GT40 Radiator and Fan Study
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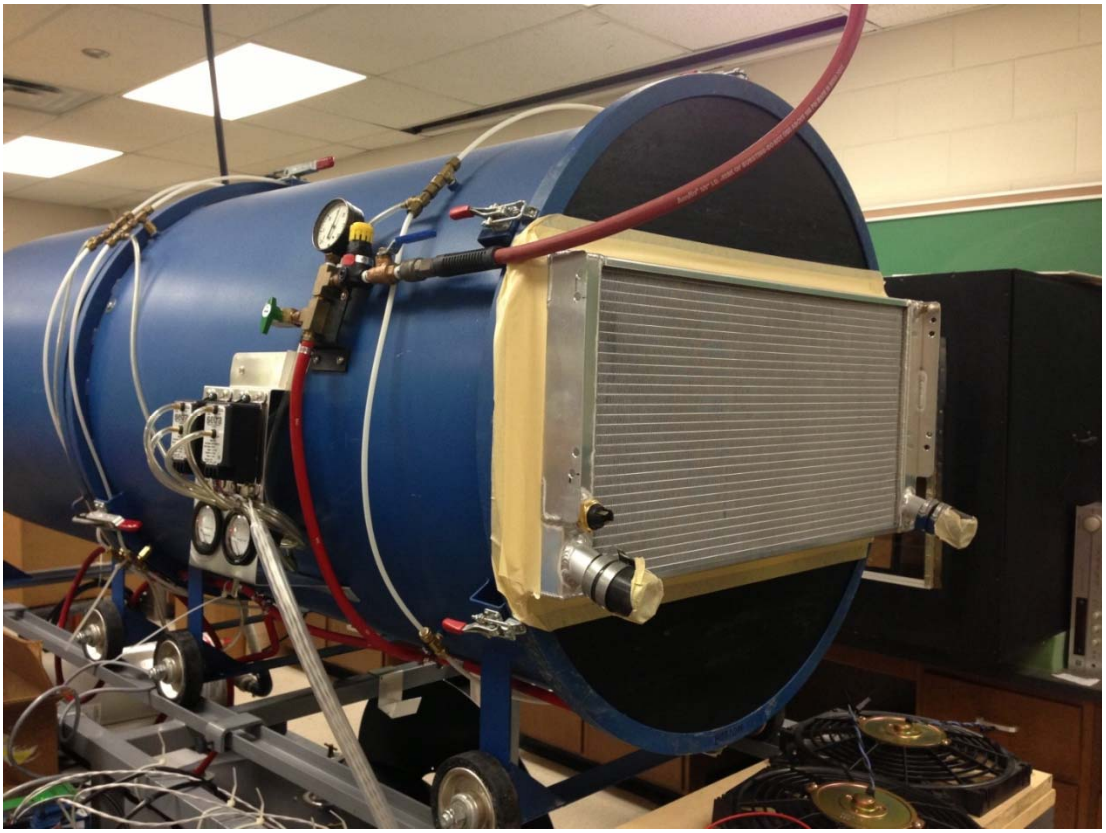
There are a lot of different approaches to radiator and fan mounting configurations. The purpose of this study is to actually test the pressure-flow characteristics of these different configurations. I have reported some of this in my posts 124, 129, 130, 132, and 180. This report summarizes all of my studies and gives the rationale for my final design.

Forced Flow Characteristics

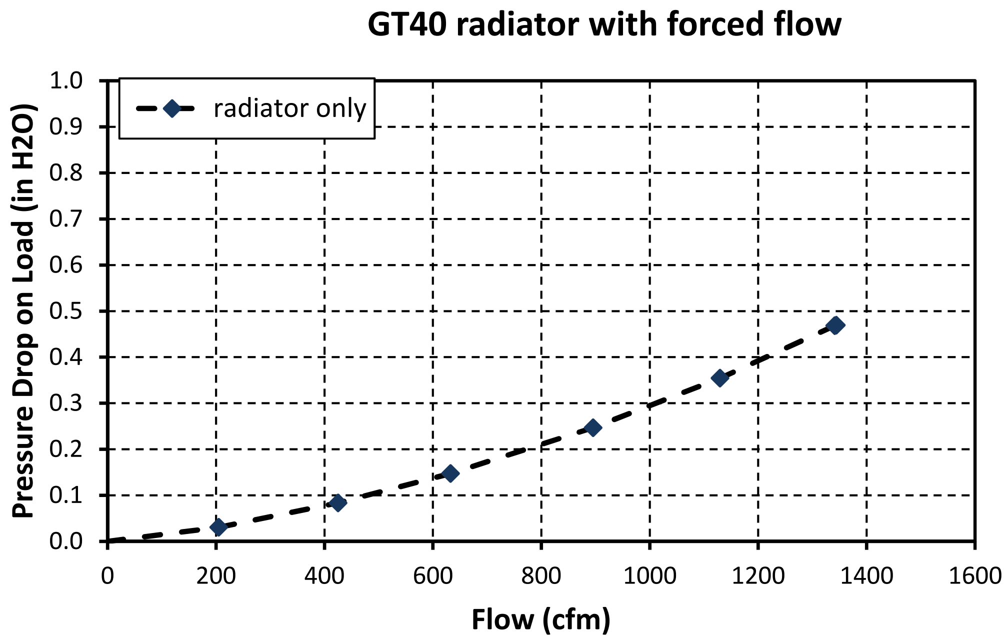
I have access to a large flow bench that can create enough flow to simulate what the radiator will experience. First, I will describe the pressure-flow characteristics of the radiator with various attachment techniques for the fans and A/C condenser.

As a baseline, the radiator without any attachements is shown below. We will first consider the pressure-flow with forced air with the fans turned off.

