Curtiss Chieftain Engine

Editor's Note: Throughout all the 1920s and most of the 1930s, undue emphasis was placed on engine frontal area, resulting in novel approaches to engine design. Development of the Townsend ring and NACA cowl eventually put this concern to rest. In the mean time, several noteworthy engines of small diameter and unusual construction competed with the usual air-cooled radials and liquid-cooled vees. One such engine was the Curtiss Chieftain. The following account is taken from Victor Page's 1929 work, *Modern Aviation Engines, Vol. 2.*

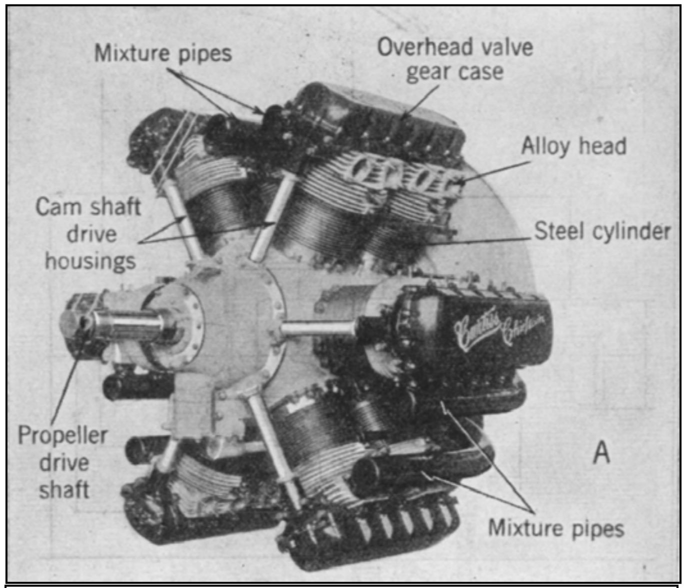


Fig. 666A. View of the Curtiss "Chieftain," aTwelve-Cylinder Aviation Engine of the Hexagon Type.

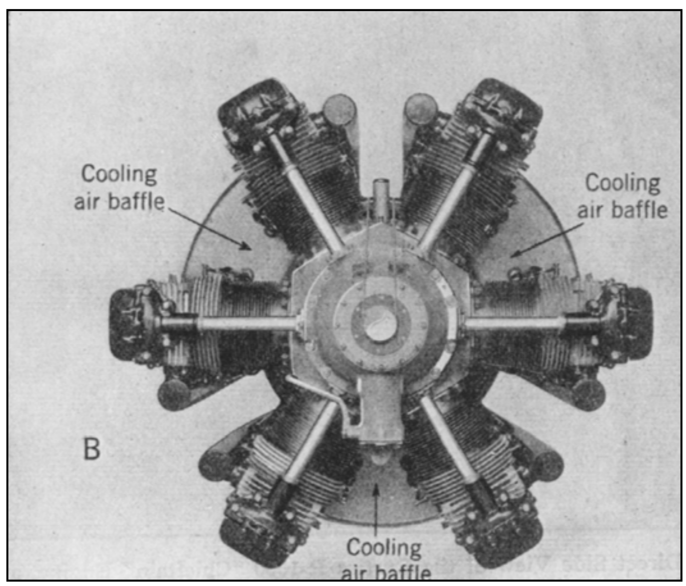


Fig 666B. Front View of Curtiss "Chieftain"

Flight tests were recently completed at Mitchel Field, N. Y., on the new 600 horsepower Curtiss "Chieftain" one of the largest air-cooled aircraft engines in this country. The tests were conducted with the engine installed in a two-seater Curtiss Falcon, standard observation and attack plane of the Army Air Corps. The plane was flown by Lieut. E. P. Gaines, Army Pilot stationed at the Curtiss factory, and by "Casey" Jones, veteran Curtiss pilot. Equipped with the "Chieftain" engine, the "Falcon" showed a performance that was superior to that of any other two-seater in the service. Its top speed was 158 miles per hour, and the, service ceiling 22,350 feet, while the initial rate of climb was 1,870 feet per minute. The most remarkable feature of this performance is the speed of 158 miles per hour, which is exactly the same as could be obtained from a water-cooled engine of the same power in the same plane. Curtiss engineers point out that this is the first time in history that air-cooled engines have been able to compete directly with water-cooled types in pure speed. Usually, the substitution of an air-cooled engine for a water-cooled engine of the same power, while producing improved climb and ceiling, has resulted in a sacrifice of several miles per hour in top speed. The excellent speed characteristics of the Chieftain engine is due to its unusual design, which is different from that of any other air-cooled engine. Instead of having one row of cylinders arranged radially, as is the common practice, the Chieftain has two rows one behind the other, with six cylinders, arranged hexagonally, in each radial group. This arrangement materially reduces the overall diameter of the engine, thus reducing the head resistance and increasing the high speed and is shown at Fig. 666 C which is a direct side view. The frontal area per horsepower of the Chieftain engine is approximately one half of the conventional nine-cylinder air-cooled engine. The Chieftain engine has been under development by the Curtiss company for over two years, with the assistance and guidance of the Air Services. It performed excellently throughout the trials.

