There is no one magic formula to spec'ing, buying, or building a top quality radiator. There are many complicated inter-related factors at play and designing and building a great radiator is both art and science. Fortunately, this is something Griffin Thermal Products are very, very good at. Keep in mind, as you read the following considerations that a radiator is only as good as the sum of its parts, that there is a lot more to a quality radiator than meets the eye, and that there are few hard-and fast rules, despite what some would have you believe (for example, you can't say that a 3-row rad is always better then a single-row rad.)

As you read this section, keep in mind that the job of the radiator is to expose as much hot coolant as possible to the inside surfaces of the rows of tubes that connect the radiator tanks. Heat is thus transferred from the coolant to the tubes. From the tubes, the heat is transferred to the fins. Airflow passing over the fins then dissipates the heat into the air.

That said, here are some of the factors to keep in mind when selecting or spec'ing a radiator:

Material

There is only one choice of material for a top-quality radiator today - aluminum. Not only does it have a very efficient rate of heat transfer - it also has far superior structural strength compared to an older copper core radiator. This means the radiator will be able to withstand higher system pressures. The greater strength of aluminum also means the aluminum radiator can be built with wider tubes which allow more direct contact between the coolant and the tube surface as well as more contact between the fins and tube, both of which increase the radiator's capacity to dissipate heat. Because of these wider, more efficient tubes, an aluminum radiator with 2 rows of 1" tubes is equivalent to a copper radiator with 5 rows of 1/2" tubes! The greater structural strength of aluminum also means that radiators can be built with very wide cores without risk of collapse, which provides greater coolant capacity and greater cooling surface area.

All things considered, an aluminum radiator will be more efficient, longer lasting, stronger, and lighter than a traditional copper radiator.

Surface Area

Surface area is king. Get the biggest rad you can fit (length x width). In fact, if maximum cooling performance is your goal - consider getting a bigger rad than you can fit and then building the chassis around the rad. This is exactly what I did when building the cooling system for my 525HP LS2. I knew it made a lot of power. I knew power = heat. So I chopped off the whole front of the truck and built a new front end specifically around my Griffin rad. Surface area - yes, it's that important!

There used to be an old-school rule that stated that a rad should be 1 square inch for every cubic inch of engine displacement. This was an old rule from back in the days when making 1hp per cu. in. was considered pretty high performance. These days engines are routinely making more than 1hp per cu. in. so the rule needs revising since cooling capacity is related to power and not just engine size.

For high performance use - like offroad racing, my rule of thumb is to size a rad based on 1.1 sq. in. per hp produced. This is a fairly conservative rule of thumb, which works well for aluminum motors.

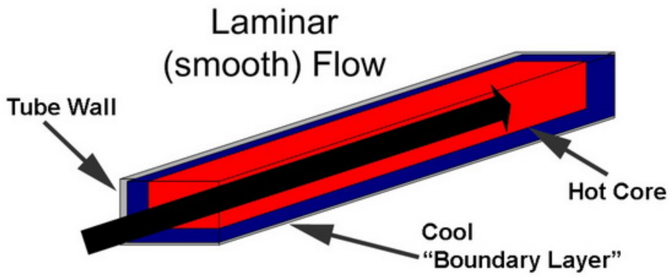
Here are some common rad sizes and their areas in square inches:

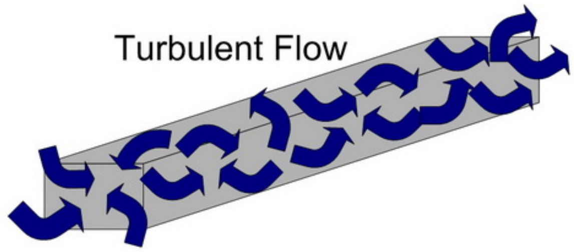
width (in.)	height (in.)	Area (sq. in.)
22	19	418
31	19	589
31	16	496
28	19	532

Turbulence

It is very important that the coolant flowing through the radiator's tubes does so in a turbulent or "rough and tumbling" fashion. This is so that the maximum amount of hot coolant can come into contact with the surface of the tubes so maximum cooling can occur. If the flow is not turbulent, but instead is smooth or "laminar" in nature, a thin boundary layer of fluid will tend to "stick" to the inside walls of the tube, insulating the rest of the fluid from the cooling surfaces of the tube. The result is, the outer boundary layer cools, but the hot inner core never gets cooled.

The following diagram illustrates the difference between laminar (bad!) and turbulent (good!) flow.





There are a number of ways a radiator or cooling system designer can achieve turbulent flow. They include:

- Ensuring sufficient velocity of the coolant flow.
- Optimal tube shape. Wider tubes with small cross-sectional area allow for better turbulence. This is another example of the advantages of aluminum - it has the strength required for fewer, wider tubes.
- The use of special techniques in the construction of the tubes themselves - such as the addition of "turbolators" or small fin-like projections that promote turbulent flow inside the tubes. Such techniques require advanced engineering and flow modelling to strike the best balance between promoting turbulence while maintaining adequate flow and minimizing pressure drop through the radiator. In their latest high-performance products Griffin employ a patented ported Micro Extrusion tube construction technique using a 3000 series aluminum alloy for durability and enhanced fluid turbulation.

Thickness

If you have maximized the surface area and there's absolutely no way to go any bigger, then there may be some advantage to using a thicker rad.

Adding thickness to a radiator does not increase its efficiency to the same extent as increasing its surface area does, but as long as there is sufficient airflow it will not decrease the efficiency.

Thicker radiators do have slightly more airflow resistance than thinner radiators but the difference is minimal at speed when there is good airflow through the radiator. Where issues can crop up is at idle when the fan(s) alone must supply the needed airflow. Use of a quality, properly shrouded fan or fans is a must to produce the required airflow at idle and slow-speed conditions. Of course, this is true to some extent in all case, but especially so with particularly thick radiators.

You may have heard people claim that installing a thicker radiator resulted in a net drop in cooling ability. This may be attributed to one of two possible causes. First, the fan(s) and shrouding may be inadequate to supply the required airflow. Second, in the case of older radiators (especially copper) that used narrow tubes with fairly large cross sectional area, the increase in thickness and therefore tubes, actually reduced coolant velocity to the point that the coolant flow lacked the required turbulence. In no case, however, can a drop in cooling with a thicker rad be attributed to the air getting fully heat-soaked before it has flown completely through the thick rad - this is an old wives' tale that may have come about as a result of misdiagnosing one or both of the above conditions.

Rows

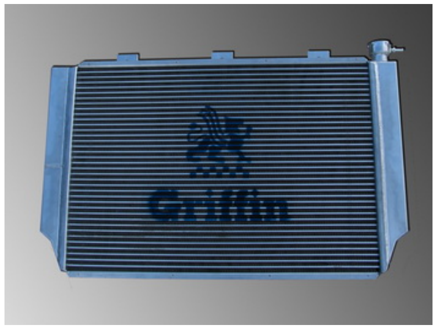
One row? Two rows? Three rows? (Or erroneously, single-core? Double core? Triple core?) Which is the best? There is no hard and fast rule here. The number of tubes in each row (from front to back) is only a part of a radiator's overall design. One cannot say that two rows are always better than one. It all depends on the size and profile of the tubes, as well as all the other design features of the radiator - not the least of which is the overall size. The best bet is to choose or spec a radiator using the other criteria for which there are firm guidelines (aluminum, largest area possible, etc.) and then leave the other design elements, such as the number of rows, to a trusted expert such as Griffin.

