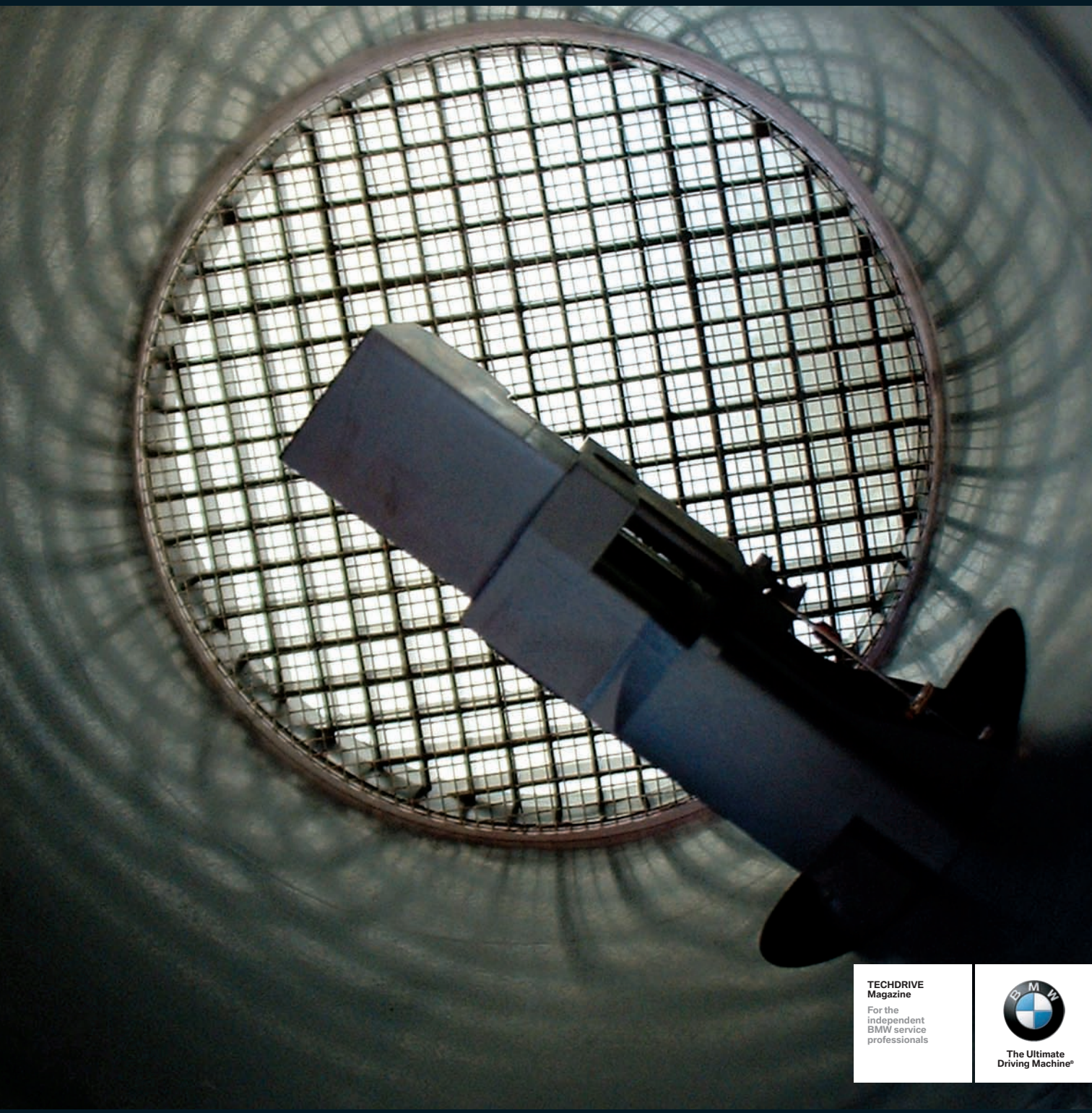
TECHDRIVE

Original BMW Parts

VOLUME 2 NUMBER 2

A PUBLICATION FOR INDEPENDENT BMW SERVICE PROFESSIONALS SEPTEMBER 2005



TECHDRIVE Magazine

For the independent BMW service professionals

The Ultimate Driving Machine®

AIR MASS METERS • TECH INFO SITE • COOLING SYSTEM SERVICE

TO OUR READERS

— What could be more useful to independent service technicians who work on BMWs than a publication dedicated specifically to them?

