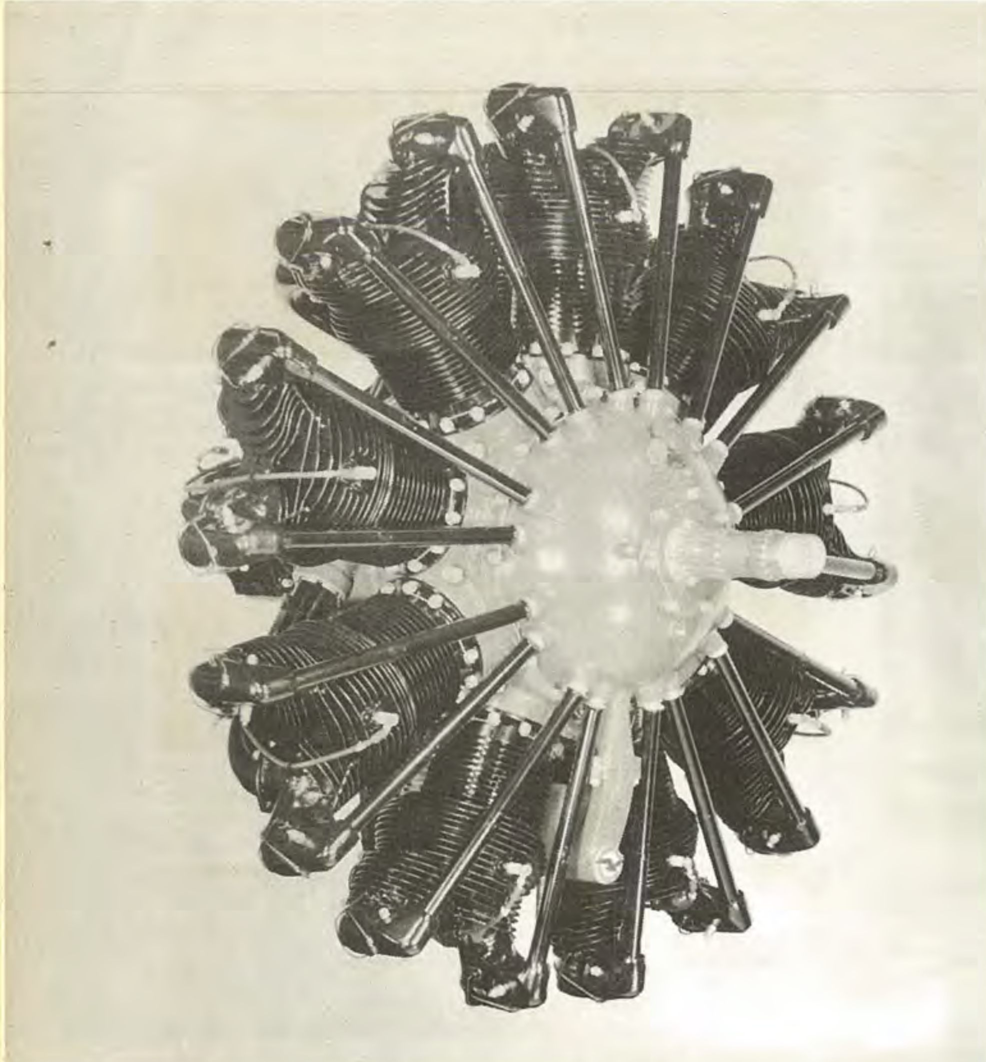


THE NAVY GETS AN ENGINE

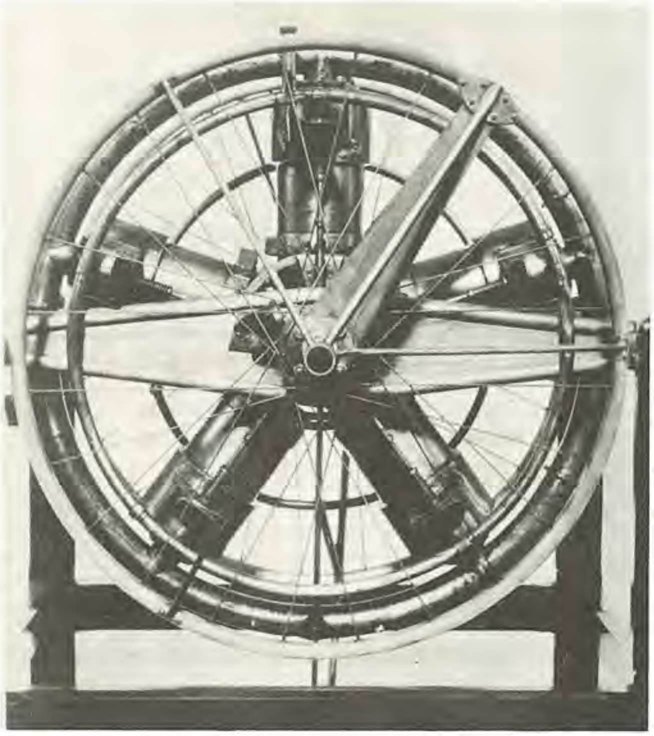
By HARVEY LIPPINCOTT

The Pratt & Whitney "Wasp A" of 1926. 410 HP at 1900 rpm. Weight 650 pounds. 1344 cubic inches displacement. It was the culmination of the Navy's efforts to develop, competitively, large radial, air-cooled engines for its aircraft in the 1920's. Photo - Pratt & Whitney Aircraft No. H-9801.

It was the day before Christmas 1925. The little group of dedicated men in a corner of the top floor of a dingy factory building in Hartford, Connecticut, hustled smoothly and skillfully through their task of assembling an engine. The new engine, tentatively called the "Scout", was the most modern and powerful air-cooled radial engine in the United States. This was the culmination of the vision and labor of Frederick B. Rentschler and his group of thirty employees, at this time partners in fact and in spirit. The "Scout" was also the vision and hope of the United States Navy which wanted a truly reliable, high-performance, radial, air-cooled aircraft engine to bring a high degree of utility to operations of Naval aircraft from ships at sea.

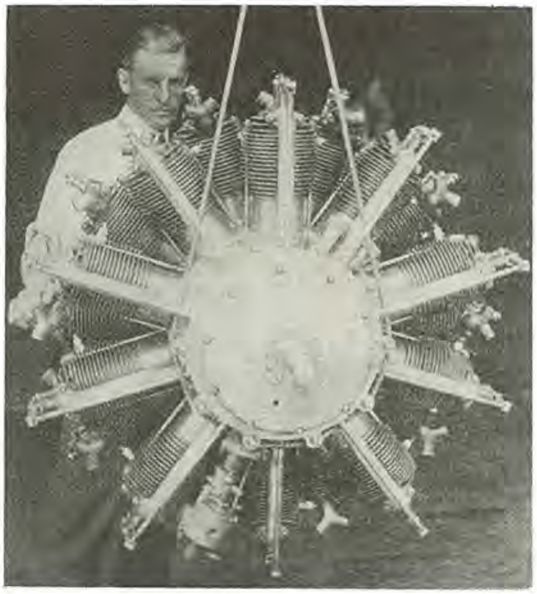
The workers were mindful of Col. E. H. Deed's promise that if the engine was completed before Christmas Eve each one would receive a Christmas turkey at his expense. Several days previous the men felt so confident of their goal that they all went to the meat market and selected their birds. But much remained to be done on this last day. Even the Vice President for Engineering, George Mead, and his engineering staff stopped work on the new large "Hornet" engine design and pitched in to help the mechanics. In midafternoon the workmen could almost smell the turkeys in their ovens the next day. By late afternoon the last nut was screwed down and smiles and cheers and conviviality circled 'round. Mrs. Rentschler and Mrs. Mead passed out each man's turkey while Mr. Rentschler and Don Brown, the Factory Manager, expressed thanks to each man for his effort. With the last "Merry Christmas" and as the men headed home for a well deserved day off, Rentschler, Mead and Brown well

Right - Completing the original "Wasp" brought Christmas turkey to its builders. Photo - Pratt & Whitney No.84233.



Left - The 1902 Manly engine of 52 HP, world's first successful radial aircraft engine. Photo - Smithsonian Institute No. 30592 A.

Below - Anzani 20 cylinder 200 HP engine of 1915. Photo - Janes' All the World's Aircraft, 1919.



knew that the assembly of the engine was not really the end of their efforts but just the beginning - for these were the most experienced men in radial air-cooled engine design in the United States. They were well aware that their sleek new engine would have plenty of "bugs" to be worked out before the Navy would buy it and it could be said that the engine was successful.

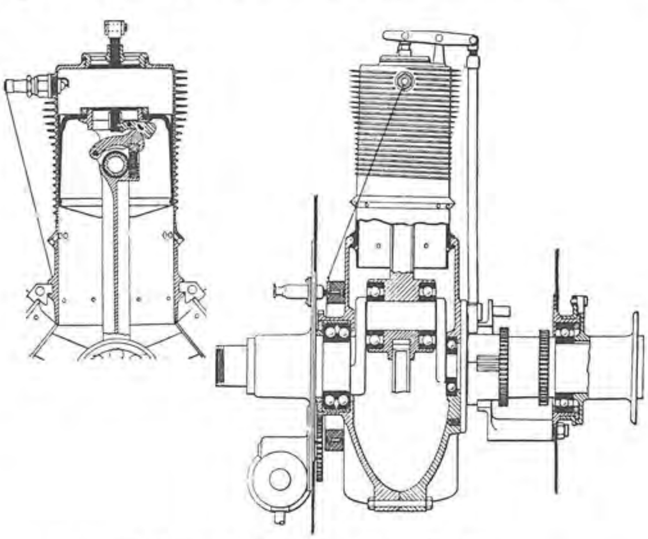
One last thing had to be done, give the engine a vital name. Somehow the "Scout" did not seem to be properly expressive. Sometime previous Mrs. Rentschler had suggested "Wasp", looking at the shiny new engine with its "hairy" arms radiating from its body, it did indeed look like an insect. So "Wasp" it became - a name immortal in aeronautical history!