Fin Density

Normally, the greater the density of fins between the tubes, the more surface area there is to be subjected to cooling airflow. However, there is a limit - more is not always better and too much of a good thing becomes a bad thing. Imagine a fin density so high it was almost a solid - obviously that would not be optimal for cooling as no airflow could pass. Another factor involved in the optimal fin density calculation is the operating conditions to which the radiator will be subjected. Dirty, clogged fins are inefficient and even useless, and extremely dense fins are very difficult to keep clean. Not only that, but the fins are fairly delicate and cleaning them can sometimes cause damage that again reduces their efficiency or renders them useless. For these reasons, often the best choice for an off-road rig is a slightly less dense fin count compared to a street or track car - and the overall result will be better real-world, in-service cooling. Griffin understands this and, unlike some others, will not just sell you the product that sounds best on paper (highest fin density). Rather, they will take the time to understand your application and will either design a custom product for you or sell you an off-the-shelf product best suited to your actual needs.

Flow - cross and down

Almost all radiators today are "cross-flow". This simply means that the tanks are on the sides of the core, and that the coolant flows horizontally through the tubes from one tank to the other.



A cross-flow radiator with tanks on the sides of the core.

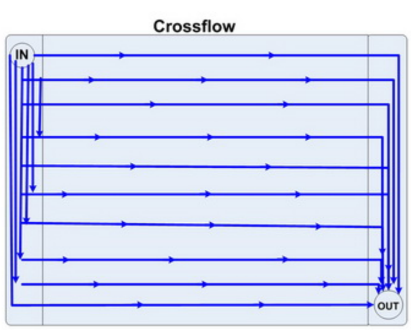
Years ago, most radiators were "down-flow" design where one tank was on top of the core and one was below so that the coolant flowed down, vertically, from the top tank to the bottom. This style is still popular today in some circles such as the hot-rod scene.

A down-flow radiator with tanks above and below the core.

Many, many myths and old wives' tales can be traced back to the old down-flow style radiators and their design and construction. We will deal with them in a separate section. For now, unless you are trying to reproduce a classic hot-rod look or are intent on replicating the factory setup in a rig that originally used a down-flow radiator, know that a cross-flow radiator is the better design because:

- In a cross-flow radiator, the radiator cap (pressure relief valve) is located on the low pressure (non-inlet) side of the radiator. This prevents the pressure created by a high-flow water pump from forcing coolant past the radiator cap at high engine RPM.
- Because the rad cap is really a pressure-sensitive relief valve that sets the system pressure, when it is located on the high pressure side (as it is in a down-flow radiator) it "senses" the high pressure side and sets the system pressure based on this and therefore overall maximum system pressure is less (the valve opens when the high-pressure side reaches the cap's rating). In contrast, when the cap is located on the low pressure (non-inlet side), as it is in a cross-flow radiator, the cap "senses" and sets the system pressure based on the low-pressure side - with the result that overall system pressure is higher in this configuration. For example, a 22PSI rad cap located on the low pressure side of a cross-flow rad effectively becomes a 10PSI cap if it were located in the high pressure side of a down-flow radiator.
- Because the rad cap on a down-flow radiator is located on the high-pressure inlet side, coolant flow/velocity must be reduced so that rad pressure doesn't exceed the cap's rating. As we have seen, when flow is reduced so is cooling efficiency,and when velocity is reduced, so is flow turbulence and therefore cooling efficiency.

Flow - single-, dual-, triple-pass

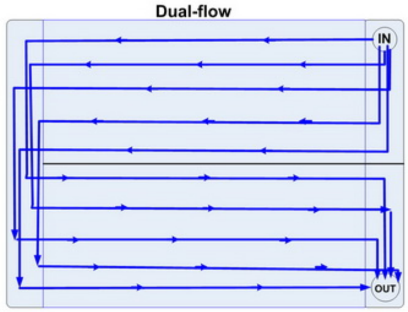


The diagram at left depicts the flow in a single-pass cross-flow radiator.

The tanks are completely open inside and coolant flows horizontally, in one direction only, from the inlet (high pressure) side to the outlet (low pressure) side.

This results in the inlet and outlet being on opposite sides of the radiator.

If a rad cap is mounted on a single-pass rad, it is located on the low pressure (outlet) side.



Pictured at left is a dual-pass cross-flow radiator.

In this configuration, the inlet and outlet are located on the same side of the radiator, and the tank to which they attach is separated in half vertically.

This forces the coolant to flow from the inlet to the opposite side tank, then back through the rad to the outlet, as pictured.

This essentially doubles the length of the tubes between inlet and outlet, halves the cross-sectional area for flow, and results in:

- Increased pressure drop across the rad from the inlet to the outlet.
- Decreased flow rate.
- Higher velocity and more turbulent coolant flow, with attendant increased heat transfer coefficient.
- Intermediate delta-T between the coolant and airflow on the second pass.

Let's take a closer look at why all this is so and what it means to our cooling system performance.

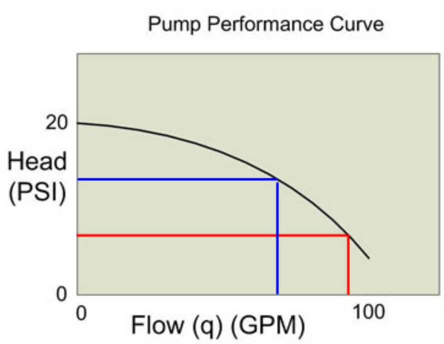
Many people mistakenly believe that a dual-pass radiator cools better because the coolant "goes through the rad twice" and therefore "spends longer in the rad and cools more". We know that this is not the case, because "time spent in the rad" is not a defining factor of how well a rad cools, and that flow, turbulence, and delta-T have a far greater effect on cooling efficiency than time. In addition, there are a great many aspects of radiator design, including tube width, tube height, number of tubes, tube construction, and fin count that, in addition to flow pattern, all combine to determine the cooling efficiency of a radiator.

So, the question is - does a dual-pass rad cool better or worse than a single cross-flow rad?

The answer is "it depends". To understand why this is the case, we need to recall the principles of Pump Performance Curve and Total System Pressure Drop and apply them to the dual-pass rad to see what is happening.

We already know that pressure and flow are related, and therefore how increasing the effective length of the cooling tubes with a dual-pass rad increases pressure drop (backpressure).

If we examine the pump performance curve, we can also see how the increased head required by the increased backpressure of the dual-pass rad also causes a reduction in flow because the pump always performs somewhere on its curve, and since its head has increased, the flow it produces will be less. The following diagram illustrates the concept, but once again the values are not intended to be representative of any real-world conditions (I just made them up to illustrate the concept).



The intersection of the red lines on the performance curve represents the flow and head of a theoretical single-pass rad - say 90 GPM at 8 PSI head. The intersection of the blue lines on the performance curve represents the flow and head of a theoretical dual-pass rad - say 70 GPM at 14 PSI head.

How large an effect on pump flow the increased head required for a dual-pass rad has, depends on the specific pump's performance curve and how large a part of the overall system pressure drop the rad is.

Now, to understand the dual-pass rad's effect on coolant velocity, we need to introduce one last equation that relates flow, area, and velocity.

Flow in a pipe (or radiator tube) is equal to the cross-sectional area of the pipe multiplied by the velocity of the fluid. If that concept is difficult to grasp, it may help to think of the units involved, as in:

Flow (q) = Area (A) x Velocity (V); or

cubic feet per minute = square feet x feet per minute

$$\frac{ft^3}{min} = ft^2 \times \frac{ft}{min}$$

(note: 1 cu ft = 7.48 US gallons)

This makes sense - the larger the pipe and/or the faster the fluid is moving - the greater the flow (the more fluid will pass through the pipe in a given time).

Now, since q=AxV, this means that if you decrease the area or the velocity, the flow decreases; and by the same token, if flow remains constant and area is reduced, the velocity or speed of the fluid must increase.

In a dual-pass rad like the one pictured above, the coolant only has half the number of tubes to flow through at a time - that is, the cross sectional area is halved. And because q=AxV, since the area has halved, for a given flow produced by the pump, the velocity of the coolant doubles. Because velocity increases, so does turbulence. Velocity also has a beneficial effect on the heat-transfer coefficient (how well the radiator sheds the heat in the coolant).

