

# Corvette Cooling System

KNOWING HOW YOUR 1963-1982 CORVETTE'S COOLING SYSTEM CAN PREVENT A STEAMING SUMMER

BY JOHN HINCKLEY

**I**f you own a 1963-1982 Corvette, chances are you ask, "Why does my car run hot and over-heat?" There are lots of possible reasons, and your Corvette may or may not be overheating at all. What we want to do here is provide an understanding of Corvette cooling system design theory and operation, present real-world solutions to cooling problems, and dispel some of the myths and hype that exist out there about cooling systems. We'll focus primarily on 1963-1982 Corvettes for specifics, as they share similar designs, although the principles are similar for later cars.

**THE BASICS:** There are three basics involved in the cooling system: The fluid (coolant) that circulates to carry heat from the engine to the radiator, the heat exchanger (radiator) whose job it is to transfer that heat from the coolant to the air, and the air flowing through the radiator core that picks up the heat and carries it off. The two most critical elements here are the heat-transfer capability of the radiator and the volume of airflow through it, and 90 percent of cooling problems involve either one or both of them.

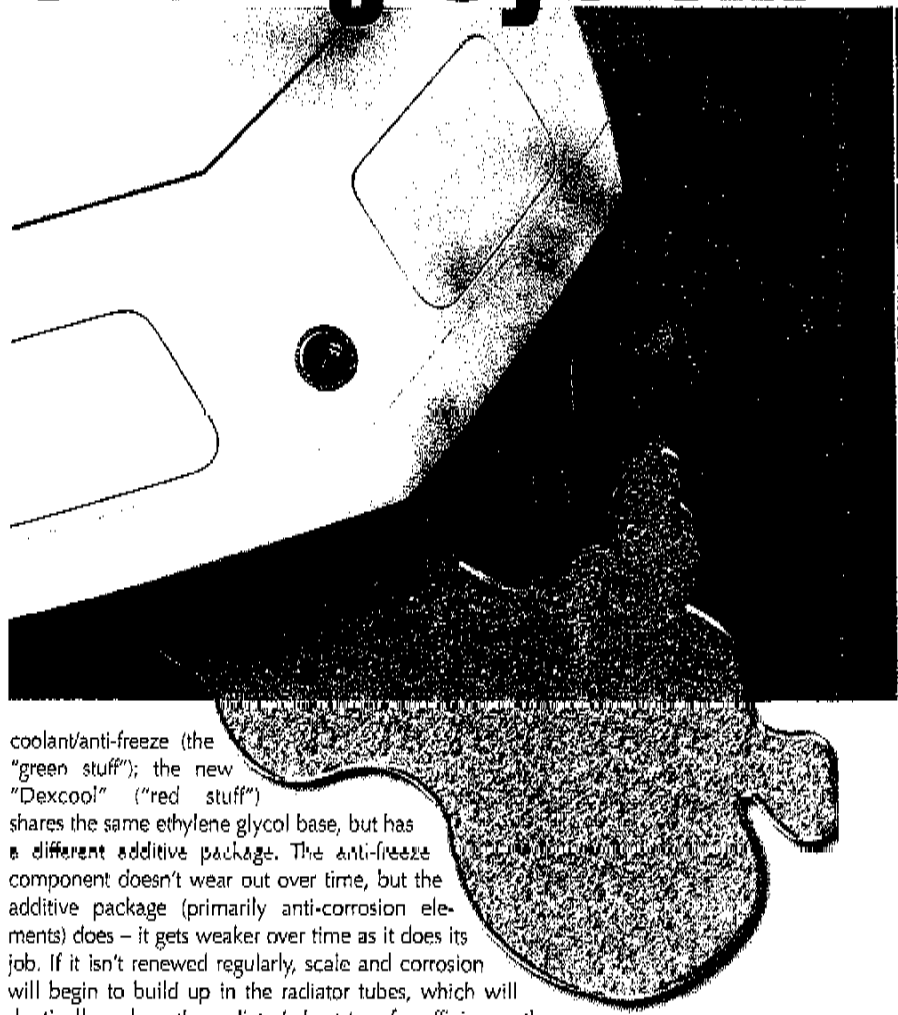
With that understood, let's examine the components of the cooling system and see what they do (and what they don't do).