The "Wasp" was a vital product of the United States Navy's long struggle to establish a healthy competitive aircraft engine industry. The story of the radial, air-cooled engine and of the Navy's singular interest in it is not often heard. Without this development Naval aviation would have taken a different turn.

The origins of the radial form of engine go back to 1887 when Lawrence Hargrave of Australia designed and built a small 3-cylinder, radial, rotary engine for his flying models, driven by compressed air. Hargrave, therefore, belatedly deserves credit for inventing the rotary engine and perhaps the radial form as well. However, Forest, in 1888, produced a radial engine, probably for non-aircraft purposes, about which information is very obscure.

F. O. Farwell, after attempting to develop a gas turbine, designed a 3-cylinder air-cooled, radial engine of the rotary type, for automotive application in 1896. With continued development he finally placed it in the Adams-Farwell automobile which went on the market in 1903. Emile Berliner adapted a five-cylinder Adams-Farwell engine for his helicopter in 1907 - the first aeronautical application of a large radial, rotary engine. In 1909 Hamilton, using an Adams-Farwell engine made the first flight of a rotary in the world at Seattle, Washington. (1) Though these successes launched Adams-Farwell into designing and producing a complete line of aeronautical engines, it remained for Laurent Seguin of France, with his very successful Gnome engine, to popularize the radial, rotary type.

It was not the rotary which became the first radial engine to be used in aircraft, however. Charles M. Manly's water-cooled, fixed, radial engine of 1902 was the first successful airplane engine, even though the Langley airplane seems to have had an aversion to flight. History has not clearly recorded the originator of the radial engine concept for Manly's engine. However, there exists evidence that Stephen M. Balzer of New York City may have first conceived the idea. In the Smithsonian Institution in Washington today there is a tricycle built by Stephen Balzer, dated 1899, and powered by a three-cylinder, radial, rotary engine. About this time and perhaps as a result of this tricycle engine and others constructed by Balzer, Dr. Samuel Pierpont Langley, then Secretary of the Smithsonian Institution, became convinced that possibly Balzer could build him a light-weight engine for his man-carrying aerodrome.



Sectional Views of the Old Gyro Rotary Engine.

(1) Aerosphere 1939 p.38. It is not clear which Hamilton is referred, Charles K. or Thomas, both were at Seattle in the early days, but Charles K is not believed to be there that early.

The John Smith engine of 1920, a refinement of his 1914 development which had excellent performance, as proven in Royal Aircraft Factory tests.

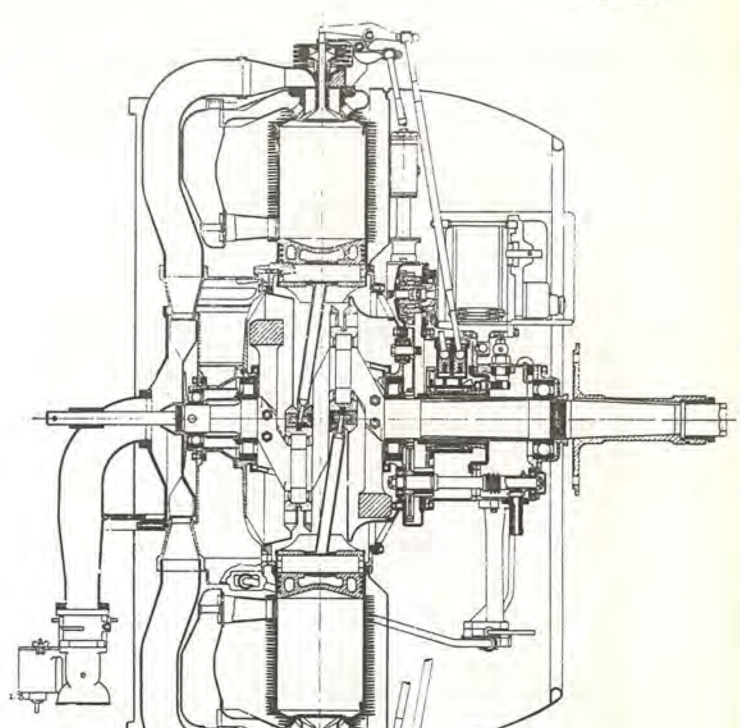
Langley had received very discouraging reports from the world's engine manufacturers on the impossibility of building such an engine. Based on Balzer's convincing arguments of his ability to produce a light-weight engine by the weight-saving, radial, rotary principles, Langley gave Balzer a contract for two radial engines, one a small version for a model aerodrome and the other a large engine for the man-carrying aerodrome. Unfortunately Balzer was unable to produce workable engines but Langley, forced by press of time, accepted the unsatisfactory articles.

At this time Langley was fortunate to have as his assistant a practical engineer in the person of Charles M. Manly. Manly proceeded to redesign and rebuild the Balzer engines. The one redeeming feature to come out of Langley's crushing failure to build a successful flying aircraft was the wonderful Manly engine. The records point to the fact that Manly retained Balzer's radial concept. Mechanical design was Manly's unique speciality. His large five-cylinder water-cooled radial produced 52.4 hp at 950 rpm and weighed 151 pounds or 2.88 pounds per hp. (This power-weight ratio was not exceeded until World War I and the advent of the Gnome and "Liberty" engines.)

After successfully completing the large engine, Manly redesigned and completed, in 1901, the small engine, the world's first, fixed, air-cooled, radial engine. This gasoline-fueled engine powered a model Langley "Aerodrome" on several successful flights. Both of these pioneer radial engines are on display at the Smithsonian Institution, along with Emile Berliner's Adams-Farwell. Unfortunately for aviation there was no market for aircraft engines at that early date and, when a market did develop, Manly was engaged in a successful career in other fields. If, in 1910, Manly could have modernized his engine and placed it in production, one can only speculate on the great contribution it would have added to the advance of aviation.

Emile Berliner, a brilliant inventor and engineer in several fields, was much impressed with the Adams-Farwell engine and organized the Gyro Motor Company of Washington, D.C., to produce radial, air-cooled, rotary engines incorporating many design features of his own conception. In 1912 Berliner succeeded in interesting the Navy in evaluating one of his Gyro engines; in July of that year its first radial, air-cooled engine was acquired.

Work commenced on July 29, 1912, to install the Gyro engine in the Navy's third airplane, the Wright B-1 (AH-4). The first flight was made on August 2nd. Various difficulties were soon encountered; loss of power due to insufficient cooling, erratic operation, and



broken inlet valves caused the engine to be in and out of the airplane for repairs and correction on several occasions.

Nevertheless the Gyro engine continued to fly in the B-1 until October 21 when the evaluation was considered complete. The Gyro also had the distinction of being the first engine upon which the Navy utilized laboratory equipment and methods for testing. At the Navy Engineering Experiment Station in Annapolis three brief dynamometer tests were conducted, along with ground runs and flight tests. The Gyro engine, in fact, the radial type in general, was not adopted by the Navy at that time. Although there is no reason to believe that the Navy had a closed mind to the radial type.

Throughout the War the in-line liquid-cooled engine prevailed as the major type of aircraft engine in Naval inventory. A few rotary Gnome and Le Rhone types were acquired when certain Sopwith, Nieuport, Hanriot and Thomas-Morse types were obtained for special purposes. They were acquired only because of their incorporation in the airplanes rather than for any consideration of excellence on their part.

Unnoticed by most of the world at war, a significant event took place in 1915-16. For the first time men began to know something about cooling an engine cylinder by air. Previous knowledge of cooling was based upon cut-and-try and empirical methods. If it ran too hot, add more water or another fin. For air-cooling, the slow speeds of the early aircraft seriously aggravated the problem by barely passing enough cool air by the cylinders.

In the years 1914-15 the Royal Aircraft Factory in England had been producing a series of in-line, vee-form, air-cooled engines using cast iron cylinders but they realized that cooling characteristics could stand improvement. Chief engine designer, Henry P. Boot had learned from an Italian engine designer, probably S. M. Viale, that aluminum had impressively possibilities for use in aircraft cylinders. Boot's suggestion to use this metal in the R.A.F. engines soon involved the Factory in a systematic research program on the fundamental principles of the design of air-cooled cylinders and the use of aluminum in their construction, the first such program ever attempted anywhere. Professor H. A. Gibson directed the program, with S. D. Heron, G. S. Wilkinson,

F. M. Green and H. P. Boot collaborating in various phases, herein called the Gibson-Heron study. The results of the study produced the following conclusions which are valid as long as air-cooled engines are produced:

1. The cylinder head should be of aluminum because of its better thermal conductivity than other metals.
2. The head should be of a single piece, since metal-to-metal joints are difficult to maintain in good thermal contact (the poultice type of head is in violation).
3. The head should be designed to offer the shortest possible escape along a path with the largest possible cross section for the heat generated at the hottest points of the head. (2)
4. Valves should be inclined to each other at a large angle for proper valve cooling.
5. Two valves are superior to a greater number. (3)

Gibson also made the first systematic study of cylinder wall temperatures in air and liquid-cooled cylinders, which knowledge helped designers to determine the size and location of cooling fins or cooling water jackets.

