Engine Cooling Systems

Proper operation and maintenance are the keys to longer engine life

by KEN GARDNER / AOPA 132319

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of these systems.

In the beginning of aviation most engines were
liquid-cooled type. This was due primarily to the subs
tion of existing automobile engines for lack of any speci
engine for aircraft use. As the state of the art developed, direct air cooling surpassed the liquid-cooled type, and by the end of World War II no more new liquid-cooled types were being designed. Each system has its pros and cons.

At any rate, the direct air cooling system is now the predominating choice simply because it offers the most desirable compromise. The radial engine had an advantage over its liquid-cooled counterparts in weight-per-horsepower ratio, but its large frontal area reduced forward visibility to a considerable degree. Consequently, in-line, direct air-cooled engines were tried in an effort to retain direct air cooling and still have desirable forward visibility. They were better, only they limited the practical amount of horsepower you could have. This type of engine got bigger a lot faster than its power output increased.

The final compromise was the horizontally opposed type, often referred to as the "pancake" or flat engine. Despite all of the arguments over the merits of other types, the opposed type offers the most of what is desired in present-day aircraft designs. As for air vs. liquid, that also is a trade-off, with air cooling offering more of the advantages desired. That doesn't necessarily make liquid cooling a poorer system, just less desirable for this particular application.

In flight instruction and in aircraft sales, the stock automobile is often used as an example because of certain similarities to aircraft operation. But statements that tend to oversimplify the aircraft cooling system, while comparing it to air-cooled automobiles, can be seriously misleading. These two systems definitely are not the same.

Air-cooled engines in automobiles such as the Volkswagen and Corvair have powerful engine-driven cooling blowers that operate whenever the engine is running. Thermostatically controlled devices direct cooling air from the blower as needed to maintain a desirable operating temperature. Furthermore, these machines are not wholly dependent upon forward motion for adequate cooling air. They do have cooling shrouds, baffles, and seals that must be maintained in satisfactory condition to prevent damage from overheating.

The aircraft engine depends almost entirely upon forward motion for its cooling airflow. Two types of cooling have been employed over the years. In the early days of air-cooled aviation engines, the cooling needs were generally satisfied with the velocity method. With this approach the cylinders and heads were adequately cooled by the airflow that resulted from forward motion.

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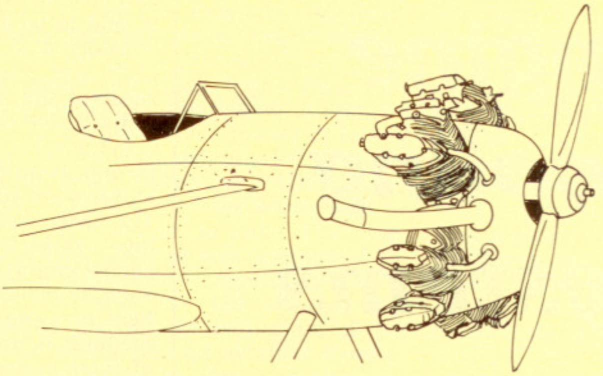


Figure 1
Typical Example of Velocity Cooling

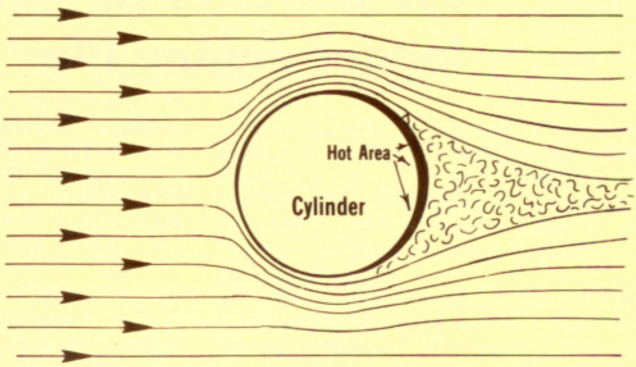


Figure 2
Airflow Pattern Over an Unbaffled Cylinder

Figure 1 illustrates an early form of velocity cooling. Notice that there is no cowling nor are there any baffles. There was little, if any, attempt to direct airflow around the whole cylinder and head assembly. The majority of heat exchange occurred at the frontal or impact area of the cylinder.

Figure 2 depicts a more-detailed airflow pattern around a cylinder when velocity cooled. Airflow tends to break away from the cylinder and form an area of vortices immediately in back of the cylinder. Needless to say, this causes uneven cooling of the cylinder and head. Despite the obvious deficiencies inherent to this method of cooling, it continued to be acceptable for many years. Velocity cooling was a workable solution when applied to the low-power-output engines of an earlier period. However, as the art improved, engines became more powerful and, therefore, more demanding of cooling requirements.