According to Arthur Nutt, Chief Engineer of the Curtiss Aeroplane and Motor Co., Inc., it was in April, 1926, that a systematic study was first started on the design of a 600 horsepower air-cooled aircraft engine. The first steps in this study were to analyze the types of engines in use at that time and then to study the possibilities of the different forms of engines which would be suitable in the large size contemplated. The types that were finally selected for study were as follows: Nine Cylinder Single Row Radial, Fourteen Cylinder Two Row Radial, Sixteen Cylinder X, Twelve Cylinder Vee, Twelve Cylinder Hexagon. In making this study ten important characteristics were borne in mind. 1. Low weight per horsepower. 2. Head resistance and propeller efficiency. 3. Visibility from the pilot's cockpit. 4. High crankshaft speed. 5. Overhead valve gear for high speed. 6. Exhaust arrangement. 7. Control of cooling air. 8. Application of reduction gears. 9. Overall dimensions particularly diameter and length. 10. Smoothness of operation.

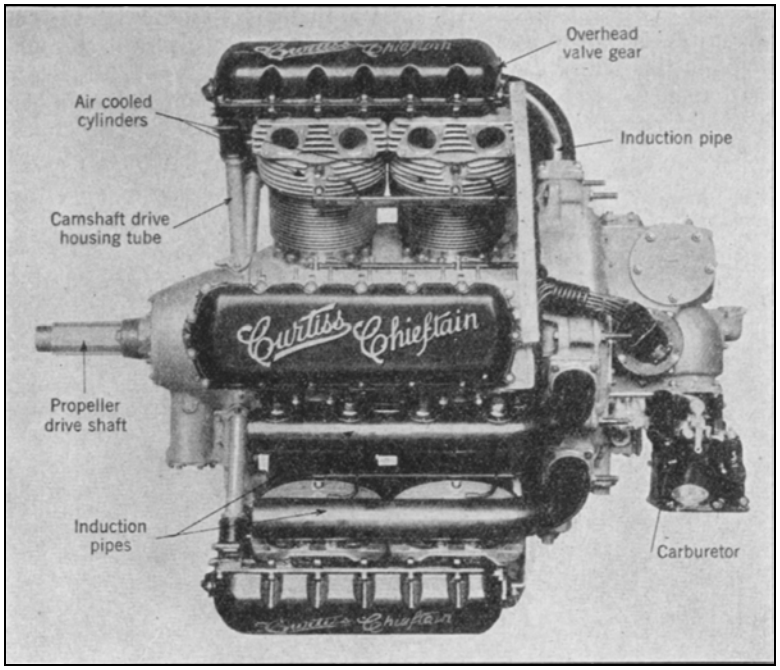


Fig. 666C. Side View of the Curtiss R-1640 "Chieftain"

Nine Cylinder Single Row Radial.-This type would require an engine of from 1,800 to 1,900 cubic inches to develop about 600 brake-horsepower at a speed in the neighborhood of 1,900 r.p.m., which is probably a rather optimistic speed at which to expect to run an engine of this power and displacement, owing to the fact that the size of the cylinder bore is reaching a point where cooling is difficult, and the reciprocating weights on one crankpin (even though it may be of the split crankshaft and solid big end type) would be a difficult problem. The outside diameter of a nine cylinder radial engine of this power would be 56 inches to 60 inches in diameter which presents a very large frontal area with severe blanketing of the propeller, resulting in poor propeller efficiency. The added diameter increases the resistance so much that it has been found by experience that the larger radial engines in Pursuit planes make practically no more speed than the lower horsepower radial engines with the smaller diameters. Of course, the rate of climb is increased but this does not offset the disadvantage of carrying high powered engines using more fuel without gaining more top speed.