Lastly, in a dual-pass radiator, the delta-T (temperature difference) between the coolant and the airflow will be less on the second pass than it is on the first pass - which means heat transfer from the coolant to the air will be less on the second pass than the first.

So again, in general, when compared to a single-pass rad, the dual-pass rad has some degree of:

- Increased pressure drop across the rad from the inlet to the outlet.
- Decreased flow rate.
- Higher velocity and more turbulent coolant flow, with attendant increased heat transfer coefficient.
- Intermediate delta-T between the coolant and airflow on the second pass.

Of course, all this is also a circular process. Area is reduced -> velocity goes up -> pressure drop goes up -> head goes up -> flow goes down -> velocity goes down (remember q=AxV at all times) -> pressure drop goes down -> head goes down -> flow goes up -> and so on (the system quickly reaches a point of balance or equilibrium, it just isn't easy to calculate with a simple equation).

There are two final considerations with regards to a dual-pass radiator compared to a single-pass:

- A dual-pass configuration is ideal for locating the rad hoses on the same side of the engine, as is often the desired configuration with "LS" motors. This is especially important if you don't have room in a cramped engine compartment to run an upper rad hose over the top of the fan(s).

- In a dual-pass radiator, the rad cap is located on the tank that doesn't have the inlet and outlet. This essentially positions it between the high pressure inlet and the low-pressure outlet - or in a region of "medium pressure". This is an important consideration in choosing a rad cap pressure rating for a dual-pass radiator. However, this region of "medium pressure" is a relative term given the greater total pressure drop through a dual-pass rad.

How all these factors balance out and therefore the overall effect on cooling system performance of replacing a single-pass rad with a dual-pass rad depends on which, if any, of these factors is the limiting factor on that system's performance. Attempting to calculate and quantify this is a complex problem requiring advanced knowledge of fluid dynamics and thermodynamics and advanced modelling techniques. It is likely well beyond the ability of any enthusiast.

The best we can do is understand the general principles at play, and then consult the experts as to whether or not a dual- or even triple-pass rad can or will be beneficial to your cooling system. One cannot definitively say that a dual-pass rad always cools better than a single-pass rad or vice-versa, but there are certainly cases where a dual-pass radiator can be very beneficial if applied to a properly engineered cooling system. The best advice I can offer is: before considering a dual-pass or triple-pass radiator for your vehicle be sure to consult cooling system professionals like those at Griffin Thermal Products.

Inlets and Outlets

Inlets and outlets should be chosen to match the diameter of the water pump inlet and outlet. In the case of the "LS" motors the water pump outlet is 1.25" and the inlet is 1.5". They can be placed on either side of the rad, either together (as in a dual-pass radiator) or on opposite sides (as in a single-pass or triple-pass radiator). For older conventional V8's, Chevy engines normally had the rad inlet on the left and the outlet on the right. In Fords they were reversed with the inlet on the right and the outlet on the left. On the older gen I GM V8's the water pump outlet was usually 1.5" and the inlet 1.75".

Filler Neck / Rad Cap Location

As has been covered, if you are going to use a radiator with a filler neck and mount the rad cap to the radiator, the filler neck should always be placed on the low-pressure tank - i.e. the one that doesn't have the radiator inlet.

Additional Ports & Plugs

Due consideration should be given to the location and size of steam ports and surge-tank vent ports. Remember they should be located on the low pressure side, just below the rad cap. Most high performance rads do not incorporate a built-in drain plug at the bottom since this can create an unnecessary potential leak point and most racers wouldn't use a drain port for maintenance since the whole system usually comes apart for inspection and replacement as necessary when maintenance is scheduled. Griffin does not normally install a drain in their race radiators since most racers don't use a drain, and, given the wide variety of chassis a race radiator can be used in, it would be impossible to find a location for the drain that would suit every possible application.

Airflow

The best radiator does no good without adequate airflow. Airflow is measured in cubic feet per minute, or CFM. In your design, be sure to allow for adequate airflow at both high and low vehicle speeds. Airflow design for low speeds is fairly easy - you need one or more good quality, powerful fans and a good, complete shroud. Without a shroud you can loose as much as 50% of the CFM you would otherwise have.

Ensuring good airflow at higher speeds is more difficult, because high-speed airflow can do weird and wonderful things and you need to account for aerodynamic flow and different air pressure zones. Rather than teach a class on aerodynamics, here are some basic tips:

- Radiator location and angle is critical to ensuring good high-speed airflow. The best installation for cooling purposes is to have the rad stand straight up vertically in the airflow. Of course, this doesn't help the car's aerodynamics, visibility over the hood, aesthetics, or engine compartment packaging very much; and brings us in to conflict with the rule about using the largest rad possible. If we install a very tall rad, there often just isn't room to stand it up straight. As a result, many people lean the rad back at an angle to lower the overall height in the chassis, while still fitting a large rad. You have to be careful when doing this though - if you lean it back too far, especially if you have poor ducting of the air to the rad, air will flow up and over the rad instead of through it. When this happens, a high-pressure zone is created behind the rad, and as we know, air flows from high to low pressure, not the other way around. This is based on the same principle by which airplane wings create lift and a carburetor's venturi works. What this can mean is, at high enough speeds, the pressure behind the rad can be so much higher than the faster, low-pressure air flowing over the rad that no air is able to flow through the rad - even with the fans on. It seems strange, but physics can be a bitch that way sometimes. I personally believe that quite a few folks tend to lean the rad back way too far without understanding or testing the effects of high-speed airflow and the high pressure zone created behind the rad. If you do happen to do this - the car will overheat and nothing else you do will help. You simply have to have good flow through the rad at the speeds the vehicle will run.

- In conjunction with maximizing airflow through the radiator, your design must allow adequate engine-compartment ventilation to allow the air that flows through the rad to exit the engine compartment. Not because it is hot air and would otherwise heat up the engine (the engine's making plenty of its own heat already) - but to avoid creating a high pressure region in the engine compartment that would prevent further airflow through the radiator.
- Minimize the objects in front of the rad that block airflow. There are usually a lot of things that take up space in front of the rad - the grill, lights, winch, auxiliary coolers, etc. All of these rob the rad of its airflow. Your design should minimize the obstruction in front of the rad that block airflow.
- Depending on the fin density, a radiator has somewhere around 1/3 of its surface area as open space through which the air flows. Maximum cooling can occur when the grill or protection is such that it has no less than 1/3 open space. In other words, try to design the grill so that it doesn't add to the restriction of airflow.
- If you mount auxiliary coolers (like a power-steering cooler) in front of the rad that rely on the rad's fans to pull air through it, keep the gap between the cooler and the rad down to 1/4 - 3/8", 1/2" max, to ensure air is pulled through the cooler and not around it before entering the rad.
- Creative bodywork and ducting may be required to ensure maximum airflow through the rad. Just because it doesn't look like there's anything impeding airflow, doesn't mean that there isn't - high air pressure is the invisible killer of airflow. For example, on many production "sports" cars, the lower air dams are there not just to scrape on every curb and bump, but because they are critical in preventing an airflow-induced high-pressure zone behind the radiator that can severely impede airflow through the rad.

Fans

As previously mentioned, electric fans offer superior flow, mounting flexibility, and computer control compared to mechanical fans. Years ago, it used to be that mechanical fans offered the best performance, but today that isn't so. Mechanical fans are subject to problems with vibration due to air turbulence when run at high RPM. This can lead to premature wear on the water pump. Mechanical fans can also consume up to 20 or more horsepower. Viscous thermo-clutches used to control mechanical fans can be inconsistent and unreliable and offer no computer control. Mechanical fans are limited in the airflow they can provide at idle and slow speeds because they are turning at low RPM. Because the mechanical fan attaches to the engine and not the radiator, clearance must be maintained so that any chassis or engine-mounting flex doesn't cause the fan to eat the radiator (which is bad for cooling!). This makes shrouding a mechanical fan a more difficult and cumbersome affair that consumes valuable under-hood space.