Just as the airflow around the sides of the cylinders creates turbulence and drag, the airflow over the tops of the cylinders does the same thing, making the engine effectively larger in circumference than it really is, so far as drag is concerned. The speed ring appeared, an adaptation designed to reduce drag losses to proportions more nearly equal to the actual size of the engine. The cowl-like ring had a circumference close to that of the engine and a width approximately that of the cylinders. Although it did more to reduce drag than to cool the engine, its lesson was an important one—it taught aircraft designers that a cowling must provide gains not only in drag reduction, but in cooling as well.

One of the first pressure-cooling systems came into being with the NACA cowling. This shrouded the entire engine and incorporated a series of baffles and seals that accomplished two purposes. They restricted the total airflow somewhat, which created a higher air pressure on the front of the engine. Secondly, they directed this higher-pressure air across the rear of the fins before it was released to escape at the rear of the cowling. Not only did this system reduce drag, it made more efficient use of cooling air and produced a more-even cooling between the front and rear fins.

Figure 3 illustrates the cooling airflow for a radial and a horizontally opposed engine. In the case of the radial, an annular seal between the cylinder heads and the inside of the cowl separates the front and the rear sections of the engine. This forces the high-pressure air to flow between the cylinders where the curved baffles, in turn, direct it closely around the rear cooling fins.

In the horizontally opposed engine, a seal along the sides of the engine separates the top from the bottom, with the high-pressure section on the top. The baffles direct the cooling air over the bottom fins before it exits from the bottom of the cowling. In both cases the flow of cooling air can be regulated by the use of cowl flaps.

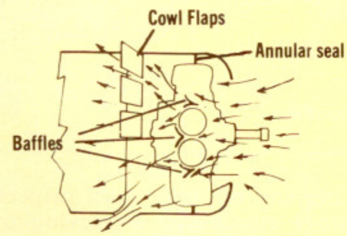
The cowl and baffles direct airflow as desired, the pressure in the forward or upper cowl provides the force necessary to move the cooling air, and forward motion of the aircraft provides the pressure. All three are relative to the cooling function and therefore must be maintained in their proper relationship.

Now let's examine the operation and maintenance of aircraft engine cooling systems.

With the older, velocity-type system, maintenance is relatively simple. Keeping the engine clean is a necessary part of its care. Greasy, oily surfaces trap dust and dirt upon contact. Layers of grime coating the cooling fins and surfaces tend to insulate these surfaces. The net result is a decrease in cooling system efficiency. Consequently, it pays to keep your engine clean.

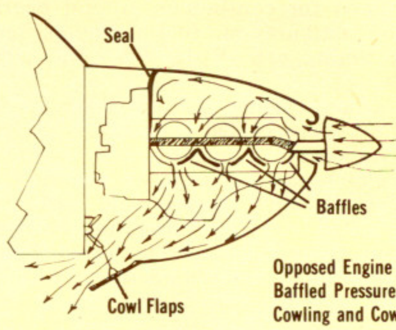
If your engine has no speed ring or baffles of any kind, a visual inspection of all cooling surfaces is usually the extent of maintenance for such a system. Some velocity systems such as that used for the Piper J-3 Cub incorporate a ram air scoop above each bank of cylinders. This directs airflow around the cylinders and should be maintained in proper condition. By the very nature of its operation the velocity system is well exposed, so examination and maintenance should be relatively simple.

The pressure system requires more maintenance and is much more critical of sloppy care. The cowling should be removed periodically and all baffles inspected. They all must be in their respective places. Opposed engines have a large aft vertical baffle and a series of side and front baffles that, together with the upper cowling, form the pressure area. The vertical baffle, side baffles, and forward baffles all have attached rubber seals to aid in properly sealing the pressure area from the lower and aft areas.



Typical Radial Engine with Baffled NACA-Type Cowl and Cowl Flaps

Figure 3 **Typical Example of Pressure Cooling**



Opposed Engine with Baffled Pressure Type Cowling and Cowl Flaps

The vertical baffle seals must lay forward so that air pressure pushing against them tends to make them seal even tighter. The side and forward seals must lay so that their outer edges point upward. These seals can easily be mispositioned during cowl installation; if placed in the opposite position, they will allow excessive cooling air to bleed past, which would be bad news for your engine.

On most engines these seals can be seen by looking into the cowling from the forward air inlet openings. This inspection should be part of your preflight if the cowling has been removed prior to this flight or if it is an unfamiliar aircraft.

Most high-performance engines have oil radiators which are also part of the cooling system. The air passages in radiators are easily clogged with large insects, and keeping them clean is part of cooling system maintenance. Bird nests are still another maintenance item. Usually found in the pressure area of the engine compartment, they not only interfere with proper cooling but can be a fire hazard as well. Fortunately, they can usually be detected during preflight. As with velocity-cooled systems, keeping the engine clean and free of oily grime enhances proper cooling.

The maintenance for pressure-cooled radials is quite similar to that for opposed types, except that they, and some opposed engines, have their oil coolers located somewhere else than in the forward area of the engine compartment.

Maintenance on the cooling system should be performed by a certificated A&P mechanic; however, the owner may remove the cowling and make his own inspection. Baffles are often frail things susceptible to cracking and breaking. It is to your advantage to check them out occasionally; they should be replaced when they no longer fit properly or inadequately serve their purpose.