**COOLANT:** Your Corvette was designed to use a 50-50 mix of ethylene glycol-based

coolant/anti-freeze (the "green stuff"); the new "Dexcool" ("red stuff") shares the same ethylene glycol base, but has a different additive package. The anti-freeze component doesn't wear out over time, but the additive package (primarily anti-corrosion elements) does - it gets weaker over time as it does its job. If it isn't renewed regularly, scale and corrosion will begin to build up in the radiator tubes, which will drastically reduce the radiator's heat-transfer efficiency; the buildup of scale and corrosion acts as an insulator inside the tubes, reducing the rate of heat transfer to the air. It's a good idea to drain and replace your coolant mix every two years to maintain the effectiveness of the anti-corrosion inhibitor package. The 50-50 mix of coolant also provides boil-over protection, as that mix, with a 15# radiator cap, raises the coolant's boiling point to 265° to prevent "puking" coolant out of the overflow hose during "heat-soak" after shutdown when the water pump is no longer circulating coolant through the radiator.

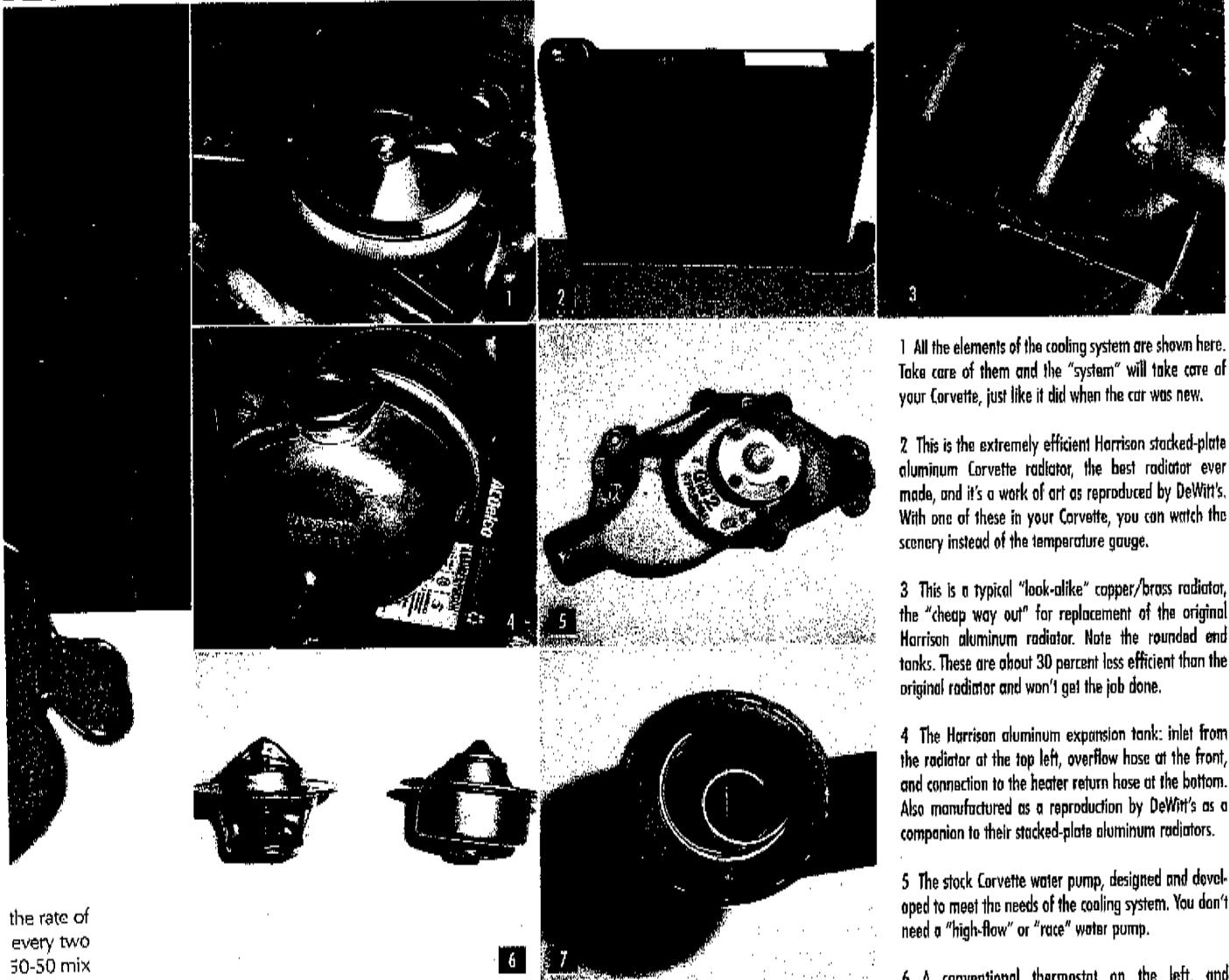
Using just water as a coolant is a bad idea, even if you live in the Deep South; you lose the anti-corrosion protection as well as some of the boil-over protection. Cures for cooling problems don't come in bottles, either; they may help the symptoms temporarily, but they don't address the real root causes - radiator heat-transfer capability and airflow management.

