Technical Description of The Martin 333 Aircraft Engine

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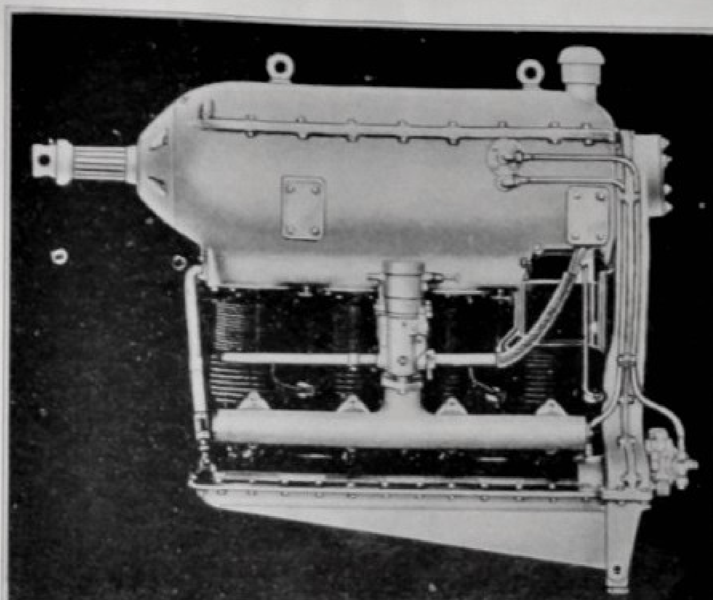


Martin 333 four-cylinder in-line inverted aircraft engine.

EARLY in 1927, Mr. Louis Chevrolet, who for years has been associated with the design of automotive engines, and who has a notable record as a driver of racing cars, started designing an aircraft engine. Engineering practice which had been proved by years of subjection to the gruelling grind of the race track was used as a basis for the development of the new engine. The in-line principal was adopted after a summing up of opinions gathered from many reliable sources of information. An interesting trend towards this type of design had been noted, and its many advantages, both from a mechanical and aerodynamic standpoint, were decidedly in its favor.

The result of these years of designing and testing was a four-cylinder in-line, inverted engine, remarkably economical, powerful, and of extremely light weight. This engine, the Martin 333, rated at 120 h. p. at 2100 r. p. m., and weighing 260 pounds, dry, has a fuel consumption of .48 pounds per b. h. p., and a brake mean effective pressure of 136 pounds per sq. in.

Every detail of this engine has been carefully studied as to its relation to the other parts of the engine, and it is to this application of balanced design that the engine owes its great performance and economy.

The Glenn L. Martin Motors Company, a subsidiary of the Glenn L. Martin Company, of Baltimore, Maryland, has been formed to produce the Model 333 engine, and to develop other models of similar construction, but of greater horsepower.

The crankcase of the Martin engine is cast in two pieces from heat treated magnesium. It is semi-elliptical in form, and divided above the center line of the crankshaft. The inherent strength of the material used in the case is amply reinforced by ribs to withstand much greater stresses than would be encountered under service conditions.

The crankshaft is forged from heat treated chrome nickel steel, then machined and tested for static and dynamic balance. The main bearings, of which there are five, are 2½" in diameter, and the crankpin bearings are 2 3/8" x 2 3/8". Thrust in either direction is taken by a single row ball bearing.

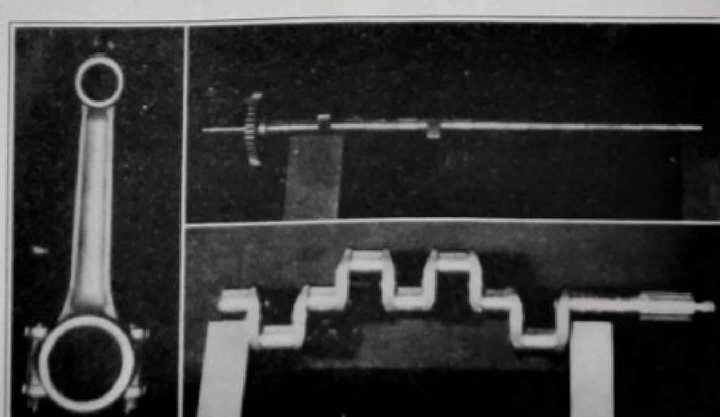
The connecting rods are H section forged duralumin, babbitt lined. Oil is taken from a small hole drilled through the crankpin bearing to the side of the rod this hole providing a spray to the pin bearing.

