Fall 2019

Dear No-Rosion Customer,

This summer's heat was a test for the efficacy of your car's cooling system. Hopefully it passed!

In past newsletters, we've addressed the topic of **electrolysis** – the havoc it wreaks, and the evasive nature of this beast. There have been some updates in this area, making it worthy of a second look.

Electrolysis occurs when electrical current routes itself through engine coolant in search of an electrical ground. It is best categorized as falling under one of two general classifications:

(1) **"Stray Current,"** caused by an improperly grounded underhood accessory as a result of fraying, shorting, or completely disconnected wire/cable.

(2) **"Galvanic Action,"** caused by dissimilar metals in a cooling system that transfer electrons by using engine coolant as an electrolyte solution.

The best way to determine which type may be plaguing your system is to quantify the current present by using a digital D.C. voltmeter. This is accomplished by connecting the negative probe to the battery's negative post, then submerging the positive probe into the coolant – being certain the positive probe does not touch any metal. Once you have an accurate reading, you can use the following rule of thumb:

< 100 mV	= No/negligible electrolysis
100 mV – 300 mV	= Galvanic action electrolysis
> 300 mV	= Stray current electrolysis

Electrolysis is destructive – in most cases, more so than corrosion. It is faster acting, and in the case of rampant stray current electrolysis, can zap its way through an aluminum radiator in a matter of weeks or even days. Worst of all, you usually don't even know it is happening until it's too late, and you've sprung a leak.

The vast majority of damage resulting from electrolysis occurs with aluminum radiators. But first we need to take a step back, and realize that referring to a radiator as "aluminum" is somewhat of a misnomer. What is commonly referred to as an "aluminum" radiator is actually an alloy, of which aluminum is the primary constituent (at least 85% by mass). Other metallic elements in modern alloy radiators include magnesium, manganese, copper, tin, and zinc – as well as the non-metallic element silicon.

Alloys in today's radiators are becoming increasingly "complex." What do we mean by *complex*? Technically speaking, an alloy's complexity relates to the microstructure of intermetallic particles bound between multiple, metallic elements in an alloy. Simply stated, the more elements an alloy contains, the more complex it becomes.

For radiator manufacturers, the advantage of increasing an alloy's complexity is higher tensile strength. This allows radiators to be made with thinner tubes/fins, which enhances heat transfer and reduces weight. Good in theory, but the reality is slightly different. Complex alloys are more electrochemically active on an intragranular basis, due to slight differences in electronegativities of each of the metallic elements bound together in an alloy. A metal's "*electronegativity*" is a measure of its tendency to pull away electrons from other metals. **This makes today's complex alloy radiators more reactive than less complex alloy radiators of the past.**

Worse yet, by having thinner tubes, today's complex alloy radiators take even less time for electrolysis to fully penetrate their surfaces and cause pin hole leaks. Net, by being more reactive, and thinner, the life expectancy of modern alloy radiators is shorter than ever.

What are some tell-tale signs of electrolysis? If a cooling system continues to build pressure even after it has cooled, and you hear "gurgling" inside the radiator when the engine is not running (this is off-gassing), and/or you find a white powder (aluminum oxide salt) in your engine coolant, then you probably have electrolysis.

When electrolysis strips electrons from an aluminum-containing alloy, aluminum oxide salt is formed. The chemical equation for aluminum oxide formation is:

$$\mathbf{2Al + O_2 + H_2O \xrightarrow{(current)} Al_2O_3 + H_2}$$

Where:
- Al = Aluminum (from alloy)
- O_2 = Oxygen (from dissolved oxygen in coolant)
- H_2O = Water (from water in coolant)
- Al_2O_3 = Aluminum Oxide (white salt)
- H_2 = Hydrogen (off gas)
- Current = Catalyst (from electrolysis)

Electrolysis will create pinholes that eventually penetrate the full thickness of alloy radiator tubes, causing a leak. Even if you replace the failed radiator with a brand new one, the situation will repeat itself over and over until you identify the source/cause of the electrolysis, and mechanically correct it. But how?

Begin with the digital D.C. voltmeter to determine whether it is being caused by stray current or galvanic action.

Stray Current – Before the days of alloy radiators and electric fans, stray current was a less frequent problem. But now we see it more than ever. The two most common causes are: (1) poor ground to the radiator's electric fan, or (2) a poor ground from the starter motor/engine block to the battery. Inspect both of these for obvious signs of shorting, fraying, or disconnects that may result in improper grounding.

