The cause and cure of corrosion in radiators and cooling system components is a story with no end.

While ever corrosion is lurking, waiting for its planets to align so that it can begin its cancerous journey, there will always be anecdotes from technicians who have had to deal with it, more often than not flying blind.

The story that triggered this whole debate began with a fascinating test by TaT subscriber Anthony Tydd who, showing commendable initiative, proved conclusively that there was such a thing as true stray current, a corrosion in which the radiator turns itself into a battery and virtually attacks itself from within, with no outside influences whatsoever.

Following the publication of Anthony’s story, the wires ran hot with opinions, which varied widely. One radiator company roundly criticised TaT’s approach to the story, arguing that ‘you could write a more informative and balanced article that actually helps mechanics and auto electricians to diagnose the cause of the failure more accurately’. And then did what other radiator companies did and provided precious little else.

But the biggest reaction came from the workshops, accompanied by the cry ‘it’s about time this problem with radiators was brought into the open’. It was a cry for help, for what Anthony had highlighted was a subject that needed airing, along with some practical advice on how to deal with corrosion.

Rightly or wrongly, many technicians believed that the radiator manufacturers or suppliers were in denial about radiator corrosion, asserting that corrosion, caused by stray current, or whatever else you like to call it, was a problem for the sparkies and had nothing to do with the way radiators or other cooling system components were built.

This perception was fuelled to a degree by the apparent reluctance of one of the major radiator manufacturers in Australia to even talk about it, claiming ‘we are not in a position to share our knowledge’.

As TaT technical research director Deyan Barrie and his team of ‘thinkers’ began trolling the internet and reading books and articles about stray current and corrosion it became apparent that there was no definitive answer to the question of ‘why?’

There were in fact dozens of reasons and answers.

Deyan set about gathering credible information and conducting tests to produce what we should call the TaT Corrosion Prevention Procedure Manual.

The finished document was so big it wouldn’t fit on these pages, so much of it will be shared with TaT subscribers at www.tat.net.au

Probably the main finding that emerged was that the term ‘stray current’ had been bastardised through the years, used as a scapegoat to explain away far too many cooling system faults.

Stray current, in short, had been given a bad and undeserved rap.

As you read on, you’ll discover that the true stray current is likely to affect an incredibly small percentage of radiators.

Anthony Tydd’s initial story was undoubtedly proof positive that a poor quality radiator, without any external influence, can generate the stray current needed to cause corrosion.

Like many other issues in automotive repair, corrosion in radiators and cooling systems generally can be the result of many factors.

Reading between the lines of this story, you could be excused for thinking that a combination of service laziness, ignorance or
just blind faith that it will go away if ‘we just replace the radiator’ are the main factors contributing to the diagnostic confusion. A cooling system, once filled with water, will always generate stray current and that’s where the coolant or inhibitor plays its vital role.

Like all products, there are good and bad, and in this case, replacement with the cheapest radiator heater core, water pump or hose can increase the risk of stray current substantially. It’s the workshops’ job to educate their clients that cost savings come with this risk.

Like many automotive problems, the basics, or why things happen, need to be understood before anyone can come to grips with remedies.

In 1998 and again in 2000 the Victorian Automobile Chamber of Commerce (VACC) addressed the corrosion problem with some good technical articles.

Their story began, ‘Ever since motor vehicles have used water as a means of cooling the engine, repairers have been pointing out to their customers a myriad of failed components highlighting areas of corrosion that blind Freddie could see.

‘However, Blind Freddie can only see it when we can too. The trouble with cooling system corrosion is that unlike body panel corrosion, not only can’t we see if it is occurring, but we can’t see how advanced it is. Without, at the very least, a partial disassembly and inspection of either the engine or radiator or both, we’re all as blind as Freddie.’

Technicians don’t need to be alchemists to be able to deal with issues that stem from cooling system failures such as contamination and corrosion which can damage the radiator or other parts of the cooling system.

One thing is guaranteed – if cooling system maintenance is overlooked, corrosion and component damage is inevitable.

In the good old days, most engines were big, thick, heavy lumps of cast iron and steel.

Untreated water was used for the cooling system and a heavy copper or brass radiator was up front in a system that was low pressure and low temperature.

There was so much excess metal in the block and head that the rust flakes could fall away from the cooling jacket for years and the worst result would be a partially blocked radiator, a few rusted welsh plugs, and maybe a blown head gasket as the major penalty for negligence.