The cylinders of the Martin engine are machined from chrome molybdenum steel forgings, heat treated, and are supplied with ample fins for cooling. The cylinder head is machine molded, aluminum alloy, so designed that the exhaust port comes out from the bottom of the head when the engine is in its inverted position.

Pistons are of trunk type, of aluminum-silicon alloy, having four rings, three compression and one oil scraper.

Two camshafts, one for intake, and one for exhaust, are located under the head. Each camshaft is supported by eight bearings, and is driven by a triple link chain and train of gears. The camshafts are interchangeable.

The valve mechanism of the Martin engine is a new departure from conventional aircraft engine valve gear. The valves are actuated directly by the cams through lifter cups of Nitralloy steel. The cams strike the lifter cups a trifle off center, causing the cup to rotate each time it is struck. The valve springs are both wound the same direction, and each

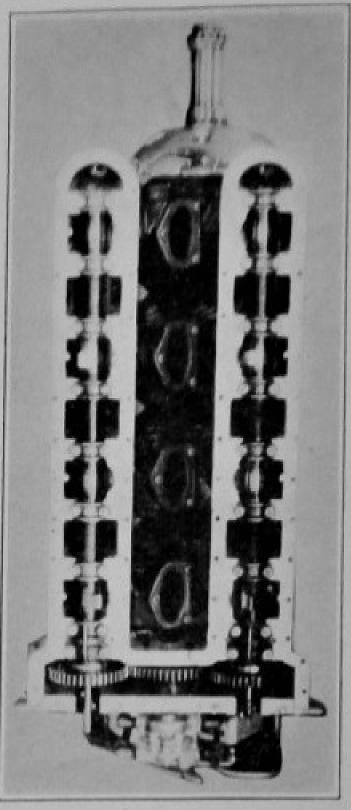


Left: Connecting rod.

Above: Camshaft.
Below: Crankshaft.

time the valve operates, these springs have a tendency to twist the valve on its seat thereby equalizing the seat. Two oil ducts are located in the cylinder head, and open into the valve housing. The camshaft bearing oil holes are timed to coincide with one of these oil ducts as soon as the valve closes and the other just before it opens, spraying clean fresh oil against the valve stem. The oil then runs down the stem and back into the cam housing through holes in the lifter cups. The entire valve mechanism is in a constant bath of oil. No adjustment is provided for as adjustment is unnecessary in the field. Exhaustive tests have shown that wear on these vital parts is practically negligible.

An oil pump of the dual gear type supplies oil to all bearings under pressure.



Cover removed, showing valve action of the Martin 333.

Cylinder walls and piston pin bearings are lubricated by spray from the crankpin bearings.

Scintilla Magnetos mounted on S.A.E. standard flanges on the gear case at the rear of the engine supply dual ignition to each cylinder.

A Zenith down-draft carburetor with altitude regulator and hot and cold air control supplies the carburetion, which is a distinct advantage from the standpoint of power with economy.

The passage of air through a small scoop on one side of the cylinder heads insures efficient cooling. This scoop is furnished with the engine. Because of the special design of the head, the cooling air coming through the scoop has no interference from exhaust stacks and strikes directly on the hottest spot of the head, keeping its temperature very low and uniform.

The Design of Air-Cooled Cylinders

By E. H. Godfrey, Chief Engineer
Glenn L. Martin Motors Company

THE air-cooled cylinder as it exists today is the result of a gradual evolution, extending back over quite a few years, and it is the work of many designers rather than that of one. We might, therefore, expect it to be something very complicated in appearance, but the opposite is true. We see, usually, a steel barrel with an aluminum head, and both head and barrel liberally covered with very simple looking cooling fins.

That apparent simplicity is most deceiving. The placing and spacing, and the height and thickness of every fin is the result of hours of work on the part of the designer, and the result of many more hours of testing, both on the stand and in the air, before the cylinder was released for production.

