-5 type that had a finned steel cylinder barrel with a screwed-on head and much more fin area, especially around the exhaust valve port. A major step had been taken in improving the radial air-cooled engine but much remained to be done.

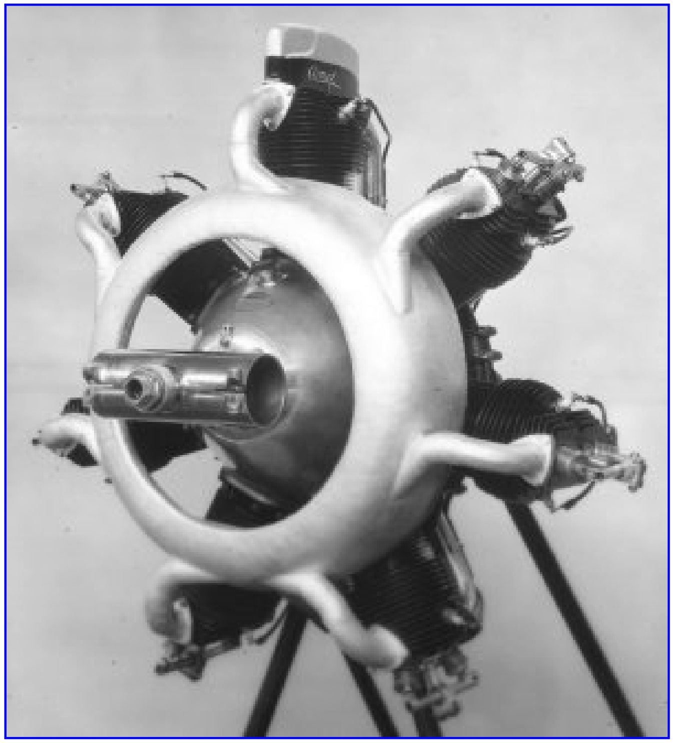
Samuel D. Heron played a key role in cylinder development.



Pratt & Whitney set a new standard for cylinder design with its first engine, the Wasp

A New Player in the Horsepower Race. Pratt & Whitney set a new standard for cylinder design when their first engine, the Wasp (which we now know as the R- 1340 in its military designation) was introduced in 1926. It incorporated the best features of Heron's latest cylinders and improvements such as integral rocker arm housings and additional fin area. That some of the best features of the Heron cylinder design should appear in this new engine is not surprising since Pratt & Whitney was formed by F. B. Rentschler, who had resigned as president of Wright in 1925. George Mead, Wright's former Chief Engineer, and Andrew Willgoos, Assistant Chief Engineer for Design, left Wright to assume similar positions at Pratt & Whitney. The Wasp was an immediate success and the Navy, by now heavily committed to building a carrier force, ordered 200 engines, an especially large order for that era. Almost immediately, the Navy expressed a need for a larger engine and the 1,690 cubic inch Hornet was designed and built, passing its Navy type test in 1927. The horsepower race had started in earnest.

Wright responded to this challenge with an even larger engine, the 1,790 cubic inch single row direct-drive nine cylinder Cyclone. Its displacement was soon increased by 30 cubic inches and as the R-1820, it powered a number of military and civilian aircraft. Its rated power output rose from about 500 horsepower in 1927 in its original direct-drive form to as much as 1,525 horsepower in the versions produced after World War II. The author clearly remembers an instance in the early 1980s during forest fire season when a heavily loaded (very probably overloaded) ex-Navy Grumman S2F “borate bomber” took off from the Ramona Airport in southern California on a fairly hot day. The rate of climb was minimal but the sound of the two very hard-working Wright R-1820s echo off the surrounding hills was memorable.



The unique Comet engine, manufactured in Wisconsin in 1929, had a semi-desmodromic valve actuation system that required only one push rod and one rocker arm. The cam ring follower was similar to that used on the LeRhone rotary engines. Note the fore-and-aft alignment of the valves.

The power output of other engines that were developed during the World War II period was also increased substantially. This can be attributed largely to advances and innovations in cylinder design and construction, metallurgical progress, and improvements in foundry capability in the U.S. American foundry men, through intensive experimentation, had developed procedures for casting thin, closely spaced fins on a production basis and had progressed well beyond the British in this critical area. One cannot help but be impressed, in looking at a World War II era Pratt & Whitney or Wright engine, at the skill of those who produced those beautiful cylinder head castings literally by the hundreds of thousands, and in some cases, by the millions.