At first these principles were not generally accepted by engine designers, but as the former R.A.F. engineers took other employment through the industry, they slowly proved the efficacy of the principles. Eventually all successful air-cooled engines used cylinders designed around these principles. Several years later S. D. Heron introduced them to the United States.

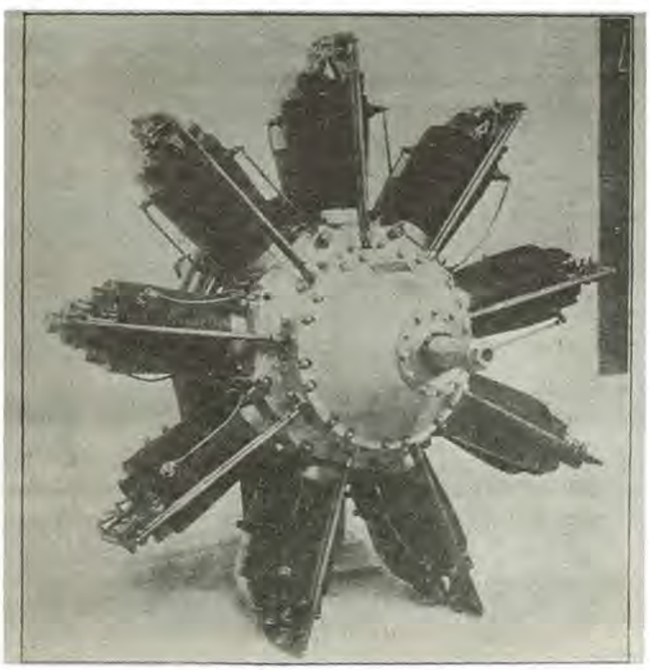
In aircraft engine conception the United States had been foremost. Manly produced the first fixed, radial, liquid- and air-cooled aircraft engines which were also the first successful, gasoline, airplane engines. The Wright brothers produced the first successful airplane engine to fly. Farwell produced the first successful, large, rotary, radial, engines and the first of the type to fly. The U. S. Navy was the first military service to evaluate a radial engine. But for all of the United States' production and application ability, it remained for France, in the initial years, to exploit and produce the radial engine in all its forms; the rotary by Gnome, Le Rhone, and Clerget; liquid-cooled, fixed, radial by Salmson/Canton-Unne and air-cooled, fixed, radial by Anzani.

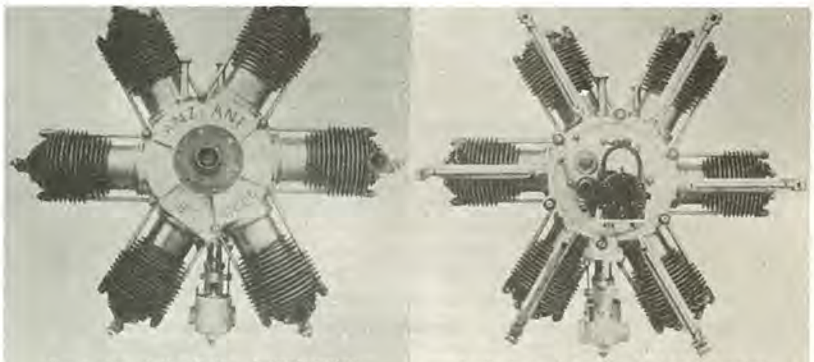
No significant aircraft engine forms evolved during World War I. All developments were in the form of improvements of existing types. In Europe the rotary was developed to its fullest, but by the middle of the War the realization that the rotary was an archaic type became perfectly clear. It had many inherent disadvantages being wasteful of power and fuel with poor operating characteristics and limited development potential. All further improvement of this type would eventually cease at the conclusion of the War. Availability and production considerations were the principal factors in keeping the type alive through 1918. The only reason for building a rotary was to enable the engine to be reasonably cooled by fanning the air at low aircraft speeds then prevalent. This need was put to an end by the tremendously important investigations of air-cooling and cylinder design by the British engineers under Professor Gibson at the Royal Aircraft Factory, and by the general improvement of aircraft speed and performance. By 1917 both the British and French were thinking of the

(2) Schlaifer and Heron "Development of Aircraft Engines and Fuels", p.125.

(3) Ibid, p.178.

320 HP A.B.C. "Dragonfly" was to have powered large numbers of fighters and bombers in 1918 and '19. War ended before the program got going. Photo - Janes' 1919.

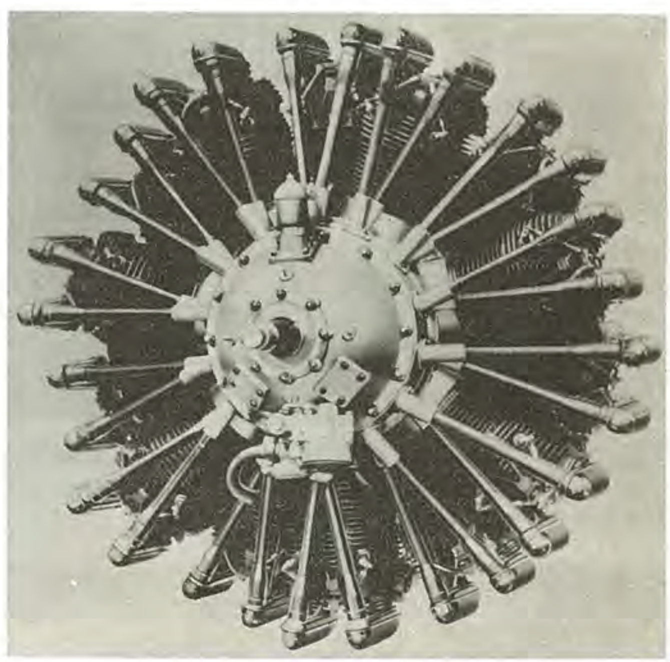


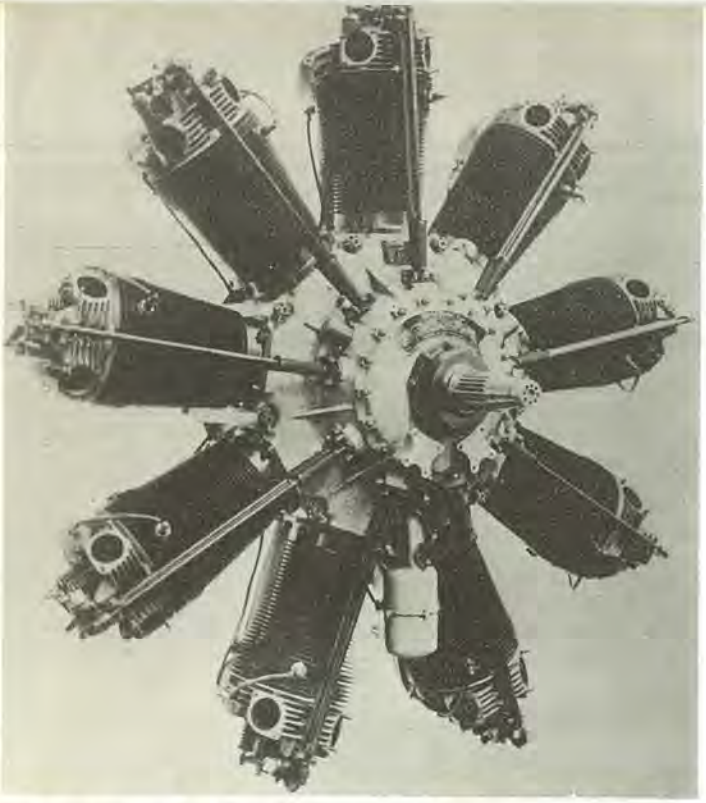


Front view of the 45 h.p. Anzani engine, 6 cylinders. Back view of the 45 h.p. Anzani engine, 6 cylinders.

This simple six cyl. engine was but one of many by the famous Alessandro Anzani.

The "Jaguar", begun as the R.A.F. 8 engine, eventually became very successful in the early 1920's. Photo-Bristol Aeroplane and Engine Company.





The "Jupiter" design, begun as the "Mercury" by Brazil-Straker, later Cosmos Eng. Co., later purchased by the Bristol Aeroplane Co.

fixed, air-cooled, radial for new development. The British had a stable full of new aircraft prototypes ready in mid-1917 each equipped with A.B.C. fixed, air-cooled, radials. The War ended before the disastrous collapse of the A.B.C. engine program could hurt the British war effort and hinder the acceptance of the air-cooled, radial engine.

Outside of the "Liberty" engine development - which was developed ultimately into a reasonably satisfactory engine - all other aircraft engine development in the United States remained at a standstill during the War. With the conclusion of the War and the onset of the difficult reconstruction period, the stage was set for a complete reformation of the American aircraft engine industry. Curtiss cleaned house and brought in a new design team. Packard, released from the "Liberty" program, put its imaginative designers to work. Frederick B. Rentschler, an Army inspector at the war-time Wright-Martin Company, organized the Wright Aeronautical Corporation and acquired the assets, plant, labor force, and Hispano-Suiza licenses of the defunct Wright-Martin company. With his industrial and financial background and connections, Rentschler rapidly built Wright Aeronautical Corp. into a solid organization and set his engineering staff, under George Mead, to work on improving the Hispano-Suiza engine and to design a line of large, 12-cylinder, liquid-cooled engines. Soon both Packard and Wright pulled ahead of Hall-Scott with better engine designs and Hall-Scott ultimately withdrew from the aircraft engine field. Hence by 1922 the aircraft engine field was dominated by the liquid-cooled engine.

