Cooling System Overview

Read this, or risk faulty diagnoses.

Any internal combustion engine produces far more heat than it can convert to mechanical work. Some is lost to the atmosphere as exhaust, but there's a stubborn last third or so that has to be forcibly extracted. Hence, our heat sink, the cooling system, which, if everything is working as designed, carries away the excess, thus keeping the engine below the point of self-destruction. Actually, it's this way for nearly all mechanical systems — especially those that generate usable power. We have no alternative to making excess heat that's not being turned into useful work, or to using marginal, relatively-crude mechanical systems to extract or convert the energy, then finding ways to shed the excess BTUs before they destroy our fragile mechanical contrivances. We're getting better, though. Electronic engine management, and improved coatings, materials, lubes and designs are gradually increasing the amount of energy we can get from our chemical reactions, but into the foreseeable future we are going to be stuck with cooling systems on cars.

The operative word here is "system." It's a radiator, it's a pump, it's flexible hoses to connect an engine that rocks with torque to a stationary chassis. It's coolant, fans, belts, thermostats, restrictors, reservoirs and radiator caps … and one thing out of shape will put us over the top and into thermal overload. We all know the results of neglected cooling systems. Muddy coolant aside, there are scored pistons, blown head gaskets, overheated and destroyed engine and transmission oils. The modern cooling system is a violent place, full of localized hot spots, boiling, pressure surges, cavitation and flow restrictions, slag or pockets that create low pressure swirls that flash hot coolant into foam.

Above: *Subaru vehicles have always been designed with sensible airflow patterns. Even the latest models have grilles that admit plenty of air for proper cooling. That's different from other makes that depend on bottom breathing that can be defeated by a lost deflector or shroud.*

Keep it Moving

Water pumps are an interesting subject. In designing an engine, you want to put the pump as low as possible so that it won't start to cavitate if the coolant level should fall. That's where all powerplants have it except for one French car we remember that actually had it at the very top — it's no wonder that that make isn't being imported anymore.

Subaru vehicles power the water pump with the back of the cam belt, or, in the case of the 3.0L six, by means of the timing chain. This makes it impossible to run the engine without the pump shaft spinning, thus avoiding the possibility of truly disastrous overheating.

Thermal Map

The hottest area is the head, particularly around the back of the exhaust valves/ports. There's less heat as you approach the crankshaft since cylinder pressure and temps drop as the piston is pushed away

Right: *Another smart thing Fuji Heavy Industries did when designing Subaru high-performance vehicles was to position the turbocharging system intercooler on top of the engine so that it breathes through a hood scoop. Other makes seem to think it's okay to put it in front of the radiator, thus increasing the heat load on the cooling system. Go figure.*

from the combustion chamber, which is concurrent with the flame extinguishing in the cylinder.

Why hold boiling point up? Obviously, we need to keep the coolant inside the system, so tightly capping it accomplishes this, but also raising overall pressure keeps the coolant from boiling in tight turns or sharp radii inside the system and at the suction side of the pump. Foam or vapor is a lousy heat transfer medium. The walls need to be fully bathed to transfer heat. Plus, the collapse of vapor bubbles in the system as they transition from low pressure to high leads to a condition called cavitation erosion, typically seen on aluminum surfaces near the water pump.

Radiator hose clamp positioning actually does matter. You might as well do what you can to prevent any areas from having trapped coolant, which will promote corrosion.

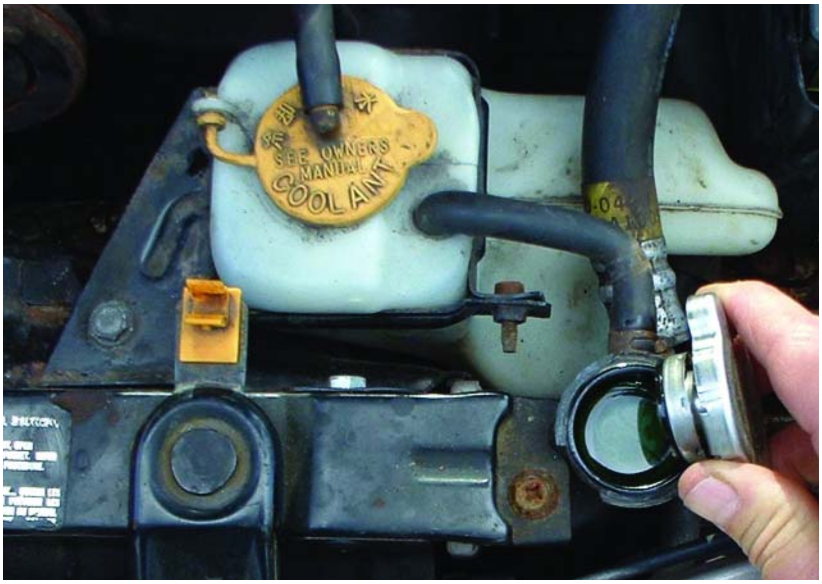
Crevice corrosion occurs in tight spaces where a lack of flow keeps the trapped coolant from mixing with the main flow, thus depleting additives and setting up high rates of corrosion. This occurs mostly on hose nipples where the clamp is positioned improperly. They should be as near to the nipple flange as possible to keep coolant out of the space between the nipple and hose. It's not uncommon to see aluminum pocked with ruts and holes or steel nipples rotted through.