**RADIATOR:** There are two types in Corvettes - the stacked-plate aluminum Harrison design with a separate expansion tank, and the conventional copper/brass type with no expansion tank. The Harrison aluminum design is by far the more efficient, as it has the most fin-to-tube contact area, which is how the heat is transferred to the air. Copper/brass



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# m Basics



1 All the elements of the cooling system are shown here. Take care of them and the "system" will take care of your Corvette, just like it did when the car was new.

2 This is the extremely efficient Harrison stacked-plate aluminum Corvette radiator, the best radiator ever made, and it's a work of art as reproduced by DeWitt's. With one of these in your Corvette, you can watch the scenery instead of the temperature gauge.

3 This is a typical "look-alike" copper/brass radiator, the "cheap way out" for replacement of the original Harrison aluminum radiator. Note the rounded end tanks. These are about 30 percent less efficient than the original radiator and won't get the job done.

4 The Harrison aluminum expansion tank: inlet from the radiator at the top left, overflow hose at the front, and connection to the heater return hose at the bottom. Also manufactured as a reproduction by DeWitt's as a companion to their stacked-plate aluminum radiators.

5 The stock Corvette water pump, designed and developed to meet the needs of the cooling system. You don't need a "high-flow" or "race" water pump.

6 A conventional thermostat on the left, and a Robertshaw "balanced-flow" type on the right; you want a 180-degree version of the one on the right for accurate calibration and fail-safe operation.

7 This is the coiled steel reinforcement inside a quality replacement lower radiator hose. If this has deteriorated or corroded away, water pump inlet suction can collapse the hose and restrict coolant flow into the engine.

conventional radiators need larger cores, as they have less fin-to-tube contact area due to having narrower tubes, and they're heavier. Another key difference is that aluminum radiators can't be repaired, and they're expensive to replace; copper/brass radiators can be repaired or re-cored using the original side tanks, and they're also less expensive to replace.

Your radiator's biggest enemy is internal corrosion. Internal scale formation and corrosion caused by the reaction of dissimilar metals in the cooling system and by "worn-out" anti-corrosion inhibitors in the coolant causes both structural failure (leaks) and drastic reduction of heat-transfer capability due to the "insulation" formed by the built-up deposits inside the tubes. Radiators don't age well; nobody ever expected them to last more than 10 years to begin with, and without regular coolant changes, it doesn't take long for scale to build up and reduce their efficiency. Regular cooling system maintenance is the best recipe for keeping your radiator working, but once scale and corrosion

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has built up, there isn't much you can do to remove it; eventually it's new radiator time. A typical 10-year-old radiator that hasn't seen regular coolant changes has lost anywhere from 20 to 40 percent of its heat transfer capability, although it may "look good." Don't be fooled by a "flow test" at a radiator shop - all that tells you is that the radiator isn't plugged or severely restricted; it can't measure the radiator's heat transfer capability, which is what really counts. When the time finally comes to replace your radiator, don't be tempted to buy on price; buy a *quality* radiator that at

(which is why they use a unique RC-26 filler cap with no plain steel exposed to the coolant).