By contrast, electric fans can be very neatly packaged and integrated with the radiator and shroud.

Because they aren't coupled to engine speed, electric fans can produce full airflow all the way down to idle.

Quality fans like those from SPAL are rugged and reliable with sealed waterproof motors and tough plastic housings.

Because they are electrically powered, electric fans can be computer controlled by the engine`s ECM or thermostatically controlled via a thermistor (a temperature sensitive switch installed in the coolant flow).

Electric fans are available in a large variety of styles and sizes to fit any size or shape radiator. I like to run two smaller fans in an offroad rig simply for redundancy`s sake - that way, if one quits, you still have one operational. You don't get this choice with a mechanical fan.

"Puller" style electric fans that mount behind the radiator and pull air through the radiator, as shown here, are the best choice because they are both more efficient (move more air for given fan RPM) than pusher fans, and they obviously don't block airflow from the front of the rad like a "pusher" style fan does.

A fan's capability is measured in CFM, as we have noted. However, the consumer needs to be careful when shopping for a fan by rated specs. Any given measurement for a fan's CFM must be taken (and therefore should be quoted) at a given air pressure (hey - that sounds familiar - pressure and flow being related! Man - physics rocks!). Too often this information is not quoted, and you can bet that the CFM spec is therefore rated at 0PSI which is not representative of actual operating conditions. Just as important, a fan's flow spec should

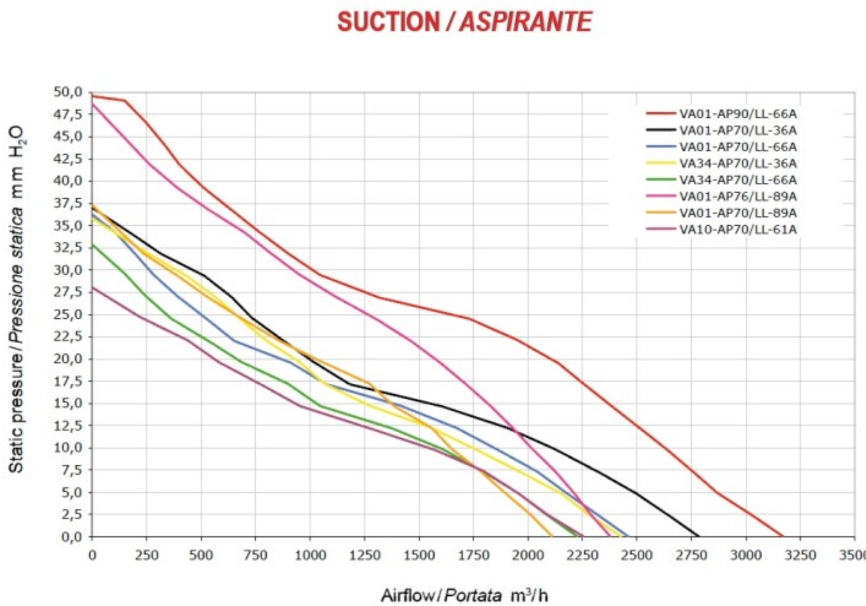
also include the voltage provided and amount of current drawn for each pressure/CFM rating. This is a good sober second-check of a fan's claimed capabilities. Be extremely wary of a fan that claims it pulls 3000CFM while drawing only 10amps - it's just not realistic.

My Griffin radiator uses twin 305mm (12") SPAL VA01 - AP70/LL - 36A electric axial motor paddle-blade high-performance individually balanced fans with sealed waterproof motors.

From the spec sheet of the fans, the pressure / flow / amps specs are as follows (note that the units in the table are metric - the fans are Italian dontcha know!):

	suction / *aspirante*			blowing / *soffiante*			
Static pressure *Pressione statica* mm H_2O	Airflow *Portata* m³/h	Current input *Corrente assorbita* A	Airflow *Portata* CFM	Airflow *Portata* m³/h	Current input *Corrente assorbita* A	Airflow *Portata* CFM	Static pressure *Pressione statica* inH_2O
0	2780	13,9	1640	2860	13,9	1687	0
5	2490	15,2	1469	2560	14,8	1510	0,2
10	2120	16,0	1251	2280	15,8	1345	0,4
15	1600	15,9	944	1920	16,6	1133	0,6
20	1020	16,7	602	1360	17,1	802	0,8
25	730	18,0	431	890	17,8	525	1
30	510	18,9	301	500	18,5	295	1,2
35	160	20,5	94	0	21,0	0	1,4
40	0	21,8	0				1,6

And here is the graph, taken from this document.



Water Pump

Because cooling efficiency is directly related to coolant flow, the more flow the better, the higher the water pump's output the better. Typical small-block water pumps flow anywhere from 35-50 gallons per minute (GPM) which is sufficient for stock-like power in the 200+hp range. The "LS" series of water pumps flow about 100 GPM which is equivalent to a high-flow SBC water pump and sufficient for 5-600+ horsepower. Aftermarket pumps for many different engines are available for the harshest racing conditions that can flow up to 180+ GPM.

If I were spending money on a high-performance aftermarket pump, I would make sure it came supplied with a characteristic performance curve, if only to make sure that the supplier really knows his stuff, and isn't simply marketing something with a label of "high flow" or "high performance".

Because flow is king, it is not generally advisable to use an underdrive pulley (larger pulley) to slow down the water pump. The rare exception would be if you regularly run a race motor at 7000RPM or more, as this is about the max RPM that a water pump is effective at. Because of the centrifugal design, at very high speeds the water pump can cavitate and pump more air than coolant, so in this case the pump would need to be slowed down - but remember, this is only true for those running consistent high RPMs. Of course, by slowing down the pump, what you gain on the top end you loose on the bottom so at low RPM the pump will be too slow and the cooling system will suffer from inadequate flow - which isn't normally a concern for race cars that are always run at near max RPM. For everyone else, some claim that by under-driving the water pump some horsepower can be saved, and while this may be true, the small gain is usually more than offset by power loss due to higher temperatures that result from the reduced coolant flow.

On the other hand, if you suspect that you are not getting all the performance you need from your cooling system you can usually safely overdrive (speed up) the water pump by 20-30% to increase flow and this can make a noticeable difference in cooling performance.

The first indication of a weak or failing water pump may often be observed as a problem with the rear-most cylinders - such as a lean condition (evident in plug readings or exhaust temperatures or a pre-ignition condition). This is because the engine block and cylinder head water jackets form a manifold through which the water pump must pump the coolant. If the pump is unable to produce the required pressure or flow, the farthest point from the pump (the rear cylinders) will experience the problem first.

Thermostat

My recommendation is to always use a thermostat. The reason is simple - its job is to regulate operating temperatures so that the engine warms up as quickly as possible, and then remains at the designed operating temperature. Without a thermostat, the engine may take far too long to warm up, and in some conditions may not warm up properly at all. When the engine is below operating temperature the oil's viscosity is too high to properly lubricate the engine, particularly the critical bearing clearances. Combustion efficiency (and therefore power production), emissions, and component wear also suffer.

One thing to be careful of though, when designing your system and using a thermostat, is to ensure your water pump has an internal bypass circuit (refer back to #6 in the flow diagrams above). Most do, but some aftermarket high-flow racing pumps do not. For these pumps, a special thermostat with a bypass hole is used, or the user drills their own bypass holes in the thermostat (typically one to three 3/16" holes) so that the system can flow when the thermostat is closed.

If you choose to run without a thermostat, do not use a restrictor. The restrictor will do nothing for you except reduce coolant flow which ultimately reduces cooling.