— That's the idea behind the magazine you're holding, TECHDRIVE. BMW of North America both sponsors the publication and provides much of the information that's included. A big part of the rationale behind TECHDRIVE is the belief that if you are able to diagnose, repair and maintain BMW vehicles properly and efficiently, your reputation and ours will be enhanced.

— TECHDRIVE's combination of feature service articles (written from both BMW tech information and interviews with successful independent BMW specialists), new technical developments, systems evolution, as well as the correct BMW replacement part, and service bulletins are intended to help you fix that BMW right the first time, on time. Our list of BMW dealers will assist you in finding Original BMW Parts.

— There's more to this effort, including highly-informative and user-friendly web sites, which we'll explain in future issues.

— We want to make TECHDRIVE the most useful and interesting technical magazine you receive, and you can help us do that. Please let us know what topics you'd like to see covered, and provide any other comments you might have. With your involvement, this publication can evolve into one of your most important tools.

Thanks for your continued interest.

For more information please email us at:
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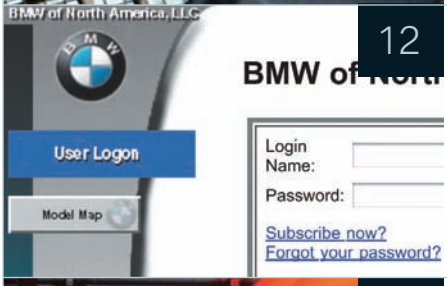
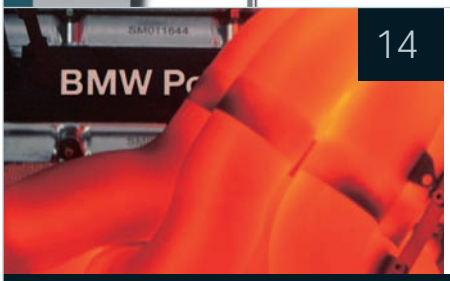
Feature Articles





Departments

TECHDRIVE Magazine

For the independent BMW service professionals

The Ultimate Driving Machine®

Diagnosing BMW Air Mass Meters

Whether you know it as an air mass meter or a MAF, no input is more important to performance than that which informs the engine management computer of how hard the engine is breathing.

Did you ever think that a carburetor is actually a crude air mass meter? Or, are you of the younger generation that never worked on a carbureted car? We often get a wake up call on our own age when we talk about such things, but being in California, we still get a small percentage of vehicles with carburetors, though obviously not BMWs, which have had fuel injection, whether K-Jetronic, L-Jetronic, Motronic, etc., for decades. In any case, the job of the carburetor with its throat and venturi was to approximate the volume of air passing into the engine and add the appropriate amount of fuel. With or without a feedback system, anything that upset the ability of the carb to control the amount of intake air, or to meter the proper amount of fuel atomized into that air would skew the air/fuel ratio. Vacuum leaks, PCV problems, fuel supply restrictions, heavy floats, and so forth would all have their negative effect on engine performance, idle quality, acceleration characteristics, and exhaust emissions.

Just as many techs of the past working without proper diagnostic strategies used to condemn carburetors when the problem was really in another area, so today an improper approach to diagnosis will result in condemning air mass meters that are not necessarily defective.

