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Barrel Aircraft Engines: Historical Anomaly or Stymied Innovtion?

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ABSTRACT

Paralleling development of radial and in-line aircraft engines in the period 1910-1940, interesting barrel engine configurations evolved in three distinct forms. One form died of its own complexity, one fell dormant at the start of World War II, and one still lives as a potential light aircraft engine.

Compared to conventional designs, barrel designs promise little vibration, smoother power strokes, and more power and torque for less frontal area, weight, and parts count. Offsetting problems appear to be tricky cooling, lubrication, structural design, and servicing and maintenance challenges. Current design lessons may still be learned from these devices.

INTRODUCTION

Barrel Engines are reciprocating, internal combustion engines that have their cylinder axes parallel to and arrayed like barrel staves around the axis of the central power shaft. (Figure 1.) Early models of barrel engines resemble radial engines whose cylinder jugs have been bent backwards parallel to the air flow. Various drive mechanisms, involving gears, cams, or wobble plates, are used to create rotation of the central power shaft from the reciprocating motion of the pistons.

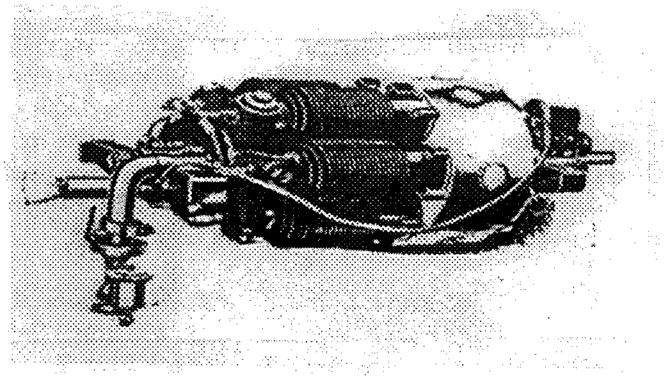
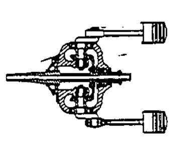


Figure 1. Trebert barrel aero engine (1912). NASM file.

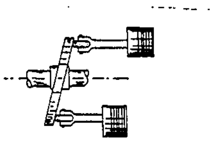
These designs are historically interesting because their development appears to have been international in scope in the early part of this century, because World War II seems to have stymied much of the further interest in the configuration, and because the technology has some interesting characteristics which have been seen in tested prototypes, regardless of the ultimate outcome of the sometimes abortive tests. From 1910 into the 1930's many military and civilian development organizations, in this country, in Europe, and even in Australia, were trying out or using various configurations of the barrel engine in aviation and automotive applications. As wartime development and production ramped up in the 1940's, ever larger radial engines were developed, and turbine engines ultimately proved their worth, barrel engine development lost momentum. At least one group of developers, however, claims to have recently flown a prototype of a barrel engine in a light aircraft, and they hope to commercialize their device for aircraft, marine, and other applications. If that becomes successful, it may induce more attempts to develop alternate configurations of the barrel engine.

Sources of information on barrel engines consist of contemporary technical reports, journal articles, and patent filings. This paper cites the most comprehensive sources of information and then discusses the three principal barrel engine configurations shown in Figure 2. The ganged crankshaft type of engine can be thought of as a collection of smaller powerplants joined by a gearing system. The wobble plate system provides a surface canted at an angle and fixed to the central power shaft that, as the shaft turns, generates a reciprocating motion at any point on its circumference. In a similar fashion, the cam driven system provides a programmable surface at the circumference that allows the designer to tailor piston motion for each stroke.

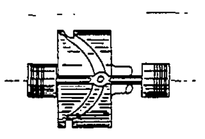
Other classification schemes could have been selected. Since all of these devices are reciprocating engines, they can be designed to follow any thermodynamic cycle such as two stroke, four stoke, or some hybrid kind of logic. It is



GEARED CRANKSHAFT ENGINE



WOBBLE PLATE ENGINE



CAM DRIVEN ENGINE

Figure 2. Engine Types.

also possible to design barrel engines for different kinds of fuels and ignition schemes (gasoline, diesel, or multifuel), for fuel injection or carburetion, and for turbo charging. Further, these units may be designed as conventional fixed block or rotating cylinder block (rotary) engines. Lastly, they may have conventional cylinder heads, or they may be headless, opposed piston engines similar to Jumo aircraft diesels. Since these attributes are all shared with conventional crankshaft engines, in one way or another, none of them appeared to be useful as a way of classifying and conveying their unique properties.

SOURCES OF INFORMATION ON BARREL ENGINES

The first analytical report on barrel engines was issued in 1927 as N.A.C.A. Technical Memorandum 462 [1]. This document was a translation of an article which had appeared in a German publication known as "Motorwagen". The report discusses the Michell Crankless engine at length, but also gives examples of other designs, including an outboard motor. One interesting chart, shown, here, as Figure 3, compares a conventional 4.65 liter, six cylinder auto engine with a smaller 4 liter, eight cylinder Michell Crankless. This comparison shows the barrel engine exhibiting lower internal friction, a straighter set of high rpm (n) power and torque curves, and higher mean effective piston pressures. These findings are consistent with the attractive features of the barrel engine.