Years ago restrictors were popular for two reasons that do not hold true today. First, as we have discussed, older radiator designs (large cross-sectional area copper tubes) were poor at promoting the necessary coolant turbulence in the radiator, so a restrictor was used to cause the coolant to begin tumbling as it exited the engine and entered the radiator. Secondly, with engines that had the thermostat located in the outlet of the engine combined with down-flow radiators that had a fairly low pressure radiator cap on the high pressure inlet side, if the thermostat was removed the increased pressure seen by the cap from the water pump could cause the cap's rating to be exceeded and the valve to open and purge coolant. Since this opening of the rad cap is what regulates system pressure, it meant that the overall system pressure would now be lower - the cap would open sooner than if the thermostat were in place holding backpressure in the cylinder head. Since system pressure was now lower, coolant vapour point was lower, and therefore the coolant's ability to effectively carry-off heat from the engine at higher temps reduced. This in turn would result in eventual overheating. Many folks erroneously assumed that the overheating was due to the coolant flowing through the radiator too quickly with the thermostat removed, that it didn't have time to cool in the rad. As a result, restrictors were used to "slow the flow of the coolant" and the car stopped overheating. Unfortunately, these folks didn't understand the real cause and effect of the overheating that they experienced after removing the thermostat, and this led to two enduring myths that persist today.

What was really happening was that the removal of the thermostat didn't cause the coolant to flow too fast to cool (we know this is an impossibility), but rather caused a condition where either system pressure (and therefore coolant vapour point) was lowered or where the rad purged coolant which caused the car to overheat. The end result was the same - the car overheated - but the cause and effect were confused and so the myths that a) removing a thermostat can cause a car to overheat and b) coolant can be pumped too fast through a radiator to cool properly began. Neither of these are true.

Of course, today's cross-flow radiators that locate the rad cap on the low-pressure side, do not subject the rad cap to the maximum pressure created by the water pump and so are not susceptible to the pump forcing coolant past the rad cap. We also know now that all systems benefit from maximum flow - never from reducing flow.

Ultimately, reducers reduce the flow of coolant which actually hurts system cooling efficiency, not improves it.

Plumbing & Bleeding

Coolant hoses should be as large as possible consistent with the diameter of the water pump inlet and outlets. radiator inlets and outlets should be spec'd to match. Small Block Chevys typically use a 1.5" engine outlet and a 1.75" water pump inlet. "LS" motors typically use a 1.25" water pump outlet and a 1.5" water pump inlet.

Where bends are necessary, they should be large radius bends. It is a good idea to use some sort of internal support inside a hose bend to prevent the hose from collapsing and reducing or shutting off coolant flow. High quality hoses and periodic hose checks and replacement are a must. If a fairly high pressure rad cap is used, consideration should be given to double-clamping all hose connections. The higher the system pressure, the more critical hose inspection and replacement become.

The use of stainless-steel braided hoses in the coolant system is actually a detriment to cooling as the outer metal braid serves to insulate the hose and trap heat inside. The use of all-metal pipe or hose is ok, as it will actually help to dissipate heat. So, all-rubber, or all-silicone, or all-metal hoses (with rubber connectors) are ok, but metal coated or sleeved rubber hoses should be avoided.

In addition, stainless-steel braided hoses with AN style fittings are often sold in kits with smaller ID than the standard hoses they replace. There's nothing wrong with AN style fittings per-se, but they should only be used with careful knowledge of the ID of the fittings and hose so as to avoid unnecessarily reducing the ID of the plumbing and thereby restricting coolant flow.

When filling a coolant system, either after maintenance or for the first time, there will always be some air trapped inside and it is important to bleed the system of this air. Here are some tips:

- The radiator cap must be the highest point in the system. If this can't be achieved on the rad, use a surge tank to remote-mount the rad cap.
- If you have an engine-outlet thermostat (as in a SBC), drill a small bleed hole in the flange of the thermostat to prevent air from becoming trapped under the thermostat on initial assembly.
- Trapped air and produced steam always seek the highest point. If you are fortunate enough to have "steam tubes" use them and plumb them correctly! Do not simply cap them off or plumb them back into

the system at a point lower then the cylinder heads.

- The cooling system will only achieve full system pressure when it is filled cold. A warm system contains coolant and trapped air that are already expanded due to the heat. If you open a warm system, fill it, and then seal it - when it cools the coolant will contract and you will not have a full system and the resulting trapped air will compress under the action of the water pump and prevent the system from achieving full system pressure.
- Never use an aftermarket thermostat housing that mounts the rad cap in the high-pressure (outlet from engine) side of the system - high water pump RPM will force coolant out of the cap.
- Makes sure the engine is in good condition and tuned up. This will cause your engine to work more efficiently and therefore produce less heat at idle and slow speeds. No mega-cooling system can make up for underlying mechanical or fuel/ignition problems. A too-lean condition is often found to be the underlying cause factor in an engine that overheats either at speed or at idle.

Electrolysis

Electrolysis is the name given to chemical changes that are caused by passing an electric current through an electrolyte. An electrolyte is a nonmetallic electrical conductor in which current is carried by the movement of ions. Coolant is an electrolyte. In a cooling system, the chemical change caused by electrolysis results in the stripping away of metal (aluminum ions) from the inside of the radiator. This damages and can eventually weaken and destroy the radiator. The use of dissimilar metals, particularly brass or steel with aluminum, as well as contaminates and corrosion in the coolant and the use of water with high trace elements all contribute to or compound the harmful effects of electrolysis. To prevent electrolysis and corrosion from damaging your cooling system you must:

- Use distilled water.
- Use an appropriate mixture of water and commercial coolant that contains corrosion inhibitors.
- Not use any brass components - especially fittings screwed into the radiator as brass promotes electrolysis in aluminum.
- Ensure that no electrical current passes through the coolant.
- Use nylon or rubber washers or bushings, to isolate the aluminum radiator from steel chassis mounting tabs and steel fasteners. Use stainless steel fasteners to mount the radiator on order to reduce the chance of electrolysis.

The source of harmful electrical current passing through the coolant can either be from the circuits of poorly grounded vehicle electrical components seeking ground (in which case the current will be DC) or from static electricity developed in the drivetrain components (transmission, transfer case, and axle differentials) seeking ground (in which case the current will be AC). Both are harmful.

Methods to eliminate current in the coolant and therefore electrolysis include:

- Ensuring that all electrical circuits are properly grounded.
- Ensuring that drivetrain components have an appropriate path to ground - especially if such components are mounted with rubber or other non-conductive isolators or bushings.
- Installing a ground strap from the radiator to the chassis.

In order to test for electrolysis, it is necessary to use a multi-meter to check for voltage in the coolant. The procedure is as follows:

To test for DC voltage:

1. Connect the negative test lead of the meter directly to the ground terminal on the vehicle's battery.
2. Set the meter to display from 0-15 volts in tenths of a volt.
3. Have an assistant hold the positive probe of the meter's positive test lead in the coolant and make sure it touches only the coolant.
4. Take a reading with everything off.
5. Crank the engine and take a reading when the starter is engaged (turning over the engine).
6. Start the engine and turn on every single electrical system. Take a reading with the engine running and all electrical devices operating.
7. In all the tests listed above, if voltage reads from 0.0 to 0.3 volts in an iron block engine, or from 0.0 to 0.1 volts in an aluminum engine, you shouldn't have a problem with electrolysis. Readings as low as 0.5 volts in an iron engine or 0.2 volts in an aluminum engine are cause for concern and must be corrected.

If you detect DC voltage in the coolant using the above test, you will need to repeat the test as you systematically switch off electrical systems one by one in order to isolate the circuit that is at fault. Once the circuit is isolated, you must correct the improper grounding situation in that circuit.