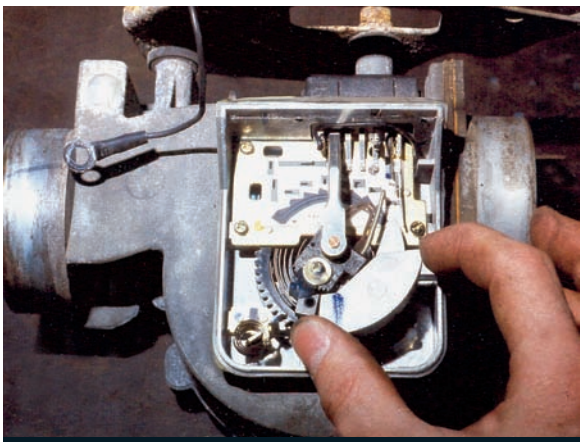
Transfer of learning

As they say, the more things change, the more they stay the same. That is a fortunate fact for us in the vehicle service business. If we could not transfer forward our knowledge (educators call it "transfer of learning"), we'd be hung out to dry as far as keeping up with technology. We need that basic understanding of operating principles in order to build skills that apply to today's technology.This is not to suggest it isn't tough enough as it is, but the very fact that you as a technician are reading this magazine and this article suggests that you have an interest in keeping up. So let's see what we can do to further our understanding of the hot film air mass meter used in BMWs, based on what we already know about engine dynamics, fuel delivery, and the ability of the DME to control air/fuel ratio. Though BMW used vane airflow meters, then hot wire sensors before 1996, for the purposes of this article we will stick to the hot film air mass meter.

Nothing else yet devised is as good at telling the engine management computer the actual mass of the air it's ingesting as the air mass meter, otherwise known as the MAF.

Any of the problems that we mentioned above concerning a carburetor will also affect an air mass meter system. All of the air being fed to the engine, minus air coming through the PCV and canister purge systems, needs to travel through the air mass meter (or, to use the standardized SAE term, Mass Air Flow sensor, or MAF).

Principles



The old L-Jetronic vane airflow meter, or VAF, was ingenious. The swinging spring-loaded flap rotated a variable resistor (or, potentiometer) according to the cfm of air that was entering the engine. The trouble was, it couldn't account for the actual mass of the air, just its cubic volume.

The first Robert Bosch electronic fuel injection system was D Jetronic. Introduced way back in 1968, it used a vacuum sensor (the "D" is for "Druck," which means "pressure" in German) to inform the electronics about the intake situation, but in '74 the air flow meter, or VAF (Vane Air Flow) showed up on L Jetronic (the L stands for "Luftmengenmessung" auf Deutsch, meaning "air flow management"), also known as AFC (Air Flow Controlled) fuel injection. At the time, we thought the concept was ingenious: A vane rotated against spring pressure according to how much of the atmosphere the engine was ingesting, and this movement turned the shaft of a variable resistor, thus changing the reference signal before it returns to the computer. Simple, and much more accurate than anything else ever devised.

The jump to direct mass measurement occurred in 1984 when LH-Jetronic with its hot wire sensor was introduced (to continue our foreign language lesson, the "H" stands for "Heisz," German for "hot"). Then came the hot film MAF (Mass Air Flow) sensor.

A retail analogy will help illustrate this evolution. Suppose you were in the business of selling air. You could calculate the amount delivered by using a complicated formula that takes pressure, temperature, and the diameter of the valve into account, but that would be slow, unwieldy, and probably not very accurate (think of the speed-density systems you may have seen on Asian cars).

You'd improve the efficiency of your operation considerably if you had a way of directly measuring the volume flowing into your customer's air canisters in cubic feet per minute. That would sure speed things up, but it wouldn't be perfect, either. On cold days, they'd be getting a big bargain because any gas is denser when it's cold than when it's hot -- in essence, you'd be giving them a baker's dozen and then some. Sales would go way up (and profits way down) in winter as soon as your patrons realized that fact of physical reality. And they'd always try to buy at sea level in dry weather because altitude and humidity affect density, too.