**WATER PUMP:** The water pump just circulates the coolant; its speed relative to the crankshaft and its impeller design was carefully arrived at by the engineers who developed it to move the correct volume of coolant at the proper velocity through the calibrated restriction of the thermostat to serve the needs of the cooling system under all operating conditions. Its shaft rides in sealed bearings; there hasn't been

the cause of a cooling problem, unless they're really ancient and the impeller blades have corroded away.

**THERMOSTAT:** Probably the most misunderstood component in the cooling system, the thermostat has absolutely *nothing* to do with controlling maximum engine operating temperature. Period. What does it do? At cold start, it blocks the flow of coolant out of the engine until the trapped coolant reaches the thermostat's rated temperature, at which point it opens and permits coolant to begin circulating. This

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8 The fan, clutch, radiator, and shroud are an engineered "system." Keep them as originally configured, and replace any missing or deteriorated seals to maintain your Corvette's original cooling airflow management.

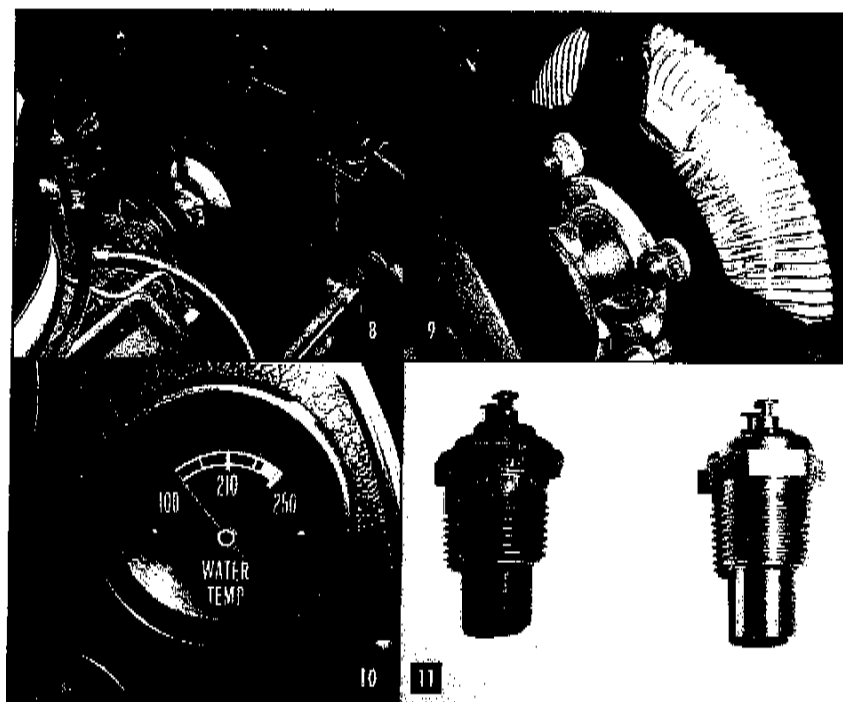
9 The temperature-modulated Corvette fan clutch; current replacements are calibrated for full engagement at higher temperatures than the originals, but you can have your original rebuilt.

10 The gauge you hate to look at if your cooling system isn't up to snuff. Verify its accuracy with an I.R. gun. You can identify individual components by taking a reading on their external temperature to troubleshoot an overheating cooling system.

11 The original GM (AC) sending unit on the left, and a Wells TU-5 replacement on the right. A check with an I.R. gun will verify whether it's correctly calibrated and sending the right signal to your temperature gauge.

least matches the cooling capability of the original.

**EXPANSION TANK:** Conventional copper/brass radiators with fill openings have side tanks that serve as reservoirs to accommodate coolant expansion; that's why the "Full Cold" mark is several inches below the filler neck - to allow for expansion of hot coolant. The Harrison stacked-plate aluminum radiator has no side tanks - it's all core, from end to end, so it needs an external reservoir to provide a fill point and to accommodate coolant expansion. The companion Harrison aluminum tank has the cap/fill point, an inlet from the top of the radiator to provide a path to the tank for expanded coolant, an overflow hose from the filler neck, and the bottom of the tank has a fitting connected with a tee to the water pump inlet fitting so the tank is connected to the coolant circulation system and functions as a reservoir. They are trouble-free unless the relatively thin aluminum has been attacked by corrosion