Coolant-Recovery System Snafu

The vented recovery system was a great invention, and Subaru has employed it for many years. One of the ongoing concerns with this system, however, is its failure to self-recover. If you drink a milkshake, you'll see what happens when you try to pull a viscous liquid through a small opening. You can easily breathe through the straw, since air is a lot less dense than the milkshake. The same thing happens in the coolant recovery system, which is why we find the recovery tank full and the radiator six inches low. The engine heats up, coolant leaks out. The system pulls a vacuum on cool down, but instead of drawing the viscous coolant through that same tube back into the radiator, it pulls air back in through the leak. In some cases, the leak occurs somewhere between warm up and cool down, so it's dropping fluid on the road, where it can't be seen by the customer. Or, it boils away as it escapes the pressurized cooling system, leaving nothing on the pavement to indicate a problem. The result is a recovery tank that maintains its level, while the radiator level is falling, unbeknownst to all parties concerned. If you're servicing a vehicle, you must pull the radiator cap! Just because the recovery bottle is full doesn't mean the radiator is full.

What kind of anti-freeze should you use in Subaru vehicles? Well, we believe you should avoid generic aftermarket brands, especially those that rely on organic acid technology for corrosion inhibition (they have a bad reaction to air in the system if the level should be allowed to fall). Nothing else protects Subaru engines, which are built with a very high percentage of light-alloy components, as well as genuine Subaru anti-freeze. See our sidebar, "Don't be Fooled by Semantics."

Just because the overflow bottle has a sufficient level of coolant in it doesn't necessarily mean the pressurized part of the system is actually full. You can only be sure by removing the radiator cap. You'll often find the level in the radiator to be low, which is a function of vacuum leaks that prevent coolant from being drawn back into the radiator from the bottle.



*We know what should be in that cooling system — Genuine Subaru Anti-Freeze, distilled or deionized water, and the approved cooling system conditioner — but what's **actually** in there? Only you can make sure your customers' cars get the right stuff for longevity and trouble-free operation.*

While pressure testing is probably your first diagnostic choice, nothing beats UV for zeroing-in on those sneaky leaks.

Troubleshooting

Handy items include dyes, a UV/black light, a pressure tester, a non-contact infrared thermometer, a belt tension gauge, and a refractometer (a bit pricey, but nothing else works nearly as well, or is as accurate). A way of measuring the actual flow rate to determine if the water pump is still moving a sufficient volume of coolant would be helpful in determining if that essential component needs to be replaced. Such a thing exists (the Radi-Cool from Hickock), but very few shops have it, or have even seen it. So, you'll probably have to use your own judgment. Take the coolant level down until it's just above the radiator fins and peer down into the neck with a flashlight.

You should see a robust flow, similar to what you'd expect from a garden hose. A variation on this is to remove a heater hose, stick the end in a bucket and start the engine. Since Subaru cooling systems don't use a valve that shuts off flow to the heater core, you should see a strong stream no matter where the controls are set. Finally, clear tubes are available that you attach in series with the upper radiator hose that allow you to see the flow.

Damage from poor coolant system management takes one of three forms. There's erosion, the thinning of material by mechanical force or impingement — remember we're dealing with the vigorous movement of coolant, and abrasives or debris slamming into aluminum, copper or brass can literally "sand blast" its way through such soft materials. There's also corrosion, the result of a chemical attack on the metals or rubber, much like acid would do. And there's electrolysis, the stripping of donor material from one source for deposit in another location — sort of a mini plating cell — created by stray electrical currents passing through the coolant stream. In all cases, one of the largest contributors to the destruction of the system is water. Chlorine, calcium and magnesium from treated or hard tap water dramatically accelerate the onset and progression of erosion and corrosion. Most experts are beginning to recommend de-ionized or distilled water for fill or makeup.