Life was so much simpler.

Consider the demands on a typical modern engine. It is expected to:

- produce higher power and higher torque figures from less engine capacity
- drive a high output alternator that in turn powers a vast array of electrical and electronic equipment
- drive the air-conditioning system and power steering pump and fulfil the modern motorist’s expectation that the heater and demister will be fully operational even before the vehicle has been backed out of the driveway
- produce less noise, vibration and harshness
- produce lower exhaust emissions idle smoothly and rev higher deliver increasingly better fuel economy
- start immediately the button is pushed or the key is turned

and do it all in a confined engine bay with a typically small air-cooling intake.

The challenge for the technicians of today is to be able to understand the cause and effect of corrosion in cooling systems, then with confidence we can evaluate and rectify the problems and discuss the issues with our customers and educate them about looking after their vehicle cooling system, the importance of doing regular inspection service of the system and how the customer plays their part.

Technicians need to understand what term applies to what condition.

Chemical reactions
A process that results in the inter-conversion of chemical substances or a
process that leads to the transformation of one set of chemical substances to another.

Classically, chemical reactions create changes that strictly involve the motion of electrons in the forming and breaking of chemical bonds.

This reaction can be either spontaneous or requiring no input of energy, or non-spontaneous which might follow the input of a type of energy such as heat, light, motion or electricity.

There is synthesis, where two or more atoms or molecules combine into a new molecule.

For example, iron plus oxygen forms iron oxide, or rust. Another is an analysis reaction, or a chemical decomposition, where a molecule breaks apart into smaller parts of a compound. This occurs when the electrolysis of water produces oxygen and hydrogen gas.

There is also substitution, which happens when a more reactive atom or molecule ejects a part of another molecule and takes its place. This occurs whenever an acid eats into a metal.

**Corrosion**

Corrosion is the disintegration of an engineered material into its constituent atoms due to chemical reactions with its surroundings – the metal wears away due to a chemical reaction. With metals, corrosion is helped along by oxidation and moisture. Wherever metals or dissimilar metals are immersed in an electrolyte, they may be subject to acid attack, galvanic corrosion, cavitation corrosion and other forms of corrosion. This is a fairly accurate description of any modern automotive cooling system.

**Galvanic reaction**

The principle behind galvanic reaction (corrosion) has long been used to generate electricity in lead acid batteries.

Two dissimilar metals placed in a solution use the electrochemical reaction to generate a charge.

Unfortunately, the same thing can happen in the cooling system under the right circumstances.

In the absence of an effective corrosion inhibitor the engine's cooling system can effectively become a large low output wet cell battery, but this has disastrous implications for its alloy components.

**Why use dissimilar metals?**

In an automotive application this is not just for economic reasons, but a necessity for strength and efficiency. In the case of cooling systems, it relates to different metals and a combination of fluids to carry out a specific job of moving the heat as quickly from one area to the other and then out of the system altogether.

**Crevice corrosion**

This takes place in narrow crevices where moisture is present but coolant movement and flow is poor or non-existent.

This can be found typically where radiator and heater hoses join to metal clamping sections such as the thermostat housing.

This is why hoses often bulge around the clamping area. The metal is corroding and expanding from the outside in.

Crevice corrosion causes potential differences to occur between the beginning and end of the crevice, which in turn causes intensified corrosion.

Gasket surfaces and particularly head gasket surfaces are prone to this form of corrosion.

It is this type of long-term corrosion that causes a cylinder head surface to be eroded away, to the extent that combustion gases eventually enter the cooling system.

This is in spite of an intact cylinder head gasket.

**Electrolyte**

Any substance containing free ions that make the substance electrically conductive is an electrolyte.

Electrolyte solutions are normally formed when a salt is placed into a solvent such as water and the individual components dissociate due to the thermodynamic interactions between solvent and solute molecules.
For example, when table salt is placed in water, the salt (a solid) dissolves into its component ions.

**Electrolysis**

Electrolysis of water is the decomposition of the liquid (H2O) into hydrogen gas (H2) and oxygen (O2) due to an electric current being passed through the water.

Electrons can be removed from the outer orbits of atoms by various techniques such as chemical reactions, friction, light, heat, pressure and magnetism.

Electrons in a circuit of a conducting material under the influence of an electromotive force will move towards a point in the circuit that has a shortage of electrons.

