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COOLING A HOT OFF-ROAD REALITY

If I can't make the following statement with absolute authority nobody can. It's a fact. As the founder one of racing's most renowned and experienced component manufacturers that specializes in the art and science of engine cooling, let me state once and for all that off-road racing is one of the toughest forms of motorsports on the planet. I don't care what form of racing you compare it to, today's off-road environment is as specialized and nearly as sophisticated (especially when you consider the fact it's almost entirely funded by enthusiasts or comparatively small, non-factory sponsorships) as anything else, and becoming more professional all the time.

The overused cliché that this form of racing is the ultimate test of man and machine isn't just hype. It's a truth that I have personally experienced in this sport's incredible punishment and also one of its most consistent challenges – the overwhelming reality of having to cool the off-road beast.

Engine cooling is always a factor in the pursuit of ultimate racing performance. Heat is a byproduct of making horsepower and also in making that horsepower live to see the checkered flag. Now take that racing constant into a brutally hot environment like Baja, the Nevada desert or even a high-rpm environment like short-course racing and the need for understanding the basics of engine cooling becomes painfully clear. Indeed, a very crucial element to getting the most out of any race car with reliable consistency is the cooling system. From my experience, it's also a system that many race mechanics, regardless of the machines they work on, surprisingly do not totally understand.

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While we have strived to keep the Competition Corner of *Dirt Sports* as unbiased and objective as possible, the fact is that my company, C&R Racing, specializes in building racing radiators for the top motorsports series in the world. Most every team in NASCAR runs our cooling systems and we also have radiators in IRL, Grand-Am, ALMS, NHRA, ALMS and other professional racing series. In recent years, C&R cooling systems have also found their way into a growing number of off-road machines.

I share this information with you in the interest of keeping my section of *Dirt Sports* as honest and balanced as possible. The cooling principle's that you will find below are not intended to reflect my opinion from a C&R corporate stand-point, but rather from my interest in sharing some valuable insight gleaned from decades of real-world, hands-on experience.

For the past several years, I have had the pleasure of prerunning and racing several desert races including the Tecate SCORE Baja 1000. Those were huge eye opening experiences and I was able to see many things regarding cooling that need closer attention given the sport's harsh environment. I hope you can take away many cooling tips from my experiences.

THE OVERALL OBJECTIVE

Simply stated, the overall goal any good crew chief or fabricator is seeking in engine cooling is to get efficient heat rejection by incorporating the correct components for the application at hand. Heat is measured in BTU's and the more horsepower generated, the higher the BTU's. Other factors that affect heat generation are fuel mixture and ignition timing.

For off-road racing applications, there are several areas that I would strongly suggest to make a bulletproof cooling system. Start by making sure the water pump will flow at least 50 GPM through the cooling system. A high-flow electric fan is a lifesaver. After all, air is the key to rejecting the heat energy generated by the engine. We have special high-flow fans from Spal that are the most efficient electric fans made for the harsh environment of racing. The third component that will keep the water in the system and prevent overheating is a properly pressurized system. Keeping the pressure in the cooling system is also very important to making it through those extreme situations. And, of course, a properly sized radiator with the right fin density and tube size is the most critical part of the system. Every application is different and obviously a rock crawler is in an entirely different environment than a Trophy-Truck.

THE RADIATOR

The key component to the cooling system is the radiator. Many things need to be considered when finalizing the right radiator specifications to meet individual applications. To determine this spec, we use an engineering formula that incorporates the BTU's created by the vehicle's engine, the air velocity that the radiator will see and the water flow rate. Based on these calculations, we can determine an optimum radiator configuration for the vehicle, which is usually just a bit larger and will fit into a chassis configuration. Like anything, many times racing is all about balancing many compromises.

A radiator is really a simple part. Basically, water flows through a tube with its heat transferring into the cooling fin. Air flow through the fins carries the heat out of the core. It's all based on the amount of surface area of the tube and fin. Inside the fins are small louvers that help reject the heat into the air stream. Although radiators are simple in principal, there is still a tremendous amount of engineering that goes into a top-level racing design.

Today, racing radiators are made of aluminum. Aluminum radiators are more efficient than copper and brass primarily because they are brazed from the same parent material thus creating better heat transfer. Many will argue with that statement because copper is a better conductor of heat. The problem with copper/brass radiators is the copper fin is brazed to a brass tube using lead solder, which in turn reduces heat transfer to the copper fin.