The exhaust problem on a nine cylinder radial becomes more difficult as the size of the engine increases. The manifold must be made very large in order to decrease the back pressure. The manifolding assembly then becomes very heavy, unreliable and cumbersome, resulting in the necessity of locating it between the propeller and cylinders where it undoubtedly has a detrimental effect on the cylinder cooling as well as making the cylinders very inaccessible. A large diameter radial engine does not lend itself to good cowling and the adaptation of shutters for control of cylinder temperatures and oil temperatures under various weather conditions. It is
necessary to use push rod valve mechanism with the attendant difficulty of lubrication of the rocker arms, and the ball and socket joints. The lubrication cannot be fully automatic without adding a great many pipe fittings and tubing which would not be reliable, would increase the expense and would be very unsatisfactory.

Fourteen-Cylinder Two Row Radial.-This type of engine has been used by several manufacturers in powers up to 450 horsepower, and is objectionable on account of the lack of satisfactory cooling of the rear row of cylinders, since the cylinder spacing is so close when the outside diameter of the engine is held to a minimum that the rear cylinders get hot air from the front cylinders. The push rod valve mechanism is also unsatisfactory on account of the necessity of staggering the cylinders to a great degree in order to keep the engine diameter down, resulting in high angularity on the push rods and possibilities of increased wear on these parts. The weight per horsepower on the double row radial is slightly higher than the single row radial but it has the advantage of a small diameter which was the reason for investigating this type of engine. The displacement would have to be approximately 1,800 cubic inches, which would allow smaller cylinders than could be obtained in a nine cylinder type. Both these engines, the nine cylinder radial and fourteen cylinder using push rod valve gears, are probably limited in engine speed although this engine speed has in the past few years been increased slightly over what was originally thought could be used with this type of valve gear. There is no question, however, that the push rod valve gear is inferior to the overhead type when high engine speeds are used.

Sixteen-Cylinder X.-The X sixteen-cylinder engine has not been given a great deal of consideration on account of the large number of cylinders making the engine more expensive and the necessity of using very heavy counterbalances on the crankshaft to make the engine run smooth. The engine would also be heavier than the radial types on account of the longer crankshaft, although the diameter would be very satisfactory.

Twelve-Cylinder Vee.-This type of engine has been built successfully with air cooling, it has one very great objection, namely, its overall length which automatically gives a high weight per horsepower as compared with the other types of air-cooled engines. This overall length is necessary on account of the large cylinder centers necessary to get cooling on each cylinder barrel and on the cylinder head. The air-cooled Vee engine is eight or ten inches longer than a water-cooled engine of the same bore, however, the engine has a-very great advantage of being able to run at high engine speeds on account of the overhead valve gear and the light reciprocating parts on the crankshaft. The exhaust arrangement is very satisfactory, particularly when the engine is built in the inverted form. The cooling air to the cylinders can be controlled by means of shutters, if necessary, and the air to the crankcase can also be controlled by shutters. One of the biggest problems with this engine, however, is proper intake manifolding.

Considering all of these types of engines the rotary inductor and supercharger have been included in the study of the design, therefore, when connecting the supercharger in the Vee engine to the cylinders, the straight or gallery type manifolds have usually been employed which are extremely unsatisfactory at high altitude, owing to the fact that the gas distribution with this type of manifold is very poor. The engine runs very well at sea level where the manifolds are not subjected to the cold air blast and where the heat of the mixture is higher owing to the higher initial temperature of the charge. In order to apply a satisfactory manifold to this engine weight and frontal area are increased, inasmuch as the manifold arrangement must be on the outside of the cylinder banks.

Twelve-Cylinder Hexagon Type.-After making the above study it was decided to attempt a combination of the radial and Vee engine which would satisfactorily combine the good features and do away with the objectionable features of both. The type of engine selected is that for which the Curtiss company has coined the name "Hexagon." In other words, the Vee engine was cut into three sections, these sections of four cylinder Vee engines being placed in radial form 120 degrees apart, resulting in a two row radial twelve-cylinder engine, one row directly behind the other. By blanking off the rear end of the exhaust Vee in each of the three Vees, Vee engine cooling was obtained.