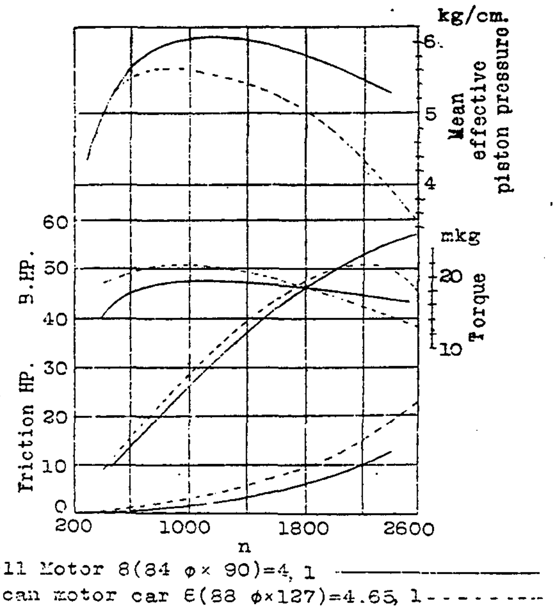


Figure 3. Barrel engine performance comparison [1].

In a comprehensive technical overview in the SAE Journal, Hall [2] reflects the most promising approaches of 1940 and provides sketches and descriptions of the mechanisms used. In a diagram, he compares the smoothness that harmonic piston motion, using wobbler or cam mechanisms, has over the more extreme motion seen in conventional crank throw motion. (Figure 4).

Aerosphere (1939) [3] presents a catalog of aircraft engine developments of all types, as they were known in 1939. Individual engine descriptions include a brief technical description (arrangement, displacement, and claimed power and weight parameters). Some descriptions offer a diagram or photo of the design, and some give the time period during which development was carried out. Not all designs in this publication had yet been prototyped and some were obsolete at the time of publication.

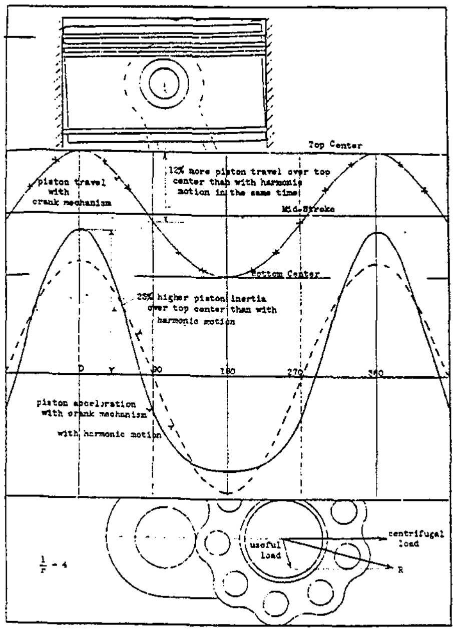


Figure 4. Harmonic piston motion compared with crankshaft driven piston motion [2].

Approximately twenty-three barrel engine designs are described.

In his historical compendium of aircraft piston engines, written in 1981, Smith [4] provides a brief but somewhat negatively biased introduction to barrel engines in the chapter entitled "Lost causes, oddballs, and unconventional engines." However, because of the extensive technical data on powerplant sizes, weights, and performance, for all types of piston engines, this reference should prove useful to those who wish to make comparisons between barrel and conventional designs of the same time period.

For historical accuracy, in the engine descriptions that follow, the measurement units presented are those found in the literature for that design. Equivalent SI or English units, as applicable, follow in parentheses.

GEARED CRANKSHAFT ENGINES

These engine designs consist of multiple conventionally cranked engines, with their output shafts ganged and geared at right angles to one or two straight through shafts. They first appear as attempts to get multiple large displacement cylinders into a configuration that offers reduced frontal area, while still using the basic crankshaft concept to change reciprocating motion into rotation. Other benefits that arose from this approach included the availability of a straight-through power shaft that could be hollowed out to accommodate gun barrels or propeller control mechanisms, and the ability to use the gearing system to reduce rotational speed of the output shaft below that of the reciprocating units. Two designs are noteworthy: the Cleveland engine designed by Walter Willard, and the French Gadoux design.

Cleveland

This engine consisted of six single cylinders, each with its single throw crank geared to the central shaft. (Figure 5.) The design provided for standardized parts in modular arrangements so as to provide a growth path starting at 100 h.p. and ending at 600 h.p., merely by adding more cylinders around the central core power shaft [3]. Bore was 5 in. (127mm.) and stroke was 6 in. (152mm.), giving a displacement, for this configuration, of 707 cu. in. (11.6 liters). Power rating was 150 h.p. No weight was given. The engine was a four cycle water cooled design with an aluminum head/manifold casting and steel cylinder sleeves. It needed no camshaft because the output shaft gearing slowed shaft speed to one half that of the individual cylinder cranks. Because the cylinders lay parallel to the shaft, a cam system on the main shaft could activate the valves at each cylinder head. The Aerosphere writeup implies that both valves were actuated by a single rocker mechanism which pushed for one valve and pulled for the other, whereas the schematic suggests that there was one cam for intake and another for exhaust, and that the rocker arm mechanism was mounted on a common pivot for both. Exactly which design was used is not clear, but the economy of parts for the valving system was probably offset by the extra hardware and gearing for the six individual cylinder cranks.This engine appears in the NASM files under both Cleveland and Ackerman names. The date of the design is unknown, but the photographs in Figure 6 suggest that it is probably in the 1910's or 1920's. The individual cylinder cranks can be seen in the left photo. Despite the massive propeller in the right photo, it is unknown if anything ever flew behind this engine.

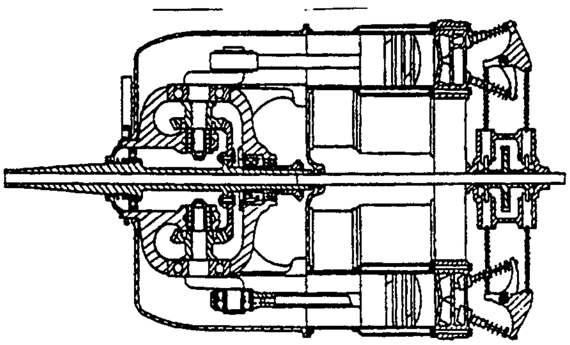


Figure 5. Cleveland/Ackerman barrel engine [3].