Just looking at an airplane's cooling system, it could easily appear that there is little if anything to operate unless it had cowl flaps. Of course there is much more than meets the eye. Since all flights begin and end on the surface, we will start with ground cooling. The stock aircraft engine is not designed for continuous ground operation. Fuel-air distribution, carburetion, fuel injection, ignition timing, and valve timing are all designed and adjusted for peak power operation.

As mentioned earlier, cooling is most efficient during flight. However, the velocity-cooled engines did derive better cooling during ground running. Air driven aft by the propeller could easily reach the exposed cylinders. This aspect, coupled with the lower power (and heat) output of these engines, resulted in fewer overheating worries during ground operation. Nevertheless, velocity-cooled engines should not be operated unnecessarily on the ground. Other factors, such as distribution and ignition timing, contribute to spark plug, combustion chamber, and lubricating oil fouling.

The pressure-cooled engine is more easily susceptible to overheating during ground operation. This system must have pressure in the forward or upper cowl in order to provide adequate airflow around the cylinders and heads. The propeller blast does provide some pressure on radials, but not enough for extended ground operation.

The situation for the horizontally opposed engine is even more difficult, due to the limited size of the openings for cooling air relative to total engine-cooling fin area. Furthermore, the cooling air inlets are usually located near the propeller hub where there is little airfoil section on the propeller to provide air movement. During the heyday of radial engines, cooling cuffs were sometimes fitted to the propeller-blade shank area. These airfoil-shaped cuffs somewhat increased the airflow into the forward cowl area to aid cooling on the ground.

It should be obvious that excessive ground operation is detrimental to engine life. The rules are simple: Always head the engine into the wind, if possible. Avoid engine speeds above 1,200 rpm (crankshaft) except for preflight runup. Avoid full-power operation except where absolutely necessary. Temperature control devices, such as cowl flaps, should always be full open. Above 40°F, get airborne as soon as safely possible; below that, a longer warmup will be necessary to assure proper lubrication, otherwise the same rules will apply.

Engine cooling during takeoff and climb is perhaps the most critical of all operations. Under these conditions, the engine is liberating more heat than during any other mode of operation, while receiving the least cooling air. With all engines, unless otherwise specified, always use full-open throttle for all takeoffs. Maintain full throttle until at least 400 feet above the departed runway. The added fuel flow at full throttle aids engine cooling, definitely desirable under takeoff conditions.

Cowl flaps should always be full open during takeoff and throughout at least the early part of the climb. Once climb power has been established, the angle of climb should not be steeper than that for best rate of climb. As ambient temperatures increase, so should climb airspeeds. There is no real advantage in maintaining best rate of climb to cruising altitude unless there are very fast tailwinds aloft.

Furthermore, if you climb at an airspeed so low that you can't recover the ground-speed difference during descent, you are kidding yourself anyway. So always climb at an airspeed that is adequate for engine cooling and you will probably get there faster.

Cowl flaps should remain full open throughout the climb unless ambient temperatures are so low that you cannot maintain cylinder-head temperatures in the first third of the green arc. Mixtures should remain on the rich side during climb. Lean only enough to eliminate engine roughness from overrich mixtures. The added fuel flow assists engine cooling at a time when it is needed most.

When you do reach your cruise altitude, don't be in a hurry to close the cowl flaps. It is better to let the aircraft reach the maximum speed that you intend to cruise at before you lean the mixture or close the cowl flaps. To do so will allow the engine temperatures to stabilize at that speed and give you a better picture of what is needed in cowl flap adjustment.

Many pilots will completely close the cowl flaps for cruise flight, believing that minimum drag results. This is not always true. Some aircraft have cowl flap controls that will allow the cowl flaps to trail (seek their own position). When the cowl flaps are set to trail, they automatically seek the position of least drag. If the trail position provides satisfactory engine temperatures, you will do well to leave them in that position. Remember, if the air entering the front of the cowling cannot get out, then you are, in effect, increasing the frontal area with a resultant increase in drag.

During descent it is in the engine's best interest to keep its operating temperatures in at least the bottom of the green. Now the cowl flaps will usually need to be fully closed. The engine should develop sufficient power so that it is driving its propeller and not vice versa. The mixture should be leaned to match descent power and not full rich as is so often done. If cowl flaps, power, mixture, and airspeed are properly regulated, the desired minimum engine temperatures will be maintained during descent.

During landing the cowl flaps should be closed when final approach is begun. They should be opened during rollout or upon leaving the runway. In hot weather it will aid in cooling down the accessory section if the cowl flaps are opened after the engine is shut down. In cold weather they should be left closed to extend heat retention.

Some pilots leave the cowl flaps closed during cold weather warm-up in the belief that it aids in engine warm-up. While that practice may have some value, it can have more serious effects in overheating the accessories plus overheating various areas of the cylinders and heads. The cowl flaps should always be open prior to startup and during ground operation, takeoff, and most climb operations. □