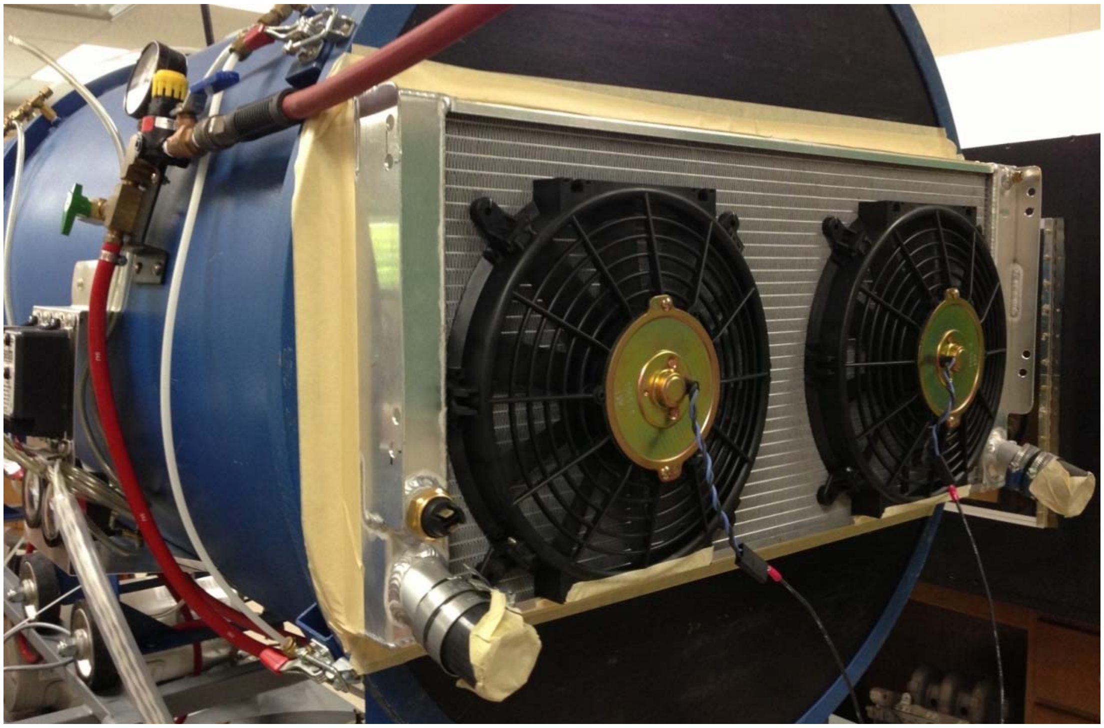


Radiator only

The resulting pressure-flow characteristic is shown below.

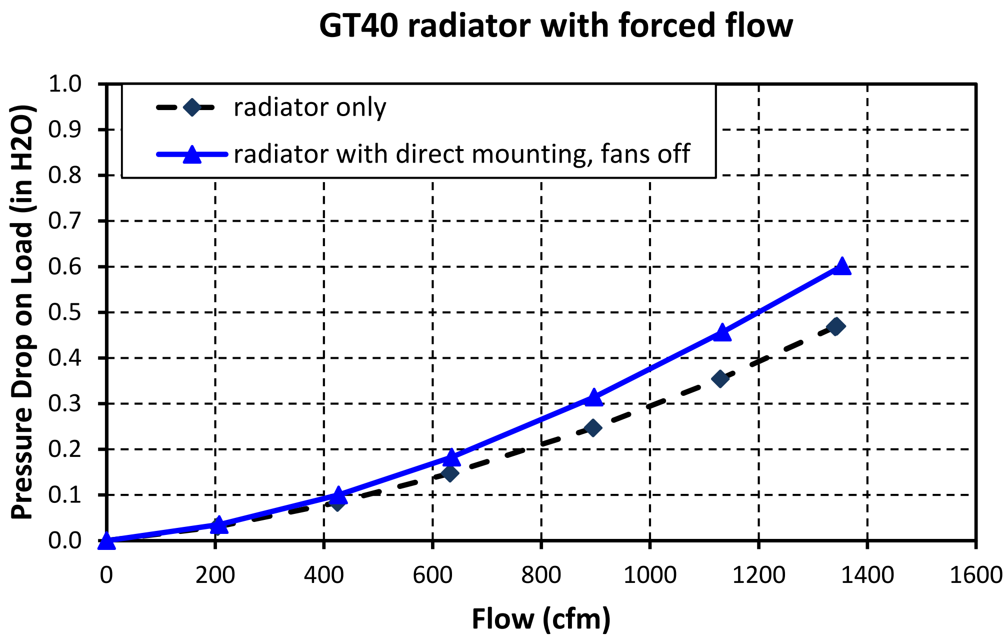


The traditional method appears to be to mount the fans directly on the radiator core using plastic ties. I worry that the vibrations of the fans touching the radiator core will ultimately wear through the fins and the plastic ties will wear through the tubes. Further, the vibrational noise will not be damped. The other concern is that the fans will only pull flow through the area directly underneath the fan. A third concern is that the fan blades are too close to the radiator to properly draw air.

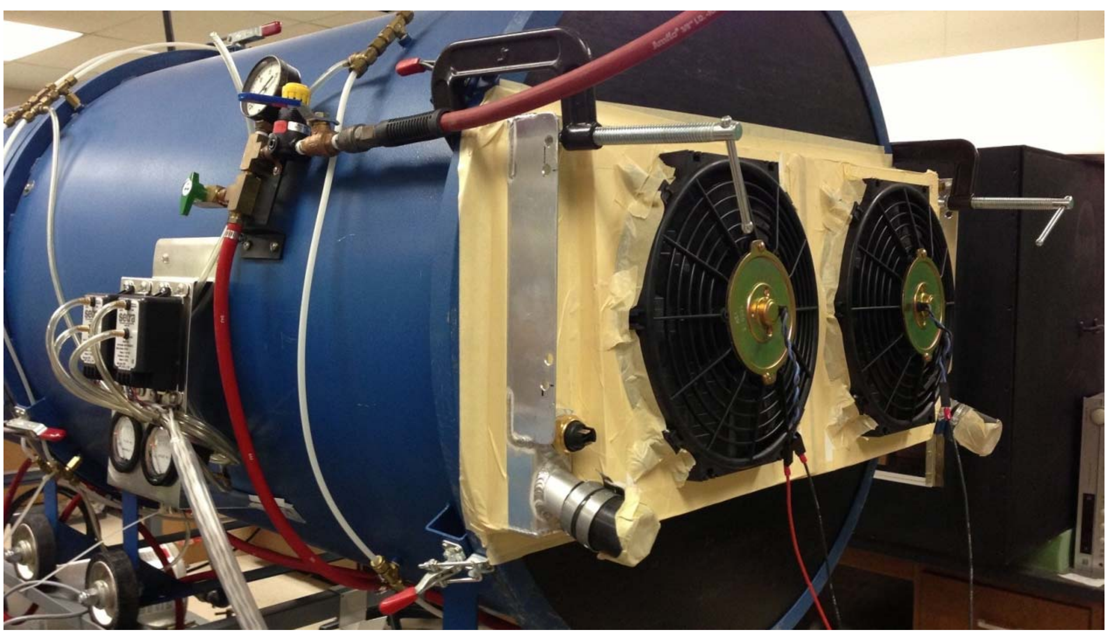


Radiator with fans mounted directly on the radiator surface

The direct-mounted fans cause a slight increase in pressure drop compared to the isolated radiator as shown in the following graph.