In other words, the flow is from a place of excess electrons (negative terminal) to a place where there is a deficit of electrons (positive terminal). This cycle of electrons flowing from a negative terminal towards a positive terminal is known as electron flow.

Electrolysis can be created by using electrical energy, as in passing a current through it, in electroplating. This is the flow of electron movement from the anode to the cathode creating current flow when a load is applied.

Electrolysis can also create a current and voltage (two dissimilar metals and an acidic liquid, as in a battery). The movement of electrons is minimal until a load is applied such as when a globe is connected.

Consider how many ways electron flow can be assisted and electrolysis formed.

1. Friction, due to internal engine component movement
2. Heat, with the engine block and air conditioning system all contributing to the shifting of heat into the coolant
3. Pressure – the cooling system is under pressure
4. Flow and movement of coolant
5. Magnetic fields which could vary greatly from vehicle to vehicle. Look at the number of things that take or make a charge that creates magnetism – alternator, starter motor, ignition coils, wiring looms – they all generate a magnetic field of varying strengths and directions. This does not mean that they create stray current, but it may aid in the decoupling and movement of electrons, aiding electron flow and electrolytic reaction
6. Stray current
7. Galvanic corrosion
8. Pitting corrosion

**Coolants – properties, functions and importance**

Coolant contains antifreeze and inhibitors.

It is a fluid that flows through the cooling system to facilitate the transferring of heat produced by the engine friction and combustion through to the radiator and the heater core to dissipate the heat outwards.

Coolant has chemical compounds (inhibitors) that are involved in slowing down the degradation of dissimilar metals in the cooling system.

Antifreeze protection is an ethylene glycol solution, with a higher boiling point and it provides advantages for summertime use as well as during cold weather.

This higher boiling point is reached by keeping it under pressure which is what the radiator cap is for. Coolant assists in equalising the internal temperature.

The heat inside the engine is stabilised by the thermostat with the assistance of the radiator cap. Coolant also reduces the steam wall effect, allowing a fast transition of heat from the metal to the coolant.

An ideal coolant has high thermal capacity, low viscosity and is low cost, non-toxic and chemically inert. It doesn't cause or promote corrosion of the cooling system.

Traditionally, two major corrosion inhibitors are used in the coolant, silicates and phosphates.

Quality coolants give great heat transfer characteristics and provide electrical reaction inhibitors. Coolants also protect the inner walls of the cooling system from corroding and flaking by creating a protective film or skin that is constantly moving and regenerating.

The inhibitor is moved around in the cooling system by the glycol.
What's wrong with water?

Straight water should never be used in a cooling system, especially long term.

Water freezes at zero degrees Celsius and boils at 100 degrees Celsius.

This temperature is close to the normal operating temperature of many engines and provides no corrosion protection whatsoever. Water assists electron flow and electrolysis begins to take a hold and corrosion follows.

There are specific corosions that cause premature failure of cooling systems.

1. **Pitting corrosion**

This is responsible for around 90 per cent of the corrosion affecting the aluminium radiator and heater cores and can destroy the cooling system quite rapidly.

Pitting corrosion occurs as a result of:
(a) improper repair technique and poor work practices when replacing cooling system components and not flushing the system thoroughly
(b) diluting the coolant by just adding water when some coolant has been lost due to a leak or repair
(c) topping up the coolant system with a different coolant, creating a cocktail chemical mix
(d) ignoring timely coolant system servicing including flushing and replacement – coolant deteriorates and stops working as a protective element, can deposit a combination of materials and turn into a fine slime or sludge
(e) sub-standard flushing after a major cooling system repair, be it a radiator, water pump, heater core or blown hose replacement – even though the coolant has been replaced after the repair, a catastrophic system failure is still possible

In all of these conditions, deposits of debris at the bottom of the radiator or heater core tubes, even if they cover a small area, may stop the new coolant from protecting the space in between.

This material mounds up and sits jammed between the tube walls and then the chemical reaction starts through hydrochloric acid being formed in those spaces

The coolant and its inhibiting properties can’t reach the area where it needs to disperse this acid reaction.

In the smelting process to create aluminium alloy, a hard skin of oxide coating is created on the external surfaces and this protects the softer underside.

Corrosion is what breaks down the alloy oxide coating and this process starts eating away at the softer aluminium centre.