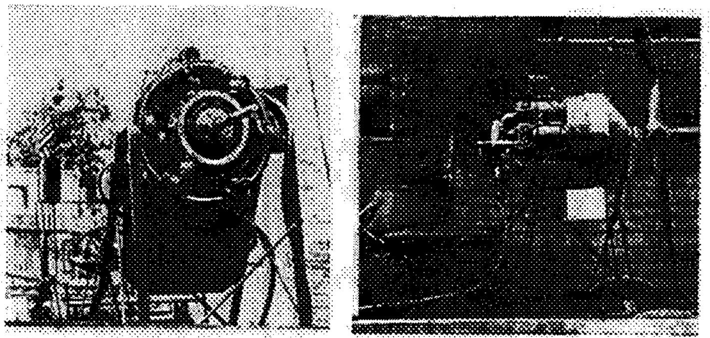


Figure 6. Cleveland engine mounted on auto chassis.

Gadoux

In 1938, a barrel design from France (Figure 7), specifically intended for a through hub cannon and applicable to a small fighter aircraft, was announced by Maurice Gadoux, who had worked for Hispano-Suiza and Delauney-Belleville as Assistant Technical Director and Chief Engineer, respectively [3]. This design consisted of six conventional horizontally opposed twin cylinder engines, supercharged and arranged in six-shooter fashion around two coaxial central drive shafts, which drove a counter rotating propeller set. Specifications included bore of 6.3 in. (160 mm.), stroke of 4.33 in. (110 mm.) and total displacement of 1555.5 cu. in.(25.5 liters) and a rating of 900 h.p. Other than construction by Regnier in France, no mention is made of test results or further applications.

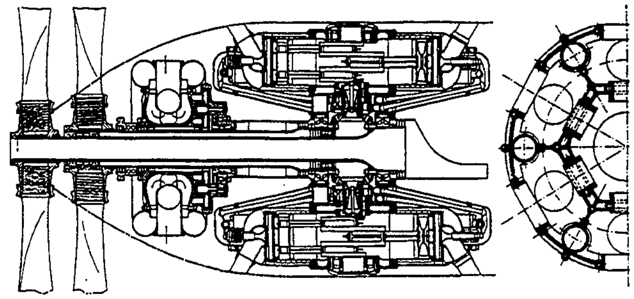


Figure 7. Section through Gadoux design [3].

These designs provided concentrated power with minimum frontal area and, consequently, the promise of minimum drag. The straight through nature of their power shafts also offered the possibility of armaments, propeller pitch controls, or other coaxial devices and systems being run through the main shaft. The extensive nature of the gearing, however, with its weight, cost, service requirements, and complexity, probably doomed this class of barrel engine from the start, despite the advantages reduction gearing offered. No evidence of any work on these designs appears after the late 1930's.

WOBBLE PLATE SYSTEMS

Wobble plates (sometimes spelled wabble plates) are circular surfaces fixed at an angle to a rotating shaft, so that they "wobble" as the shaft turns. Wobble angles used were usually 20-23 degrees (often 22.5 degrees) off of a plane perpendicular to the axis of the output shaft. A wobble plate rotating inside a non-rotating swash plate can then transmit nearly reciprocating motion to any point on the circumference of this "wobbler assembly". Z-cranks are a modified way of driving these wobbler mechanisms. Examples of these concepts are described in this section.

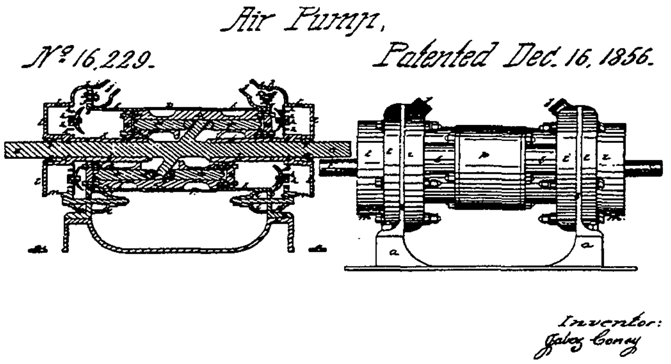


Figure 8. Early wobble plate patent [2].

The first wobble plate type of barrel mechanism was patented as a pump in 1856 [2]. (Figure 8.) The inventor used a rotating wobbler with slippers to drive double acting pistons back and forth. This mechanism, with refinements, appears almost continuously in one or another barrel engine design of this type up through the 1940's. The most representative designs were by Statax (1913-1929), Michell (1918-1930), Redrup (1936), Almen (1917-1939), Alfaro (1939), and a mysterious German unit (1945). These are discussed, in the order mentioned, below. Others, such as Salmson (1913-?), the prolific French radial engine manufacturer, with at least three different barrel designs, appear in Aerosphere, 1939, but either not enough information is available about these designs or their features overlap the others so much that individual discussion of them is not warranted here.

Statax

According to a 1929 G-2 report from the U.S. Military Attache for Air in Berlin [5], one of the first barrel engines to be flown was a Statax. Design work on this family of engines was started in 1913 by Dr. Friedrich Hansen, a German born naturalized Swiss and was interrupted by the First World War. An early design is shown in Figure 9. The Model 29 was developed during the late 1920's. In early 1929, Hansen installed the engine in a Miller aircraft and accumulated 100 hours, and the German Aviation Experimental Station in Berlin (Adlershof) was planning tests for June, 1929.