The sales techniques of the 1929 era combined a display that demonstrated the operation of the valve mechanism, crankshaft, and cam ring along with a personal touch.

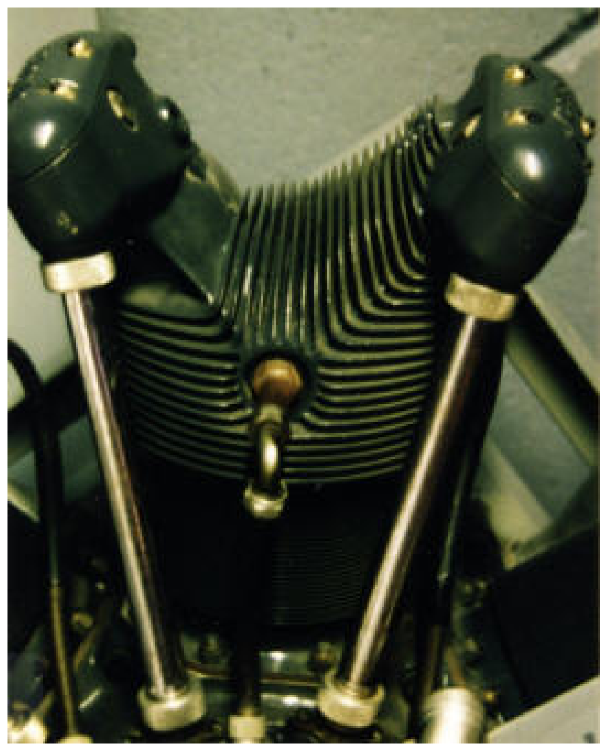
By the early 1930s, cylinder design in the U.S. for large radial engines had become somewhat standardized, with bores of about six inches and two large valves per cylinder in a hemispherical combustion chamber. Valve actuation was by means of ring cams housed in the nose section or the crankcase, enclosed push rods, and rocker arms in individual housings cast integrally with the cylinder head. While all engines of any consequence had enclosed valve mechanisms, it wasn't until 1932 that automatic pressure lubrication with engine oil was introduced on the Pratt & Whitney Wasp. Much of the subsequent development work involved experimentation with materials, sodium-cooled valves, improvements in piston rings, better foundry practices, and many other minor improvements that would extend engine life and allow higher power outputs. Near the end of World War II the much more widespread use of forged cylinder heads with machined fins was a major factor in allowing engines to be operated at higher manifold pressures because of the greater mechanical strength and better heat dissipation capabilities of such heads.

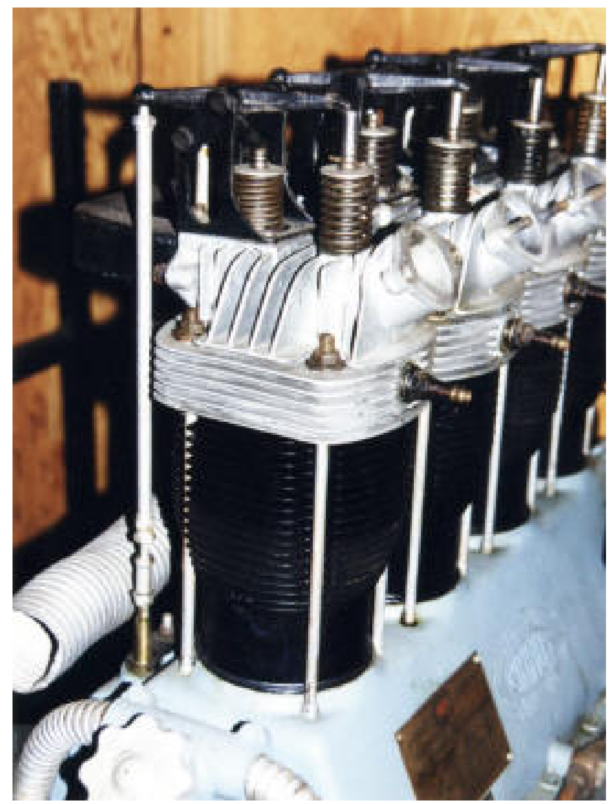
Engine development has always been a long, often unrewarding, and always expensive process that can often be affected by events beyond the designer's control, such as limited finances or a major war. One of the inescapable conditions imposed by war is that survival and victory often depend on the ability to adapt and change rapidly to meet new challenges. In the late 1930s and throughout World War II military necessity made performance the dominant concern, and when cost became a secondary factor progress was almost inevitably more rapid.

