Wright J-5 “Whirlwind”

By Kimble D. McCutcheon

On May 21, 1927, Charles A. Lindbergh stunned the world by flying solo and non-stop from New York to Paris in an airplane powered by a Wright J-5 Whirlwind engine. To accomplish this, the engine had to run continuously for over 33 hours. The astounding thing is that only five years before, no successful air-cooled engine even existed in the United States. The story of this engine is not one of the revolutionary genius of one man, but rather of the evolutionary effort of many individuals and organizations who collectively produced an engine that was light, reliable, maintainable, and had good fuel consumption. This was done in the classical engineering development tradition: the cycle of designing, testing, and improving. With the exception of supercharging, propeller reduction gearing, turbo-compounding, and direct fuel injection, the J-5 was everything an air-cooled engine would ever be.

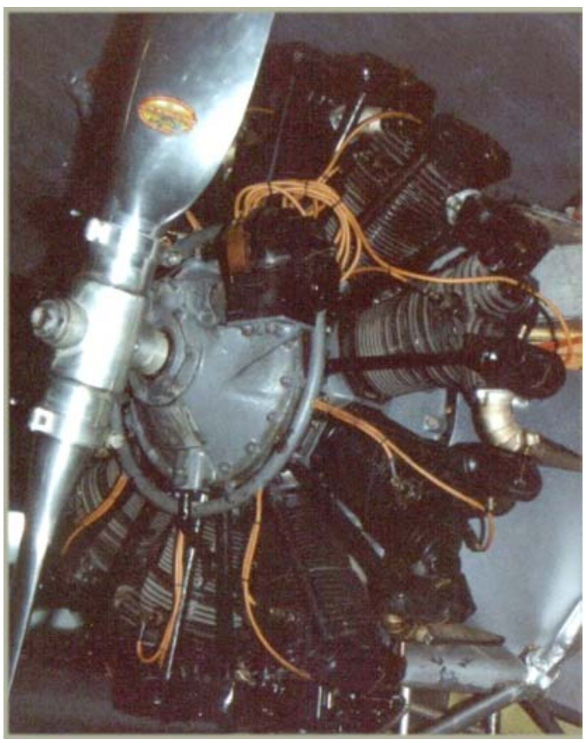

Figure 1. Wright J-5 Whirlwind

History

NAVY

At the end of World War I (WWI), the role of naval aviation changed from one of training and coastal patrol to a more integral part of the fleet, with aircraft capable of going to sea. This required light, small aircraft with light, reliable, fuel-efficient engines. Analysis revealed that when the sizable 0.6-0.7 lb/hp penalty for the cooling system was taken into account, air-cooled engines were lighter than liquid-cooled. Further, nearly one-fifth of engine failures were due to problems with cooling system plumbing. The Navy established a set of engine requirements that are classic in the aircraft field: (a) low weight per horsepower, (b) high economy in fuel, (c) maximum dependability, (d) maximum durability, (e) maximum ease in maintenance, (f) minimum cost, and (g) easy adaptability to quantity production. This set of requirements favored air-cooled engines, but none available were satisfactory. The Navy tried unsuccessfully to interest U.S. engine makers in development of air-cooled engines. Finally, they awarded an experimental contract to the Lawrance Company for the development of a 9-cylinder radial using cylinders from an earlier Lawrance 3-cylinder radial.

LAWRANCE

Charles L. Lawrance had designed racing car engines before WWI, and had become interested in air-cooled engines. He had formed The Lawrance Aero-Engine Corporation, and was producing the only air-cooled engine in the United States at the end of the war. The Lawrance firm at that time consisted of a drafting room in New York City, with all engine components being purchased from outside vendors. Contracts with the Army and Navy along with engineering expertise from all three parties allowed Lawrance to push the state-of-the-art, eventually contracting on February 28, 1920 to deliver the Navy five J-1s, a 200 hp 9-cylinder air-cooled radial. Before the J-1 could pass its 50-hour endurance test, the Navy, in a rush to spend year-end money, contracted for 50 engines with the verbal agreement that production would not begin until the 50-hour test was successful. This test was passed in January of 1922 and “quantity” production began.

