Cooling Guidelines for V8 Engines in Aircraft

Introduction:
The goal of this article is to share our experiences regarding engine cooling with the Experimental world so that more auto conversion aircraft can benefit from our successes and failures.

Synopsis:
Auto engines in aircraft operate under constant load and therefore produce more heat than would be produced in an earth bound vehicle. With increased engine load comes increased heat production by the engine, therefore, an auto engine in an airplane requires greater cooling capacity than is required for the same engine in a car or truck. Cooling capacity must be increased proportionately in order to keep the engine operating in a temperature range that will preserve the engine and increase efficiency.

Our description of proper engine cooling is that a V8 engine in an airplane should never exceed 200°F except momentarily during climb out, cooling off to 170-190°F at cruise, and never exceed 210°F under any but the most extreme circumstances. High engine temperatures only serve to fatigue components prematurely, and with proper cooling that can be avoided altogether. Many will argue that their engines run just fine at 230-235°F, but we do know that high engine temperatures such as this will dramatically shorten the engine life and contribute to engine failures.

Again, there are those who argue that our cars run over 200°F and that seems to be alright…but consider this…auto manufacturers run engines at 200°F and above in order to satisfy EPA requirements, not because the engines run better at higher temperatures and certainly not because it is better for the engine. Any long time auto racer will tell you that every effort is made to help racing engines run cool both for engine longevity and for fuel efficiency.

This system of cooling is based upon each of the following requirements being met completely. Any one of these recommendations that are not followed could be reason enough for the cooling system to fail. In other words, not one item mentioned below is optional, and is only variable if it is mentioned to be. When followed to the letter, this system will cool a V8 engine in an airplane, every time.

Formulas:
The following are the basics upon which we have developed the best and most complete cooling system that we have ever seen. When followed, under just about every circumstance, the aircraft will run cool.

1. **Requirement:** Radiator surface required is 1.5 sq in of surface area per cubic inch of the engine. For example: LS1 V8 Chevrolet = 350 cu in x 1.5 = 525 sq in of radiator surface area required. For this purpose, this applies only to the surface area of the radiator that the air flow first makes contact with.
2. **Requirement:** Minimum of 3.0 cu in of cooling volume per HP produced. For example: We only utilize up to 300 HP of an LS1 for aircraft use. Using a dual radiator configuration with two radiators measuring 15" x 18" x 2.25" thick = the total cooling volume is 1215 cu in. Therefore, our cooling volume to HP ratio: 1215 cu in cooling volume ÷ 300 HP = 4.05 cu in per HP. With this formula, we have been able to maintain climb out temperatures of around 200°F and 190°F at cruise on a 100°F day. With a cooling system like this, we could taxi from Houston to Dallas with no overheating problems.
3. **Requirement: Abandon the conventional front air inlets and close them off altogether.** Why do we think that front air inlets provide enough air? Because every airplane you have ever seen with a piston engine has front air inlets. If we have always used them they must work, right? We advocate the use of side cowl scoops to get enough air into the cowl, and when these are installed, the front air inlets will literally will negate their value because front air inlets, when combined with the side air scoops, will set up high pressure in the cowl, not allowing enough cool air in and not enough hot air to exit the cowl, and the end result is engine overheating.
   On their own, there is not enough air volume through conventional front air inlets to cool the engine effectively. One contributor could be because the root of the prop blade of most propellers does not have enough of an airfoil shape to move much air and actively blocks airflow when the blade passes the opening, or because the boundary layer of air on the surface of the cowl behind the prop root is too still to provide much air volume into the cowl. With the increased cooling requirements of a 300 HP V8 engine under constant load in an airplane, we have found it to be true that front air inlets do not provide enough volume of air, nor does it direct what air it does direct to the right spot within the cowl to effectively cool the radiators and the engine.
4. **Requirement: Move to the side of the cowl and add exterior mounted air inlet scoops.** The sides of the cowl receive large volumes of air from off the prop whether it is taxiing or flying. NACA scoops look great, but are recess mounted inside the profile of the cowl and simply will not force enough air through the radiators to cool the massive heat produced from the engine. We have found that to get enough air volume it is required that exterior air inlet scoops be mounted on the sides of the cowl. These scoops should cover an opening on the side of the cowl that is large enough to expose most of the radiator core to the fresh air stream. Scoops that extend 2" from the outside profile of the cowl will reach out beyond the quite boundary layer of air,

capturing high velocity air from off the prop and forcing it through the core of the radiator. Once through the radiators, the air then circulates around the engine and out the exit air location.