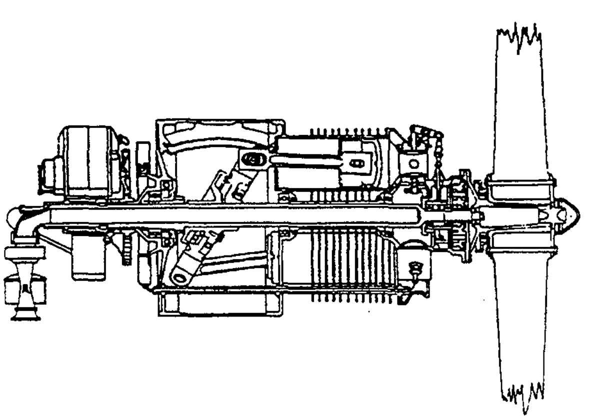


Figure 9. Section of an early Statax. NASM file.

The Statax Model 29 was a 7 cylinder rotary, 4 cycle engine of 2.35 liters displacement with a bore of 62mm. (2.4in.) and stroke of 110mm. (4.33in.). Slide valves controlled breathing. Rated at 40hp continuous, it weighed 110 pounds (50kg.). Licensees and builders of the engine existed in England and the U.S. as of late 1929. Light weight per horsepower and a small frontal area were the features claimed in both the G-2 report and the Statax literature. (Figure 10.)

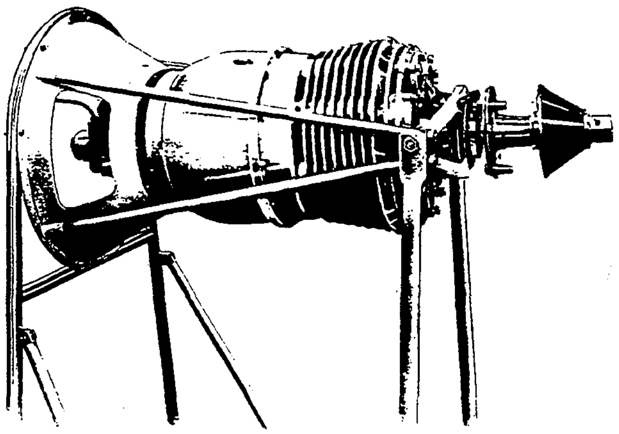


Figure 10. Statax Model 29 (1929). NASM files.

Michell

A.G.M. Michell was an expert in lubrication and a pioneer in the development of high capacity thrust bearings for ship propellers, knowledge which he brought to air compressor and engine design. His basic approach consists of a wobble plate on which ride, over a lubricating film, a set of slippers backed by spherical joints embedded in double-ended piston assemblies that reciprocate in double-ended cylinders. This mechanism resulted in the Michell Crankless engine used in ground transportation.

As reported by the Military Attache in London, strong interest in aspects of the Michell design was evidenced in a project that the Air Ministry sponsored at Rolls Royce in 1926 [6]. No results of this program were available in the files, however.

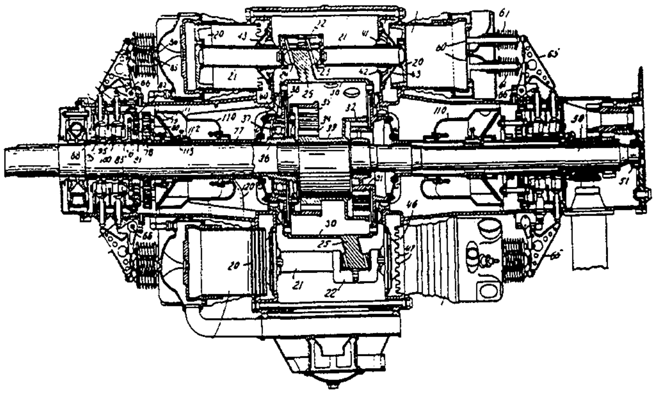


Figure 11. Michell Crankless aero engine (1929) [2].

A version of the Michell design for aircraft (Figure 11) was tested in 1929-30 [2]. This unit featured two banks of six cylinders, located on either end of the engine. Each cylinder fired one end of six double ended pistons in a four stoke cycle. Bore was 6.25 in. (159mm.) and stroke was 5.75 in. (146mm.), giving a displacement of 2120 cu. in. (35 liters). The engine was rated at 800hp. at 2600 rpm., and it weighed 1350lb. (614kg.)

This engine failed on test at 480 hp., running at 2100 rpm. The nature of the failure is not known, but it probably was due to the failure of lubrication, cooling, or structure where the wobble plate and the pistons intersect. This is an area of reduced piston cross section in the Michell design, but it is also one of considerable stress, where sliding contact is used to wedge each piston back into its cylinder on the compression stroke and where each piston wedges the wobbler and central shaft into rotation on the power stroke. It is an area that has plagued other designers of this type of engine, as well.

Redrup

In 1929, in England, C.E. Redrup used a Z-shaft to drive the wobble mechanism (Figure 12) [2]. This is similar to a crankshaft with a conventional throw, except that one end of the throw has been rotated 180 degrees to create an angled effect. Redrup apparently created a successful bus engine for the City of Bristol transit system, and subsequently, tried to adapt the technology to aviation powerplants.

The Redrup group's engine was a seven cylinder, single ended design. The individual pistons were connected to the wobbler mechanism by spherically ended connecting rods. This engine is reported to have developed 95hp. at 2200 rpm. It weighed approximately 200lb. (91kg.) Aerosphere's description indicates that the engine was air cooled, with a porcupine-like set of fins sprouting around the nose of the engine [3].

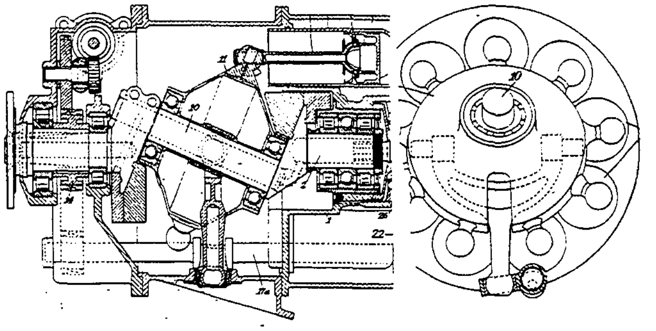


Figure 12. Redrup Z-shaft engine [2].