The British, perhaps earlier than most, foresaw the limitations of the rotary engine and the distinct advantage of the fixed radial type. Much of this conviction came as a result of the evaluation by the British Admiralty and the Royal Flying Corps of an advanced fixed, radial, air-cooled engine. Strangely enough, the American, John W. Smith of Chicago, had created such an engine incorporating, for the first time, most of the basic design features of what in 1925 was considered a modern engine. Finding no interest at home, Smith took his engine to England in January, 1915 and succeeded in stirring the interest of the Admiralty.

The Smith engine, as studied by the British, had 875 cu.in. displacement with ten cylinders in a single row. A two-throw crankshaft carried offset connecting rods in clusters of five. This unorthodox arrangement provided simplicity and reduced overall engine length and weight. Bench tests showed an output of 150 hp at 1250 r.p.m. The engine was installed in a Vickers "Gun Bus" and flown for 200 hours. "It is the first instance of an air-cooled, radial engine delivering as much as 150 hp ever being operated successfully in actual flight". (4) A contract for the production of the Smith engine was given to Heenan and Froude, but only a few were produced by the Armistice. Though built only in small quantities, the brilliant mechanical design, performance and reliability of his engines established Smith as an outstanding pioneer and pace setter in the field. All subsequent aircraft engineers and designers, both here and abroad, studied the engine in the early twenties and were inspired therefrom. One particularly advanced feature not generally used until 1925 was the rotary, fuel/air induction system. The Smith was the first engine in the world known to use such a system. A rotor, driven by the crankshaft, completed vaporization of the fuel, thoroughly mixing both fuel and air and distributing the mixture evenly to the cylinders - a forerunner of the modern engine centrifugal supercharger. John W. Smith certainly was the "father of the modern radial engine".

Meanwhile, in 1916, the Royal Aircraft Factory produced the design of a large air-cooled, fixed, radial engine of 300 hp with 14-cylinders in two rows, called the RAF 8. The RAF 8 later established the basis of design for the Armstrong-Siddeley "Jaguar" and further served as the inspiration for an Air Board Specification known as Scheme A, issued on April 5, 1917 at the request of the Admiralty. This specification called for an air-cooled fighter engine of not less than 300 hp and not over 42 inches in diameter. Scheme A was the first government support for the development of fixed radial engines and set into motion the extensive development program for this type in Britain during World War I. England can be proud of its leadership in this field.

Four British engine firms submitted designs and bids on Scheme A. Brazil-Straker and Company, whose chief engineer was A. H. Roy Fedden, won the competition with their 14-cylinder two-row "Mercury" and received a contract for 200 engines. Fedden had very carefully inspected the Smith engine and had been greatly impressed with it. He became convinced that a satisfactory fixed, radial, air-cooled engine was possible.

One of the participants in the Scheme A competition was A.B.C. Motors, Ltd., who submitted a nine-cylinder 1,389 cu.in. engine called the "Dragonfly". It had 340 hp for 600 lbs. weight.(Previously A.B.C. had submitted for evaluation a small seven-cylinder engine called the "Wasp".) The "Dragonfly" performed quite well and was favorably received. Granville Bradshaw, Chief Engineer of A.B.C., did an extremely adroit and able sales job on the British Government and industry. The "Dragonfly" was straightforwardly and attractively designed, with consideration for ease of production even though some design concepts were known to be inferior.

Sir William Weir, Director of Aeronautical Supplies in the Ministry of Munitions, threw caution aside and plunged England into a major production program on the unproven "Dragonfly", cancelling out production on all other engines except three water-cooled models. This was a serious error which, except for the saving grace of the Armistice, would have created the most severe crisis imaginable, for the "Dragonfly" engine was a complete failure and ultimately had to be abandoned. Technically, the "Dragonfly" contributed little, but the act of the British Government in concentrating engine production on the fixed, air-cooled, radial put the aviation world on notice that this type engine was here to stay. The U. S. Navy purchased one "Dragonfly" for evaluation but since it did not order more, the engine's

(4) Aerosphere 1939, p.719

Charles L. Lawrance

troubles evidently were apparent.

With the reorganization of the Royal Aircraft Factory early in 1917 as the Royal Aircraft Establishment and its functions limited to aeronautical research, many of its prominent engineers left and entered private industry. Capt. F. M. Green, former Chief Engineer of the Factory, became Chief Aeronautical Engineer for Siddeley Deasy Co. (later Armstrong-Siddeley Motors, Ltd.) and brought S. D. Heron and the design of the RAF 8 engine with him. J. D. Siddeley, owner of the company, was familiar with the evaluation of the Smith engine and accordingly entered into active development of the RAF 8 under the direction of S. D. Heron for competition in Scheme A. Even though it lost out in the competition, Siddeley continued to develop it, as the "Jaguar". As originally developed the "Jaguar" was a 300 hp, 14-cylinder two row, air-cooled, radial engine of 1,374 cu.in. It was technically important as the first engine to have a modern cylinder design, developed at the Factory by Gibson and Heron, i.e., a single-piece aluminum head with two poppet valves inclined at a large angle to each other and with the steel barrel screwed into the head.

Heron parted company with J. D. Siddeley and in time emmigrated to the United States to begin an eminent career here, first with the U.S. Army Air Service at McCook Field and later in private industry. With this loss, the "Jaguar" development lagged but ultimately passed its official air ministry type tests in June, 1922 and was immediately placed in production.

As previously mentioned the Brazil-Straker Company received a production order for 200 "Mercury" 14-cylinder, two-row engines. The "Mercury" was brought to "hardware stage" and flown shortly but early in 1918 new owners purchased the company and renamed it the Cosmos Engineering Company. Meanwhile Roy Fedden had become convinced that a large 9-cylinder, single-row engine could be satisfactorily developed to 500 hp and still be produced easier and more economically than a two-row engine. The British Government agreed and cancelled the "Mercury" program. A development contract was given Cosmos for six experimental "Jupiters", as the engine was now called. The first engine was completed in October, 1918. By early 1920 two engines had been built and had given a splendid accounting of themselves, but their development proved so expensive that Cosmos failed and all work ceased.

While the Company's affairs were being liquidated, the Government had Fedden put the "Jupiter" through its 50-hour type test which it successfully passed - the first engine to do so. Now it was decided that the "Jupiter" engine development must continue and strong pressure was placed on the Bristol Aeroplane Company to take over the development. This was accomplished. By the fall of 1921 the "Jupiter II" had become the first engine to pass the official 100-hour type test and the first production order was received.

The "Jupiter II" produced 400 hp at 1,625 rpm with 1,753 cu.in. displacement. Intense competition developed between the "Jupiter" and the "Jaguar", with the later taking technical lead and the bulk of the orders.

Let us examine more closely the performance and technical features of these two engines in mid-1925.

Performance

	"Jaguar"	"Jupiter VI"
Displacement, cu.in.	1512	1,753
Max. Sea Level Horsepower	425 @ 1900	480 @ 1870 rpm
Normal Sea Level Horsepower	385 @ 1700	440 @ 1700 rpm
Dry weight	590 lbs.	720 lbs.

SUPERIOR TECHNICAL FEATURES

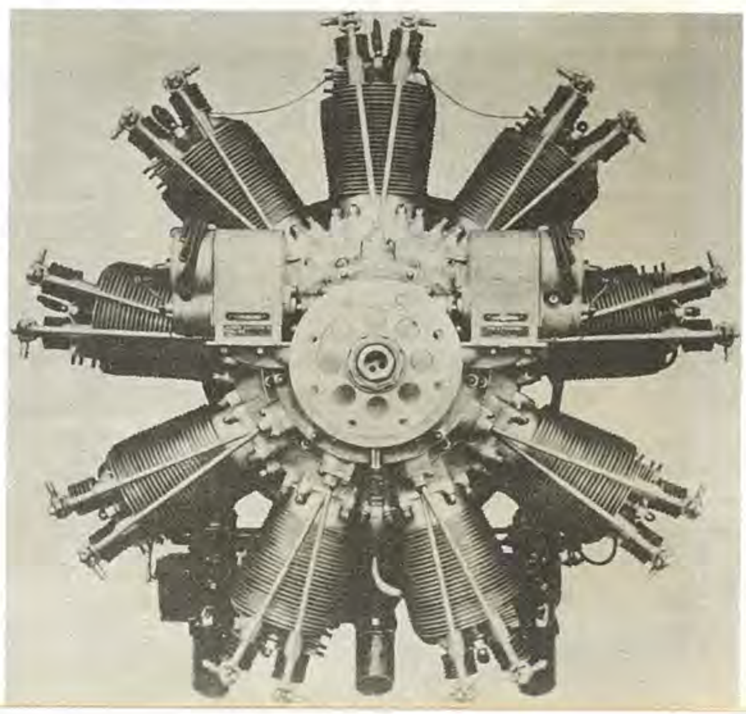
"Jaguar"

1. Cylinder design: - all aluminum head, two poppet valves inclined at large angles, superior fin shapes, enclosed valve gear, head and barrel screwed together.
2. Supercharging: - an internal single-stage single-speed centrifugal impeller providing increased power and altitude rating and relatively even fuel distribution.
3. Overhaul periods of greater length.

"Jupiter"

1. Mechanical design: - (a) forged duralumin light weight two-section crankcase joined at plane of cylinders; (b) two-piece crankshaft and solid single-piece master rod and bearings; (c) crankshaft carried on antifriction bearings in main crankcase; (d) forged, machined H section connecting rods.
2. Weight: Lighter by 130 pounds
3. General standard of workmanship better.

A significant milestone in the history of the radial air-cooled engine developments, the Lawrance J-1 engine of 1921-1922.



INFERIOR TECHNICAL FEATURES

"Jaguar"

1. Mechanical Design: - (a) two-throw crankshaft unsupported at center limited power output and suscepti-- ble to torsional vibration; (b) crankshaft anti-friction bearings not carried in main crankcase but in front and rear cover; (c) cast aluminum crankcase; (d) tubular connecting rods.