Looksee

As any believer in disciplined diagnostics knows, the first step in the process is visual inspection. How's the level? Is there a 50/50 mixture? Too much or too little anti-freeze, either is a problem, and not just in regard to the boiling/freezing points. Vehicles equipped with level sensing may misread an improper mixture leading the driver to believe that the coolant level is low when it's not, or full when it's low. Hoses all okay? Do we have leaks or are the core fins plugged with bug splat and cottonwood tree lint? Are the electric radiator fans working? How about the shroud? Or, the chin dam under the front bumper, which is used to create low pressure under the car that radiator air flow exhausts into. Is it intact?

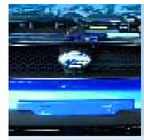
The convoluted plumbing of late models makes vacuum filling equipment attractive. It'll pull nearly all the air out for you and draw the fresh coolant into the deepest recesses as it fills. We've used this time-saver for years, and not only is it generally a lot neater to use, with less spillage and better inventory control, but it works the first time.

Details

On radiator caps, application is critical. Make sure you get exactly the right part. Don't just take something out of stock that may fit physically. Ditto for thermostats. Look it up. Gaskets and seals must work properly. Most manufacturers use a mild sealer/cooling system conditioner with the factory fill to prevent weeps and seeps. This is supposed to be replaced after service, but rarely is. If called for, make sure you are installing seal tabs after flush/fluid exchange.

All told, it's a miracle that modern cooling systems/coolants function as well as they do. We have systems with higher temperatures, pressures and flows, made of all sorts of different materials put together by all kinds of different processes. Everything from aluminum to plastic or impregnated resin end tanks and plastic/rubber or silicone sealing systems are in use, and, given human nature, they're commonly exposed to coolants pushed well past reasonable limits and diluted over their lifespan with corrosive make-up water. They do pretty well when you put it all in perspective.

A refractometer is fairly expensive, but nothing else comes close to its accuracy and speed of use. You don't have to wait for all those floats in a hydrometer to settle down to get an idea of the coolant concentration. Plus, it works with both EG and PG (the latter being the non-toxic anti-freezes, such as Sierra).



Don't be Fooled by Semantics

Even though you're a Subaru specialist, you've probably heard horror stories about the long-life anti-freeze formula embraced by some other makes, most prominently the largest domestic manufacturer. This stuff is based on OAT (Organic Acid Technology), and its additive package can indeed last a long time. The trouble is, its anti-corrosion properties are defeated by one simple thing: air. If the coolant level in the system should be allowed to drop (if you don't have some customers who tend to neglect fluid maintenance, you live in a better world than we do) so that all surfaces aren't continually immersed, oxidation occurs rapidly. The dusty deposits that form accumulate into incredible amounts of crunchy glop that clogs up the works.

The anti-freeze that Subaru specifies and makes available through its dealership parts departments uses a different sort of anti-corrosion formula that combines the benefits of OAT and phosphate (non-amine) chemistry, which establishes a semi-permanent protective coating on metal surfaces even if the coolant level is allowed to fall (see the "Insider Info" section of this issue of ***The End Wrench*** for a new technical service bulletin that explains this, and also provides recommendations on hard water and cooling system additives —show it to any customers who want you to go the cheap route).

Genuine Subaru anti-freeze says “Long Life” right on the bottle, but that doesn’t mean you should leave it in there seemingly forever. It simply refers to the fact that if the car’s cooling system maintenance is neglected, there will be less damage from corrosion and clogging than would be the case with a less sophisticated formula.