This VAF variable resistor sensor is installed on an old M inline six. Performance was great, but would've been even better with a MAF/AMM.

To keep from losing your shirt, you'd still have to use a formula that varied the price per cubic foot according to temperature, altitude, and moisture content. Wouldn't it be a lot easier, faster, and more precise if you had a meter that read out in the actual weight instead of just the volume? Sure it would.

Back to engines. A direct reading by means of a VAF sensor aids swiftness and accuracy, which are both critical if optimum performance, high fuel efficiency, and low emissions are to be achieved. Since air/fuel ratios are by weight (stoichiometric is 14.7 lbs. of air to one lb. of gasoline -- in gallons it would be about 2,000 to one), however, measuring mass makes even more sense, so for many years BMWs have had sensors that do just that.

An air mass meter has some other advantages besides its ability to account for density: no moving parts, restrictions, or compensating sensors. A typical late-model BMW MAF has a film element that's kept heated to a specified temperature above ambient (180 deg. C.) and is exposed to intake air. Through a Wheatstone bridge circuit and dedicated electronics, the amount of current required to maintain that temperature becomes the signal to the computer. High air flow obviously has a greater cooling effect than low, but so does the denser air of cold days and low altitudes, so the DME gets the true data on mass it needs to provide the longer injector pulse width that extra oxygen needs to fire dependably. The units used in BMWs produce an analog voltage output.

Bosch or Siemens?

The hot film air mass meter has been around for many years now, one version manufactured by Robert Bosch and the other by Siemens (Hint: Bosch systems are labeled “M,” while Siemens systems are identified by “MS” -- for example, the M5.2 Bosch, or the MS41.1 Siemens). Since they have no moving parts and are less apt to foul than the hot wire type, both are very reliable meters. They operate on a principle of thermodynamics: If we move air over a heated surface, the heat from the surface will transfer to the air and there will be a cooling effect. The meter will attempt to hold the surface at a specific temperature (the 180 deg. C mentioned above) by supplying more current to the heating element as airflow and therefore heat transfer increases.

This effort is translated into an analog signal. That is, its output voltage changes based on airflow from around .6 volts at idle to over four volts under heavy throttle conditions. How this is reported to the scan tool varies by model and year, but most commonly the tech will see the parameter reported in kilograms per hour (kg/h) rather than a voltage value or grams per second (gm/s). Hot film sensors are generally less subject to contamination problems than the previously-used hot-wire sensor. Low-quality air filters, filters that use oil as a filtering aid, and dirty air in general are very hard on hot wire sensors. They can affect the hot film sensor as well, but are less likely to do so.

Codes and scan tools

Air mass meters are notoriously poor at diagnosing themselves directly, particularly when the failure is due to a loss of accuracy in reading airflow. Many techs have trouble as a result when they find codes that are based on a problem with multiplicative or adaptive fuel trim, specifically P codes 0170 and 0173, or FC codes 202 and 203, 227 and 228. In talking to techs who own the BMW factory-specific GT-1 tool with the DIS software, we find they rarely discuss failures in terms of codes since the scan tool software will lead them down a diagnostic path based on the scanner’s interpretation of the FC code.

While a lack of power or a rough idle due to an AMM problem might not bring the customer in, an illuminated MIL probably will. Ditto for a failed emissions test.

Most independents will be working with an aftermarket scan tool instead of the GT-1, so you'll probably be proceeding on the basis of trouble code descriptions of what system may be causing the code. This means engaging your understanding of electronic engine management systems in general and your skills in using OBD II in order to perform effective diagnoses.

Customer communications

When a vehicle comes into the shop with a potential air mass meter problem, chances are it is due to one or more of four possible customer complaints. Number one would probably be lack of power; number two would be rough idle; number three would be an illuminated MIL (Malfunction Indicator Lamp); and number four would be a failed emissions inspection.