Some correspondence to this firm from Grover Loening, past Chief Engineer of the Air Service, aircraft designer and aviation pioneer, who was on a trip to Europe to view engine developments in 1929, acknowledges a Redrup proposal to Loening and Loening's reluctance to invest because, "Since leaving England, I have not only had a look at some French developments, but also have found one or two interesting new ideas here (in Berlin.) Their possible success would make it unwise to act on your proposition - at least until you have passed the Air Ministry tests" [7]. Follow-up correspondence, indicates that at the end of Loening's trip, he had learned of new, but confidential, developments in Germany and "the fact that gearing is a fundamental necessity in aircraft development in these engines." There is no mention of specific interest in barrel engines on the part of Loening, but barrel engine development was being pursued in Berlin at this time (see Statax.)

About 1939, Redrup's efforts were merged into another syndicate that produced the Fury air cooled barrel design. Because of the reduced frontal area and densely packed nature of barrel engines, attempts at air cooling have usually resulted in unsuccessful designs. It is not known how successful the Fury design was.

Almen

The most tenacious U.S. based developer of barrel engines in the period from 1910's to the 1930's was J.O. Almen, who designed many versions of his wobble plate engine for the Engineering Division of the U.S. Army Air Service at McCook Field (later Wright Field). The first of his designs is described, as of approximately 1917-1920, in a patent drawing. (Figure 13.) These designs were double ended, water cooled, four cycle engines, with a

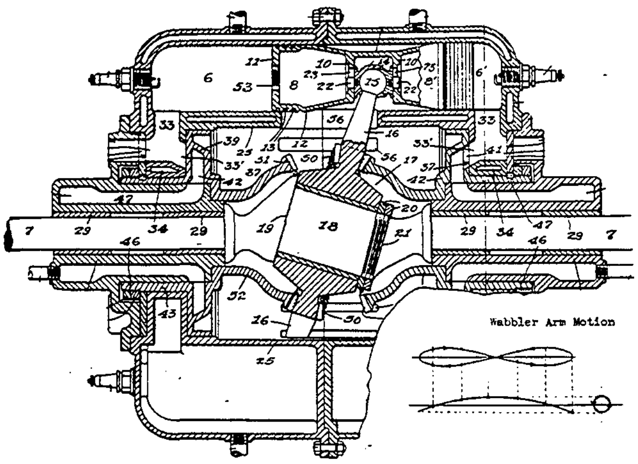


Figure 13. Early Almen design [2].

centrally located, non-rotating wobbler driving each piston first to the cylinder head at one end of the engine and then to the other. The wobbler was mounted on a plain bearing on the Z-shaft at the center of the engine, and was restrained from rotating by a set of bevel gears on its surface that meshed with stationary gear surfaces on the internal shell of the engine.

Since the design is a four cycle engine, each cylinder fires every other revolution, and it requires valving of the cylinders to arrange this. Almen's design for the valve system consisted of a single flat plate at each end of the engine, acting like a mobile cylinder head and valve system and containing passages for intake and exhaust and a flat surface with embedded spark plug to fire the cylinder. This assembly was geared to move in a hypocycloidal manner, against the rotation of the engine shaft, at one sixth speed, and it provided intake, compression, ignition, and exhaust functions to three cylinders at a time.

As tested, the A-1 version of the engine was a 14 cylinder design (2 banks of 7 cylinders, each), with a bore of 2.5in. (63.5mm.), stroke of 3.5in. (89mm.), compression ratio of 4.5, and a displacement of 241 cu. in. (4 liters). It weighed 409 lb. (186kg.) [8]. On test in 1921, it developed 21.9 hp. at 1550rpm., a figure that was quite low, even for that time, largely because of its low compression ratio and high friction valving system.

The test pleased the Air Service, however, judging by the conclusions of the test report, which noted that with higher compression and better valving, "power output and mechanical efficiency could be increased to a point where they would favorably compare with more conventional engines." It further reported, "This type of engine lends itself readily to a cannon installation firing through the propeller, and because of its low head resistance in proportion to displacement, compactness, ease of armoring, etc., is unusually well adapted for aircraft use."

This mechanism no longer uses shoes or slippers on the wobble surface, nor does it use connecting rods. The pistons gain rigidity and alignment from their double ended nature. To accommodate the rise and fall of the wobbler joint within the piston, each piston is fitted with a sliding bushing containing a spherical socket, all of which are directly lubricated by a pressure system.

Air Service interest continued, and tests of revised versions of the Almen engine were conducted into the early 1920's. Some test reports from early models of the engine are available in NASM archives. It is interesting that these reports remained classified Confidential until January, 1956. Almen designs up through A-5 are shown in the literature, although it is not known how many were actually built. Hall indicates that the A-4 model was run through initial tests with an advanced wobbler mechanism [2]. Simultaneously, however, Air Service policy on the development of engines changed from funding the development of selected technical approaches to encouraging the submission of independent designs from private industry. Hall's conclusion is that the merits of the wobble mechanism, and the Almen engine were not fully explored because of the policy shift [2]. It is probably also significant that increasingly compact Curtiss engines were being announced at this time (ca. 1923) [9], but it may still be true that, even now, the full potential of this engine type has not been fully explored.