There is no real practical way to test for AC voltage generated by static electricity, unless you have access to a chassis dyno. Grounding each of the drivetrain components is a good preventative step.

Finally, if you detected current in the coolant, after correcting the electrical problem, always change the coolant as it will have been damaged by the current.

Myths

For those that cling tenaciously to myths, I am going to take one last crack at forever dispelling the Granddaddy of them all when it comes to cooling systems.

The myth is stated as either:

1. Coolant can be pumped too fast through the engine for it to absorb enough heat, or
2. Coolant can be pumped too fast through the radiator for it to cool properly, or
3. Cooling can be improved by slowing the flow of coolant through the radiator so it cools more completely.

NONE of these is true. The simple truth is that higher coolant flow will ALWAYS result in higher heat transfer and improved cooling system performance.

The reason the myth is so persistent, is that: a) without knowledge of fluid dynamics and laws of thermal conduction it does make a kind of intuitive sense and b) it is based on a tiny kernel of truth, but that kernel of truth does not explain the overall system behaviour and so, interpreted out of context, leads to a completely erroneous conclusion.

So, let's start with the tiny nugget of truth. If you had a sealed rad (no flow) full of hot coolant, and subjected that rad to airflow, yes, the longer you left the coolant in the rad, the more it would cool. However, if you were to plot that cooling over time, you would find that the RATE at which the cooling takes place is an exponential curve that decreases with the temperature difference between the hot coolant and the air. Put another way - when the temperature difference (delta-T) between the hot coolant and the airflow is large, heat transfer (cooling) initially takes place very, very quickly (almost instantaneously). But as that happens, and the coolant cools, the delta-T becomes less, and the RATE at which further cooling happens gets less and less until the point where the coolant and air are almost the same temperature and continued cooling takes a very long time. This is Newton's law of cooling. To illustrate this, recall my "quenching steel in a bucket" analogy.

> A good example of this law can be seen when quenching a red-hot piece of steel in a bucket of water. At first, the temperature difference (delta-T) between the red-hot steel and the water is huge - therefore the initial heat transfer occurs at a great rate - the steel initially cools very fast - almost instantaneously. However, after this initial cooling, the delta-T is much smaller, so the remaining cooling occurs much more slowly. If you removed the steel after a second or two - it has cooled a lot - but it will still be warm. To continue cooling the steel to the temp. of the water, you have to leave it in there quite a bit longer - because as it cools - the **rate** of cooling continually decreases as well. In short - initial cooling is fast, but subsequent cooling occurs more and more slowly until cooling that last little bit takes a long time.

So what does this mean? Basically it means, the longer the coolant stays in the rad, the **less efficient** the cooling that takes place is - to the point that the rate of cooling is so slow as to be **detrimental to overall system cooling**. Better to dump the big load of heat right away and go back quickly for another load than hang about waiting for a last little bit of insignificant cooling to happen.

To understand fully, we have to put our rad back into the whole system where coolant is flowing and consider the effects of flow rate on the system as a whole.

Slowing the coolant in the rad may allow that coolant (the coolant in the rad) to dissipate a little more heat (but not much), and at an ever decreasing rate (exponentially decreasing) BUT since the cooling system is a closed-loop system, you also have to consider what's happening outside the radiator if you slow the flow - especially to the coolant in the engine. If you slow the coolant through the rad, you slow the coolant through the engine too. And this coolant is subject to the same laws - the greater the initial temperature difference between the engine and the coolant, the greater the rate at which the coolant absorbs the heat from the engine. BUT - if we leave the coolant in contact with the engine for longer by slowing the flow through the rad, the delta-T between engine and coolant decreases and with it the rate at which the coolant in the engine absorbs the heat from the engine. Meanwhile the engine is banging away producing heat, but the coolant is absorbing it at a slower and slower rate - that heat has to go somewhere, and since the slow coolant is becoming less efficient at absorbing it - it stays in the metal - and the metal overheats!

Meanwhile, back at the rad, you're wasting time trying to shed the last little bit of heat when the delta is small instead of carrying away the “big chunks” of heat. And the situation just gets worse and worse in a downward spiral.

Imagine emptying a truckload of sand using a small wide-mouth container vs. a larger narrow-mouth container. The job will get done quicker by making more trips with the smaller container that takes less time to fill and empty, rather than taking the time to fill the larger narrow-mouth container and then taking the time to empty it – that extra in the larger narrow-mouth container isn't worth it – better to dump the load and go back for more.

Or, how about this for those who are fans of elaborate metaphors

Imagine a circular train track with two stations opposite each other and rail cars that fill the whole track. One station has an endless supply of passengers trying to get on and the other is where they get off and disperse. Your job as the train driver is to move as many people as possible to keep them from accumulating at the embarkation station and crushing each other. Now imagine the passenger cars are funnel-shaped on the inside. This means the first big batch of people can get on and off quickly, but completely filling the car takes a lot longer as people have to squeeze into the narrower portion.
So, you could drive the train slowly, only moving along after each car has completely filled and completely emptied… but efficiency will be greatly reduced as it takes so long to get those last few people on or off the car – meanwhile the never ending supply of people at the embarkation station never stops and the system backs up and the people get crushed because, even though more people get on or off each car, the whole system is less efficient.

OR

You could drive the train fast, quickly loading and unloading the big, easy-to-fill, portion of each car, forget about the smaller portion, and keep picking up and dumping off a large group of passengers as fast as you can. In fact – the faster you go, the better…the more efficient at moving large numbers of people the system will be. Screw the last stragglers – they're insignificant and won't help you – just move the big chunk and move on, going back for more, more often.

So – you want high flow / high (turbulent) speed so it picks up and dumps off the most heat quickly – it's inefficient to try and shed the last little bit of heat when the delta is small, and can lead to overheating because you're wasting time not carrying away the “big chunks” of heat.

Griffin Thermal Products "King of the Hammers" Rad Review

Now that you are all cooling system experts - you are finally ready to see and appreciate the awesomeness of the best offroad radiator money can buy - the

Griffin Thermal Products "King of the Hammers" Radiator

For those that may be unfamiliar, the name is taken from the name of the toughest, most gruelling one-day off-road race in the world - the King of the Hammers (KOH). You can learn more about the race at the official KOH

website. Suffice to say, the race is absolutely brutal on equipment, notably cooling systems, and the Griffin KOH rad was specifically designed and developed to cool offroad race rigs under the brutal onslaught of hour after hour of combined desert racing and tortuous rock crawling!

In short - it is one hell of a radiator built for the toughest job a radiator can be asked to do - here's a look:

The first thing you need to know is that Griffin is a true manufacturer. Almost anyone can buy components and assemble a radiator, and the truth is that a lot of so-called "manufacturers" do just that. Griffin is an integrated manufacturer. They make the tubes, fins, headers, side bands, mounting brackets and tanks. By controlling every step of the manufacturing process, they produce a radiator with components that are performance matched for optimum cooling capability. A Griffin is more than some off-the-shelf, one-size-fits-all, cookie cutter product. It is a performance radiator made to meet the customer's specific application.

The other thing you need to know is that Griffin manufacture a huge range of radiators to suit many needs and applications - from budget replacement models to custom race radiators like the one I'm about to show you. As such, after reading and digesting this article, the first thing you need to do is call and speak to the appropriate expert about your needs and application.

To talk off-road applications and about the KOH rad, call Vice President Tom Beebe and / or Off-Road Sales Tech Benji Durham who are both reachable at 1-800-RACERAD and 1-864-845-5000. Tell them I sent you and they will take care of your questions and needs.

After speaking to them, if you decide to have a KOH off-road race radiator custom built for you like I did, the first thing you need to do is provide them with a diagram of what you need. They told me they accept everything from full CAD drawings to doodles on the back of a bar napkin - but obviously the better your diagram the more quickly they will be able to produce your radiator.