any need for "water pump lubricant" for decades. When the bearings deteriorate, you can feel both radial and axial slop in the shaft, and that will start to tear up the seals. That becomes obvious when you see coolant dripping from the "weep hole" in the bottom of the snout portion of the casting. Stock water pumps work just fine; there's no need for "high-flow" or "race" water pumps, unless you like their appearance. NASCAR "race" pumps are uniquely designed so they won't cavitate at 9,000 rpm while moving coolant that has to absorb the heat from constant wide-open throttle from an 800-hp engine. You don't need that on the street, and "race" pump impellers are much less efficient at normal street operating rpm than the impeller in a stock factory pump. If your pump leaks, either have it rebuilt or replace it. Water pumps are hardly ever

aids rapid warm up, which reduces cylinder bore and piston-ring wear by bringing the engine up to operating temperature relatively quickly. Once it's open, it modulates the flow of coolant through its calibrated restriction so coolant temperature never drops below its rated opening point, assuming the cooling system is efficient enough to cool the engine down to that level. In most cars, it's essentially wide open all the time, and only the heat transfer efficiency of the radiator and the airflow through the radiator determine the engine's maximum operating temperature.

If you have a 180° thermostat and your engine operates at 220°, changing to a 160° thermostat won't change your operating temperature one bit - you need more radiator, more airflow, or both, to reduce operating temperature. If you have an extremely efficient cooling system with

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more heat-rejection capability than your engine needs (runs at 180° with a 180° thermostat), changing to a 160° thermostat may result in reducing your operating temperature to 160°, but this is rare except in cold weather. Furthermore, 160° is too cold; OEM testing has proven that the rate of cylinder bore and piston-ring wear at 160° is *double* the wear rate at 180°, and a coolant temperature of 160° won't let the oil in the pan get hot enough to boil off condensed moisture and blow-by contaminants, which then remain in suspension and accelerate the formation of acidic

coolant expands (which vents through the overflow hose nipple in the filler neck when that pressure is exceeded). The vacuum side of the valve allows air (or coolant, if you have a coolant recovery bottle) to flow back into the radiator as a vacuum is created when the system cools down.

The radiator cap, like the thermostat, has absolutely *nothing* to do with maximum operating temperature. Period. If you have a cooling problem and replace your 15# cap with a 22# cap, your operating temperature won't change one bit. What

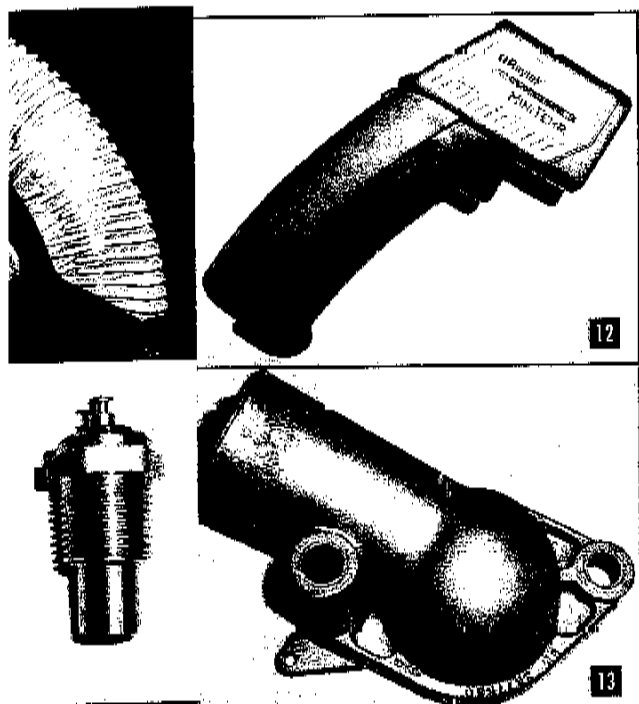
12 The Raytek MiniTemp MT-4 Infrared temperature gun, the best cooling system diagnostic tool you can buy. It tells you the exact temperature of any component the red laser dot is aimed at.

13 Here's "the house" where your thermostat dwells. "Shoot" it with an I.R. gun to determine your engine's actual operating temperature, and compare that with the temperature gauge so you know what the gauge is telling you.

will change is the temperature at which the coolant will boil (and "puke" out through the overflow hose), as the coolant's boiling point increases with increased system pressure. There's another coolant lesson here – a 50-50 antifreeze/water mix at 15 psi boils at 265°, while a water-only coolant at 15 psi boils at about 250°; another 15 degrees of boil-over margin with a 50-50 mix.