Alfaro

The last engine design of the wobbler type to be forthcoming on this side of the Atlantic, was the Alfaro engine, designed by Heraclio Alfaro of Aircraft Development Inc., Boston, Massachusetts. Under contract to the Civil Aeronautics Board, in 1935, a proof of concept, double ended, single cylinder engine of 110 cu. in. (1.8 liters) displacement, with a bore of 3.75in. (95mm.) and stroke of 5in. (127mm.) on each end, was built with a 9.5 to 1 compression ratio at the Indian Motorcycle factory in Springfield, Massachusetts. On test at MIT [10], the engine delivered 80 b.h.p. at 2000 rpm.

Subsequently, a design prototype of four cylinders was built and tested, successfully, in 1938 at MIT. This engine had four double ended cylinders with 2.7in. (68mm.) bore, 3.375in. (86mm.) stroke, and 167 cu. in. of displacement (2.7 liters).

This engine used a different kinematic scheme. Two single headed pistons were installed in each cylinder, and they were forced together by wobble mechanisms at each end of the engine (Figure 14). Thermodynamically, the engine was a two cycle unit which fired on each stroke. Breathing was accomplished through ports in the cylinder walls which were uncovered at appropriate times in the stroke. Fuel injectors and spark plugs were located where the two opposed pistons reached their closest point. The engine had no valves, camshaft, or valve train requirements but did use scavenging air at about 6 ½

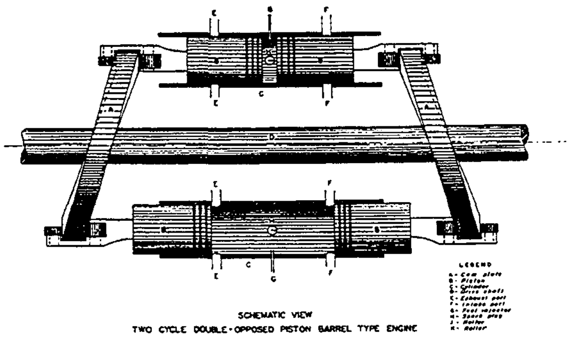


Figure 14. Schematic of Alfaro Engine [10].

inches of pressure forced into the cylinders at the bottom of the power stroke. A geared blower, operating at ten times shaft speed, was mounted at the front of the engine. As the pistons traveled apart, one of them first uncovered the exhaust port to lower pressures and temperatures while the other followed by uncovering the intake port to admit scavenging air. This scheme also appears in Professor Junker's Jumo diesel aircraft engines.

Under acceptance test, this engine delivered 113 b.h.p. at 2030 rpm, at full throttle, operating for almost two hours on a dynamometer with only minor problems from a set of experimental injectors [9]. Even though its block was of cast iron, its tested weight of 269 lb. Gave it a specific performance of 2.34 lb. per h.p. This was in line with other engines of the time, but the agency and the designer believed that, using aluminum castings and refined weight saving design, the power to weight ratio could be significantly improved. Other observations made during the test program suggested that the design was entirely practical, that it could be adapted to compression ignition or diesel operation, and that an eight cylinder, 265 h.p. version could be developed weighing approximately 400 lb.

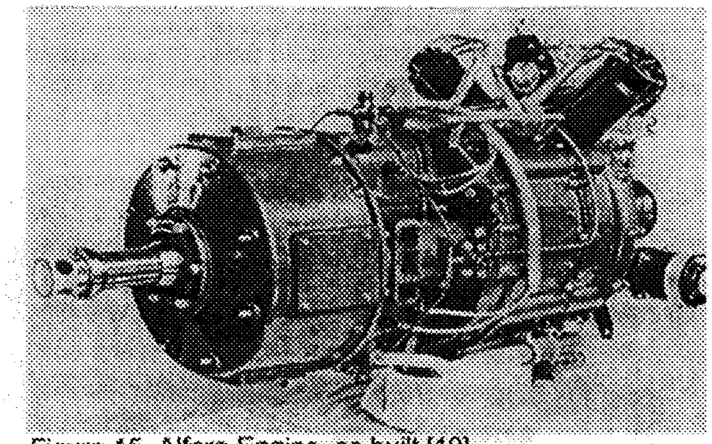


Figure 15. Alfaro Engine, as built [10].

No comments were made on the vibration characteristics of this engine, but since it seems to have matched pairs of components going in opposite directions at every stroke, dynamic balance should be good and vibration very low. This engine would give four power strokes every revolution, so it should have the smoothness of an in-line or opposed four stroke eight cylinder engine.

German Engine (1945?)

Following the Second World War, the allies discovered a German barrel engine, similar to the Alfaro, but air cooled. (Figure 16.) It had apparently been developed in the 1930-40's and tested further during the war. Nothing is known about its dimensions or its performance characteristics. However, it appears to have reached a highly developed mechanical state of design. Like the Alfaro, there are two wobble plates, one at each end of the engine, and they force the two pistons together in the center of the engine during compression [11].

Echoing the recommendation in the acceptance test report by the CAB on the Alfaro, the design appears to be an eight cylinder model. The wobble plate arms have been transformed into potentially stiffer circular shafts, with what appear to be ball bushings, projecting into the pistons that they operate. Next to no detail is given on the breathing arrangements, but there appear to be injector pumps for each cylinder, operated by cams on the main shaft, indicating the unit is a two stroke one. A scavenging or supercharging blower is evident at the right end.

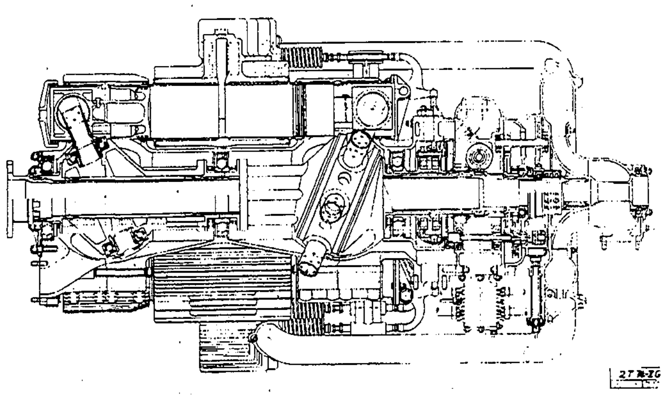


Figure 16. Internal arrangement of German engine [11].