Absent any visual indicators, the next step is to methodically shut off or disconnect one electrical component or accessory at a time, while watching the voltmeter. When the voltage reading drops, you've found the source with the defective or missing ground. Since electrolysis may occur only when a certain component is energized, have a helper switch each component on/off while you observe the voltmeter. Do all testing with hot coolant.

To check components or accessories that don't have an on/off switch, use a long jumper wire connected to the battery's negative post to provide a temporary ground to each electrical accessory. Ground each component with the jumper wire and watch the meter. If the jumper restores a missing/faulty ground, the meter will drop.

Be sure to check for voltage surges caused by the starter during cranking. To do so, watch the meter while you crank the engine. A jump in voltage during cranking indicates a loose, faulty, or missing engine ground. Any electrical device with a current draw, like a starter motor or radiator fan, will cause damage to a cooling system much quicker than a trickle of voltage from a poorly grounded under hood relay or other low-amp device.

Identifying the source of stray current can be an arduous process. The key is: Don't give up!

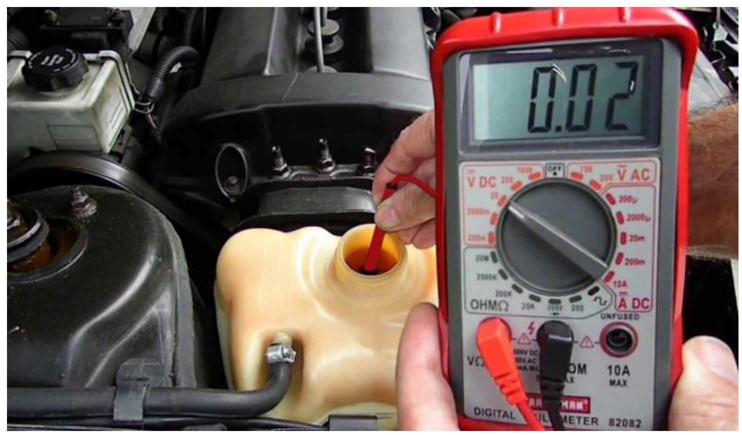
Remember this: ELECTRICAL CURRENT ALWAYS FOLLOWS THE PATH OF LEAST RESISTANCE. Current uses coolant as a convenient pathway to return to ground, since it offers less resistance than an imperfect ground connection. This is why you do **NOT** ground an alloy radiator. Rubber radiator mounts are not only intended to reduce damage from vibration. They also insulate it from any stray current – which means that grounding the radiator and/or heater core effectively defeats this insulating mechanism by creating a path.

Galvanic Action – As with stray current, before the days of aluminum alloy radiators and engines, galvanic action electrolysis was an infrequent problem. Cooling systems having cast iron engine blocks and cylinder heads with a copper/brass radiator are much less electrolytically active. Why?

Once again, it has to do with a metal's "*electronegativity.*" In the case of galvanic action, the metal with the stronger electronegativity uses the coolant as an electrolyte to strip away electrons from the metal with the weaker electronegativity. Think of it as an electrochemical "tug of war," with the metal having the stronger electronegativity a guaranteed winner. The result is a net transfer of electrons away from the "donor" metal, resulting in it being stripped of mass and damaged to form pinholes. This is why galvanic action is also referred to as "*dissimilar metal*" electrolysis – as it can't happen unless metals of dissimilar electronegativities are together in the same cooling system.

<u>Important note</u>: Iron and copper have electronegativities that are more similar to one another than are iron and aluminum. This is the reason why electrolysis is far less likely to occur in a cooling system with a cast iron engine and copper/brass radiator. This also explains why cooling systems that previously never experienced electrolysis all of a sudden are plagued by it after a copper/brass radiator is removed and replaced with a new alloy one!

<u>So, what to do if your problem is galvanic action electrolysis</u>? In some ways, it is more challenging to solve than stray current electrolysis, because it is not being caused by a correctable mechanical defect. Rather, it is being caused by metals that "don't get along" – or in technical terms, have electronegativities that are too different from one another. Granted, all the same rules apply regarding the importance of grounding, etc. But suffice it to say, the vast majority of galvanic action electrolysis cases we see occur after switching to a new aluminum alloy radiator.