"Jupiter"

1. Frontal area 60% greater.
2. Poultice cylinder design: - (a) poor heat transfer in combustion changer due to bi-metal steel head and aluminum cap or poultice; (b) different rates of expansion of two metals; (c) four small valves instead of more efficient (two) large valves; (d) normally asperated engine.

A few scattered efforts, particularly those of Fred Weinberg, Adams, Farwell and Gyro, were made to produce radial engines in the United States, but none of them were the equal of European designs which had saturated the American market. Only one designer in the United States was working toward the modern radial engine, during the period from 1915 to 192 , Charles Lanier Lawrance.

Lawrance was an engine man. Initially he designed engines for automobiles and racing cars. Then he became interested in airplanes and airplane engines. When a student in Paris, he had worked briefly with Alessandro Anzani. As a builder of motorcycle engines in Italy, Anzani drifted into adapting a few of his engines for aeronautical work but, believing France held greater opportunity, Anzani left his native Italy and set-up shop in Paris. His first aeronautical engine appeared in 1908. Both air and water-cooled, vee and fan (a form of radial) types were first manufactured. By 1910 when oil scaverging problems were solved, completely generated radial cylinder arrangements were produced in 3, 5, 6, 10, 14 and 20 cylinder versions. Anzani engines sold reasonably well, continuing in production with some changes for nearly twenty years. When Anzani began production, the theory of air cooling and air-cooled cylinder design was not well established, nor was it until the Gibson-Heron study of 1915-16. All of his early engines were relatively low in power - between 30 and 125 hp and tended to overheat and lose power.

Though Anzani made a mistake in supplying too many models, with insufficient development of any one type, he nevertheless established a successful business and reputation based upon the fixed, radial, air-cooled form. Though John W. Smith was promotionally ineffectual, his engines were better designed and had superior performance. History gives the laurels to Alessandro Anzani as the "father of the radial aircooled engine." John Smith should have gotten the wreath, but fame passed him by. Years later when the Wright J-5 engine had earned its well deserved niche as one of the great engines, well meaning friends, who did not know the history of the subject, publicly dubbed Charles L. Lawrance "the father of the radial engine". Though he deserves honor, this title does not belong to him since he had, after all, first learned the principles of air-cooled, radial design from Anzani, the master.

Lawrance was an able and energetic engineer. After the outbreak of the War, he returned to this country and promptly engaged in aircraft development. Circumstances soon pressed him into engine design and before long he was devoting his full time to the engine business.

When an opportunity presented itself for the Navy to undertake the development of an air-cooled engine it did not lag. Lawrance presented a plan to the Navy to develop a small two-cylinder, opposed, air-cooled engine to be used in conjunction with the Loening "Kitten", a very small Navy seaplane. During World War I responsibility for aircraft engines in the Navy was under the jurisdiction of the Bureau of Engineering, where Cdr. A. K. Atkins was Chief of the Division of Aviation and Lt.Cdr. S. M. Kraus was head of aircraft engine design. Atkins and Kraus were much impressed by Lawrance's ability and his proposal. As a result, the Navy agreed to finance the project and to assume the entire risk.

The engine was successful. Later study indicated, however, that the desired airplane performance could not be attained without more power. At Lawrance's request the contract was altered to provide for a larger 3-cylinder, radial, air-cooled engine. By the end of 1918 the 65 hp "Model L" was completed and proved satisfactory for its intended use. A limited number of L's were used by the Navy. It was the first recorded instance where the United States Navy directly sponsored initial

Architects of the Navy's radial engine program: Cdr. Eugene Wilson (l.), LCdr. Bruce Leighton, and Adm. William A. Moffett.

The builders of Pratt & Whitney Aircraft: Frederick B. Rentschler (l.), George J. Mead, and Andrew Van Dean Willgoos.

development of a radial air-cooled engine.

The Air Service next entered into discussions with Lawrance toward the development of a suitable radial, 150 hp engine for trainers, and a contract for development was given. The resulting R-1 was an enlarged Model L with nine-cylinders. Four engines were built, one of which passed its 50-hour endurance test in 1921. However, the R-1 did not go into production.

Atkins and Kraus, of the Navy, clearly foresaw the need for light, high-performance aircraft to operate with the fleet with a minimum of maintenance and trouble. Consequently these two officers worked industriously with Lawrance. Upon studying his design for the Model J they decided that it was exactly the engine needed. Accordingly on February 28, 1920 a development contract was placed with Lawrance for the Model J. This engine was to produce 200 hp at 2000 rpm with a displacement of 787 cu.in.

Early in 1921 Lt. Commander Leighton relieved Lt. Commander Kraus as Chief of Aircraft engine design in the Bureau of Engineering. Leighton quickly became imbued with the Navy's enthusiastic embrace of the radial, air-cooled engine, and he undertook to push the development of the Lawrance J engine. Also, in mid-1921 an extremely important event took place which was to have great influence upon the concentration and speed-up of Naval aviation material development - the creation of the Bureau of Aeronautics under the command of Rear Admiral William Aiger Moffett. Lt. Commander Kraus was placed in charge of procurement, Commander Jerome C. Hunsaker was in charge of aircraft design and Lieutenant Leighton was made chief of the engine section.

Admiral Moffett, a forceful and able leader with a flair for public relations and a knack for practical politics, was certainly more than just instrumental in the creation of the Bureau of Aeronautics. He had expected to bring all aviation functions under its jurisdiction, material, personnel, and operations but he was thwarted in obtaining full control over the last two functions. Over material he held full sway. Though not a technical man, he had rare insight on how to pick an able man to boss a technical field. When once selected, Moffett placed great loyalty in his subordinates and their knowledge. As a concept became fully established, and he became convinced of its value, Moffett would use his full ability to "bull-dog" it through and obtain the funds to pay for it. Such was his work on behalf of the radial, air-cooled engine which he and his staff wanted for the new airplanes planned for the carriers the Navy was then creating.

During World War I aircraft engine reliability had never been spectacular, and had been a source of much distress to the Navy. In short, engines had proven so unreliable "that aircraft were of virtually no real use to the fleet; their frequent forced-landings in over-water service made them more trouble than they were worth". (6) Commander Atkins, Chief of the Division of Aviation, became convinced that engine reliability had to be improved if the airplane was to be of real use to the fleet. He set into action a plan to persuade the engine manufacturers to put their utmost into improving reliability by giving greater attention to detail design and metallurgy. It involved testing and proving with a program of high-power running until a part failed, redesign and rerun until something else failed, and repeat. The Navy paid the costs; in time this became the standard engine development pattern whether the Navy paid for it directly or not.

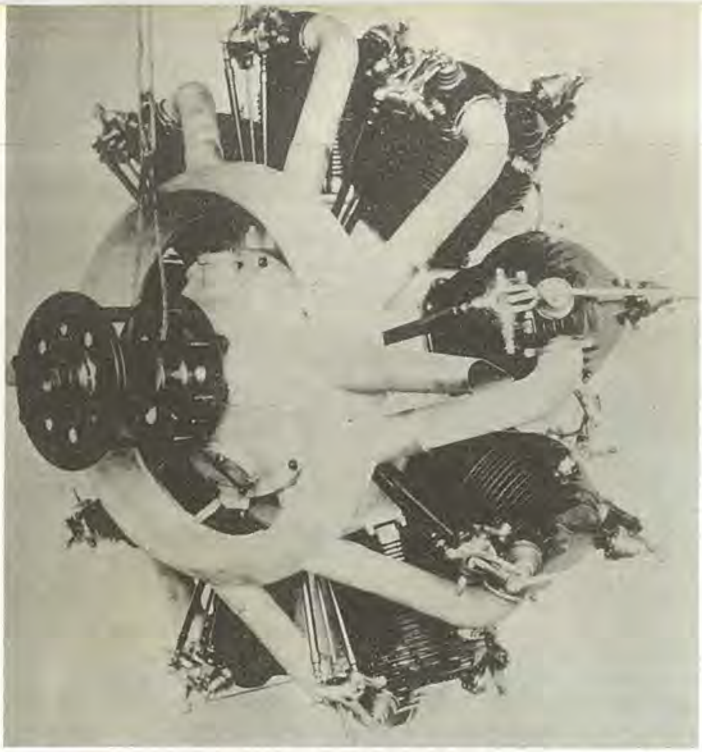
When Lt. Leighton took over from Lt. Cdr. Kraus, he continued this policy, putting full pressure upon the development of reliability in the Lawrance Model J. The first experimental "J" was delivered to the Navy in May, 1921; it soon failed on test even though the rated power was easily obtained.

Meanwhile a curious event took place which absolutely committed the Navy to the Model J. The Navy found itself with uncommitted funds available near the end of the fiscal year 1921. If unspent, these funds would revert to the Treasury, not unheard of even in modern times. A quick, but unprocedural, decision was made to purchase 50 Model J-1's, as the production type was called and to construct 50 TS-1 aircraft for them. A contract was signed with Lawrance on the last day, June 30, 1921, with a gentlemen's agreement that production would not begin until the 50-hour endurance test had been satisfactorily passed.

Lawrance's small shop, in a New York City loft building, was incapable of handling the production of such a sizable order. He therefore sub-contracted the manufacture of the larger parts to the De La Vergne Machine Company of New York. Fabrication of small parts and the assembly of the engines was done in the Lawrance shop. Although this split manufacturing arrangement actually increased the cost of the engines, the Navy wanted engines and the higher price was accepted.