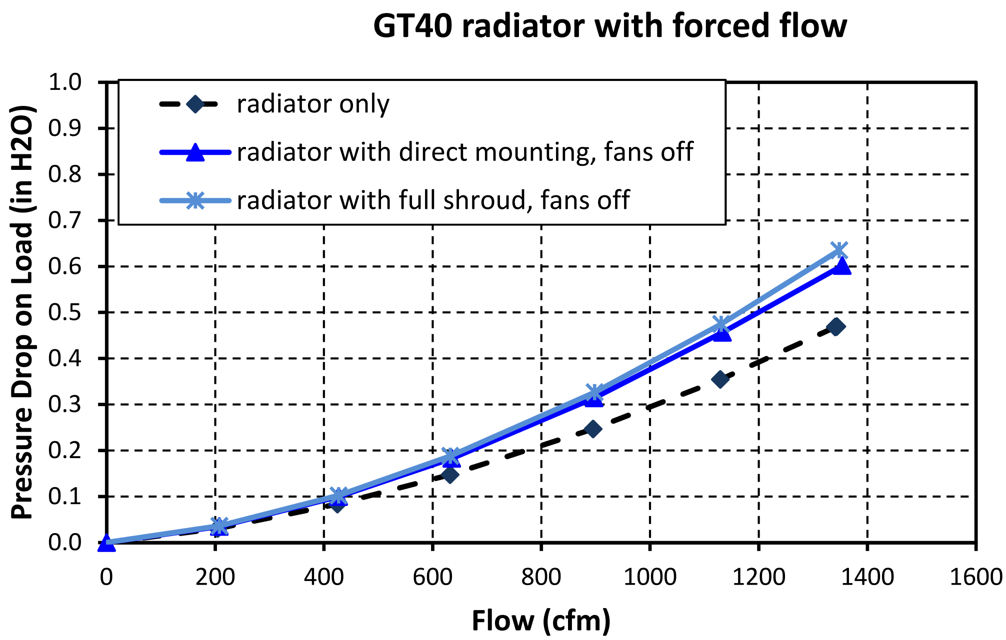


A better approach would to build a plenum before the fans so the fans can pull from the entire radiator. This plenum has a depth of 0.75" at the top and 1.50" at the bottom. The plenum has a second advantage in that the flow has a chance to develop before coming out of the radiator and before hitting the fan blades. This causes only slightly more pressure drop than with the directly mounted fans.



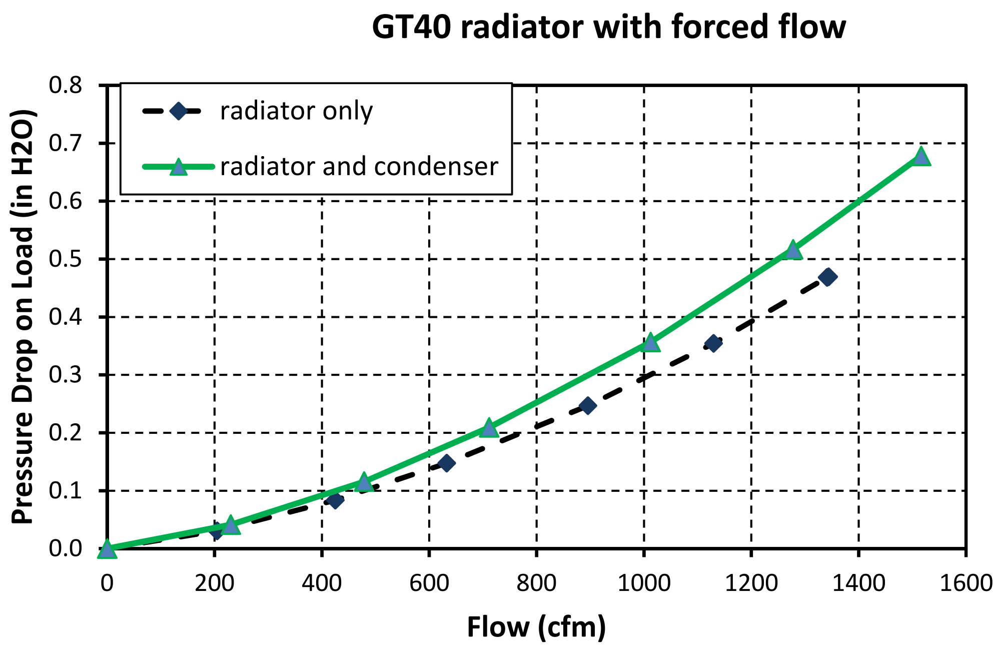
Radiator with fans mounted on a shroud or plenum

This causes only a slight increase in pressure drop for forced flow.



The application on my car will have a condenser for the A/C. This adds a small pressure drop compared to the individual radiator.

Radiator with condenser

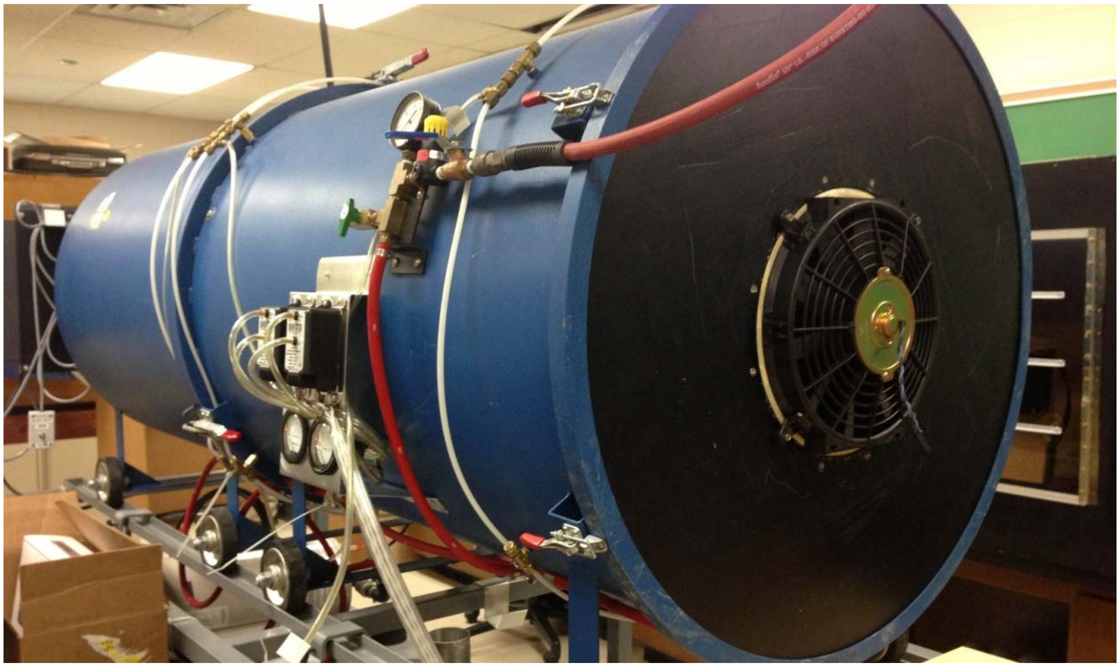


Even though I tested other configurations, this summarizes the pressure-flow characteristics for forced flow or flow experienced at speed.