Before swapping out your old-school copper/brass radiator for a fancy new alloy one, know this: <u>Copper conducts heat much better than any alloy</u>. Whereas a new alloy radiator attempts to achieve heat transfer efficiency via thinner tubes (composed of reactive, complex alloys for tensile strength), a copper/brass radiator relies on copper's far superior heat conductive properties. Comparatively, copper conducts heat at a rate of 223 BTU/(hr·ft·°F), versus aluminum's 118 BTU/(hr·ft·°F). Karl Benz knew what he was doing when, over a century ago, he decided to use good ol' copper for radiator cores. Pure copper offers not only better heat transfer, but also is <u>not susceptible to the intergranular type of electrolysis</u> that plagues mixed-metallic complex alloy tubes.

<u>**So, unless you are prepared to swap out your cast iron engine for an aluminum alloy one at the same time as you swap out your copper/brass radiator, you may want to think twice about changing to an alloy radiator**</u>.

Yes, it is getting hard to find shops to repair copper/brass radiators. (But they're out there.) And yes, fixing an old copper/brass radiator sometimes ends up costing more than buying a brand new alloy radiator. (But copper lasts longer.) And yes, copper/brass weighs more than alloy. (But so does the overall car that came with it as an OE part.) There are some very real and distinct advantages to repairing your old copper/brass radiator instead of replacing it with alloy – not least of which is the fact that you won't have to worry about galvanic action.

That said, there are certainly scenarios when sticking with your original copper/brass radiator just isn't feasible. When that's the case, what options do you have as a means of attempting to remedy galvanic action with an alloy radiator?

Many different alloys are used to manufacture radiators, each composed of a different "recipe" of metallic ingredients. Depending on what other metallurgy you have in your car's cooling system, some alloy radiators may have metallic elements with electronegativities more dissimilar to the other metals in your system than others. The point being: You may need to try a few different alloy radiators before finding one that is compatible with other metals in your cooling system. (That can get expensive in a hurry.)

There's one other option that we've seen work in <u>some</u> cases. **HyperKuhl SuperCoolant** contains a robust aluminum-specific inhibitor package. It's mechanism of protecting alloy radiators involves stimulating formation of a passive, endogenous oxide surface film inside radiator tubes. Because the oxide form is <u>non-reactive</u>, this helps prevent stripping of electrons, and can therefore reduce galvanic activity. Depending on certain factors – i.e. flow rate, radiator metallurgy, engine/head metallurgy, quantity of current, etc. – we've seen instances in which HyperKuhl provides protection sufficient to prevent damage from galvanic action electrolysis.

If you use **HyperKuhl SuperCoolant** as a means of addressing galvanic action, there are a few keys that will help stack the odds in your favor. <u>**First**, use Reverse Osmosis (RO) water</u>. This electrochemically-balanced, pure water contains no minerals and has zero electrical conductivity. Pure water does not conduct because it contains no electrolyte.

<u>**Second**, don't use any antifreeze</u>. Different antifreeze blends contain varying amounts of additives that will further increase electrical conductivity. It is best to keep this as low as possible, and at a constant, by using only HyperKuhl with RO water. HyperKuhl's inhibitors do increase water's conductivity to a certain extent, but in a controlled amount – and less than would be the case if antifreeze were added to the mix.

<u>**Third**, mix HyperKuhl with RO water at an exact dose of 4.2%</u>. For example, one gallon of water is 128 ounces, so: 128 x 0.042 = 5.4 ounces of HyperKuhl per gallon of water. The best way to guarantee your dose is spot-on is to pre-mix HyperKuhl with water BEFORE adding to the cooling system. More often than not, a system's capacity is altered by switching to a new alloy radiator. So if you mix by what the capacity was prior to swapping in the alloy radiator, you could end up improperly dosing the HyperKuhl. Pre-mixing eliminates this possible error.

<u>**And fourth**, drive your car at least a couple hundred miles after adding the HyperKuhl mix</u>. Formation of the previously-referenced protective surface film is entirely dependent on HEAT and FLOW of the HyperKuhl/water mix. Absent sufficient quantity of both, the product cannot and will not function per spec, meaning it will be all but certain NOT to aid your fight against galvanic action. After you've completed driving, use the voltmeter to once again check your reading, and determine whether any current reduction has resulted.

Over the past 24 years, we've been witness to countless customers' efforts to find and eliminate electrolysis. It can be a needle in a haystack. But it is entirely possible to resolve by taking a logical approach, and remembering the key points presented herein. In the end, it's nothing more than restoring a defective circuit's natural path to ground. With patience and persistence, and often by process of elimination, you can and will get it resolved.

Thank you for being a customer. We appreciate your support, and look forward to continuing to be of service.

Sincerely,

Applied Chemical Specialties, Inc.