Fuji’s engineers are more prudent than those of some other carmakers, and they want people to enjoy their Subaru vehicles for a long, long time without encountering expensive and inconvenient problems. So, they’re sticking with the recommendation that the coolant be changed every two years or 30,000 miles. Sound wisdom in our opinion, and something you can easily justify to your customers. ■

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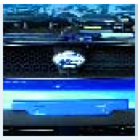
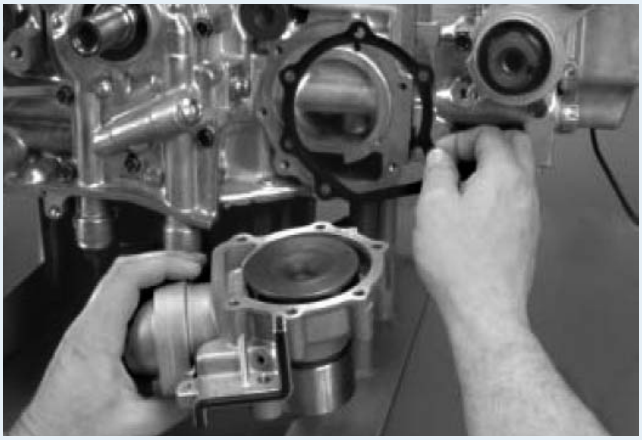


Subaru Cooling:

Pumps, Hoses & Additives

Three hot topics that concern Subaru vehicles.



Removing water pump.

Every make of car has cooling system service subtleties, some of them shared with other brands, some exclusive. Regardless, the following will help you be successful in this important maintenance and repair area on Subaru vehicles.

Coolant circulator

As you know, most of the Subaru engines out there have an OHC timing belt. Not only does it keep the cams and crank in synch, but it also drives that all-important water pump off its back side. One advantage to using this means of powering the pump is that if the belt should ever snap (something to be studiously avoided), the engine can't run, so doesn't run the risk of catastrophic overheating. As we're sure you've seen on other engines where the external serpentine accessory belt is ultimately responsible for moving coolant, that preoccupied motorist might very well keep driving, blithely unaware that he or she has lost the serp and is in the process of melting the engine down into a useless heap of scrap.

This brings up an important point to remember whenever you're replacing a Subaru water pump. Does it make any sense to do all the disassembly involved, then put the old T-belt back on? Certainly not, yet we still see people doing it. That's false economy taken to a high degree. After all, a new belt is a relatively inexpensive part. You should explain to your customers that it's your policy to replace both at once.

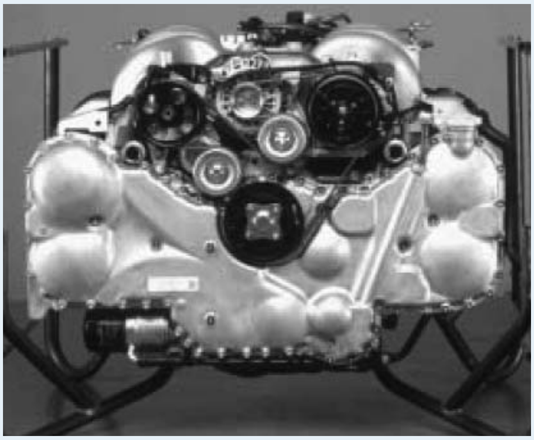
The flip side of this situation occurs when you're replacing a timing belt. Should you add a new pump while you're in there? Given that late-model Subaru vehicles carry a 105,000-mile belt replacement interval, definitely. Sure, the pump seal may go for quite a while longer, but certainly not until the next belt change.

While we're on the subject of pumps, we'd like to explode a couple of myths. Contrary to what you've probably heard, water pump seal failures are usually not due to warping or fracturing of the precisely-made rotating elements. What happens is the rubber cup or the boot that surrounds the spring disintegrates. Think about it. Haven't most of the pump failures you've seen occurred shortly after an overheating incident? When the element has to run dry, it gets extremely hot, which takes the rubber parts close to it way beyond the maximum temperature they can survive.

Then, there's the faulty idea that phosphate and silicate additives in the anti-freeze tend to wear out those precisely-made sealing elements of the shaft. Sorry to burst a balloon, but that's simply not so.

59 bolts!

How about that recent Subaru 3.0L six? A very cool motor, right? They've even eliminated the timing belt in favor of a forever timing chain, which also makes the engine a little bit shorter so it could be placed in existing chassis.



3.0 liter engine with stands.

Because it was introduced in 2001, many of you haven't had the opportunity to install a water pump in one yet. So, you may be surprised to hear that the pump is driven by the timing chain. That should make it stone dependable. On the other hand, the job of replacing the pump when it either starts leaking, or has an impeller problem, is a big undertaking. Believe it or not, there are 59 bolts of various lengths holding that nice cast timing cover on. Once you get that off and the chain out of the way, you can use two M8 bolts to force the pump out of its recess (it's sealed with an "O"-ring). Then comes the job of getting the chain back on in proper synch, and remounting the cover so that it doesn't leak oil.