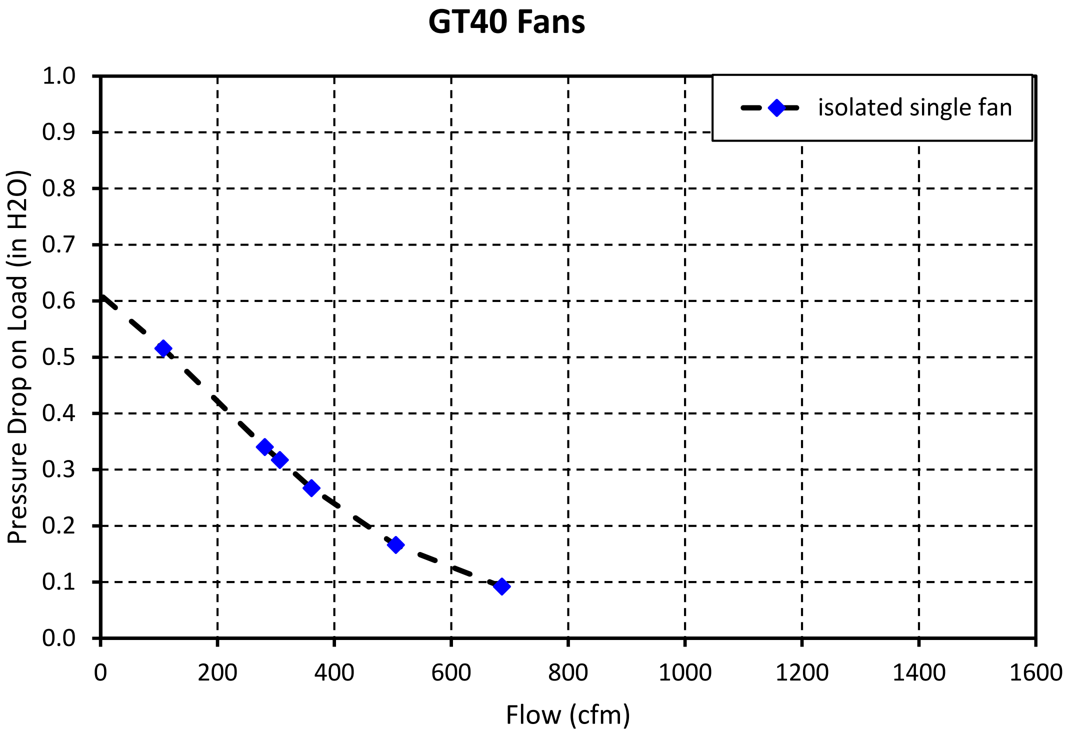
Fan Characteristics

The fan needs to pull air through the radiator. Now knowing the pressure-flow characteristics of the radiator with attachments, we need to find the performance of the fans in the various mounting configurations.

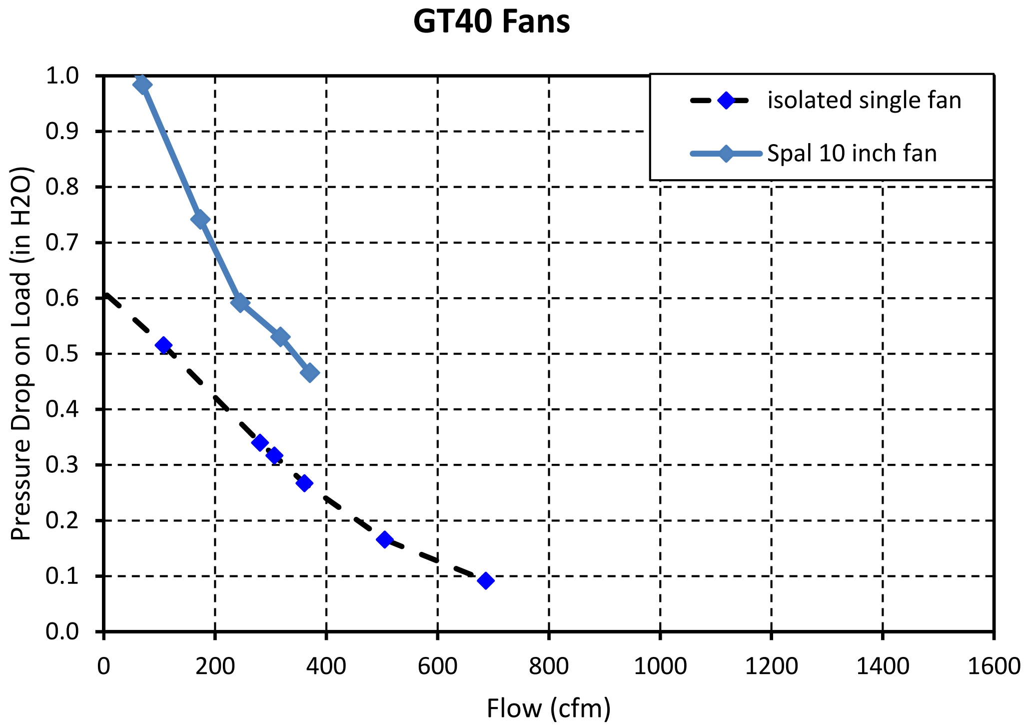
First is the ideal pressure-flow characteristics of the fan mounted in a circular panel with no restriction before the fan. The results reported here are with the fan that was provided with the Tornado package. It may not be the best fan available.



Ideal single fan



For what it's worth here are the characteristics of a Spal 10" fan. It has more pressure and more flow and I think it draws less amps (6.5 vs. 7.5). I think the Spal is a brushless DC motor. I don't really know why I didn't switch to the Spal instead of the original Tornado fan.