5. **Requirement: Fresh air scoop** volume recommended at 20 sq inches per side. The fresh air scoops we recommend are only 20 square inches in inlet size, and provide ample air to the radiators when mounted on the side of the cowl as mentioned above, even when taxiing. This is not a lot of inlet space. RV-10's front air inlets average 36 sq inches per side for a total of 72 sq. inches. Our fresh air scoops total only 40 sq inches of air inlet. You may experiment with the size of the scoop inlets but it is always better to have more than not enough.
6. **Requirement: Exit air volume** In order to keep the air moving through the cowl it is recommended that you utilize 1.5 to 2.0 the amount of the fresh air inlet for the cowl exit air. Failure to have enough exit air volume will make the engine run too hot or even overheat. This is more difficult to achieve with a retractable gear airplane but must not be ignored. Ground and taxi testing may produce successful results, only to have the engine overheat on climb out due to insufficient exit air volume now that the gear doors are closed, dramatically cutting down on the exit air volume.
7. **Requirement: Baffle only between the radiators and the cowl** to direct as much of the air from the side cowl scoops through the radiators as possible. Once the air passes through the radiators, it passes over the engine and out the exit, also serving to assist in cooling. A V8 engine radiates a great deal of heat and adding additional baffling to the inside of the cowl only serves to inhibit air circulation around the engine, so do not add any additional baffling or plenums within the cowl.
8. **Requirement: Use water for engine cooling, and add only enough antifreeze to keep it from freezing.** Water takes the most heat energy to change its temperature than anything else and that makes water the most efficient in terms of its ability to conduct heat with minimum temperature rise. Antifreeze, or ethylene glycol and propylene glycol, have higher vapor points and therefore can absorb heat at higher temperatures without boiling. However, even with its lower vapor point, water still carries more heat per unit than other coolants.
    a) **Alternative to Water/Glycol: Use a waterless engine coolant.** Evans has developed a waterless engine coolant that has several advantages over water/glycol coolants. Being waterless there is no corrosion, only very light pressures of less than 2 psi which extends the life and reliability of hoses and radiators, it can't create steam pockets in the engine, boils at 375F instead of 248F, freezes at below -40F, and can improve engine performance. The major down side is it costs a lot more, and the minor down side is it is 2% less efficient at heat transfer. To compensate for the slight reduction in heat transfer simply use a lower temperature thermostat.

9. **Requirement: Use all aluminum two pass radiators.** We recommend that your high pressure system consist of all aluminum radiators configured to a two pass system, which increases dwell time in the radiator, and enhances heat transfer even more. Hard plumb as much of the water line as you can, using minimal rubber radiator hose for increased durability. The fewer rubber hoses you have to watch over, the better.
10. **To thermostat or not to thermostat** There are a couple of schools of thought regarding thermostats in auto conversions for experimental aircraft. You are likely aware that Bud Warren has not been an advocate for using a thermostat. He has stated numerous times that racers don't use thermostats because if it sticks-the race is over. In an aircraft, this happening has more dangerous implications. His opinion has always been to eliminate the incidence of a stuck thermostat by simply not using one.

    We have been flying the Ravin 500 with great success since Oshkosh last year, and we have not been using a thermostat. During the peak heat of summer we have experienced engine water and oil temps at climb out not to exceed 200°F, cooling off to 180°-190°F at cruise. This system utilizes a dual radiator setup and we have been happy with the aircraft performance.

    However, in colder weather, engine operating temperatures have been a lot colder that we would like to see. These excessively cool temperatures have triggered the ECU to keep the engine in warm up mode; adding additional fuel to the cylinders in an attempt to warm the engine and causing it to run richer than we like. This is turn causes the check engine light to stay on. We would rather stop this from happening so that the check engine light will be available to warn the pilot if there are any other potentially more vital concerns.

    After much thought, Bud decided to install a thermostat in the LS1 engine of the Ravin 500 to do some test flying. During cold weather the resulting engine temps have remained stable at 190°F at cruise, and near 200°F during climb out; just about what we see during the warm months of the year. This has corrected the check engine light coming on due to the engine remaining in warm up mode.

    We can't say unequivocally that we recommend you use a thermostat in your engine as each situation is different. We would suggest however, that you carefully determine the correct stance for you to take regarding using or not using a thermostat in your engine. It is a personal decision, with each option offering different potential results.

    If you choose to use a thermostat, we highly recommend that you test the thermostat before you install a new thermostat. This can be accomplished by simply dropping it into some boiling water to determine that it does indeed open. Once you take it out of the boiling water it should close again. This might seem silly, but there have been incidences of new thermostats not working. In addition, we recommend that you maintain the coolant in system using the lowest percentage of antifreeze to water that will keep the

engine water from freezing. Also supplement with an anti-corrosive additive to condition the inside walls of the cooling system which may help to maintain the thermostat as well, and make a note in you POH to change the thermostat out for a new one periodically.

On the up side, modern thermostats driven by all aluminum engines are designed to fail open rather than closed like the old thermostat designs. The risk of warping a new engine due to the old thermostat design failing closed and causing high warranty claims is a very good thing for aircraft use. These modern thermostats are commonly called "fail safe" thermostats. They still need to be replaced after failure or the engine will not warm up. For water/glycol use a thermostat of 180°. Also, if you are using the Evans waterless coolant you need to use a lower thermostat of 160° or 170° if possible. Bottom line, use a thermostat if necessary if you choose, but do so with the utmost of care and caution and use a modern fail safe thermostat.

11. **Radiator Caps:** For a cooling system that uses water/glycol coolant a high pressure radiator cap is required for aircraft use. One that is rated at between 22-24 psi can easily be found in most automotive parts stores. For a cooling system using the Evans waterless coolant at very light pressure radiator cap is all that is required. One that is rated for between 4 - 8 psi can easily be found in the same automotive parts stores.