The feature of the low weight per horsepower of the radial was partially maintained, as there is no question that the single row radial is the lightest form of engine at a given r.p.m. and displacement that is known today. However, by increasing the engine crankshaft speed this difference was offset. Second, the head resistance was kept very low, the engine outside diameter being 45 inches, and the cowling diameter 39 inches, which results in high propeller efficiency as the ratio of the diameter of the propeller to the diameter of the engine becomes larger than on the big radial engines, leaving the propeller tips in clear unobstructed air in a symmetrical form around the engine. In fact, the propeller has less flutter when operating in front of a symmetrical body than it would behind a form of engine such as the inverted Vee, particularly if the propeller runs very close to the engine. On account of the small diameter and a short

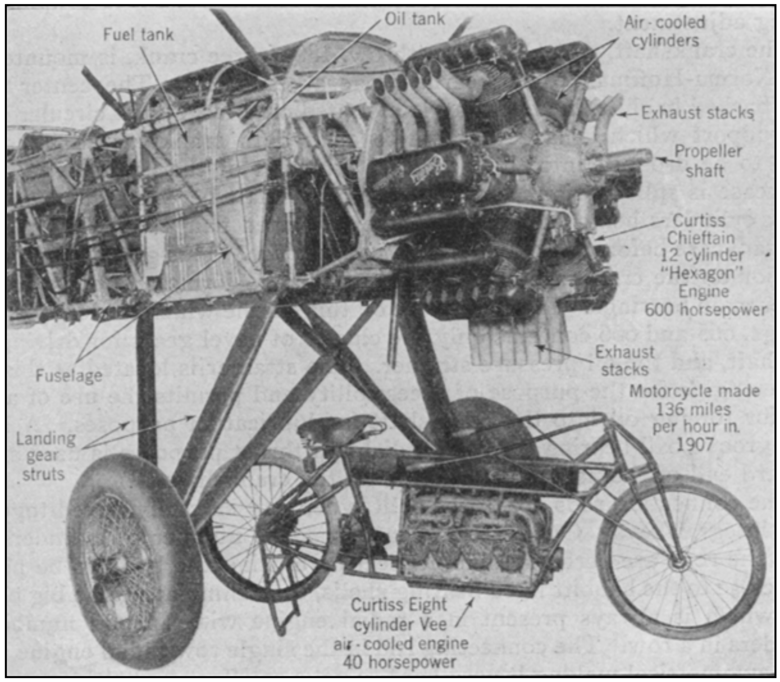


Fig. 666D. An Interesting Contrast in Design. The first air-cooled Curtiss Vee aviation engine was tested on a motorcycle. Compare this with the "Chieftain" engine shown above it.

engine very high visibility was obtained. With six cylinders in a radial row there are large spaces, 60 degrees between each cylinder bank, which permits isibility as obtained on a 39-inch diameter since the 45-inch diameter prevails only at the overhead valve gear covers which extend for only a very short part of the circumference and are streamlined easily.

With only six cylinders on a crankpin the weight of reciprocating parts was greatly reduced permitting higher crankshaft speeds. Overhead valve gear similar in design to the D12 valve gear was used which again permitted the higher crankshaft speeds. The exhaust arrangement is exactly the same as on any Vee engine with the addition of an extra row of exhaust ports at the bottom of the engine which can be manifolded with a muffler in a single row at the two sides and. bottom adding practically no head resistance and not interfering with visibility. The cooling air to the cylinders can be controlled as on the Vee engine. Reduction gears of either the concentric type or the spur type can be used, the latter possibility being a very great advantage on the engine and one which cannot be used on any other form of engine without interfering with cylinder cooling or increasing the frontal area of the engine, as would be the case on the inverted Vee engine should the reduction gear or the spur type be raised above the crankshaft center line. The application of the spur gears in this way on the inverted Vee engine would also entirely ruin the visibility from the pilot's cockpit. The spur reduction gears would not interfere with cowling or visibility on the Hexagon engine and they would raise the center of the propeller shaft, giving more clearance for the propeller which naturally would be larger in diameter if run at a slower speed. The overall length of the Hexagon type of engine is only about eight inches more than the single row type which is a negligible figure when the installation in an airplane is considered. There is also no question that the larger the number of cylinders on an engine of this power the smoother the operation of the engine will be. Twelve cylinder torque has been demonstrated repeatedly to be very much more satisfactory than the torque from a smaller number of cylinders of the same size when the engine is run at the same crankshaft speed.