Many times we double pass the radiator. In other words, we weld a baffle in the radiator tank on the inlet side that splits the core in half. Therefore, the water will flow through the core twice. This serves two purposes. First of all, the hot water will see cool air twice before going back into the engine. The second advantage to a double pass is that it increases water velocity through the core, creating more turbulation inside the radiator tube, thus increasing heat rejection. This turbulation is the biggest advantage to double pass.

If a very strong, high-flow water pump is used, and you have at least a 65 Gallon Per Minute (GPM) flow rate through your cooling system, a single-pass radiator will be more efficient. A single pass will have the inlet from the engine on one tank and flow the water through the entire core and return to the pump from the opposite radiator tank. As you'll soon discover, a high water flow rate will create the velocity and turbulation needed for the most efficient level of heat rejection.

COOLING FANS

An efficient cooling fan is very important, especially in off-road applications that too often combine high horsepower and very low air speed due to digging through silt beds or climbing steep grades. In the past, mechanical fans had the highest air flow available. But today, electric fans have advanced to the point of being equal to their mechanical counterparts. In many cases, they are better from the standpoint of providing greater air flow at low engine RPM's. The other advantage of electric fans is that they mount to the radiator, which allows radiator mounting to be optimized for the best chassis location. In contrast, mechanical fans limit the radiator's mounting position relative to the engine. There are electric fans that can pull up to 3200 cubic feet per minute of air through the core, which is usually enough to keep temperatures in check during low-speed, high-temperature off-road running.

WATER FLOW RATE

Research has shown us that water flow rate is very important to a cooling system's overall efficiency. Contrary to old-school thinking, the higher the water flow rate the better the cooling. Flow rate is regulated by the size and speed of the pump, restrictions in the engine water passages, radiator size and plumbing. High-flow rates provide two benefits; insures good pressure in the combustion chamber area of the cylinder heads and raises water velocity flowing through the radiator tubes. The higher the velocity through the cooling tubes, the more turbulence in that tube, which equates to increased heat rejection. Good water pumps will flow up to 100 gallons per minute (GPM) when unrestricted. With cooling system restrictions, your pump should be capable of at least 50 GPM. Remember, a good flow rate will help keep temperatures in check when conditions are adverse as they are in off-road racing. Don't forget to look at the manufacturers recommended pulley and pump speed.

AIR FLOW

The second most important ingredient to proper cooling is air flow. Without air even the greatest radiator in the world is merely a water reservoir. Heat rejection relies on the volume of air available at a given air speed (velocity) to pull the heat out of the radiator. Attention to detail on ductwork, radiator fin density, and good cooling fans are vital to insuring sufficient airflow through the radiator.

SIZE MATTERS: The correct combination of radiator size, density, and proper flow make all the difference especially in severe applications like off-road racing.

It's important to realize that radiator fin density is yet another key piece of the cooling puzzle. For instance, in NASCAR, we provide a very dense radiator to run at places like Taladega where top speeds are reached. In that application, the radiator may have 28 fins per inch (fpi). It takes a lot of air speed and velocity to get enough air through a core that tight. That same radiator core would be wrong in a Trophy-Truck or any other off-road application for that matter.

This concept is really simple to understand. Remember, air follows the path of least resistance. If the radiator core is too restrictive, air will find another place to go, like over the hood or around the sides. We recommend a 14 to 15 fpi core for most off-road applications. Finally, sealing the radiator's incoming ductwork to insure all available air is being forced through the radiator is also very important.

PRESSURIZED COOLING SYSTEMS

Unlike most off-road installations I have seen, most of today's professional cooling systems utilize pressurized technology.

What is a pressurized cooling system and how does it work? In essence, a pressurized system eliminates an old-fashioned radiator cap by incorporating a more accurate PRV (pressure relief valve). The PRV is set at approximately 36 to 40 psi, which adds about 12 psi to a cooling system via an accumulator (a really a fancy header tank). With the added pressure in the system, the boiling point will be at least 290 degrees depending on the vehicle's atmospheric altitude. This cooling system upgrade is fairly simple to do if the proper components are used and the correct installation procedures are followed. Most crew chiefs and fabricators in the off-road world are still confused and a little gun-shy about incorporating a pressurized system into their high horsepower race and prerun vehicles.