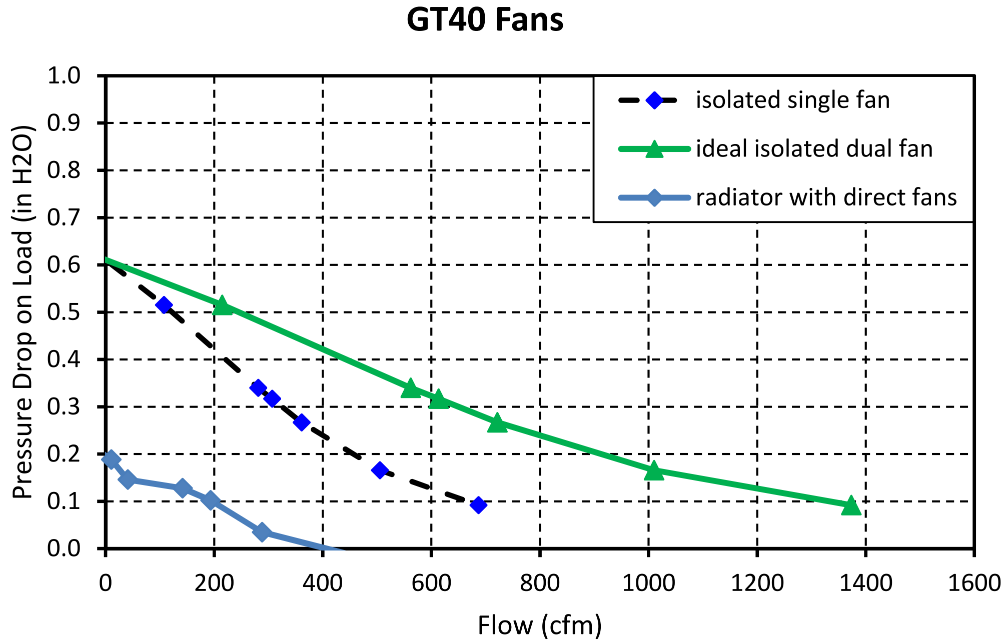


Before we discuss some of the next tests, we need to understand what goes on in a fan. These fans are axial flow puller fans (which means it pulls air through the radiator as opposed to pushing air). In other words, the flow is supposed to go straight through the fan from front (radiator side) to the back (exit side). The fan blade develops a negative pressure and a high air velocity near the tips of the blades. This is where most of the flow goes. If there is any restriction on the front side of the fan, such as a radiator, then a below ambient pressure is generated on the front (suction) side of the fan. Thus, the pressure on the front side of the fan might be lower than the pressure on the back (exit) side of the fan.

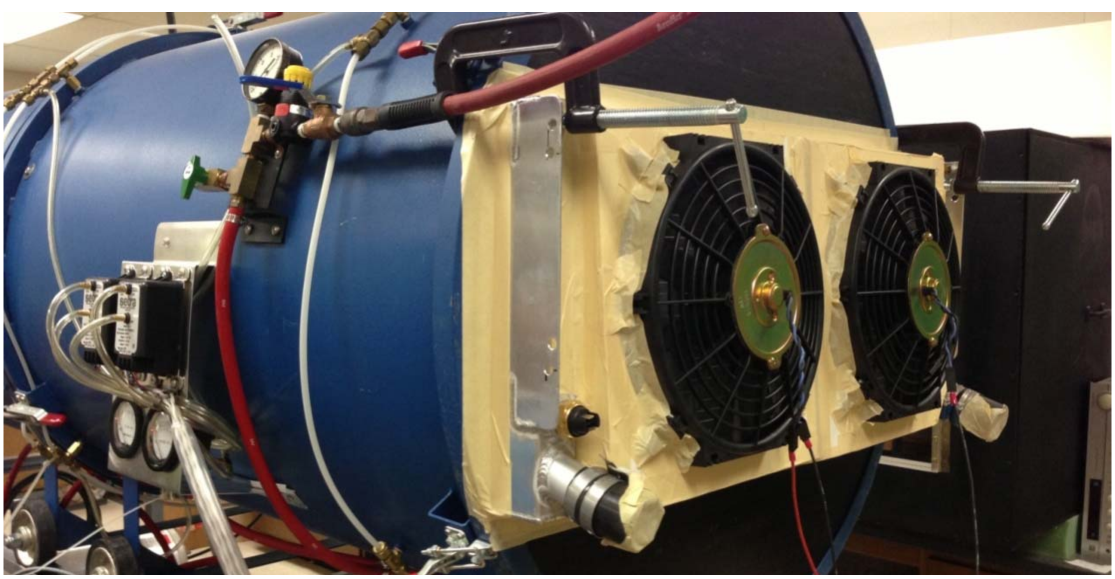
The upstream resistance does two things: first it will cause reverse flow at the center or inside edge of the blade. Therefore flow around the center of the fan will actually go backwards through the fan and hence reduce the pressure capability. The second thing that it does is to make the flow exit more radially or to the side of the fan blade. In a heavily restricted case the flow will exit almost directly radially and there will be a large back flow at the center.

The first graph showed a single fan in a circular mounting yielding axial flow. If we had two fans mounted side-by-side, then we would expect the combination to have the same pressure with double the flow. This ideal dual-fan curve is shown in the following graph. This represents the maximum flow we could get. We will not be able to achieve this due to the restrictions of the radiator and how we channel flow to the fan (with a shroud for example).

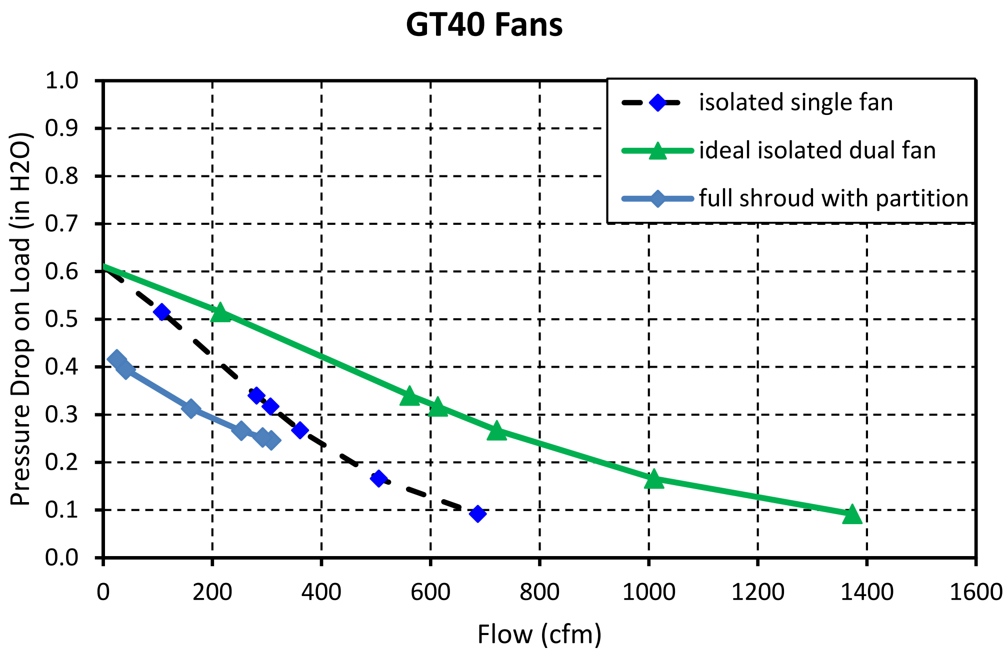
The pressure-flow characteristic of fans mounted directly on a radiator is shown below along with the single fan and the ideal double fan. Notice a significant loss in pressure. Notice also that even though the pressure is reduced, the slope is the same as the ideal double fan meaning that we just lost pressure.