That's because, after deciphering your diagram, the first thing they will do is send you a proper engineering diagram of what you have requested for your approval.

Only after you have approved, signed, and returned the diagram will they build your custom unit.

I ended up humming and hawing over options and what I wanted and we sent the diagram back and forth a few times as they made the changes I requested each time I changed my mind or thought of something else.

Never once did they loose patience with me.

This was my old setup with a puny 28x16 rad.

Not only was it not going to cool the new LS2, but looking back it wasn't really the prettiest looking front end either.

As I mentioned earlier, after some head scratching I decided that, instead of fitting the biggest rad I could, I would re-do the front end to fit the rad I wanted - which was approx. 31"x19".

I wasn't kidding when I said I cut the whole front end off...

... not kidding at all!

First came the basic re-design to fit the size I wanted.

And it looks like I was enjoying myself back then - you know - the way you do at the beginning of a project!

Then, before making and sending my initial drawing to Griffin, I did a bunch of test fitting with a drywall-and-2x4 mock up to get the exact dimensions I wanted so that the rad would tuck nicely into the chassis.

A couple of 2x4 blocks were used to hold two pieces of drywall apart at the right distance to simulate a 3" thick radiator.

I knew I wanted to lay the rad back a little, to prevent it from sticking way up in front.

But not so much as to induce flow problems.

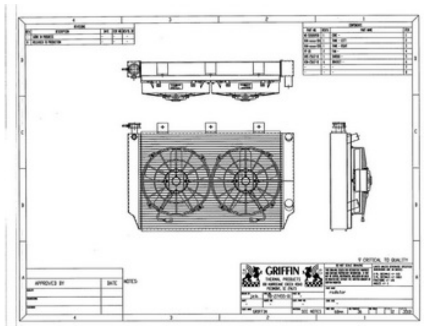
I settled on about 20°, and the top engine cover cradle was bent to clear the mock-up rad at the right angle.

Now I was committed!

To get the height and angle exactly where I wanted them while maintaining as large a surface area as possible...

... the lower end of the tanks would have to be notched to fit between the frame rails.

At this point I was sure hoping that Griffin hadn't overstated it when they said they could build anything I could draw!



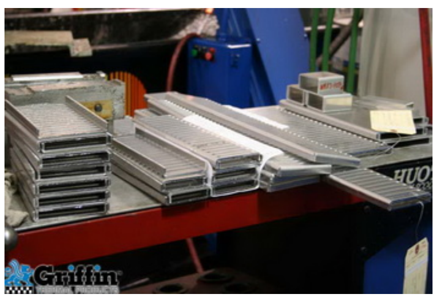
After sending them my chicken-scratch drawing, they produced the engineering diagram and we sent it back and forth a few times as the details were finalized.

Here is my final approved diagram.

And they hadn't overstated anything - sure enough they were going to build me my rad exactly as I had wanted!

Note: Some detail and the dimensions have been removed from the diagram at left to prevent unscrupulous entities from knocking-off Griffin's products. The actual diagram you get is full-blown engineering diagram with all the dimensions.

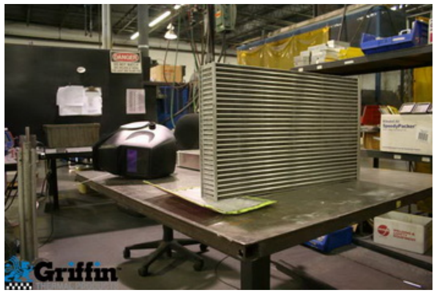
With the diagram approved - Griffin set about building my rad. Here's a look behind the scenes:



Here are the CNC'd headers.

Here is the core assembled, post washer, and just before going into the braze oven where it will be vacuum brazed with a magnesium based cladding.

Here's the core heading into the 1200°F braze oven.



Here's the core after the braze oven, completed and ready to have the tanks TIG welded on.

Here are the raw materials used for the C-channel tanks.

Here the radiator is being TIG welded together.

The radiator tank material for the KOH radiator is 0.125" thick.

Here's an interesting tech tidbit that you wouldn't know from reading most other manufacturers marketing material.

A lot of so-called manufacturers (most of whom are actually just "assemblers") like to make a big deal about not using any epoxy in their construction. The thinly-veiled insinuation is that those who do are somehow using an inferior process to "glue" the radiator together. If you don't know any better, they make it sound as if the mere mention of epoxy signals some cheap throw-away product. What they don't bother explaining is what epoxy use is really about. So here's a little useful tech on the subject.

First, Griffin's core is always welded to the tank. Griffin does not use any glue in the manufacturing process.

Second, at Griffin, epoxy is a secondary process applied to *some* radiators to increase durability. All Griffin radiators are vacuum brazed with a magnesium based cladding. The purpose of the epoxy is to relieve the shear stress on the tube-to-header braze joint to ensure a long leak free life for radiators used in extreme conditions. The common misconception is that epoxy is used to “glue” radiators together. Some manufacturer's may do this, but Griffin does not.

And remember, because they make so many different types of radiators for so many different applications from race cars to locomotives to aircraft, and because they manufacture everything from scratch in-house, they use many different designs and techniques, depending on the product in question, and not all use epoxy. In fact, my KOH radiator does not use any epoxy at all in its construction - I'm just making a meal out of this issue because it's a perfect example of the type of misinformation contained in marketing hype passed off as "tech" by so many companies that ticks me off so much it's one of the reasons I got started in writing tech articles in the first place many years ago.

Phew - I feel better now!

And here is the shroud that has been punched and formed and is waiting for the the addition of fans, followed by installation on the radiator.

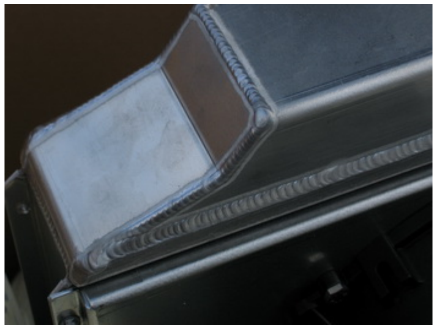
A short time later, this giant box arrived in my driveway.

Inside was a very carefully packed radiator, some instruction sheets, and a rad cap taped to the inside of the box.

Rad cap.

The rad cap is a cool blue colour stamped with the Griffin logo.

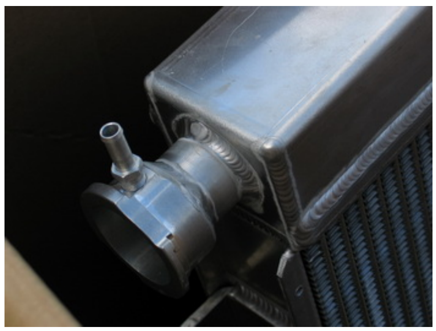
The radiator was well protected for its journey.



Before I even got it out of the box I started snapping pictures of the awesome build quality.

This is the notch in the tanks I requested to clear the lower frame rails.

The quality was evident immediately.



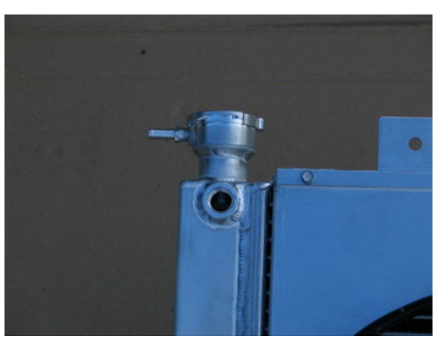
And everything, including the location of the filler neck and the orientation of the overflow tube was exactly as I has spec'd.

Out of the box at last, it was an awesome piece.