**LOWER RADIATOR HOSE:** The upper radiator hose is always under pressure, but the lower hose lives at the intake (suction) side of the water pump, and under some operating conditions (acceleration, sustained high rpm) is under a partial vacuum. That's why quality lower radiator hoses have an internal coiled steel wire reinforcement to keep the hose from collapsing and restricting flow back into the water pump. Over time, this coil corrodes (and sometimes disappears completely). It won't be obvious visually with the engine idling, as pump inlet suction is minimal at idle. Squeeze the hose with your hand. If it collapses, the reinforcement is history, and the hose should be replaced. This is frequently a contributor to abnormally elevated highway-speed operating temperature.

**FAN SHROUD AND SEALS:** Managing airflow through and across the entire surface of the radiator core is the fan shroud's job, especially at idle and at low



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sludge. 160° thermostats were specified in the 1930s for the old alcohol-based antifreezes, which would boil off and evaporate at 185°; there's no other reason for them.

"Balanced-Flow" thermostats like Robertshaw makes (also sold by Mr. Gasket with their name on them) are calibrated much more accurately than conventional parts-store thermostats, and if they fail, they do so in the open position. Conventional thermostats fail closed, which can cause a lot of engine damage in a big hurry if you don't spot the sudden temperature rise.

**RADIATOR CAP:** The radiator cap simply seals the cooling system, and it has a two-way pressure-vacuum valve to maintain a given pressure in the system (typically 15 psi) after the system warms up and the

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speed in traffic (in combination with the fan). The shroud must be the correct part to fit the radiator configuration, and the gaps between the two should be sealed with foam strips or rubber flaps so the fan forces all incoming airflow through the radiator core, not around it. The radiator itself should also be sealed to the radiator support for the same reason, and most original A/C installations included these seals. Many configurations also have a rubber flap or foam seal between the top of the radiator support and the hood inner panel. This closes that gap when the hood is closed, and does two things: It closes off another path for outside airflow to go over (instead of through) the radiator, and it stops the phenomenon where hot under-hood air is drawn over the top of the radiator support and gets recirculated through the radiator again. You want only cooler outside air flowing through the radiator, not hotter under-hood air.

**FANS AND CLUTCHES:** The fan's job is to pull as much air as possible through the radiator core at idle and in low-speed traffic, and to present minimum airflow restriction to ram-air through the radiator at highway speeds. Factory fans are very carefully designed for maximum efficiency (and minimum noise, which is why the blade positions are staggered), and are designed to provide maximum efficiency when the tips of the blades are half-in/half-out of the rear edge of the shroud, with approximately 1/2" clearance from the blade tips to the shroud. The radiator/shroud/fan combination on each Corvette is the result of a lot of tedious hot-weather development work by the engineers who designed it, and the original system is tough to improve on, assuming that all the components of the cooling system are functioning properly and haven't been butchered, altered, removed, substituted, or backyard-engineered to "improve" them. These cars didn't overheat when they were new, and they shouldn't now, if the "system" is still composed of the correctly configured components.

The job of the thermo-modulated fan clutch is to move as much air as possible at high coolant temperatures, and to "relax" at high rpm and at normal operating temperatures for reduced noise levels when maximum cooling isn't required. Most of them essentially disengage over 3500 rpm,

and in the '60s and '70s they were calibrated to tighten up and engage fully at about 190°, and at around 210-220° in the early '80s. Remember that when you buy a current replacement - most have the later calibration, and won't be quite as effective as the original clutch was when it was new. Several people in the hobby can rebuild your original fan clutch to the original calibration, if that's important to you.

What about "flex-fans?" GM never used them. Flex-fans aren't as efficient at moving air as the factory fans, they present more of a ram airflow restriction at highway speeds than a factory fan when the flexible blades flatten out, and some of them have a bad reputation for shedding blades due to metal fatigue at the blade-to-hub attachments. The factory fan and clutch is a much better all-around "system" than a flex-fan.