From previous work, we know that a plenum before the fan will increase the efficiency of getting air through the fan as opposed to having the blades almost touching the radiator. I built a plenum shroud and mounted the fans on the shroud that was mounted to the radiator. The radiator added some resistance to the flow and therefore the front side pressure was reduced which caused reverse flow around the center of the fans. The result was a decrease in pressure from the ideal dual fan. This flow curve follows the same slope as the ideal dual fan curve, but it just loses pressure due to the reverse flow. Even though there was some pressure loss, this is much better than directly mounted fans in the previous graph.



dual plenum



Even though it appears the fans don't perform as they should based on the double isolated fan graphs, remember that the difference here is the inclusion of the radiator upstream of the fans which causes the reverse flow and the pressure loss. Further, in this case, the flowmeter in the flow bench caused a little more pressure drop as well, so the performance will actually be slightly better than the graphs shown here.

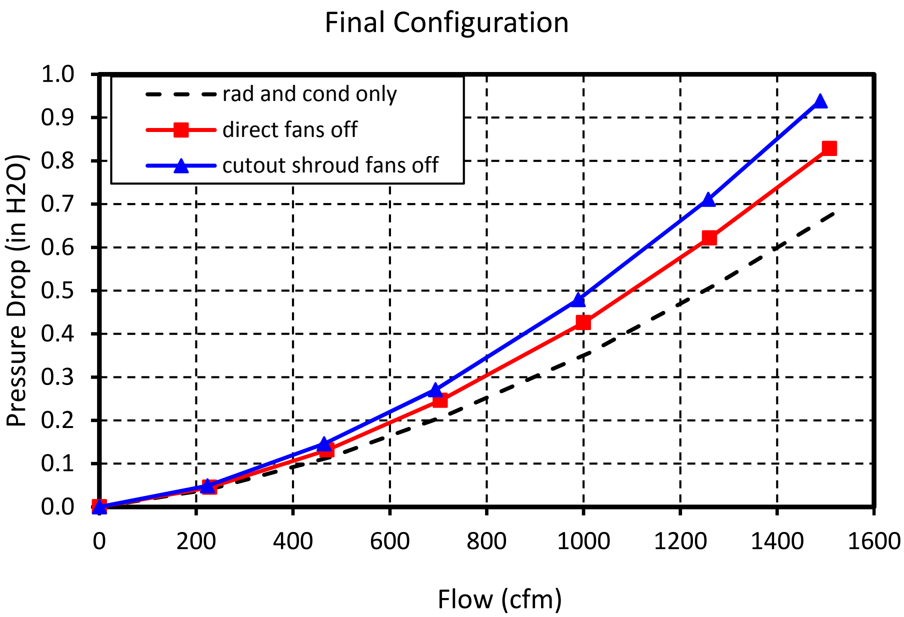
The Final Configuration

Based on all of these tests and analysis here are my conclusions. First, the plenum that gives a standoff between the radiator and the fan drastically improves fan performance as compared to mounting the fans directly on the radiator. Forced flow can go through the radiator easier if the plenum does not cover the entire radiator. If there is to be a cutout in the plenum or shroud, then the two fans should be partitioned or isolated from each other and from the central cutout to prevent reverse flow from the cutout.

The final configuration has a dual partitioned plenum with a cutout in the center of the shroud. This lets the fans pull only from the area of the radiator below each fan individually and will let free flow go through the center cutout more freely than a full shroud. The final configuration as built is shown below.

Dual plenum with central cutout

Shown below are the pressure-flow characteristics for forced flow through the radiator with condenser, the radiator with condenser with directly mounted fans, and with the dual plenum with central cutout for forced flow.



The shroud does cause a little more pressure drop as compared to the directly-mounted fans; however, as we will see performance with the fans on is much better.

Performance at Speed

The telling story of radiator and fans is what happens when stopped and at speed. I have conducted an interesting analysis that lets me determine that. First, I think it is safe to assume based on the radiator opening and placement at the front of the car that you will achieve very close to the full pressure resulting from the speed. Based on Bernoulli's equation the pressure will be close to the ideal.

$$\delta P = \frac{\rho v^2}{2}$$

If this is true, then we know the pressure coming into the radiator and with some assumptions on the pressure on the other side of the radiator, and hence the pressure drop across the radiator. Next, I have derived a math model or curve fit for the pressure vs. flow through the radiator and condenser and fans.

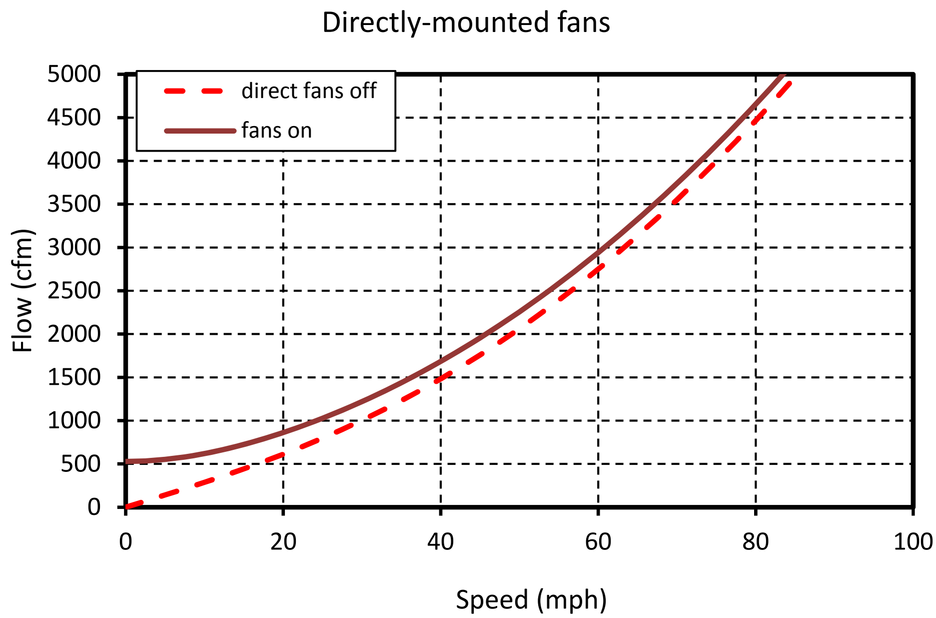
The pressure-flow curve is not linear or is it purely quadratic as you might suspect. The equation that fits the data very well is given below.