We've compiled quite a list of our own of probable symptoms of AMM trouble. Bosch tells you to expect starting problems both hot and cold, hesitation, stalling (especially under load), rough idle, and low power output. Also, the engine may fire up, then die.

Contamination of the sensing element, which slows response, will result in stumble, which brings us to the most prominent logical effect of a bad or non-existent AAM signal: transient throttle glitches, including stalling, sagging, and missing. If it's far enough out of range to cause the DME to shift to limited operating strategy, overall performance and driveability will be lousy.

But don't let these symptoms cause you to jump to an unfortunate conclusion and automatically replace that expensive sensor. Plenty of other malfunctioning components can result in the same kinds of annoying and inefficient engine behavior. So, check the basics first. That means ignition, compression, fuel pressure and volume, etc. Then there are all the other sensors and the wiring and connections that are part of every electronic engine management system. In short, don't blame the AAM right off because most of them have proved to be pretty dependable.

OBD II continually examines the MAF under the comprehensive component monitor. It looks for an out-of-range signal, and compares output to values calculated from input on rpm, manifold absolute pressure, throttle position, and intake air temperature, then sets a generic DTC if there's a discrepancy.

But codes can get you into trouble. All they should really be used for is aiming your diagnostic efforts in a general direction, not as the final word on what's wrong. You'll need to do some more troubleshooting and rely on your experience before you can be sure.

There's a good quick check: With the key off, unplug the MAF's harness connector, then start 'er up. If the engine runs appreciably better now, it's time for a new sensor.

In our shop, regardless of the customer complaint, we require that the car must be

road tested unless it is unsafe to drive. We don't know how it is in your area, but we can tell you that our customers are notoriously poor communicators. What they say they don't like may vary pretty far from your experience, so you'd better start out with a comprehensive road test, preferably with the customer aboard. If the complaint is a lack of power, and you are constrained by speed limits in your area, shift into the lowest possible gear and see how well the engine will wind up in rpm. Badly shifted air mass meters will often limit engine rpm to well below the redline, though the feeling cannot always be distinguished on a road test from a blocked exhaust or low fuel pressure.