This combination of simplicity and intricacy is due to the many requirements which must be satisfied. Three of these are given in the order of importance in which they must be considered.

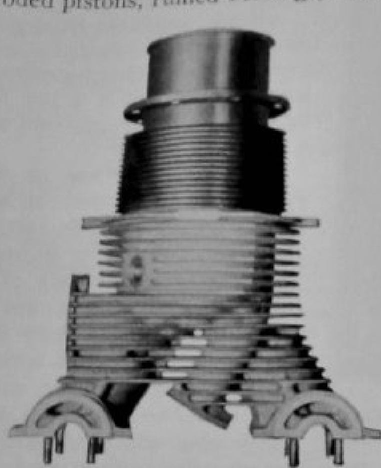
1. The cylinder must cool well while the engine is running at high speed, and with high compression ratio, and must develop great power per pound of metal and be capable of continuing this dependability, over many hours.

The term "Cylinder" has been used as though it consisted only of a cylinder head and a barrel. That is mainly what the eye sees when looking at an engine. The cylinder regarded as a functioning unit should include the piston, piston rings, as well as the intake and exhaust valves and their respective seats, guides, and ports, and finally the spark plugs. Cooling air scoops, or baffles, or both, may also be considered very essential parts of an air-cooled engine.

The most commonly used type of combustion chamber is approximately hemispherical. This form cools well, due to the small surface exposed to heat in proportion to the cylinder volume, and to the relatively large area of cooling fins which may be placed to advantage on this type of head.

The spots in the cylinder which are hardest to cool are the exhaust valve, the exhaust valve seat, and its immediate surrounding area, the exhaust valve port, the exhaust valve guide, and its boss, and the spark plug, last, but not the least troublesome.

Having determined the grade of fuel, the compression ratio, and the number of explosions per minute, the efficiency of the cylinder is controlled by the weight of fuel and air mixture introduced per cycle, and also the degree to which this mixture is burned. In order to avoid the phenomenon known as detonation, it is important to maintain a uniform head temperature, and to avoid as far as possible localized hot areas if a maximum efficiency is to be obtained. It is generally admitted that the point of maximum temperature is a factor controlling detonation, and when detonation starts the power falls off, and temperatures suddenly rise. Continuing to run the engine under these conditions may result in badly erroded pistons, ruined bearings, or a host of other



Cylinder of Martin 333.

spoiled parts, not the least of which might be scored pistons and cylinders, or even seized pistons, with the necessity of a forced landing. Therefore, a relatively cool cylinder with an even heat distribution is of primary importance.

The methods of getting rid of heat are many, and often all will be found in one cylinder design, in order to obtain the best results possible.

The joint between the cylinder head and barrel must be given careful consideration. The most commonly used method is to screw and shrink the aluminum head upon the steel barrel. Both heat flow and tightness must be considered. The spaces at the roots of the threads must be reduced to a minimum to prevent leaks and in order not to interrupt heat flow unnecessarily. All joints are an obstacle to heat flow and should be eliminated when practicable.

The intake valve opening and the intake ports must be sufficiently large to permit a maximum flow of mixture into the cylinder without undue interruption. The exhaust valve opening and exhaust ports must be large enough to provide for the rapid passage of the burned charge, and thus prevent overheating with its consequent loss of power and increase in fuel consumption per power unit. At the same time, the exhaust valve must be no larger than necessary, due to the difficulty of cooling larger valves, because of the low heat conductivity of steel and the distance through which the heat must travel, as it all passes out, either through the valve seat or the valve stem.

The exhaust valves should be made from special alloy steel forgings. The material selected must maintain its strength at extremely high operating temperatures, as well as be highly resistant to corrosion due to impurities in the fuel and to scale formation at high temperatures. It must have a high heat conductivity. The tulip valve seems to meet the requirements of gas flow and heat conductivity most satisfactorily.

The shape of the intake valve should be such as to allow a maximum free area for the passage of the mixture. The material must be able to resist corrosion, due to impurities in the fuel.

Salt cooling of exhaust valves has been resorted to in some cases. The hollow stems of the valves are filled approximately five eights full of a fused mixture which is usually lithium nitrate and potassium nitrate. This salt melts when the valve temperature rises, and splashes up and down in the stem, carrying the heat from the valve head to the stem, and so on to the valve guides.