With the completion of the 50-hour test in January 1922, production promptly began since both Lawrance and De La Vergne were tooled up and ready to go. (Even before the 50-hour test was completed Leighton was after Lawrance to improve the engine.) For its time the J-1 was remarkably successful in spite of its mechanical faults. Additional orders were received and, all told, 250 were manufactured.

(6) Schlaifer and Heron, p.168

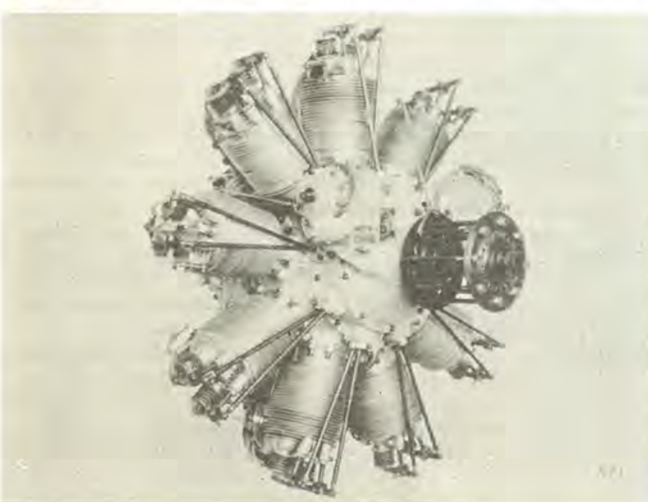


The Wright P-1, the progenitor of both Wright "Cyclone" and Pratt & Whitney "Wasp" engine lines.

It became obvious to LCdr Leighton that, if the Navy was to be assured of an adequate supply of J-1's and other subsequent Lawrance designs, something had to be done to put Lawrance Aero-Engines Co. in a more sound financial condition with adequate resources; in 1922 this company was its sole source of supply for radial, air cooled engines and Admiral Moffett had little enthusiasm for single supply sources in private industry. It was dangerous from a national emergency viewpoint and apt to invite Congressional criticism. Accordingly the Navy began to look for another source of supply for air-cooled engines with the belief that some competition would spur development of the J-1 and possibly bring out other engines which might be better. In the middle of 1922 the Navy invited both of the established engine manufacturers, Wright and Curtiss to engage in the development and manufacture of radial air-cooled engines of 200 hp.

Curtiss Aeroplane and Motor Company had a history, dating back to 1909, for in-line, liquid-cooled engine development and manufacture. They were absolutely convinced of the superiority of this type and would not consider building an air-cooled radial. Furthermore, its excellent large engine, the D-12, offered the prospect of greater profits. This attitude remained consistent throughout the Company's history.

Lawrance's J-1 engine which brought Wright into the radial field through purchase of Lawrance Aero-Engines Co.



The Wright Aeronautical Corporation, formed shortly after World War I by Frederick B. Rentschler, centered its efforts upon the improvement and manufacture of 200 hp Model E-2 and 300 hp Model H Hispano-Suiza engines, and, somewhat later, the large 500 hp Model T. Essentially, Wright was committed to a liquid-cooled program and was not vitally interested in producing a 200 hp engine in competition with its Model E.

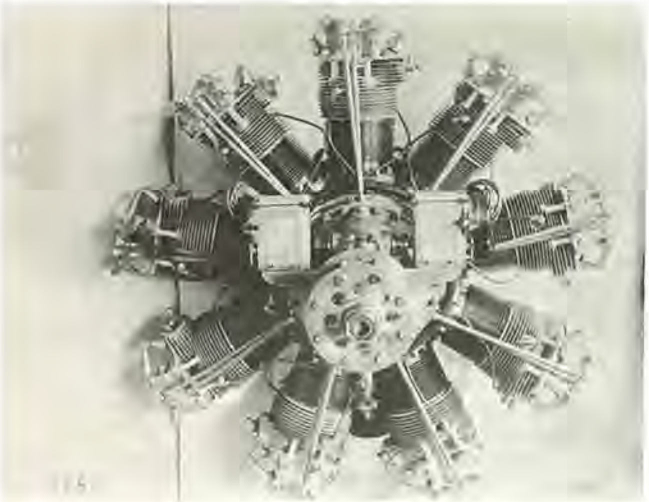
The superior performance of the TS-1 airplane powered by the J-1 over versions with the liquid-cooled Wright E-2 or Aeromarine U-8D, and the conviction that ultimately the J-1 would become more reliable than the Wright Model E, influenced the Navy to place additional contracts with Lawrance. With the desirability of competitive engine sources thus temporarily thwarted, Lt. Leighton then decided to force a consolidation of the best design with the best manufacturer. Whereupon Leighton informed Rentschler that the Navy would cease procurement of 200 hp Hispanos and their spare parts. Existing engines were to be maintained by utilizing parts from unserviceable engines. Rentschler assumed this to be a bluff and continued to refuse involvement with Lawrance or development of a 200 hp air-cooled engine. To his discomfort he learned that Leighton's stand was no idle threat; Wright received no further contracts by the end of the fiscal year 1922 (when the money was usually spent). Also the Air Service was no longer purchasing the Model E and the end of the road was in sight for Model H, for it was now evident that future Army fighters would use the larger Curtiss D-12. Black days loomed ahead for Wright.

Knowing that he was boxed in and that there was no other choice but to build what the Navy required (in those days the only reliable customers for new engines were the Army and the Navy), he decided to purchase the Lawrance Company as the quickest way to get a 200 hp engine into production. The purchase was eventually accomplished on May 15, 1923 for a half-million dollars. Charles Lawrance became a vice-president of Wright Aeronautical Corp. J-1 manufacture was promptly transferred to the Wright factory at Paterson, New Jersey.

Now that Wright was committed to the Lawrance engine, Rentschler swiftly took steps to make a satisfactory engine of it. Shunting C. L. Lawrance aside, he handed the program over to his Chief Engineer, George J. Mead - in whom he had confidence, with orders to straighten the engine out - quick! Mead and his Chief Designer, Andrew V. D. Willgoos, set to work and redesigned the mechanical parts of the engine, correcting the weak points which had been causing some trouble in service. (7) By Fall of 1923 Mead had a new Model, the J-3, ready for production.

Rentschler kept Lawrance out of the way of his engineers by assigning him to other areas of activity where he had little to say about his engine. Naturally this was a matter of annoyance to Lawrance but in the end his enforced occupation with the business and manufacturing aspects of Wright Aeronautical Corp. were to serve him well, when he eventually became president. Also, initially, there was considerable resentment toward Lawrance from the old-school Wright personnel because of the forced marriage of the two concerns. Many of these people felt that Lawrance did not stand up to his reputation as an engineer and could not compare with the brilliant George Mead. Less partisan engine engineers maintained that Lawrance was a good, able engineer. But in any event the J-1 was the last Lawrance engine that came to quantity production. (Lawrance actually designed the larger 250 hp J-2 before the merger; only two were built.) The remainder of Charles Lawrance's career was in the field of management where, of course, his decisions often influenced subsequent Wright engine designs.

(7) Interview with John J. Borrup, 1959



Mead and Willgoos' first radial, the Wright R-1, designed for the Air Service in 1919.

Needless to say the Navy was pleased with the merger. This turn of events now turned Wright whole heartily to the production of the radial, air-cooled engine, though Hispanos and Model T's continued to add income. The J-3 was the culmination of Lt. Leighton's efforts, as his term of Chief of the Engine Section in BuAer was coming to a close. In March, 1924 Lt. Cmdr. Eugene E. Wilson became Chief. Leighton had forced a merger to establish the source of air-cooled, radial engines. It was Wilson's job to perfect this supply.

The Navy standardized on the J-3 for the 200 hp class and, meanwhile, Mead continued the advanced development of the Model J. Additional improvements resulted in the J-4 of 1924 (the principal change was in a cylinder revision to improve serviceability). The name "Whirlwind" was first applied to the J-4 and the model was extensively used in Naval aircraft of the trainer and observation types.

In view of the foregoing it should not be taken for granted that Wright was totally disinterested in aircooling. Rentschler's objection had been primarily economic. Wright had a large investment in Hispano development costs and tooling which it desired to recover with a reasonable profit.

Going back now to the events of 1919, the Army Air Service held a competition then to develop a 350 hp fixed, radial, air-cooled engine. Air Service engineering departments were spurred by English progress with their "Jaguar", "Mercury" and "Dragonfly" developments. Wright won second place with a design known as the R-1 (not to be confused with the Lawrance R-1) employing nine cylinders with a displacement of 1,454 cu.in. A contract for prototypes was signed in 1920, long before the Navy began to pressure Wright for a 200 hp air-cooled engine. (The contest winner, the Wienburg engine, failed in its tests and was eliminated.)

George Mead, with Andy Willgoos' assistance, designed this, their first air-cooled engine, which bore some interesting design concepts not unlike those used on the "Jupiter", especially the poultice cylinder design. It will be remembered that George Mead had visited England, had observed their designs and was well acquainted with Roy Fedden. (5) One innovation, apparently Mead's, which at first caused much trouble but was used extensively in later designs, was a split crankshaft with a solid master rod. Though the R-1 met its performance requirements when tested in late 1921, it was mechanically deficient. The worst fault was to be found with the poultice cylinders. The Air Service assigned S. D. Heron to correct the difficulties. The Air Service, in contrast to Navy policy of leaving the design and development in the hands of private enterprise, followed a different course whereby it designed, tested and developed its engines with private enterprise handling only the manufacture. Sam Heron was a competent engineer and from his experience with the air-cooled cylinder he promptly put his finger on the poultice cylinder as the weakest link of the R-1. Consequently, the Air Service engine department undertook a systematic program to develop a sound cylinder for the engine. This program expanded into a full-fledged study, soon developing a whole series of cylinder designs which were ultimately to be used on nearly all air-cooled engines in the United States. This was one of the most significant contributions which the Air Service made to engine design in the early 1920's.