Did the Germans build on the earlier tests of the Alfaro? What results did they achieve? Was this design one of the "interesting approaches" that Grover Loening saw under development on his earlier visits to Berlin? These speculative questions may never be answered, but they indicate the widespread interest and common design approaches to barrel engine development in the years leading up to the Second World War.

CAM DRIVEN SYSTEMS

Cam driven systems have most frequently been designed as cylindrical cam surfaces located in the center of a double ended engine design, so that double ended pistons can be shuttled back and forth in double headed cylinders. Cam shape is programmable, allowing tailoring of velocity, acceleration, and extent of piston travel.

Laage

Although cam drive patents go back farther than the 1920's, the Laage engine, designed in France, was probably the first cam actuated barrel engine intended for aircraft use. (Figure 17) [1,2,3]. Like many of the wobble plate engines, this engine was double ended. Under its external cover, it was fitted with a cam path and rollers external to the barrel of cylinders. It was called a sixteen cylinder engine (actually two barrel clusters of eight cylinders each, one on each end.) Power was claimed to be 300hp., but no other statistics on bore, stroke, or displacement are available. As shown in Figure 17, this must have been a rotary engine, although the description says that it would work with either fixed or rotating cylinders. In any case, either the cam path assembly or the cylinder block had to rotate to make it work.

Taking advantage of the cam profile's ability to program the travel of the piston in each cylinder, Laage also incorporated an unconventional thermodynamic cycle described as a six stroke cycle. The cam path controlling this stroke consists of some half strokes, as shown in Figure 17 [1]. It is unclear whether this approach allows the engine to breathe or produce power more efficiently, and the available literature does not help clear up the question, but this approach illustrates the tailoring that is possible with cam drives.

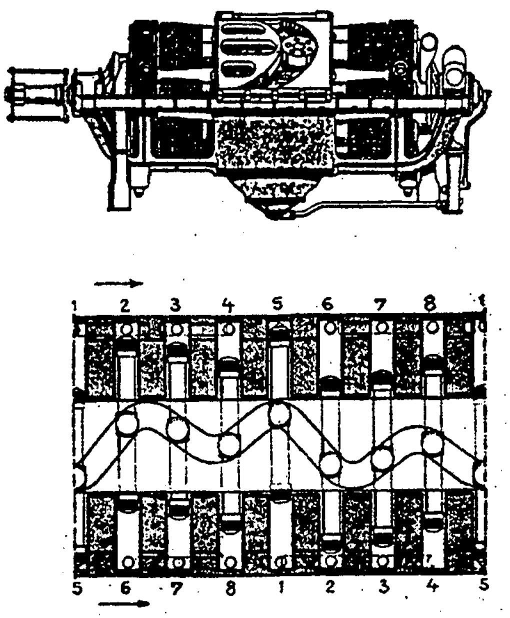


Figure 17. Laage cam driven rotary engine [1].

Franklin

In 1929, G.E. Franklin of the Franklin Aeronautical Corporation exhibited an experimental cam driven barrel engine intended for both automotive and aircraft use [3]. It consisted of two eight cylinder blocks mounted on each end of a barrel layout (sixteen cylinders in all), and operated on the two stroke cycle. Bore was 2.75in. (70mm.), stroke was 5in. (127mm.), displacement was 475 cu. in. (7.8 liters). It weighed 375lb. (170kg.) and was claimed to develop 400 h.p. at 2000 rpm. (Figure 18.) The major advantages of the design were said to be lack of vibration and small frontal area. No internal layouts, test data, or further applications are known for this design.

Bleser/Herrmann/Dynacam

Sometime prior to 1936, Bleser Motors of Springfield, Illinois, designed a four cycle barrel engine with six double ended cylinders and pistons actuated by a central cylindrical cam system. (Figure 19.) The cam was fixed to the rotating output shaft, and the pistons followed the cam using a double set of cam rollers mounted in the center of each piston. The cam programmed a complete sine wave of two high points and two low points, per revolution of the output shaft, thereby getting one four cycle power stroke from each piston for each revolution. Cooling was by water, and the valve system consisted of conventional poppet valves operated by cams mounted directly on the output shaft. Compared to a conventional crankshaft engine or a wobble plate engine, this design achieved a 2:1 reduction gear effect by cleverly profiling the cam surface. Theoretically, nothing would prevent a different cam surface from being used to provide greater reduction gearing at no increase in weight.

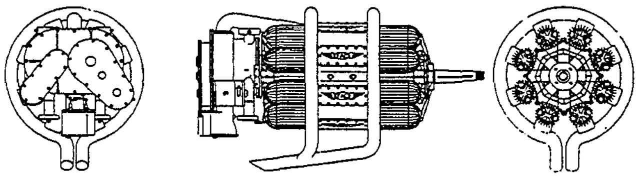


Figure 18. Franklin aircooled barrel engine [3].

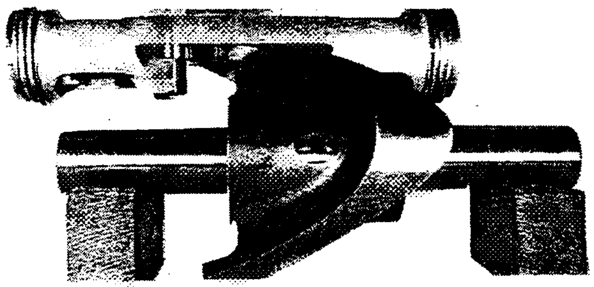


Figure 19. Piston and cam arrangement, Dynacam [12].