Oil cooling of valves has been resorted to by forcing a quantity of cool oil down a hollow valve stem each time the valve is opened. Still another method of cooling valves is to spray the springs and guides, and valve stems with an oil spray controlled by metered feeds.

Wide valve seats prove best for cooling, due to the large area of metal in contact, and also because of the lower unit loads when the valves drop on their seats.

Seats of aluminum bronze shrunk into the head at the same time the head is shrunk on the steel barrel are now almost universally used. They give the necessary hardness, together with good heat conductivity. The fins which carry the heat away from the exhaust valve seat must be placed with great care to assure maximum cooling efficiency.

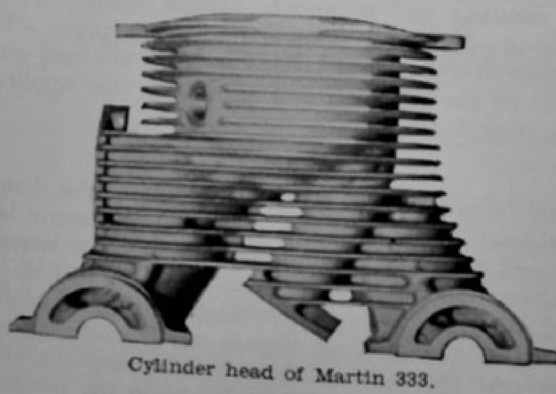
The exhaust valve guide boss should cover as much of the valve stem as possible, so that heat conducted up the stem will reach an area of heat dissipation in the shortest possible time. This also exposes the least possible area of the valve stem to the flame in the port. This boss must be of ample proportions to carry away the heat it does absorb, and it too should be exposed to the flame as little as possible.

The aluminum head is likewise designed with sufficient thickness not only to withstand the stresses, but also to provide a large enough mass of material to conduct the heat away from the hot spots to other parts of the head, whence it is more easily disposed of to the cooling air.

The flow of air around the exhaust port must be most carefully studied and the cooling fins arranged so that the air will flow freely between the fins and around the port. There must be no pockets in which eddies will form or these spots will become very hot. In some cases it is necessary to make the metal much thicker than at others, not always because that spot is more highly stressed than some others, but to provide the mass of metal necessary to conduct the heat to finned areas which are better cooled by the air flow.

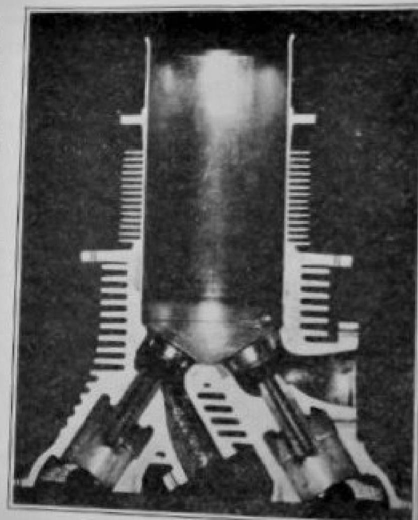
The area around the valve guide is another critical cooling fin problem. The distance from stem to fins must be as short as practicable.

The part of the exhaust port farthest from the direction of air flow, and usually called the back of the port, offers the greatest cooling problem, the cooling of



Cylinder head of Martin 333.

the other portions which are directly in the path of the air stream, being comparatively simple. The outlet is for this reason often made at the back of the port. When for other considerations, this is not done, the difficulties increase, and cooling air must often be forced around to the back of the port by some type of deflector or air baffle. Air baffles are coming into considerable use also at the back of cylinder barrels as well as cylinder heads to equalize the temperatures on the circumference of the barrel. The barrel will not stay round unless the temperature is uniform throughout its circumference. The front of the barrel receives sufficient cooling due to the cold air impinging directly upon it, and the sides are well cooled due to the rapid flow of air past them; therefore, it is only the rear which needs this extra cooling air. The terms "front" and "rear" are used here to designate the side nearest to and farthest away from the direction of cooling air flow, and do not pertain to the location of the cylinders upon the engine.



View of half cylinder of Martin 333.