The Navy not convinced that the Lawrance Company was substantial enough to be their sole supplier of engines, tried to promote competition from other engine makers. Again, neither of the big two, Curtiss or Wright showed any interest.

WRIGHT

Wilbur and Orville Wright got into the engine business when they could find none light enough to suit their 1902 engine requirements. After being the first to fly with an engine, they continued to build a series of unremarkable engines until 1916 when the Wright-Martin Aircraft Corporation was formed to make Hispano-Suiza engines under license. Wright-Martin was dispersed in 1919, and a new corporation, Wright

Aeronautical Corporation (Wright), formed with Frederick B. Rentschler as President. Wright continued to build and improve the Hispano-Suiza. Wright also developed the R-1, a 350 hp air-cooled radial for the Army. This engine, which took over five years to debug, was eventually produced by Curtiss, who had submitted the low bid for the production contract.

Try as it might, the Navy could not persuade Wright to develop 200 hp class engines for Naval use. Rear Admiral W. A. Moffett and Commander E. E. Wilson, head of Naval engine section, pushed Wright to acquire Lawrance and produce the J-1. To help Wright with the decision, the Navy informed Wright that no further orders for their liquid-cooled Hispano-Suiza engines or spares would be forthcoming. The stormy merger was accomplished, and C. L. Lawrance became vice-president of Wright.

Rentschler resigned as president of Wright effective September 1, 1924. He had grown tired of arguing with the board of directors, largely composed of investment bankers with little stock in the company, no appreciation of the technical merits of air-cooled engines, and no resolve to do the research and development required for air-cooled engines larger than the Whirlwind. Lawrance then became president of Wright. In July of 1925 when Rentschler formed Pratt & Whitney Aircraft, George J. Mead, Andy Willgoos, Charles Marks, and John Borrup left Wright to join Rentschler, creating a real technical vacuum at Wright. This was filled in early 1926 by E. T. Jones, the former head of the powerplant section at the Army's McCook Field in Ohio, and by Sam Heron.

HERON

Sam D. Heron had worked at the Royal Aircraft Factory in England from 1915-1916 with Professor A. H. Gibson on the first systematic, scientific study of air-cooled cylinder construction. Here, the characteristics of modern cylinders were developed. Heron came to the United States in 1921 to work at McCook Field where he used his considerable knowledge to enhance the air-cooled cylinder in the U.S. Perhaps his most valuable contributions were the invention of the sodium-cooled exhaust valve and contributions to the use of high-octane aviation gasoline. He assisted Lawrance in the development of the J series of engines while at McCook Field, and eventually came to Wright after the departure of Rentschler and the lead engineers. It is said that Heron personally inspected all components used in Lindbergh's transatlantic engine.

Design and Development

The Wright J-5 traces its history to the Lawrance J-1, a development project for the Navy, the first of which was delivered in May of 1921. Although the J-1 produced the advertised power, it broke down on the test stand after a few hours, and did not pass the 50-hour endurance test for another eight months. The J-1 featured nine cylinders of cast aluminum with integral cooling fins, cast-in spectacle-shaped bronze valve seats, and shrunk-in steel liners. Cylinders were attached to the crankcase via studs passing through a flange at the base of the aluminum cylinder muff. This construction was chosen because it was less costly than machining cooling fins on the steel cylinder, but was to prove troublesome in service for three reasons: The cast-in parts came loose; the shrunk-in cylinder liner did not dissipate heat well to the aluminum muff surrounding it; and the aluminum hold-down flange often broke. Two valves with an included angle of 17° were used, and the exhaust valve was mercury-cooled in early engines. Sealing the mercury-cooled exhaust valves proved so difficult that this was eventually abandoned. As we shall see, development of this engine consisted principally of cylinder improvements. Induction was via three carburetors each supplying three cylinders. A single-piece forged crankshaft necessitated the use of a split master rod. Two Splitdorf magnetos mounted crosswise on the front of the engine provided dual ignition. This magneto location was favored because it reduced the crowding of the rear accessory section. Lawrance experimented with two larger-bore variants (the J-2), but decided the displacement of the J-1 was sufficient for its intended purpose.