In 1936, this invention was licensed to Dr. K.L. Herrmann of South Bend, Indiana, who continued development of the design under his own name [3]. As an automotive engineer (Studebaker's Chief Engineer), Herrmann downsized the engine to make use of available automobile peripheral equipment. Ford V-8 valve components, and conventional starters, carburetors, generators, and distributors were used. (Figure 20) [12]. The Herrmann design used a bore of 3.25in. (83mm.), stroke of 3.75in. (95mm.), and displacement of 373 cu. In. (6 liters). Dry weight was 338lb. (154kg.).

In the early 1960's, having created an impressive patent trail but without having made a sale of the engine, Herrmann transferred the rights to Edward B. Palmer of Southern California. In Palmer's hands, this engine has been further refined. In 1981, it received an FAA type certificate [13], and an additional patent was issued on improvements in 1985 [14]. The engine has become known as the Dynacam engine, and a pre-production prototype was installed in a Piper Archer in the mid 1980's and successfully test flown (Figure 21)[15]. Palmer is survived by Patricia Wilks, who is currently trying to gather funding for initial production of a limited number of these units. Initial performance figures are for 210 h.p. at 1900 rpm with 650 ft.lb. of torque. Price will be equivalent to or somewhat lower than that of established aircraft engines of comparable power (in the mid $20,000 range.)

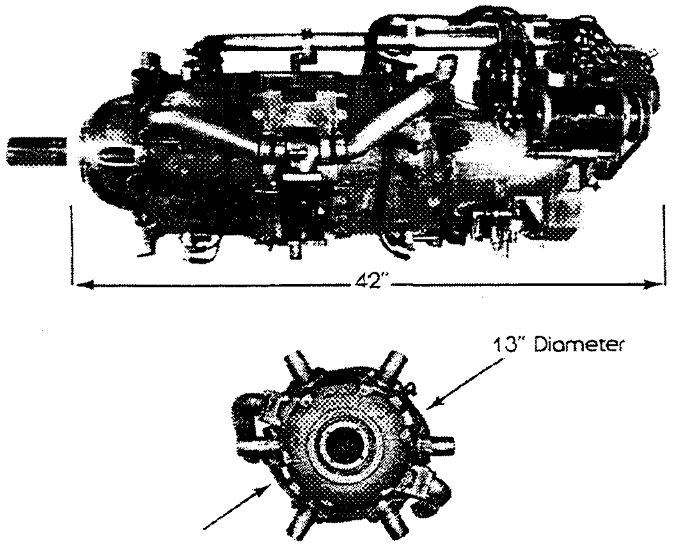


Figure 20. The Dynacam engine [13].

CONCLUSION

Of the three paths of barrel engine development examined, the geared crankshaft path seemed to die a natural death. Its designs were rendered obsolete by their own complexity and lack of accessibility for service.

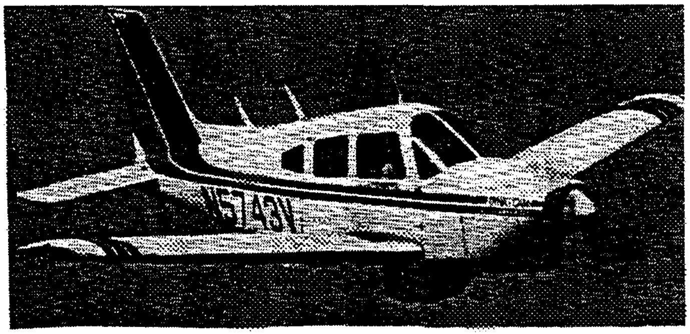


Figure 21. Dynacam in flight in Piper Archer [15].

The wobble plate path, however, still presents some open questions. These engines underwent considerable refinement from the early and successful, non-aviation Michell designs, but they were not quite able to deliver an attractive package at the start of World War II. At the same time, a sea change in the strategy underlying government sponsored engine development undercut further work. The Almen design, though it had progressed a significant way, was not able to sustain full power because of inadequate internal structure, lubrication, and/or cooling, but the Alfaro was built and tested successfully in 1939. Its smaller size and its sponsorship, under the CAA, however, did not lead to its serious consideration in the war effort. Little is known about the rather advanced German counterpart to the Alfaro, but it was claimed that, during the 1940's, it was successfully tested.

Lastly, the cam driven hardware, represented now exclusively by Dynacam, is still alive, barely. It appears to have a solid development history, its literature promises several major advantages such as light weight, lack of vibration, smooth power delivery, low parts count, and high torque at a low rpm, all relative to conventional piston powerplants. Its current disadvantages appear to be a lack of established production capacity and service infrastructure, a lack of prior acceptance in other related markets (such as automotive, marine, or agricultural applications), and potentially, a high asking price.

Due to its limited scope, this paper could not fully catalog all the technological issues faced in the development of barrel engines, but for someone wishing more knowledge about the subject, it points to the main references that lay out these issues, and it describes the major development themes. The rich history of these devices exhibits many clever, creative ideas which may yet prove useful in the future. Devices that deliver or seriously promise to deliver smoother operation, more power for their weight, all with a lower parts count and greater simplicity, should be of interest to anyone in either automotive or aircraft powerplant design.

ACKNOWLEDGMENTS

The research leading to this paper was conducted, principally at the National Air and Space Museum in Washington, D.C. The museum achives, there, have an extensive library and a very large collection of aircraft and engine files, many of which contain primary documents, in the form of test reports, drawings, and operating manuals for a wide variety of aeronautical products. Further, many of the older files from Wright Field have been given to NASM. Lastly, the staff and volunteers of the archive room are incredibly knowledgeable, often know the "war stories," and are wonderfully helpful to outside researchers.

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