It is not possible to completely balance the nine-cylinder radial engine or any other single row engine using the articulated type of rods. These engines do not run as smooth as the twelve cylinder, but they have been found to be satisfactory in service. The balance of the articulated rods on the Hexagon type is perfect, inasmuch as one row of the cylinders completely balances out the other row of cylinders on the opposite crank throw and it was only necessary to put enough balance weights on the crankshaft to take care of the unbalanced couple existing.

The above outline describes roughly the arrangement of the engine, however, a few details making this combination possible are given below: The cylinder construction is of the conventional type with the exception that a four valve flat head cylinder is used similar to the water-cooled Conqueror engine. Bronze seats are inserted in the aluminum cylinder head and the steel cylinder-is screwed in the aluminum head in the usual manner. Each cylinder in a bank has a large pilot on the top end which fits into a casting bridging the two cylinders. This casting is held in place with studs and nuts and carries the double camshaft bearings. The two camshafts on each bank of two cylinders are driven by spur gears at the propeller end, one of these spur gears being mounted on an idler shaft below the two camshafts. The' idler shaft is driven through bevels and a master gear on the front end of the crankshaft, all of the vertical shafts being driven from this master gear. Each pair of camshafts has a serrated face coupling for timing, adjustment.

The crankshaft, which is a two throw, 180 degree crank, is mounted on two Norma-Hoffman roller bearings one at each end. The center main steel backed babbitt lined bearing is mounted on a large split circular bearing support which is large enough to. clear both crankpins enabling the shaft to be dropped into the crankcase which is of the barrel type. The crankcase is split at right angles to the crankshaft between the two rows of six cylinders being bolted together on inverted flanges on the inside of the crankcase before the cylinders are put in place. This gives a very clean exterior on the crankcase and the internal flange forms a support for the center main bearings. The nose piece on this engine which is clearly shown at Figs. 665 and 666 contains only the cluster of bevel gears for driving the camshaft, and the oil pressure strainer. The strainer is located at this end of the engine for the purpose of accessibility and permits the use of an oil seal for forcing oil into the crankshaft for lubrication purposes. A large deep groove ball bearing for both radial and thrust purposes is used at the forward end of the nose of the engine on the crankshaft.

The connecting rods are of the split type, very carefully keyed together with integral keys. Owing to the fact that the number of cylinders are even, the rods are perfectly symmetrical permitting the bolts to be placed' very close to the babbitt lined bearing shells, thus eliminating the big objection which is always present in a radial engine with an odd number of cylinders in a row. The connecting rod in the single row radial engine must be unsymmetrical making it very hard to get a satisfactory bolting arrangement on the split connecting rod. Pistons are of the hollow head type and are of the conventional ribbed design which have been used by Curtiss for many years.

The engine is fitted with a rotary inductor or supercharger which will give sea level power at 12,000 feet. It is of the General Electric Company's centrifugal type and is mounted in the rear of the engine as shown at Fig. 666 C, being driven by four spur gears, two being on a jackshaft. One main shaft is carried through the diffuser of the supercharger to drive all accessories which are mounted on the back of the engine. A very unusual and novel method of mounting accessories has been employed on this engine. All accessories are mounted in such a position that they are accessible when an engine is installed in an airplane.

The starter and magneto are mounted on opposite ends of a horizontal cross shaft driven from very large bevel gears from the shaft which was carried through the diffuser. This same shaft through the diffuser carries a larger helical gear which drives two vertical shafts in the rear gearcase. Two distributors are driven from helical gears from each of these two shafts, the oil pump being driven off the lower end of one of these shafts and the gasoline pump off the lower end of the other shaft. The generator is mounted in a vertical position, on the top of the gearcase driving through bevel gears. In other words, there are only three bevel gears on the rear end of the engine, driving accessories. In addition the oil pump is driven from the lower end of one of these shafts and the fuel pump from the lower end of the other. The generator is mounted in a vertical position on top of the gearcase, and is driven through bevel gears. There are thus three bevel gears at the rear end of the engine for driving accessories. The two gun control drives are taken from the top ends of the vertical shafts, while the tachometer drives are taken from the rear ends of the camshafts, as desired.