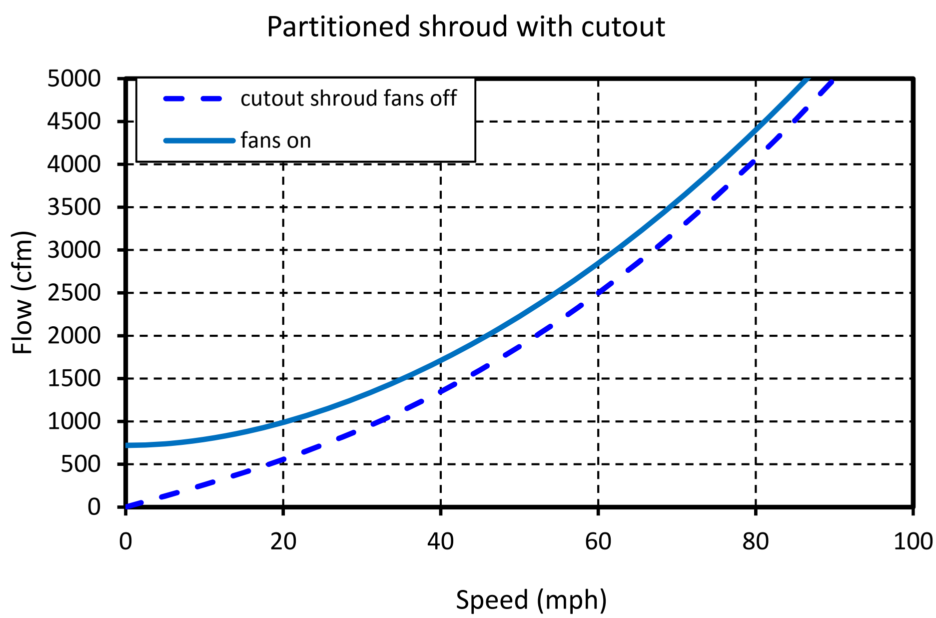
$$Q = \frac{\sqrt{\left(\delta P + P_{amb}\right)^2 - \left(P_{amb}\right)^2}}{RF}$$

In this equation the *RF* is a resistance factor that I can get by fitting the forced flow data points.

Therefore, knowing the speed, I can calculate pressure drop, and knowing pressure drop I can calculate flow. Knowing pressure and flow, I can plot flow versus car speed.

The first graph illustrates the pressure and flow of the radiator and condenser when the fans are mounted directly to the radiator with the fans on and off. The second graph illustrates the pressure and flow with the dual plenum shroud that has a cutout in the middle with the fans on and off. Notice with directly-mounted fans we will get about 500 cfm sitting still with the fans on; whereas, with the shroud the flow is about 750 cfm. Therefore you will get more cooling at low speeds with the shroud. At 80 miles per hour the directly-mounted fans will have about 4500 cfm with only a slight difference with the fans on or off. The shrouded fans will have about 4000 cfm with the fans off and 4500 with the fans on. There isn’t much need for a fan at high speeds. The main value of the fan is at lower speeds and clearly the shrouded fan is better.



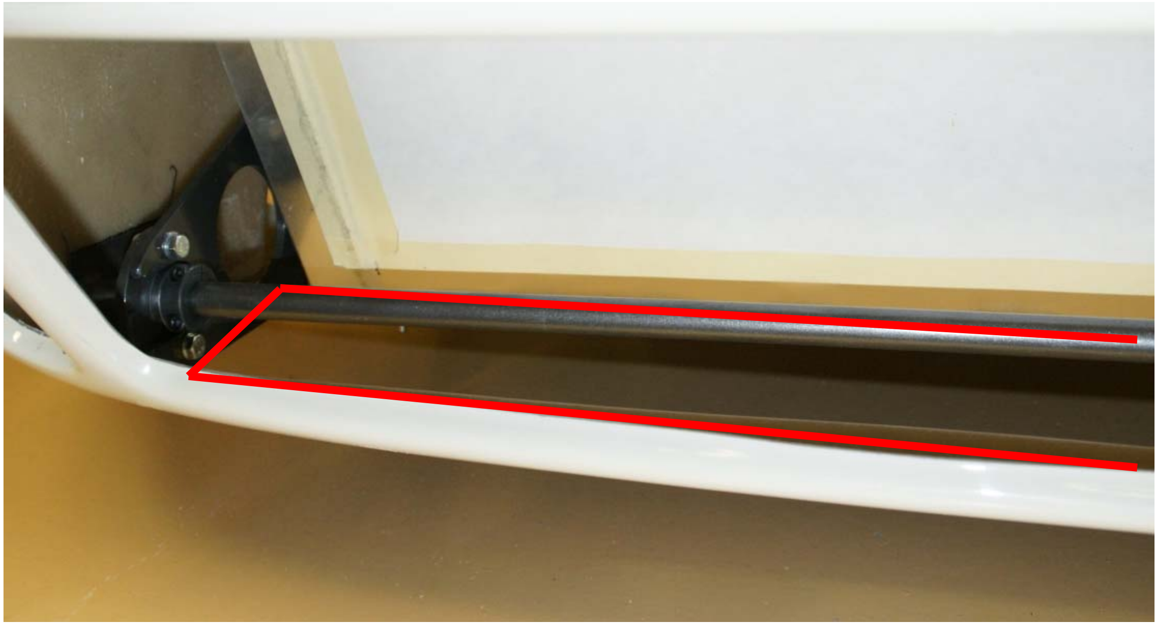


Notice further that with the direct-mounted fans, you will achieve the same static flow (500 cfm) at a speed of 18 mph with the fans off. With the partitioned shroud you will achieve the same static flow (750 cfm) at 25 mph.