The piston design will not be discussed in this article as piston design is a subject in itself, but piston heads — like cylinder heads — must have sufficient mass of material to carry the heat to the area around the rings as a large percentage of the heat is transferred to the cylinder wall through the rings.

The spark plugs are a particularly difficult problem, and must be placed so that they receive the best cooling blast possible, consistent with their necessary practical location in relation to valves and piston.

Some designers have gone so far as to provide auxiliary spark plug coolers, and have produced quite good results, but it is felt that this is an evasion of this problem rather than a solution.

A very free use of fins on the cylinder head around the spark plugs would go far towards reducing temperatures, and can be secured by casting solid raised bosses of about the usual height of the fins and then machining these bosses into closely spaced thin fins, thus forming a very large cooling surface.

Then, too, as long as it is the spark plug which we wish to cool, it might be well to increase the surface area of the plug itself until it becomes of use for cooling.

II. The cost of production must be kept at the lowest possible point, consistent with quality.

Keeping down the cost of production is a problem

(*Turn to page* 34)

Air-Cooled Cylinders

(Concluded from page 20)

which the designer must consider with every line placed on the paper. A design which may prove excellent from the point of view of performance may have been so executed as to make the cost of production prohibitive.

To be able to produce a design which will give the best performance and still be an excellent production

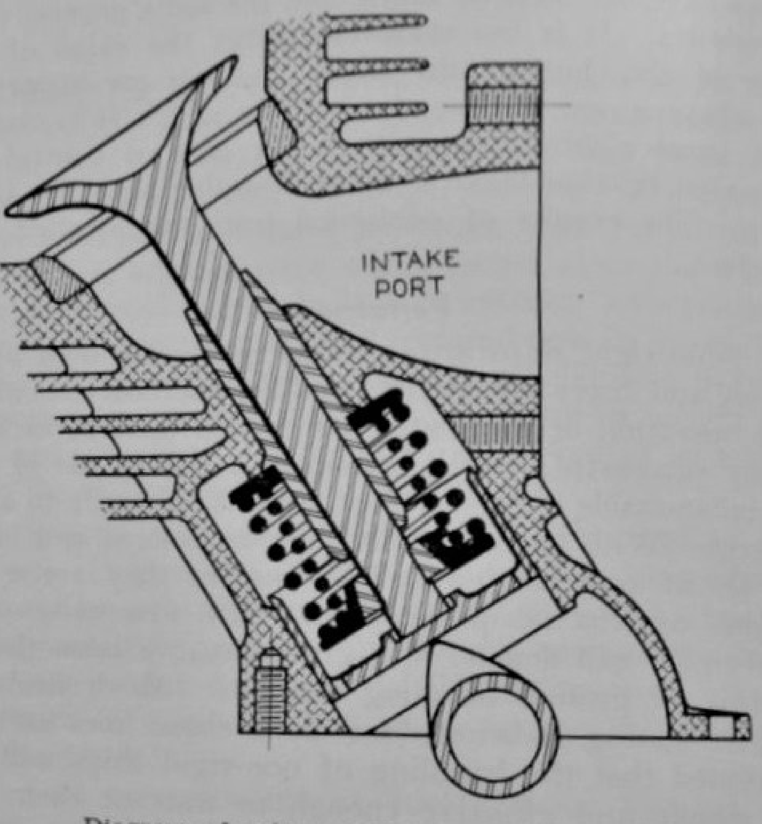


Diagram of valve mechanism of Martin 333.

job is the finest example of the designer's art. That kind of studied simplicity is the most difficult of all things to obtain.

An air-cooled cylinder head which will give the best performance and yet may have been so designed that it may be molded in the foundry from a pattern which has no loose pieces is an example of this kind of work. It requires a knowledge of every operation entering into the making of the part or parts, and also a knowledge of the assembly of these parts into a unit assembly.

It also requires a wide knowledge of materials, so that the best selection may be made for each part, again both from the point of performance and production.

III. Last but not least, the final assembled product must be pleasing to the eye, or as it is sometimes expressed, "It must pass the photographic test."

There is an old saying that what looks right usually is right, and this is particularly true of air-cooled cylinders for aircraft engines, for pleasing lines invariably mean good air flow, and good air flow means a cool cylinder.