A carburetor intake elbow is cast integral with the rear gearcase and a single Stromberg carburetor with economizer is fitted. Lubrication is by the regular Curtiss system, to which have been added a number of special features that will be described. Oil from the pressure pump is led through a steel tube to the pressure oil strainer on the nose of the engine; it passes through this strainer into the crankshaft and thence to the two connecting rod bearings and the center main bearing, which is a plain bearing. To the bearings of all the articulated rods the oil is index-fed, and the spray from these bearings lubricates the cylinder walls and the piston pin bearings. Oil under pressure is index-fed to all of the plain bearings in the gearcase of the engine and also to the ball and roller bearings wherever this was found necessary. Oil is conducted to the camshaft bearings through the vertical drive shafts and is returned to the main crankcase by geartype oil pumps formed by casings built around the spur gears which drive the camshafts. Making these gears do the additional duty of oil pumps called for very little weight increase. Two main scavenging oil pumps are provided, one taking oil from the front and the other from the rear end of the engine, both returning the oil to an outside tank.

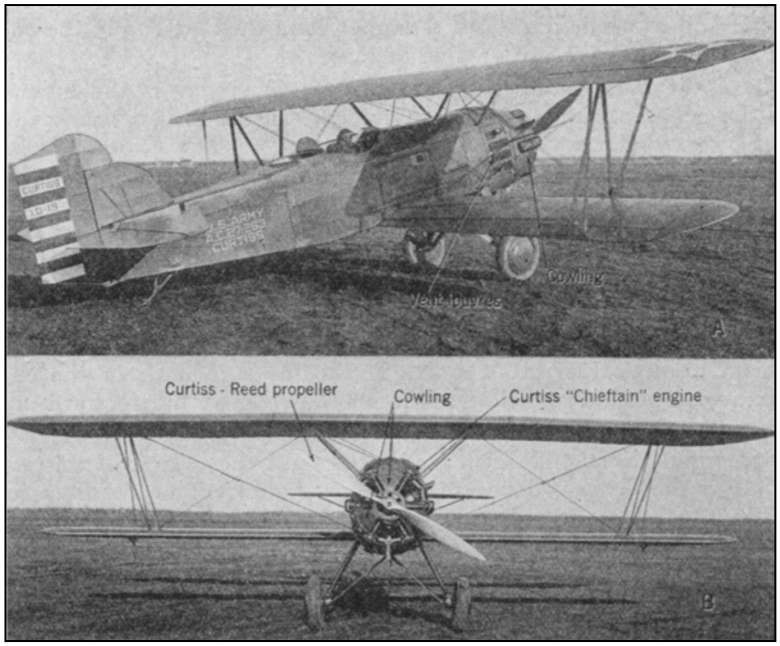


Fig. 667. Views Showing Installation of Curtiss “Chieftain” Engine in U.S. Army Airplane. Note effective cowling possible and smooth entry of nose of palne when fitted with the Hexagon type engine.

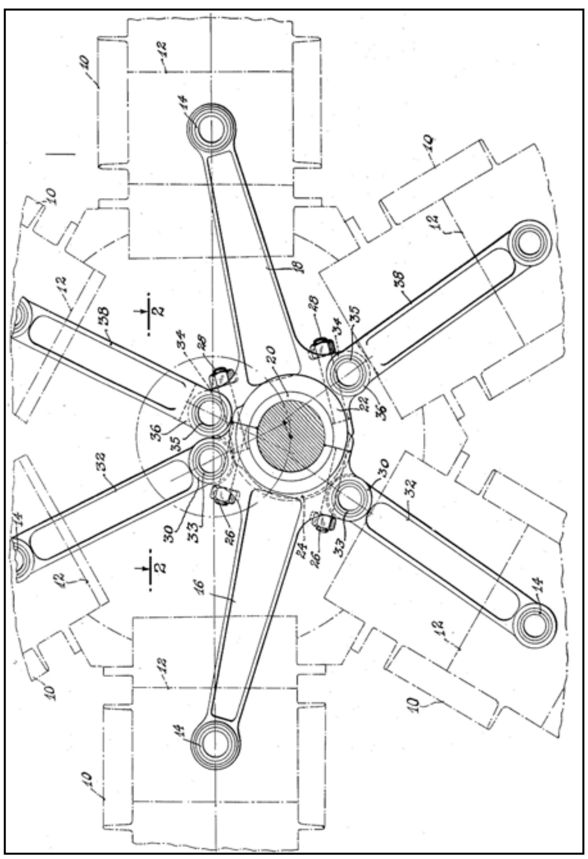
One of the most interesting features of the engine is the manner in which the cooling problem has been solved. In the past it has been considered a very difficult task to assure equal cooling of air-cooled cylinders where one or more of a bank are masked by the forward cylinder thereof. In the Chieftain every other space between cylinder banks is baffled at the rear by a plate to which the cowl is fitted snugly. The air current induced by the motion of the plane, upon striking this baffle, is deflected sideways against the rear cylinders and compelled to pass through the space between the two cylinders of a bank and around the back side of the rear cylinder, from the exhaust compartment to the inlet compartment. From the inlet compartment it passes into a space in the fuselage back of the engine, whence it escapes through louvres in the cowling at the forward part of the Curtiss Falcon plane.