This should signify two things to you. First, it makes good cooling system maintenance and regular hose replacement even more important than in other models where the water pump is relatively easy to change -- as we said, overheating will fry the pump's shaft seal. And, two, you want to be very sure the pump is actually the problem in a low-flow situation before you go in there and replace it. You can use a non-contact infra-red pyrometer to see if the heat "map" through the radiator appears normal, but that's not exactly a go/no-go test. A better way is to drain the coolant level in the radiator down to the tubes, get the engine hot, then shut it off for maybe 10 minutes and let it heat soak to make sure the thermostat is wide open. Or, you could remove the 'stat.

By showing you the pattern of heat dissipation in the radiator, a non-contact infra-red pyrometer can help you find blockage, but it's not a sure thing.

Now, fire it up again, run it at 3,000 rpm and you should see strong circulation, "almost like from a garden hose," as one radiator shop owner puts it. A simple variation on this is to remove the hose that comes out of the heater core, place it in a bucket and start the engine. Since Subaru vehicles don't have a shut-off valve to the heater, you should see a robust stream no matter where the controls are set.

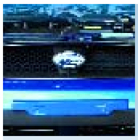
ECD

The big buzz word on hose deterioration is ECD (Electro-Chemical Degradation), which is invisible damage that can result in unexpected failure. Hoses are susceptible to electrochemical attack because the combination of ethylene propylene rubber, coolant, and metal fittings actually forms a galvanic cell. The results are cracking of the tube and weakening of the surrounding reinforcement, and the deterioration is greatest within an inch or two of the connections.

Hose replacement every fourth year is appropriate since surveys that have shown two to three times as many failures in the fifth year as in the fourth.

Finally, you're probably aware of the head gasket leak campaign on the '00 to '02 Legacy, and the '99 to '02 Impreza and Forester with the 2.5L four. There's an extended warranty for this that runs for eight years, or 100,000 miles. That is, if the customer "promptly" visits the dealer to have Genuine Subaru Cooling System Conditioner (Part Number SOA345001) added. That shows the company's faith in this additive.

You, too, should be using it every time you drain and refill a Subaru cooling system. Fuji doesn't approve of any aftermarket additive whatsoever, so why argue? Take four ounces of coolant out of the radiator, shake the bottle, then pour the contents directly into the radiator filler neck, not the overflow jug.



How's the Water?

You know, of course, that a 50/50 mix of anti-freeze (preferably S.O.A.'s own) and water is specified for Subaru vehicles no matter whether they're operated in the Tropics, or the "Great White North." So, you're filling those boxer engines with the same amount of H2O as with anti-freeze.

Nobody in the automotive service business seems to have given this situation much thought, but there's an important point to be made here if you want to insure that your customers avoid trouble in the long run. That is, the characteristics of the water in the blend.

If directly from a well, tap water in the U.S. is apt to be "hard." That is, containing a high concentration of metals and minerals — iron, calcium, magnesium, etc. If from a municipal water supply system, there's also the

This is a textbook example of how hoses deteriorate. It's actually an electro-chemical reaction that causes the damage. This one was on the verge of blowing and perhaps causing an engine-killing overheating incident.

distinct possibility that a considerable amount of chlorine and fluoride has been added.

When you take such particular care to make sure lubrication and other services are done just right to preserve and enhance your reputation, why should you put potentially-damaging substances into your customers' cars when you do a coolant change, or even a top-off? Especially when you consider that distilled/deionized water costs less than a dollar a gallon, there's no sense in not avoiding problems such as internal corrosion and electrolysis and deposits that reduce flow and cut cooling efficiency.

We should explain the difference between distilled and deionized. The former has been boiled, then condensed, which leaves the minerals and metals behind. The latter is "softened." In other words, it's passed through a bed that exchanges its calcium and magnesium ions for those of sodium. So, there's a little salt in it, but it's still far superior to what you'll get out of the tap in most locations.

This improvement in your car-care practices certainly isn't a difficult technological challenge. You can just go to the grocery store and buy plastic jugs of distilled/deionized water. So, it's a painless upgrade to the quality of the services you provide. Just do it. ■

A shop can distinguish itself from its competitors by advertising that it uses only distilled, or deionized, water to fill its customers' cooling systems. The cost is miniscule.