Why has the rest of the motorsports world adapted this cooling system? Consider this; by adding pressure to the cooling system, the boiling point is raised. This doesn't lower operating temperatures but instead allows an engine to run at higher temperatures. In off-road applications, a modern pressurized system provides a much larger margin of safety to prevent overheating.

Still don't understand? Let's say you're racing through a long silt bed in low gear, screaming that high-horsepower engine to big RPM's but still only going 10 mph. There is little

UNDER PRESSURE: A pressurized cooling system like this C&R unit is the real deal and can significantly raise the boiling point insuring water stays in the cooling system. Next month, we'll share how we installed one in our Alumi Craft Plug N' Play.

air flow through the radiator and the water temp is climbing. With a typical radiator cap at 220 degrees water weeps from the overflow, system pressure drops, and soon water starts to boil in the cylinder heads. The problem eventually magnifies and you end up with water shooting out of the overflow like a tea kettle.

But, in a pressurized system, the added pressure raises the boiling point insuring that water will stay in the cooling system while allowing the engine to run much hotter without losing power. This is why it's important to keep pressure in the engine. The added pressure keeps the air compressed, the combustion chamber wet, and eliminates damaging hot spots, thus allowing higher operating temperatures without losing power from detonation. In NASCAR, we have many teams that will tape off the grill until they are running temperatures around 260 degrees, and they can race at those engine temperatures for 500 miles thanks to the use of pressurized cooling systems.

Another important part of a pressurized cooling system is to have a radiator core that can handle the added pressure. When adding pressure over what the cooling system would normally see from typical temperature expansion, the core is going to see higher operating pressures as well as higher spikes on the inlet side of the core. Because of sudden RPM changes, the inlet side of the radiator can see pressure spikes as high as 55 psi. With this in mind, the core used for a pressurized cooling system should be able to operate at least around 60 psi without swelling the tubes.

HEAT EXCHANGERS

Basically, a radiator or oil cooler is a heat exchanger. Throughout the industry, heat exchangers are often referenced when talking about oil to water coolers. An oil to water heat exchanger is used by flowing oil through a heat exchanger core that is cooled by the same water cooling the engine. The oil heat is transferred into the water and rejected through the water radiator. Oil to water heat exchangers are a very efficient way to cool engine oil. They provide consistent cooling of oil regardless of ambient temperature, and can be mounted in the radiator tank, which simplifies the engine compartment. This takes them out of harms way, which make them even more appealing for off-road use. I feel oil coolers are very necessary for most types of racing, but in the case of off road, I highly recommend using oil to water heat exchangers.

CARE AND MAINTENANCE

For starters, keeping a high-performance radiator clean, inside and out, is critical. It's easy to see dirt that's collected on the outside, but don't forget about the inside. Mineral deposits and engine block rust are very detrimental to proper heat rejection, and anything that coats the surfaces of an aluminum radiator will also hamper heat transfer. Using distilled water and a good anti-rust corrosive like Water Wetter will help keep the radiator clean. Also, always make sure the electrical fans are working properly as part of your pre-race prep list.

If you use Stop Leak, which many do, make sure that you flush the radiator immediately after draining water out of the system. Stop Leak relies on air to coagulate its liquids and do its job. Most Stop Leak-type additives contain some type of ceramic, which is a great insulator. When water is drained from the system, this residue will be everywhere; in the tubes of the radiator, the cylinder heads and the block. Having these metal surfaces clean with no ceramic residue is important. You don't want an insulating barrier like ceramic between the coolant and the metal surface.

Making sure air is totally bled from a cooling system is also critical. The best system in the world is only good if the air is bled out. A good header tank or pressurized accumulator will help with bleeding. Having a controlled air space, like we create with a pressurized system, is important. It creates an air spring that will compress during temperature expansion. It also has a sight glass that lets you see the level of the water and check for trapped air. When pressure is applied, if the water level in the sight glass moves there is still air in the system and it needs to be bled more thoroughly.

Cooling off-road machines isn't easy. Attention to detail, choosing the right system and proper maintenance are critical to making it across the finish line. DS

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