Here are the details:

- 31" x 19" aluminum single-row, cross-flow, dual-pass (aka dual-flow) KOH race radiator using a single row of 68mm high-tech extruded 3000 series aluminum alloy tubes with patented ported Micro Extrusion construction and 12 fins per inch for offroad durability and enhanced fluid turbulation.
- Standard filler neck, 17PSI rad cap, overflow tube pointing left.
- Chevy dual-pass style inlet and outlet (both on right-hand side).
- LS steam tube port located just below filler neck.

Here's a detailed look:

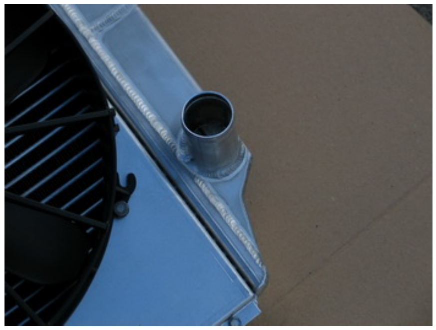


Filler neck on left-side tank.

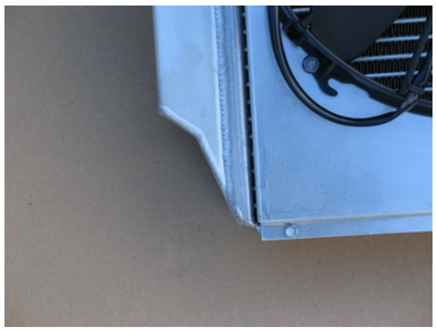
3/8" NPT port to which I will connect my LS2 steam tubes.

The port is larger than needed for connecting the steam tubes, but I chose this size so that I can convert from an overflow tank-only setup to a surge tank setup later if I need to. The 3/8" port is large enough to be plumbed to the surge tank. Of course, I would need to cap off the filler neck too.

I'll be honest - the only reason I didn't plan on a surge-tank setup from the outset is that my front-end re-design didn't make allowances for the room needed to mount a surge tank, and that only because, at the time I did the design, I didn't yet fully understand all the benefits of a surge-tank setup. If I were to start over, I would plan a surge tank from the outset - but at least I had the foresight to order a large enough port to support a surge tank in the future.

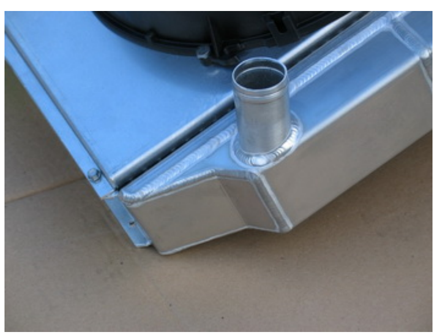


1.5" radiator outlet on lower right tank.



Custom notch to clear tubular frame rails.

1.25" radiator inlet on upper right tank.

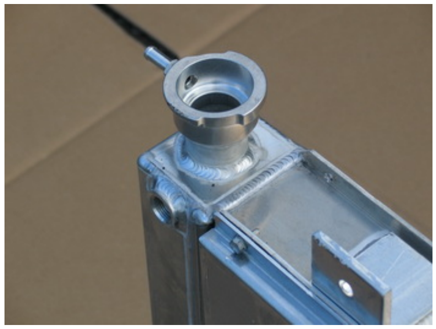


Notch and outlet.

I ordered the inlet and outlet to be installed at an angle, so that they would be level (horizontal) with the rad installed in the chassis and leaned back 20°.

Griffin were happy to oblige.

Aluminum mounting bracket welded to upper channel.



Filler neck.

These are no ordinary tubes.

They are constructed using the latest aluminum extrusion technology, for added flow, cooling, strength, and overall durability.

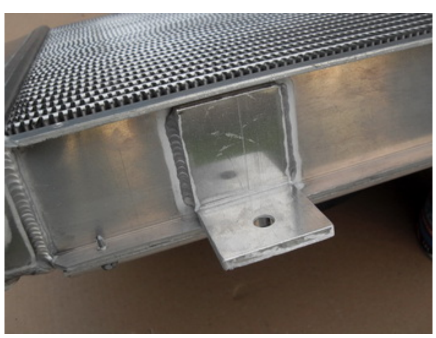
Inside, where you can't see, they are ported to enhance fluid turbulation. It's a patented design they asked me not to photograph, but I can tell you it's damn cool!

Also note the 12 fins per inch design.

Extruded tubing is the newest and most exciting thing to happen in the cooling world, especially for off-road use.

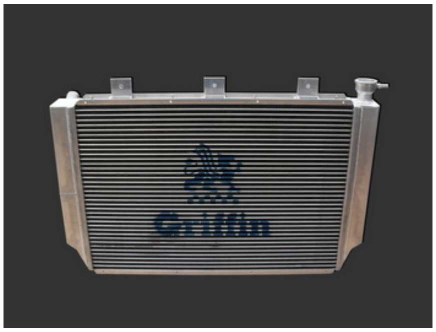
As an example, these new extrusions are so superior to older-style tubes that a single row of tube is equivalent to two older-style rows of tubes, and is much more durable and ridged for all of the hard hits off-road use can dish out.

My KOH radiator uses single rows of 68mm extruded aluminum tubes for maximum cooling performance.



Another shot of one of the upper mounting brackets.

Top-front view of the complete rad.



Front view.

Side view.

The rad is 3" thick.

With the shroud and fans it is a total of 7.76" thick.

The fans are twin 305mm (12") SPAL VA01 - AP70/LL - 36A electric axial motor paddle-blade high-performance individually balanced units with sealed waterproof motors.

The complete spec sheet for the fans reveal that, combined, they pull 3280 CFM.

Here's the complete flow chart, taken from the spec sheet and converted to Imperial units.

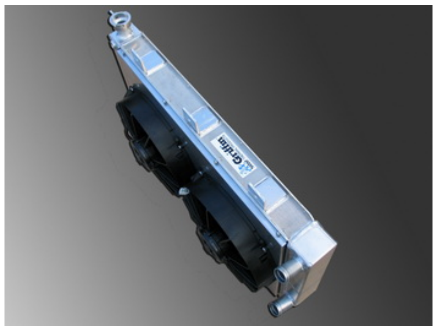
Static Pressure (PSI)	Airflow (CFM) one fan	Airflow (CFM) Combined fans	Current draw per fan (Amps)
0	1640	3280	16.5
7	1493	2985	17.4
14	1316	2631	17.7
21	1062	2124	17.9
28	702	1404	18.7
36	502	1003	20
43	366	732	20.9
50	195	389	22.1

57	0	0	22.8

As an example of why it pays to deal with the experts at Griffin, and why when they say they build to suit your application it isn't just some marketing drivel, is the fact that I originally asked for larger fans that were rated at even higher CFM.

Griffin persuaded me that this would not be the best option, as this particular model of fan from SPAL is much more rugged than the model I had originally asked for, and is far better suited to operating in the punishing offroad environment.

It's nice when experts take the time to keep you from making a mistake instead of just selling you whatever.



SPAL have this to say about the VA01 - AP70/LL - 36A

> *From our High Performance fan line this fan is designed for industrial and extreme off-road applications. It has a very rugged design with an aggressive paddle blade. It is a radiator fan that is sometimes used in pairs. It is also used in oil coolers, AC condensers and intercoolers. It features a fully sealed motor that is waterproof/dustproof. Each fan is individually balanced for long life.*

In addition, Griffin explained that they are recommended for offroad use due to the rugged design. They will not deflect under the shock as much as the other fans. These fans are also very close in performance to the larger fans due their larger motors and aggressive blade pitch but they are better suited to the harsh offroad environment.

I will be controlling the fans via the MEFI-4 marine fuel injection ECU that came with my Turn Key Engine Supply LS2 as it is already equipped to control dual electric fans.

The following gallery of pics should allow you to come as close as possible to appreciating the quality and craftsmanship evident in the Griffin KOH radiator. When you're done lookin' - go order your own - you WILL NOT be disappointed!