An aluminium radiator can be described as the anode, the sludge and scale deposits are the cathode. The radiator core becomes the sacrificial anode.

This is where pitting corrosion occurs due to localised galvanic reaction and the alloy/aluminium is depleted causing the pinholes.

**Solution:**
Maintain a proper cooling system service regime, making sure the debris is not allowed to accumulate in the first place.

This is done by making sure the coolant is of the recommended type for the job and is still within its service life and not depleted. System flushing techniques and proper maintenance of the system are paramount.

2. **Galvanic corrosion**

This is a very distant second to the pitting corrosion. Some quote it as being less than five per cent of corrosion problems.

Galvanic corrosion occurs when two dissimilar metals come into contact. Add moisture and off it goes and you have set up an electrochemical cell.

Galvanic corrosion is the process that occurs in a lead acid battery, principally for the generation of electricity, by having two dissimilar metals placed in a solution. This electrochemical reaction generates an electrical charge.

In a vehicle cooling system, the right ingredients are there to create this reaction if we are not careful.

This is why the correct type and consistency of coolant is so important. It is the coolant with its corrosion inhibitor that protects and keeps the cooling system clean and efficient.
Coolant creates a protective coating on the inside of the cooling system and maintains it constantly, thereby stopping the electrochemical reaction.

If the protective layer begins to degrade, galvanic reaction can begin. This can affect the system very quickly.

If the coolant is not properly balanced the cooling system can basically become a low output wet cell battery with catastrophic results for the alloy components in the cooling system.

Most commonly, galvanic corrosion in an aluminium radiator is the direct result of failure to maintain the coolant at the correct levels and it follows that the upper portion of the radiator is deprived of the protective layer of the corrosion inhibitor.

Solution:

Keep the coolant system to the correct level and the coolant consistency correct and clean. Radiator caps must be in good working order.

You can't have system leaks because this allows air to be drawn into the system.

Where header tanks are used make sure they are at the correct level.

Ask the customer if they fiddle with the cooling system. Do they regularly top it up?

Obviously they shouldn't do that. If they don't understand the basics of cooling system health, it is up to the workshop to educate them.

3. Cavitation erosion assisting in corrosion

This is where air bubbles in the cooling system pound against the wall of the casting and the water pump. This action erodes the protective film formed by the coolant, revealing the unprotected surface underneath. The corrosive action then begins.

Solution:

Correct coolant maintenance will help prevent this. This includes holding the correct level of coolant and internal foaming minimisation.

4. Chemical corrosion

This type of corrosion is created by the incorrect application of coolants.

Don't mix coolants, because this may create a cocktail that will inhibit cooling system performance.

Coolants can exceed their life cycle and their corrosion inhibiting properties become exhausted. Proper preventative maintenance and care will minimise this sort of problem.

Solution:

Best practice is to use only recommended coolants specific to the vehicle type.

Recommend to your customers that if the coolant system loses fluid and needs topping up, only use plain water until it can be fixed.

Advise them to bring the vehicle in as soon as possible when this happens.

The customer should not top up with a coolant even if they know it is the right type because, over time, the coolant structure may well have changed.

5. Stray current or voltage

This is the most misunderstood of all forms of corrosion.

Stray current and stray voltage are one and the same thing, but we are going to call it stray current.

Yes, stray current does exist, but in a very small percentage of cooling system failures. In the majority of cases the system failure is man made, meaning that it is created by incorrect repairs after an accident or poor workmanship around the immediate area of the cooling system.

It has been perhaps unfairly tagged as the major contributor to cooling system failures because it rolls off the tongue easier.

Stray current which can cause damage can begin with a bad electrical connection due to a bad earthing point. The earth point has to be directly related because this is part of the path of a switched-on positive source carrying a load looking for any easy way to get to the earth point. Think of it as power going through a switch to a globe and going to ground to light up.
When this path is removed or hindered, the flow will do whatever it can to find its way to the end.

The chances of a minor earth becoming the catalyst, such as claims about rear light globe earthing causing stray current, can be bit hard to believe. But we must not dismiss this theory completely because it can happen under extreme circumstances.

It is the main body earth points and engine earths that have to be looked at. The main battery earth is also very important. Panel damage touching cooling system components, earth points painted over after a respray and panel repairs are also contributors to stray current.