What about aftermarket electric fans? Unless you get a really well-engineered dual-fan setup with a full shroud that covers the entire face of the radiator core (with pressure-relief flaps for added airflow at highway speed), they're a poor substitute for the factory fan setup, and they place a major electrical current draw (30-40 amps) on the system at the worst time, when the alternator is at its lowest speed. The typical single round aftermarket fans that attach directly to the radiator core draw air only through the portion of the core that's enclosed within the diameter of the fan blades; the other 50 percent of the face of the radiator core gets no airflow at all. The factory shroud ensures that air is drawn through every square inch of the core, all the way to the corners.

**C3 FRONT AIR DAMS:** The primary difference between the C2 and C3 cooling systems is the source of outside air for the radiator. C2s have the traditional direct airflow through the grille into the radiator, and C3s were the first generation of "bottom-breathers," where most of the airflow into the radiator is deflected from below through holes in the front bumper/fascia area with the help of plastic "air dam" panels. These fragile pieces are frequently on the losing end of contact with speed bumps, driveway entries and parking-lot blocks. This doesn't affect cooling much at idle and in low-speed traffic, but loss of those panels will have a major effect on highway-

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speed cooling due to lack of adequate ram airflow through the radiator. Keep an eye on them, make sure they're in place and securely attached so they can do their job at freeway speeds.

**TEMPERATURE GAUGE AND SENDING UNIT:** Corvettes use an electric temperature gauge, driven by a sending unit in the intake manifold or cylinder head. The sending unit body is directly exposed to the coolant leaving the engine, and contains a thermistor (temperature-sensitive variable resistor). Twelve volts is supplied to the gauge, which is then connected through a wire to the terminal on the sending unit. At the sending unit, the 12 volts goes through the thermistor element to ground through the threads on the sending unit; the varying resistance of the thermistor (with coolant temperature) causes deflection of the gauge needle to indicate the coolant temperature. When the sender and gauge were made, they were calibrated to a standard value so they worked together to provide a reasonably accurate indication - they are *not* laboratory-standard precision instruments. Age, dust, dirt and moisture affect the gauge movement and its electrical components, and the sending units also deteriorate with the years. Replacement sending units are not accurately calibrated to match the gauge, and almost all of them cause the gauge to read 20-40 degrees too high, although the Wells TU-5 (\$5.00 at AutoZone) has proven to be much closer to original calibration than any of the other replacements, and several hobby vendors now have replacement senders that are advertised as being properly calibrated.

**TAKE A SHOT:** Before you dive into solving a cooling problem, make sure you really have one. The first step in troubleshooting is to either buy an infra-red temperature gun (\$60-\$90) or go to a shop that has one and "shoot" the thermostat housing with the engine at full operating temperature and compare that reading with what the gauge shows at the same time so you know what the gauge is really telling you.

**IGNITION TIMING:** What in the world does ignition timing have to do with cooling problems? Plenty. I'll go into the detail of the murky and little-understood world of ignition timing and vac-

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uum advance in another article, but suffice to say that inadequate spark advance at idle is a major contributor to idle and low-speed running problems, especially on engines equipped with A.I.R. (Air Injection Reactor) systems and "ported" vacuum for the distributor vacuum advance diaphragm. These engines (and some without A.I.R. as well) had intentionally retarded spark at idle, which significantly increased exhaust gas temperature, most of which was then transferred through the exhaust port walls into the coolant in the cylinder heads. Without going into gory detail, the cure for this is to connect the distributor vacuum advance to full manifold vacuum and readjust idle speed and mixture screws to reduce exhaust gas temperature and stabilize the idle with the vacuum advance fully deployed. You'll also need an advance can calibrated so it's fully deployed with at least 2" Hg. less vacuum than your engine develops at idle (about \$10 at NAPA).

**SUMMARY:** The coolant carries the engine's heat to the radiator, which rejects it to the air passing through it; if the radiator can't reject the heat to the air passing through it as fast as the coolant delivers it, you've got a cooling problem. Ninety percent of the time, the problem is either the radiator or airflow management. Check each component, isolate the root cause, and repair or replace it. If you add more motor (which makes more heat), add more radiator. Most low-speed cooling problems are related to airflow management and/or ignition timing, and most highway-speed cooling problems are related to the radiator or restricted air or coolant flow. The solutions come in boxes, not bottles. ■

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