Although objecting strongly, Wright Aero. Corp. accepted a contract to rebuild three R-1's with Heron's cylinder arrangement and one with a "Jaguar"-type rotary induction system to improve fuel distribution. The rebuilt R-1 with the redesigned cylinders showed marked improvement in performance, but many mechanical weaknesses remained, especially in the two-piece crankshaft.

The Air Service then decided to completely redesign the engine, now called the R-2, later the R-1454. For the R-2 Heron designed an even better cylinder (his Type M) with an enclosed valve gear automatically lubricated from the engine internal oil pressure system, (the first ever designed and not otherwise used until 1934 by Pratt & Whitney Aircraft used it in its "Wasp", Series H). The split crankshaft was eliminated and the rotary induction system was changed into a fully centrifugal supercharger, similar in detail to that used in the "Jaguar". The detail design and manufacture of three experimental engines was thrown open to public bid.

Curtiss succeeded in underbidding Wright and received a contract, on January 16, 1924. Its engine was to develop 390 hp. It is strange that Curtiss should suddenly come into the high powered air-cooled engine business when it had publicly taken the position, with conviction, that aircooling at such powers was impractical. Eugene Wilson, in his autobiography, "Slipstream", relates an interesting aspect as to why Curtiss did get into the aircooled business. He stated that, during his first visit to Curtiss Company in Buffalo with Lt. Leighton, "Roy Keyes, President of the Company, expressed no fear of competition from the air-cooled radials. Curtiss, he confided in us, had bid in the Army 1454 competition just to keep it under their control. He considered it unlikely that any radial rock crusher could replace the D-12; in fact, he had no intention of letting it."

Under the Army's bureaucratic system, aided by Curtiss' foot-dragging, development of the R-1454 crawled until late 1926 when, after years of effort, it was cancelled because of the superiority of the Navy sponsored Pratt & Whitney "Wasp". The "Wasp" took 18 months from design to production. By the end of 1926 nineteen "Wasp" engines had been delivered to the Navy. It would appear from this that the Navy had a superior procurement system for engine development. Similar failures in other procurement projects occurred due to the Army's system, with small comfort to the taxpayer.

The Navy increasingly found itself in the embarrassing position of creating and supporting a monopoly, Wright Aeronautical Corporation. Admiral Moffett was much disturbed by this trend for it was a favorite subject for Congressional investigators. Yet the Navy had little choice for both Curtiss and Aeromarine were confirmed liquid-cooled engine manufacturers and not receptive to the Navy's tenders to engage in the air-cooled field. Liquid-cooled engines for long-range seaplanes were still considered reliable and economical in fuel but Bruce Leighton saw no reason to use liquid-cooled engines of the larger type indefinitely. Accordingly, he initiated a requirement calling for a radial in the 400 hp class. Turning to Wright as the only

(5) Interview with John J. Borrup, 1959.

source, the Navy signed a contract in mid-1923 for the experimental development of three successive engine designs. The first was the nine cylinder 1654 cu.in. P-1 of 400 hp.

Though it was reported that the P-1 was based upon a design submitted by Lawrance in the 1919 Army engine competition, the design actually showed few Lawrance characteristics. For the most part, it was the work of George Mead and Andy Willgoos. One of the design criteria set by the Navy was that it should have the same frontal area as the Lawrance J-1 but with twice the power. By now, Mead had accepted Heron's cylinder philosophy and he used a modified Type J cylinder. To accommodate the small diameter criteria a complicated valve gear was employed to operate the valves, placed in fore-and-aft position. Mead also abandoned the split crankshaft concept. And for the first time magnesium alloy was employed for many of the crankcase sections. Contrary to then current practice, the magnetos were placed on the rear of the engine.

The P-1 was an interesting though unsuccessful engine; the magnesium cases proved weak, the odd valve gear caused rough operation, and excessive side pressures on the pistons caused continued scuffing. It seemed obvious that the small diameter approach was wrong; further, Wright did not put its full resources behind the engine as immediate profits seemed distant.

At this point Lt. Cdr. Wilson suggested that Wright taper off on the P-1 effort and begin design of a revised version incorporating the best features of Heron's R-1454, including a centrifugal supercharger. The P-1 taught George Mead valuable lessons in radial aircooled engine design and, further, it was the progenitor of two important engine lines - the Wright "Cyclone" and the Pratt & Whitney "Wasp".

In consultation with Wilson, Mead and Willgoos began the design of a new engine the P-2. Frontal area restrictions were removed and the designers returned to the more conventional Lawrance layout. The cylinder and valve gear, based on Heron's Type J and M cylinders, were an improvement over previous Wright and Lawrance arrangements. The supercharger boosted the power to 450 hp.

Shortly after the P-2 design was initiated, F.B. Rentschler resigned his position as president of Wright. This event later proved to have great significance. Rentschler had found himself in continuous disagreement with his board of directors, who were, for the most part, investment bankers without appreciation of the highly technical aspects of the engine business. Rentschler believed that a larger share of the profits had to be reinvested in research and development to produce long term profits. Accordingly, on September 1, 1924, he left Wright and entered a period of study, thought and rest. Before announcing his resignation, Rentschler advised Mead, Willgoos and Donald Brown, the Wright production control manager, of his decision. All indicated their desire to join him in whatever aviation venture he might engage in but they were advised to remain where they were for the time being.

With Rentschler out, Charles Lawrance was given the presidency of Wright and shortly thereafter, Guy Vaughan was made factory manager. A new team with new attitudes began to form at Wright. Lt. Cdr. Wilson approached Lawrance and Vaughan with a request to develop a new engine on a new formula; 350 hp at 650 pounds weight, established by Vought for its O2U "Corsair". Though not happy to add another engine to their work load, Lawrance suggested, and the Navy agreed, that the P-2 design be scaled down to 1200 cu.in. displacement. This procedure would reduce the engineering work load somewhat. Mead and Willgoos laid out the basic design of the R-1200, called the "Simoon", while continuing development of the P-2.

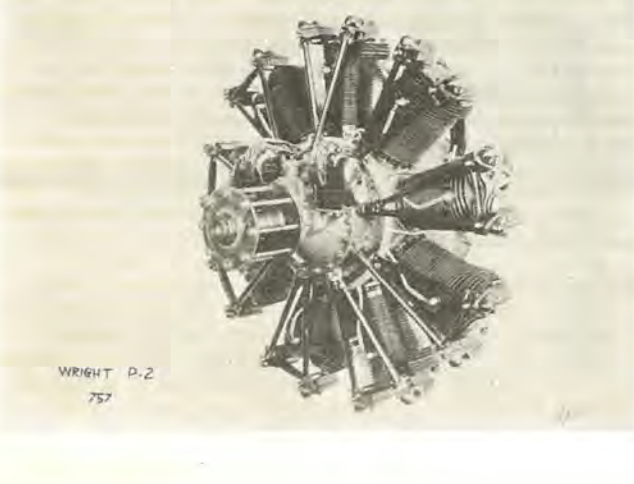
When the "Simoon" was almost ready to run, both Mead and Willgoos resigned to join Rentschler. This set back the engineering development at Wright for nearly a year. C. Fayette Taylor, project engineer on the new J-4B, was made acting Chief Engineer and he put forth a major effort to get the J-4B engine into production and the "Simoon" into test. Meanwhile, the P-2 lagged.

Lawrance brought in, as Chief Engineer, Edward T. Jones, former head of the powerplant section at McCook Field, and S. D. Heron. Since the "Whirlwind" was Wright's best marketable product, these two men were set to work redesigning the J-4, whose great drawback was its antiquated cylinder design. Using Heron's Type K cylinder and his sodium-cooled exhaust valve, a new engine evolved, the J-5. The J-5 "Whirlwind" became one of aviation's most widely used engines, bringing much fame and profit to Wright Aeronautical Corp.

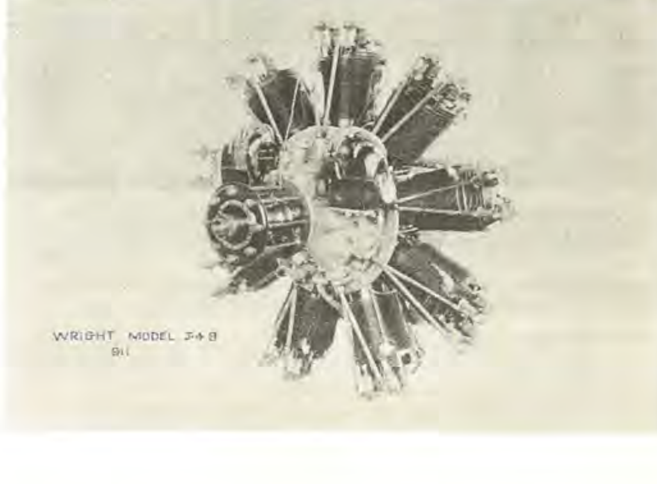
By early 1925 it was clear that use of catapults on ships would increase and that aircraft carriers would join the fleet as fighting units when the LEXINGTON and SARATOGA put to sea. New airplanes with plenty of zing were needed for these ships, and the picture was changing. The Navy's push for technical development in engines, aircraft and equipment was paying off; the technical know-how to design and build this equipment was accumulating rapidly.