If the vehicle has a true stray current situation the correct amount or quality of coolant be it new or old will not help. If stray current exists, it will destroy an alloy component, radiator or heater core very rapidly. Stray current actively breaks down the protection properties of common coolants. This compromises the inhibiting ability to protect the cooling system.

The fact is that it is no longer a closed loop circuit. The system now has energy due to an external load applied that facilitates electron flow and this is electrolysis and stray current corrosion in action.

What should we be measuring? The majority consensus is that more than 0.3 volts is too high. Some say that anything over 0.05 volts (50 mini-volts) becomes a point of concern. (How to measure this current will be covered in depth in a future edition.)

Overview:

It is TaT's considered opinion that true stray current is a minor contributor to the big picture of cooling system corrosion.

Stray current does not rear its ugly head until other symptoms have started to come into play, forming the base foundation for this catastrophic chemical reaction.

The basics

Carry out a full electrical system load test by turning everything on at the same time.

Look for any obvious external or internal visual problem with the lights on as well as functions like electrical interior fan, engine fan operation and so on.

Get your quality high impedance voltmeter and check the earthing points – post to clamp, post to block, post to body, body to chassis and so on. This may take some time before any odd reading is seen.

Check the earth side voltage drop under cranking load. There should not be any voltage differential anywhere under load and the biggest differential should be for the heaviest load of the starter motor and that should be no more than 0.3 volts post to block while cranking.

We are not introducing or asking for any current flow from the cooling system under normal circumstances. The late model cooling system is a closed loop system and there is no electrical load placed on it as long as the main earthing points are good and, as in the aluminium radiators, the core and heater cores are not grounded. We don't have a problem, but introduce a load externally like an earth that does not belong and you now have a problem.

If a radiator is on plastic tanks and rubber mounts, don’t ground it. This applies to the heater core also.

A battery in itself does not react or create electricity/current until it has a load put on it, like hooking up a light globe to make the circuit. Therefore we can assume that if a cooling system has a closed loop system there is no load to facilitate excessive movement of electrons.

The VACC, in its 2000 article, 'Corrosion in aluminium radiators – the real story', opened with the comment that stray current corrosion had become the scapegoat for just about every coolant system failure.

From the enormous amount of feedback TaT has processed since raising the lid on cooling system corrosion, it seems this perception by the industry at large hasn't changed much.

Corrosion and its many causes remains a mystery to most technicians. With so much written on the subject, it's hard to know what to believe. TaT has attempted in this article to stick to the facts.

Note also that in this story, the heater core keeps getting mentioned. We tend to forget it,
and don’t really think about why it might have failed, regardless of whether it was alloy or copper.

The questions technicians should be asking themselves when working with cooling systems and replacing components like heater cores are:

- Why are we replacing the heater core?
- Why did it fail in the first place and what was the cause?
- When the core is replaced, do we finish off the job by flushing the complete cooling system properly and is this in our quote?
- Are we only 1) adding water? 2) topping up the system with whatever coolant is on the shelf? 3) Do we capture the old coolant and reuse it?

Depending on your answers, you could well be loading your customer with a lot more than the cost of cooling system flush and new coolant.

**TaT recommendations:**

- Do not let the vehicle go without new coolant and the proper procedure being carried out.
- Tell the customer that the job has to include a proper cooling system flush and new coolant – no ‘ifs’ or ‘buts’ and no compromises.
- If you have to repair a cooling system, the system must be thoroughly flushed and new coolant added, regardless of the age of the existing coolant.
- In the event of a real problematic cooling system, it must be flushed and flushed again, and when you think it’s done, flush it again.
- Don’t change your core type, change your coolant regularly, and use only the recommended coolant for the vehicle.
- There is a good chance that the cause of a head gasket failure may be due to a cooling system corrosion problem, but this event is rare.
- If you have ticked all the right boxes to prevent a premature failure, write down the procedures involved and the products you have used on the invoice and charge for these accordingly.

**Disclaimer:** TaT provides this information for guidance to technicians and will not be held liable for any misunderstanding or incorrect application of the information. Technicians are also advised to follow proper workshop safety and environmental procedures in the handling of coolant.

In future issues TaT will cover testing, measuring, equipment types, performance and efficiencies of cooling system techniques for adding coolant.

*TaT is grateful to VACC Technical Department for the use of their corrosion images and for access to the VACC 1998 and 2000 Tech Talk publications.*