The Comet cylinders had the head cast integrally with the barrel and had a hemispherical combustion chamber. Note the single rocker stand and the short, simple ports.

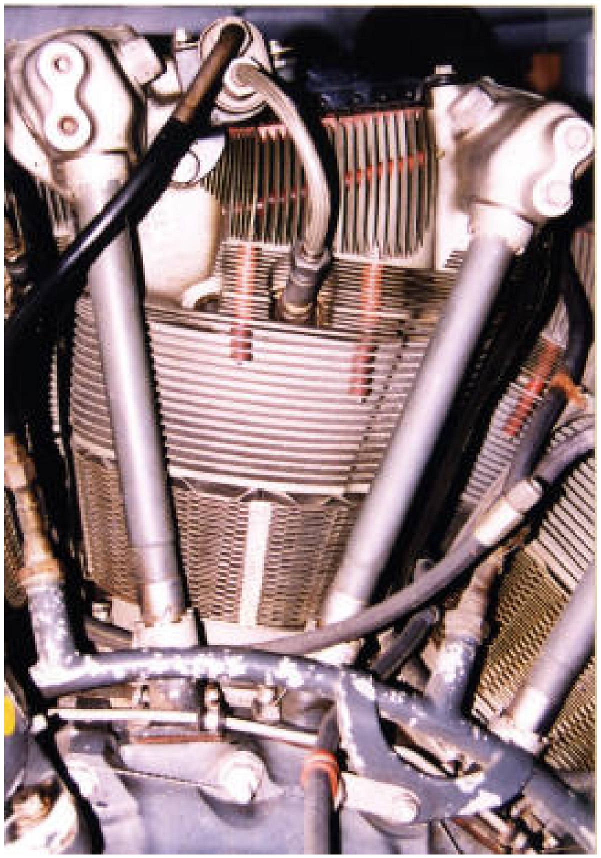
The cast aluminum head on this late 1930s Kinner engine was attached to the steel barrel by a ring of studs and nuts. The valve mechanism was enclosed (rocker covers have been removed).

The more rigorous operating conditions revealed weaknesses in cylinders and many other engine parts that might have remained hidden in normal commercial use, and by the end of the war the air-cooled cylinder had very nearly reached its peak in both performance and durability. Other than direct fuel injection, which came into relatively limited use in the last years of World War II and allowed much more accurate fuel-air mixture distribution, no major innovations appeared since it was becoming increasingly evident that large radial engines were no longer of major importance in commercial or military aviation. The gas turbine had arrived and a new era had begun.



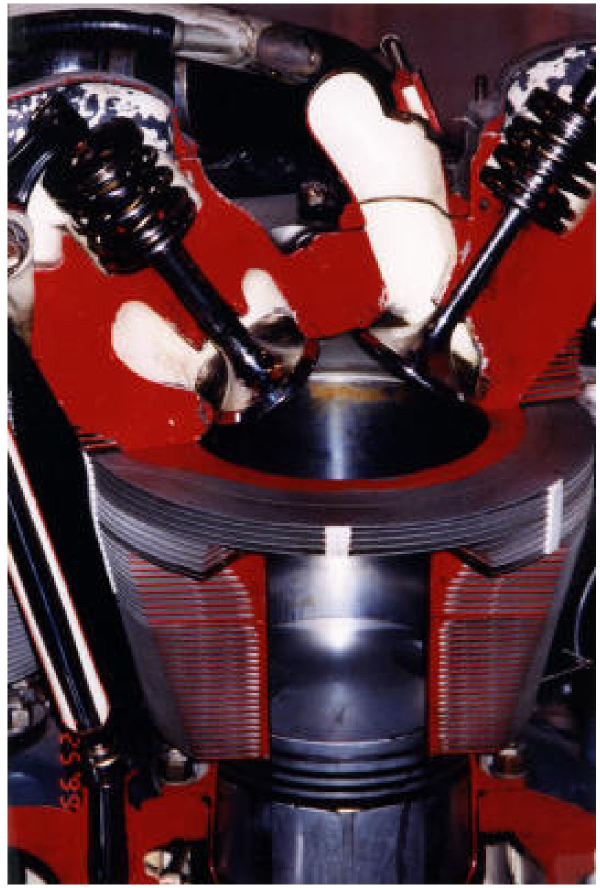


The three-cylinder Szekeley radial of the early 1930s had exposed valve mechanism and two unusual air-cooled spark plugs. The aluminum head with widely spaced fins was attached to the steel cylinder barrel with studs.