Lawrance had difficulties with development and stepping up to the demands of a 50-engine order. Navy Commander E. E Wilson essentially engineered and forced the merger of Wright and Lawrance (May 15, 1923) in order to assure a source for 200 hp class engines for the Navy. Wright retained the basic J-1 design but strengthened the crankshaft, connecting rods and crankcase. The cylinder was improved by bronze spark plug bushings, harder bronze valve seats, and increasing the thickness of metal in the combustion chamber. The three carburetors were replaced with a single one (eliminating carburetor synchronization problems), and other minor changes were made to the lubrication system. Wright also brought order to Lawrance's chaotic manufacturing operation. This new engine was the Wright J-3 and appeared in 1923. Further refinements to the series, based upon field experience, centered on improving cylinder cooling and durability, as well as the fuel consumption.

The J-4 cylinder abandoned the troublesome cast-in valve seats replacing them with seats that were shrunk-in and rolled into place. The aluminum cylinder hold-down flange was replaced with one integral to the steel cylinder barrel that was now screwed into the aluminum muff. The head and muff still retained all cooling fins. A new piston design was instituted. This updated engine, released in 1924, was called the "Whirlwind".

The J-4A model was in some respects a step backwards. Attention to weight reduction resulted in too much metal being removed from the cylinders. Problems with heat and fuel consumption resulted. However, this model did replace the Splitdorf magnetos with better Scintilla magnetos, instituted a fuel pump drive, and a single double-barrel carburetor.

The J-4B cylinder had greatly increased fin area, separated valve ports, and relocated front spark plug. This improved cooling and substantially improved fuel consumption and durability. Although the J-4B had been extremely successful, its fuel consumption still did not compete with the best liquid-cooled engines.

The J-5 introduced a completely new cylinder designed by Sam Heron. This cylinder featured fins machined on the steel barrel, with only the upper 1.75 inch screwed and shrunk into the aluminum head. The valves were placed at a greater angle to the cylinder axis, inclined at angles of 35° verses the 8.5° of the previous cylinders. The valves were of the tulip type, and were machined from tungsten steel. The hollow exhaust valve stem was partially filled with a sodium/potassium salt mixture to assist in cooling. Each valve was held to its aluminum-bronze shrunk-in seat by three concentric helical springs. The combustion chamber was hemispherical, with spark plugs located at the front and rear. These cylinder changes provided much better cooling (particularly of the exhaust valve) and much better breathing, resulting in improved fuel consumption.

Rocker arms and push rods were completely enclosed, a first for any air-cooled engine made in the U.S. Casting technology still did not allow the rocker arm chambers to be cast with the head. Rocker arm lubrication was accomplished using grease fittings. The Lindbergh engine had specially built spring-loaded grease reservoirs that allowed around 40 hours of continuous running without manual greasing of the fittings. A new three-barrel carburetor solved mixture-distribution problems that had plagued earlier models.