My conclusion is that the dual plenum shroud with a cutout is the best option. Shown below is the final configuration. Notice that the plenum actually touches the radiator with a rubber strip to seal the partition so that all the fan's air goes through the radiator below the shroud.

Getting Air Into and Out of the Radiator Area

There are two things that you can do to get more air flow through the radiator at speed that are not done on the Tornado kit. First is the air into the radiator. Notice in the photo below that as air enters through the front mouth or open area, it can go through the radiator or be diverted below the radiator in the open area at the bottom of the radiator (shown in the red rectangle).



Gap to ground in front of radiator

Clearly, the air would take the path of least resistance and just go out the bottom underneath the car.

I have placed a flat fiberglass piece that mounts on the rotation bar and is attached to the front nose piece. This effectively seals that area and forces the air through the radiator.

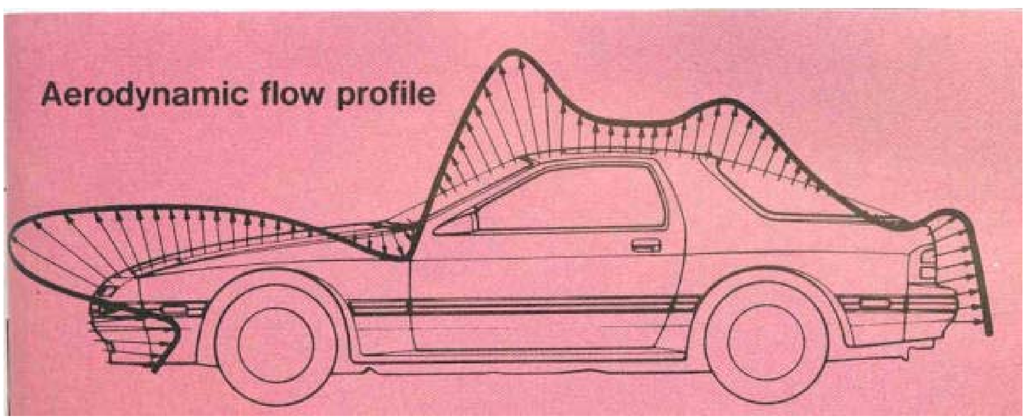
In addition to that, I have extended the air inlets normally intended for brake cooling in the original GT40s by several inches which helps block air from going out the sides of the inlet area.

Brake duct extension

Now that I have somewhat sealed the front of the radiator to help push the air flow through the radiator (see my post # 130), it is time to consider the back side of the radiator to help pull the air through the radiator.

There was some argument on the GT40s.com forum about what to do in the open area behind the radiator. Tornado argued that the area should be open to the wheel wells to let the hot air out. However, I argued the opposite and several other kit builders apparently agree since they do it as I have.

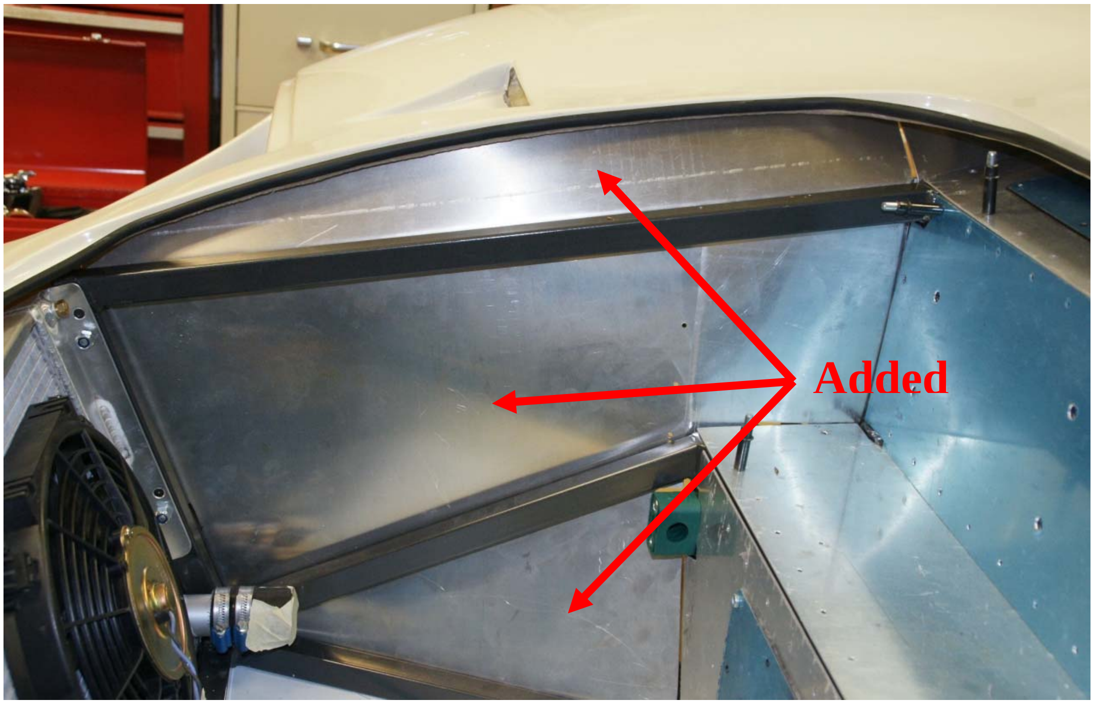
One of the lowest pressure (highest vacuum) points on the car occurs just before the nostrils on the front clip. The slight rise at the front of the nostril acts as a Gurney flap and reduces the pressure even more. Therefore there is a very low pressure region over the nostrils which will put a low pressure on the back side of the radiator when the car is driving.



Pressure distribution around a typical car

To take advantage of the low pressure through the nostrils, the bay area under the front clip needs to be sealed on the sides. If this area is left open, then the vacuum in the nostrils will suck the higher pressure air in the wheel well area into the front bay area instead of pulling the air through the radiator. Therefore, I want to seal the front bay area so the vacuum in the nostrils can only pull air through the radiator.

To do this, I put a panels on the vertical side openings defined by the steel chassis to block the air flow from the wheel well to the back side of the radiator (see arrows). This was not specified in the Tornado assembly manual. In addition to that, I attached an aluminum lip to extend the floor to the front clip. This aluminum lip comes close to the front clip but does not touch it. Now the front bay area is sealed from the wheel well area and the nostrils will suck air through the radiator more effectively.



Side walls around wheel wells

I have zero problems with overheating even in the Texas summers. The water temperatures will rise to the 190 degree F setting in my ECU when the fans switch on. On particularly hot days, the water temperature will rise from the 190 degree setting to the thermostat setting.