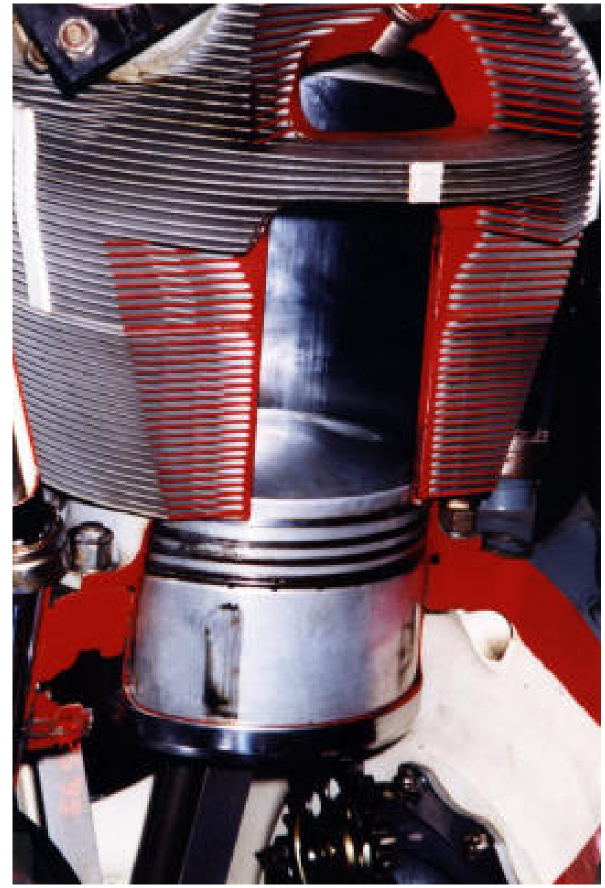
The closely spaced fins on the forged aluminum head of this late 1940s version of the Wright R-3350 were machined. The head was stronger and had more fin area than a cast head. The fins on the cylinder barrel were aluminum stampings that were swaged onto the barrel.

The cylinder on this World War II era Jacobs engine is a classic example of clean design with massive finning around the exhaust valve and port.



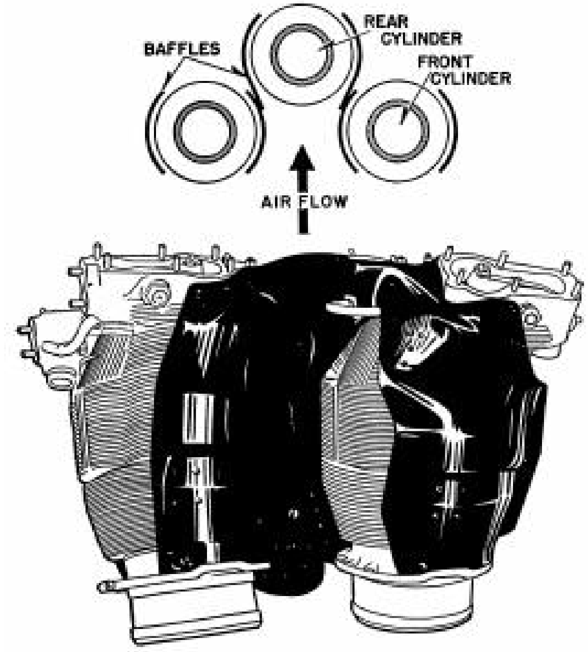
The intake port on Pratt & Whitney R-4360 cylinders is of the downdraft type. Note the relative valve position in the hemispherical combustion chamber and the large contact area between the exhaust valve stem and guide and the cylinder structure for heat dissipation.

On the Cirrus Hermes engine that initially powered Steve Wittman's *Chief Oshkosh*, the cast aluminum cylinder heads were held in place by four long studs. Note the exposed valve mechanism with adjustable pushrods, long forged exhaust rocker arms, 'the angled exhaust ports, and the mica spark plugs.



Cylinders for the Pratt & Whitney R-4360 were heavily finned. The white strips on the aluminum head fins are anti-vibration devices to prevent possible fin breakage because of sympathetic vibration during engine operation.

Sophisticated cylinder design and ample fin area allowed close cowling of the Pratt & Whitney R-4360 engine in the Boeing KC-97. Note the turbo supercharger and the air scoop for the oil cooler and intercooler.



Accurate air flow control is a critical factor in cooling large, complex cylinders.

The cylinders of the Zoche diesel engine from Germany are simple in appearance since it is of the two stroke cycle type and the cylinders have ports rather than poppet valves.