George Mead and Andrew Willgoos had spent most of their time before 1922 working on liquid-cooled engines. The Navy brought them into the air-cooled engine business. This team was responsible for six basic air-cooled engines at Wright Aeronautical Corp., R-1, J-3, J-4, P-1, P-2 and "Simoon". A detailed technical study of these engines reveals a steady improvement of knowledge, design and performance. It truly can be said that

The Wright P-2, also by Mead and Willgoos, refined the P-1 design and added centrifugal supercharging.



Wright J-4B which perhaps gave Wright Aeronautical Corp. its greatest boost as an engine builder in the 1920's.



The J-5, refined from the J-4 after Mead and Willgoos left Wright, became one of aviation's greatest engines.

Mead and Willgoos learned their radial, air-cooled engine trade at Wright.

Meanwhile Frederick Rentschler, during his six months' rest, had done a lot of thinking. A certain conclusion was that he was to stay in the aircraft engine business. He had a rare ability to foresee, on the basis of pure logic, the trend of events. Years later, his pronouncements from time to time on various phases of what the next ten years would bring in the aviation business, proved to be remarkably accurate. He could tell, in 1925, that a market was developing for air-cooled radials to power the new observation and fighter planes. He remembered the Navy's desire to have competition in the air-cooled engine field. He was sure that Mead and Willgoos could come up with an engine to meet the need. He also knew that he could count upon many of his former employees in the manufacturing end. He felt certain that all he had to do was to reveal his plans and he would have experienced men to join with him. He therefore resolved to re-enter the engine business.

One day early in 1925 Rentschler walked into the Engine Section of the Bureau of Aeronautics and coolly and logically presented to Wilson and his staff a plan whereby he would organize a competitive company to manufacture radial air-cooled engines for the Navy. He chilled Navy personnel with his knowledge of the developing merger trends between Curtiss and Wright and he implied the possible effects that this might have on air-cooled development at Wright Aeronautical Corp. Rentschler related how he had secured capital and manufacturing facilities at the Pratt & Whitney Tool Company in Hartford, Connecticut. Wilson, listening carefully, was decidedly interested in increasing competition and possibly obtaining a better engine than the Wright "Simoon" for the Vought O2U.

The conference is reported to have adjourned to Admiral Moffett's office to obtain his blessing in that the Navy should sponsor a new engine and a new company and thus end Wright's virtual monopoly. At any rate, Moffett was pleased to see the possibility for establishment of a truly competitive industry in the air-cooled engine field. Characteristically he threw his full support behind the project.

Wilson gave Rentschler the Vought engine formula required for the O2U, 350 hp and 650 pounds weight. To Rentschler's disappointment, the Navy did not give him an experimental contract; he still did not have a going organization, but Wilson promised to earmark $90,000 for six experimental engines. If these proved successful and superior to the Wright "Simoon", Rentschler could be assured of substantial business.

Rentschler returned to New Jersey and informed George Mead, Andy Willgoos and Don Brown of his plans. They promptly resigned from Wright. John Borrup, Wright's Shop Superintendent, and Charles Marks, the tooling chief, also joined. While Rentschler removed to Hartford to establish a manufacturing facility, Mead and Willgoos set up drafting in Willgoos' family garage. Here, from early June into August, 1925, the engine that was to become the "Wasp" was laid out. All men worked without pay, enthralled by the task before them in creating a new engine and a new organization. They well knew they had to move fast, for the "Simoon" was already running on test.

Lt. Cdr. Wilson had suggested that the Navy would be pleased if more than 350 hp could be gotten for the same weight. To do this Mead would have to increase engine speed. Experience with solid crankshafts and split master rods indicated that bearing failures would usually occur at speeds above 1800 rpm. A solid master rod was needed, so Mead returned to his old R-1 design and used a two-piece crankshaft of improved design. He used a forged duraluminum crankcase, split along the plane of the cylinders, lighter and stronger than previous designs. Willgoos adapted Heron's Type M cylinder and used, for the first time, a rocker-box cast integrally with the head. Mead added a rotary induction system. All accessories were placed at the engine's rear, protected from the weather. Earl Ryder joined Willgoos on detail design and became the first paid employee.

On July 23, 1925 the Pratt & Whitney Aircraft Company was incorporated. Rentschler was President, Mead, Vice-President for Engineering and Willgoos was Chief Engineer. By August the offices and shop were set up in Hartford and detail design moved ahead rapidly. The engine formula had now become 400 hp, 650 pounds and 1344 cu.in. Manufacturing was fully under way in September.

As has been told at the beginning of this article, the first engine was completed the day before Christmas. On December 28, 1925, it was run for an hour or so. In March the 50-hour test was completed. The "Wasp" was rated at 410 HP at 1900 rpm. On May 5th a second "Wasp" took to the air in the Wright F3W-1 "Apache", the beginning of an extensive flight test program. The prototype was changed and rebuilt. As testing proceeded many improvements were made. By October the six experimental engines had proved themselves in a spectacular manner on bench and flight tests. The production version was evolved by mid-year, a production contract for 200 Series A "Wasps" was received and before the year 1926 was out production engines were being delivered. Within another two years the "Wasp" was famous as the outstanding engine in the United States and as one of the greatest in the world.

Pratt & Whitney was aided in being able to start with a clean piece of paper and a simple formula, 400 hp and 650 pounds. That the requirements were met on the first try shows the exceptional talent involved. This creation came as the direct result of the U. S. Navy's struggle to establish the radial, air-cooled engine in a competitive aircraft engine industry.

Today, it is almost over. Pratt & Whitney no longer builds radial, air-cooled engines and the inevitable attrition is taking its toll of radial engines. Few, if any, of the large engines described herein are flying today; few of the men involved in their creation are with us now. Of Pratt & Whitney Aircraft only Earle Ryder, John Borrup and Charles Marks are here to tell us the intimate details. Fortunately for history many of these engines have been saved by the Navy for us to see at the National Air Museum in Washington. There, to be seen by future generations, are the J-1, J-5, P-1, P-2 and the first "Wasp", along with Manly's marvelous engine which began it all.

ACKNOWLEDGEMENTS:

The author is grateful for helpful interviews with Earle A. Ryder, Val Cronstadt, and John J. Borrup con-

(Continued on Page 285)

Engines (Continued from Page 258)

cerning the early days at Wright and P & W A; for photographic and literature assistance from N. L. Mead, Public Relations Manager of Curtiss-Wright; for similar assistance from Frank Murphy, Public Relations Director at Pratt & Whitney Aircraft; to Roy Cross and Charles Mandrake, A.A.H.S. Members, and to Philip Hopkins of the National Air Museum. Appreciation is also expressed for criticisms from Frank L. Greene and my wife, Caroline.

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ABOUT THE AUTHOR

Harvey H. Lippincott, a member of AAHS, is also founder and President of the CONNECTICUTT AERONAUTICAL HISTORICAL ASSOCIATION formed by Connecticut Members of the American Aviation Historical Society with the very considerable interest of the aviation industry in that state. An example of Member Lippincott's leadership is found in the description of the latest meeting of the C.A.H.A. in the Society Affairs column of this JOURNAL, Page 279. He is currently employed as an Installation Performance Engineer in the Sales Department of Pratt & Whitney Aircraft at East Hartford, Conn. His historical interest plus 18 years of association with P & W A, has given him a deep appreciation of the aircraft engine developments related here.

Instruments (Continued from Page 265)

in instrumentation was the use of the "mag drag" electrical tachometers. These instruments used a magnetic coupling device which limited overshoot and increased the accuracy.

1937 Boeing 314, Photo Nos. 14 and 15.
Pilot's panel - Turn and bank indicator, rate of climb indicator, compass, turn and bank (standby) artifical horizon, altimeter, airspeed indicator, compass (standby).
Copilot's panel - Duplicate of pilot's panel.
Center panel - Gyro pilot, 2 tachometers (dual types) 2 manifold pressure for venturi, clock, flap indicator, 2 oil pressure gages (dual types), 1 oil temperature gage with selector switch, air temperature gage. (Note: The total of 5 compasses, including one in the Gyro Pilot, indicated that these were still considered the most unreliable of instruments.)

1938 Douglas DC-4 Prototype, Photo No. 16.
In general this panel followed the lead of the DC-1, -2, & -3 but included instrumentation for four engines. The panel and the entire airplane were frequently altered as airline trials were run. The DC-4 prototype was eventually sold to Japan.

It can be seen that in ten short years from 1928 to 1938 many advances had been made. Sport aircraft instrumentation had changed little, though the reliability and accuracy of the instruments used had increased. But commercial transport aircraft instrumentation had advanced considerably due to the changeover from single-engine to two- and four-engine aircraft and to the improvements in design and increased requirements necessitated by changes in the basic aircraft types. In 1928 commercial air transports carried 8 or 10 unlighted instruments. By 1938 commercial aircraft carried 30 to 40 lighted instruments, many of which were dual types.

Military aircraft had likewise progressed during this decade from panels containing 15 to 20 unlighted instruments to ones containing 30 to 40 for single-engined aircraft and 60 to 80 on the most advanced four-engined bombers. It must be stressed however that both the advanced military aircraft and their instrumentation were in many cases still in prototype stages. Most of the operational aircraft in use in 1938 were of 1930 to 1933 vintage, actually little different from those of the 1918 to 1920 period.

The stage was now set for history to repeat itself with another World War. Time would tell whether the American instrument designers had learned enough since the First World War to cope on even terms with those of the Axis powers.

CHANGES OF ADDRESS
(Continued from Page 282)

John T. WIBLE, 2152nd Comm Squadron, APO 235, San Francisco, Calif.

Ed WISCHNOWSKI, 2926 Porter St., N.W., Washington 8, D. C.

Douglas WOOD, 421 E. 82nd Street, New York 28, N.Y.