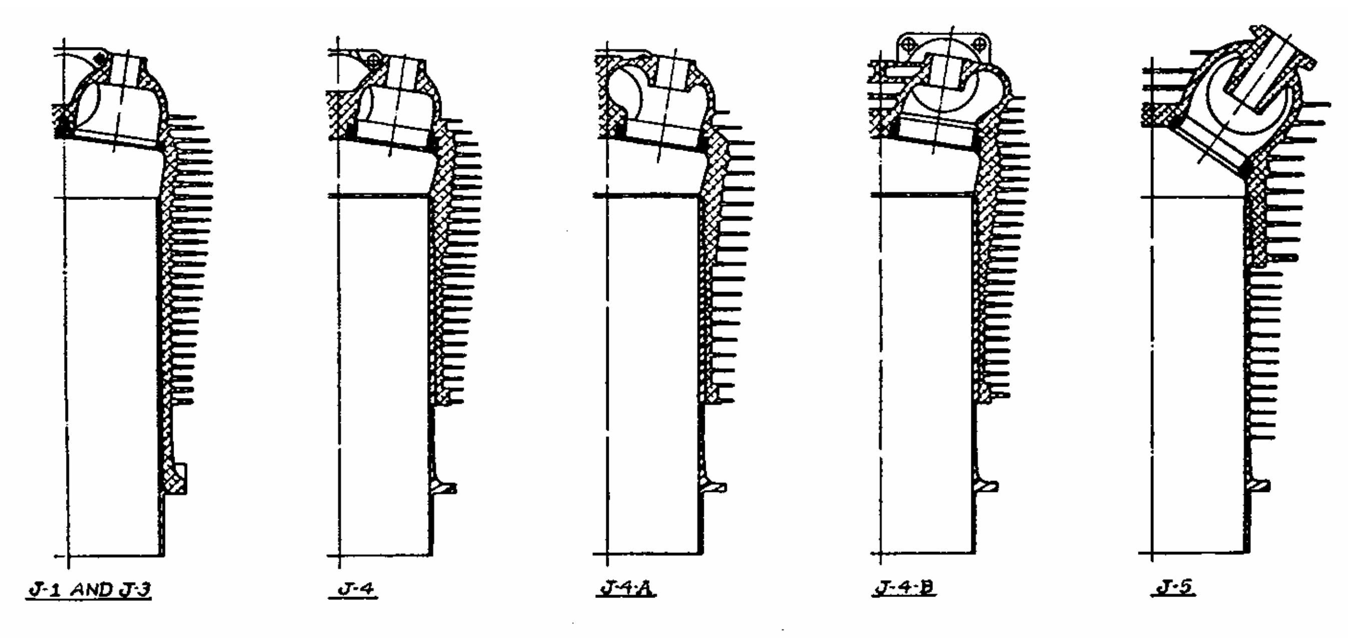

Figure 2. "Whirlwind" Cylinder development

Service

By 1927, the J-5 had become the engine of choice for world explorers such as Chamberlin, Byrd, Maitland, Smith, Goebel, Jensen, and Brock. It was also widely used in three-engine passenger planes built by Fokker and Ford. Wright went to great lengths to build quality into the engine at each stage of production from casting and forging to machining, final assembly and test. Automated machining was widely used. Aircraft builders began to see the air-cooled advantage and use the J-5 to replace liquid-cooled engines. For example, the Travel Air Company published an increase in capacity from 50 to 60 cubic feet, a payload capacity increase from 700 to 800 lb, and a speed increase from 110 mph to 120 mph by replacement of the Hispano-Suiza with a Whirlwind.

Wright continued to refine the J-5 into the J-6 with an eye toward commonality of parts and a spread of horsepower ratings. A number of 9-cylinder R-975 variants were built as well as 5-cylinder R-540s, and a 7-cylinder R-760s.

New type certificates continued to be issued for the J-6 series through 1937. Wright, never very adept of thinking up new engine names, called every one of these “Whirlwinds”.

As it turned out, betting on Lawrance and the J-1, and in air-cooled engines in general, was a good move for the Navy, one that benefited all of aviation. The J-5 achieved all the original Navy requirements and exceeded in all respects the capabilities of competitive liquid-cooled engines.

Specifics

Configuration:	9-cylinder, air-cooled single row fixed radial
Output:	220 hp @ 2,000 RPM
Weight:	500 lb
Displacement:	788 in³
Bore x Stroke:	4.5” x 5.5”
Compression Ratio:	5.4:1
Mean Effective Pressure:	123 psi
Specific Weight:	2.27 lb/hp
Specific Output:	0.28 hp/in³
Cruise Fuel Consumption:	13.2 gal/hr @ 75% power
Cruise Specific Fuel Consumption:	0.45 lb/hp/hr @ 75% power
Cruise Oil Consumption:	0.77 gal/hr @ 75% power
Cruise Specific Oil Consumption:	0.035 lb/hp/hr @ 75% power
6 hr mission specific weight:	0.99 lb/hp/hr (engine + fuel + oil @ 75% power)

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