03/08/1999 04:06 PM

Paul wrote:

> BTW I suspect these thinner rads are more aerodynamically efficient. Less drag for a given heat transfer.
>
> Paul Lamar

Here is my 2 cents on radiators for aircraft.

Those radiator cubic inch specs you put out are very significant. That is perhaps the most important spec on the radiator itself. OTOH, I would argue that THICKER radiators are the way to go on aircraft. Thinner is more efficient if you don't care how many CFM you use to do the cooling job. This results in the lowest rise in inlet air temp through the radiator but you need more CFM. More CFM used for cooling = higher drag.

With a thicker radiator, the temp rise is higher but fewer CFM are needed. This requires more internal area in the rads to get the job done (because the fins toward the back are working in pre-heated air) but this is not the parameter we are trying to optimize. Everything is a compromise but If size & weight were not a factor, the most aerodynamically efficient radiator would heat the air to within a fraction of a degree of the coolant temp.

As I recall, the P-51 radiator was quite thick.

One result of a thicker rad is more air resistance which is why all this past discussion on pressure recovery in the duct is so important. All this argument is out the window when talking about car cooling systems, but who cares about cars?

Tracy Crook

> I am not sure I buy this Tracy. I think it is better to have a thin large frontal area radiator rather a thicker one of the same volume

with less frontal area. You just mentioned one of the problems with a thick radiator. The rate of heat transfer is better when the difference in temp. is greater. I forgot the function but I am sure Jeff knows it. As the air flows from front to back it gains temperature so the back of the radiator does not work as well as the front part.

Mounted in the tail cone or at a steep angle in the cowl the frontal area is not a problem with a proper internal diffuser.

It is the same as a parallel cooling system verses a series cooling system. The average temp difference is higher for every square inch of fin area.

Jeff has come up with a test rig that can be mounted on a pick up truck. I am drawing it up as we speak. The engine will have to be re-plumbed to the test radiator and a drag racing parachute could be used to increase the load (heat output) on the truck engine. I am thinking that thick wall plastic plumbing pipe might be used to plumb the engine to the test radiator. It is real fast to just glue it together.

Paul Lamar

03/08/1999 05:25 PM

Neil A. Kruiswyk wrote:

> Paul
>
> Fins are placed in the radiator to increase overall surface area thereby increasing heat rejection. They are placed perpendicular to the airflow to

reduce drag. With the radiator setups we have been talking about the air speed reduction is around 1/3, or from 200mph to 66mph. That's still mighty fast so the last thing you'd want to do is angle the fins (if you can avoid it).

Airflow through the rad will decrease exponetially as the angle increases. It will also be reduced relative to incoming air speed (drag quads as speed doubles). If the angling of the fins can not be avoided the the air must be helped to make the bends with divertors. Idealy both before and after the rad core. (see lousy picture I did in 2 mins)

Your note about radiators in modern cars being big and thin... Thinner is better without a doubt. Heat transfer is a function of delta T. The air heats as it goes through the core so the thinner rad will have a greater temperature difference 1" in from the front than say 5" in from the front and therefore more heat transfer. Unfortunately, airplanes don't have the frontal area of modern cars so we make the rads thicker and pump more air through them. Modern cars have little or no grill to them these days but rather a giant air dam under the bumper to deflect air into the big, wide rad. I think overall hood styling has more to do with radiator design these days.

Neil

PS: did you get my email on the size of my new rad? the core is 17" x 13" x 5.5". With tanks it's 20" wide. By your calcs.. 1430 cu in.







03/08/1999 05:42 PM

Not necessarily. Actually the thin radiator may use less CFM than the thick one due to efficiency gains (as snipped form Paul's response) due to greater temp difference for the given volume. The error in your logic comes from an unnecessary assumption that the velocity through the HX is a constant. On the contrary the same ***mass*** can move through a bigger cross section, thinner radiator much slower and pick up the same or more heat.

This has the dual benefit of reducing the drag (thinner ***and*** slower) and making more efficient use of the air. The only downside to a big radiator is finding someplace to put it. In theory a bigger, thinner radiator will always be better than a little, thick one in terms of cooling efficiency. In reality airframe impact must be considered.

Jeff Spitzer

03/10/1999 11:05 AM

Tracy Crook wrote:

I think we are talking about two different kinds of efficiency here. I agree that for a given fin area, the thin radiator is more efficient in terms of dropping the water temperature a given number of degrees. It is an efficient radiator. I was addressing the aerodynamic efficiency of the cooling system as installed in the airplane, i.e., having less overall cooling drag. It WILL take more fin area in the thick radiator to do the same job (air at the back side is hotter and therefor less temp differential between air & water).

Jeff has a valid point in saying that the air could be slowed down in the thin radiator to accomplish the same thing but there are a number of factors which work against this approach, especially in aircraft applications. Not only does the size get out of hand but the same factor (low air velocity leading to laminar flow, etc.) starts to work against the thin approach. Plus, if you slow the air down to the point where the air is heated as much at its rear as in the thick radiator (less temp differential between air & water), what is the thin radiator's advantage?