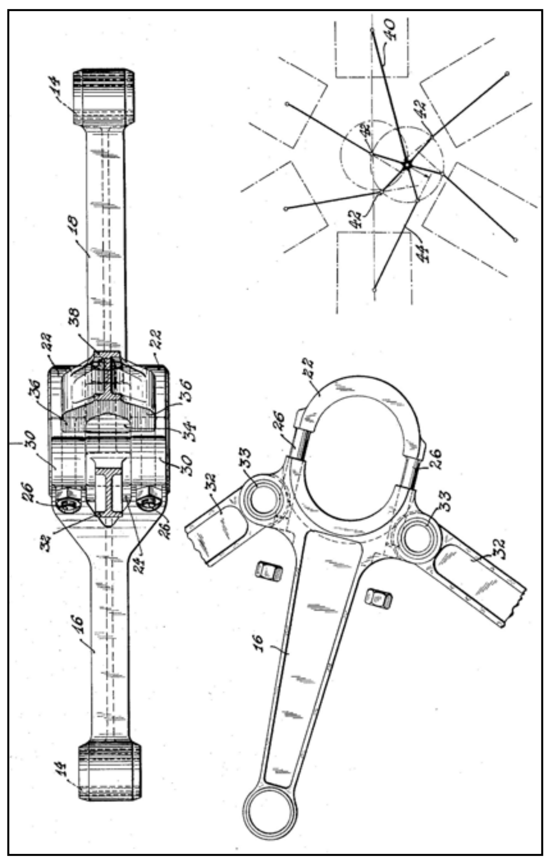
Another interesting problem connected with the design of this engine was that of the firing order. A single row radial engine requires an unequal number of cylinders if explosions are to be equally spaced. In analyzing the problem as relating to the hexagon type, it was found possible to jump from the front to the back row and to the front again. Explosions evidently must be spaced 60 degrees of crank motion, which is the angular distance between cylinder banks. Thus, after one forward cylinder has been fired, the cylinder next forward in the direction of rotation (clockwise) may be fired, or, alternately, the rear cylinder of the bank directly opposite this one. Thus there are at least three possible firing orders. Of these the one in which front and rear cylinders always succeed one another was chosen.

The tests conducted on this engine during the past eight months have indicated that the engine is a very satisfactory type. It develops 615 brake horsepower at 2,200 r.p.m. The weight, including exhaust flanges, exhaust heater, including the heater on the induction passage elbow and the throttle barrels of the carburetor (this weight is not usually included in the weight of air-cooled engines as built today) is 900 pounds, which gives a specific weight of 1.46 pounds per horsepower which compares very favorably with any air-cooled engine built today. The frontal area per horsepower of this type of engine is approximately one-half of the nine-cylinder engine of the same horsepower. This engine has the same frontal area with less head resistance on account of its better aspect ratio than the conventional 200 horsepower radial engine and with this decreased head resistance it has the advantage of over three times the horsepower. The engine has been developed primarily for pursuit and observation types of airplanes but with future development and the adaptation of reduction gears it promises to be a satisfactory engine for slower types of planes.

CHARACTERISTICS-CURTISS CHIEFTAIN R1600 ENGINE

Hp. (rated) at 2200 r.p.m	600
Model	H-1640
Type of engine	Static Air Cooled Hexagon
No. of cylinders	12
Arrangement of cylinders	2 radial rows of 6, front
	cylinders directly in
	line with rear cylinders
Dia. of engine	45 in.
Dia. of cowling	39 in.
Bore	5 5/8 in.
Stroke	5 1/2 in.
Displacement	1640 cu. in.
B.Hp .	615
Ignition system	Splitdorf Magneto
Carburetor	Stromberg NA-U8j
Cruise fuel consumption at 2000 r.p.m	53 lb. per b.hp. per hr.
Oil consumption	020 lb. per b.hp. hr.
Speed of propeller	Crankshaft
Rotation of propeller	Clockwise
Weight of engine	900 lb.





Details of Connecting Rod Construction. From U.S. Patent No. 1962246.