To avoid a long winded discussion of all the steps in between, let's look at the inputs and outputs of the cooling system. First we have to agree that less CFM (of air) through the cooling system will equal less drag, all else being equal. I will assume we agree here.

If not, stop reading here and we will discuss this area first. Remember I am talking about total aircraft cooling drag, not air resistance of the heat exchanger itself. One does not equal the other. It may not be intuitively obvious, but If you have understood the discussion on air diffusion & ducts so far, you will already know that the airplane would have less drag if you plugged up the airflow through the radiator.

For a given number of BTU heat rejection, the system which uses the least number of CFM to do the job will be the one which heats each one of those cubic feet of air the most. i.e., You can reject a certain amount of heat by heating 100 CFM of air to 50 degrees above ambient, or, 200 CFM of air if you only heat it to 25 degrees above ambient.

It is my contention that in the context of an airplane, the job of heating the air the most is best accomplished by a thick and very dense (lots of air turbulators as Jeff described) radiator. It is absolutely true that you will need more core (fin) area with this approach but minimizing core area was not the goal, cooling the engine with minimum cooling drag is. Again, such a radiator requires a relatively high differential air pressure and this is why the past discussion on pressure recovery in the cooling inlet ducts is important.

I now await the storm of contrary opinion :-)

Tracy Crook
rws@altavista.net

Jeff Spitzer wrote:

Tracy must have caught me at a vulnerable time. He almost slipped one past me.

This is where you tricked me. It was the all else being equal part. If all else is equal then the statement is true. But all else can't be equal!

This argument was very cleverly crafted. There's one fatal flaw that I didn't realize until after I responded. The aircraft drag is not related to CFM, its CFM *TIMES* pressure drop. So, in Tracy's words, all else being equal (duct efficiency, that is) the HX with the lowest product of CFM*deltaP is the lowest drag installation. The attached chart shows a

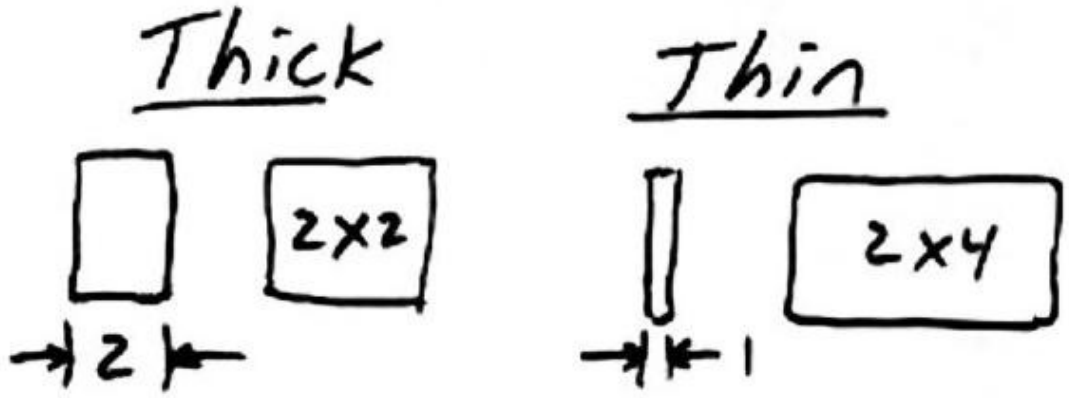
comparison of two HX's with all else being equal. The following notes apply:

* The temp rise for a HX of double thickness cannot possibly be 2X the temp rise of an otherwise identical HX of single thickness. That is because the temp difference issue. Therefore for equal heat rejection (Qdot) the thick HX must actually be as much as 3x thicker.

** I think we can all agree that an identical construction HX of double thick will have 2x the pressure drop of a single thickness for the same velocity.

The conclusion is:
Based on the attached charts the double thick HX would have to have double temp rise to be as "drag efficient" as a thin one of equal construction and volume. Because we all recognize that this cannot be done, the thick HX can never actually be as efficient. End of story. BTW, my airplane will probably have a thick HX because I cannot fit a thin one :)

Jeff Spitzer




| Item | Thick | Thin |
|---|---|---|
| Volume | 8 | 8 |
| $\dot{Q}$ | 1 | 1 |
| CFM | 1 | 2 |
| Velocity | 1 | 1 |
| $\Delta T$ | 2 | 1 |
| $\Delta P$ | 2 | 1 |
| DRAG = $\Delta P \times$ CFM | 2 | 2 |

It is now eight years later. Neils 1320 cubic inch, 5.5 inch thick rad failed miserably :) Neil gave up on the rotary and sold the airplane. Tracy is now using a thin rad with a Kays & London wedge shaped diffuser on his new RV8 :) Paul Lamar