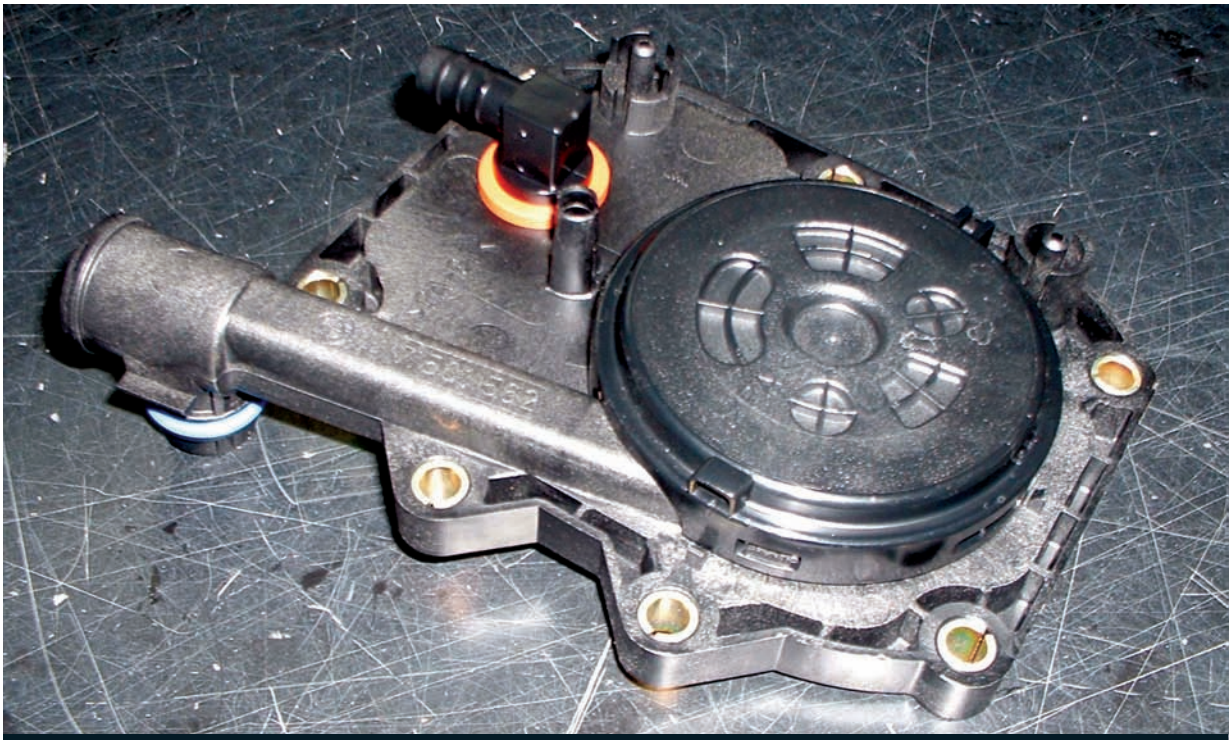
Visual and tactile

The technician's diagnostic path may vary based on the actual complaint after the road test, but an underhood inspection is always a good place to go next. Remember that unmetered air will generate a lean condition, since the AMM will underestimate the airflow and, as a consequence, the DME will produce too short an injector pulse width. Deteriorated vacuum hoses seems to be fairly common. These would include the hose going to the fuel pressure regulator and the hoses that route air to and from the idle air controller. These leaks are sometimes hard to find even with a smoke machine as the engine needs to be pulling a vacuum to get the leaks to open, while the smoke machine applies positive pressure and the leak will not always show up. From your starting point of the visual inspection, begin by squeezing the suspect rubber hoses and looking for the characteristic mushiness that may indicate a failure in vacuum tightness.

Of course, this goes doubly for the big duct between the AMM and the throttle body. For some reason, this seems to be vulnerable to the development of splits and holes.

We've said this before, but it bears repeating: Whether from heat, rough handling, or even gnawing mice, the duct between the AMM and the throttle body seems to be vulnerable to perforation, thus admitting "false air" and causing the engine management computer to supply too short a pulse width.

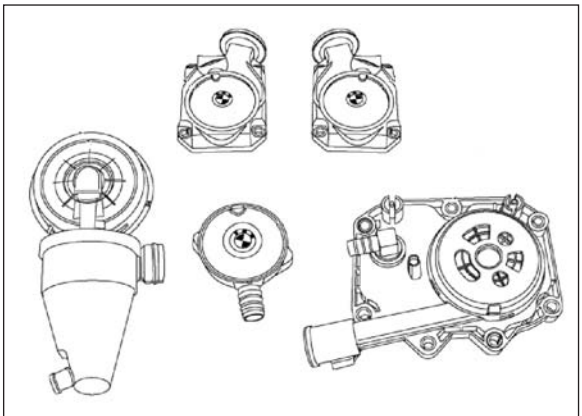
If your underhood visual inspection comes up dry, it's time to break out your scan tool -- we hope you have something that can do a better job than a standard generic OBD II code reader. Whether or not the MIL is on, check for codes. BMW is pretty good about setting codes for problems in airflow, though once again, they are systems codes, not component codes. Pay close attention to your multiplicative and adaptive fuel trim numbers. These numbers represent the amount of correction the DME has had to apply to its base injector pulse width, based on the value it calculated given the incoming parameter from the air mass meter. Multiplicative values are listed in percentage numbers, either plus or minus.



The PCV comes in downstream of the AMM, too, and BMW's unusual crankcase ventilation unit, shown here, can develop a leaky diaphragm, which not only upsets the air/fuel mix calculation, but can also cause oil burning.

Fuel trim

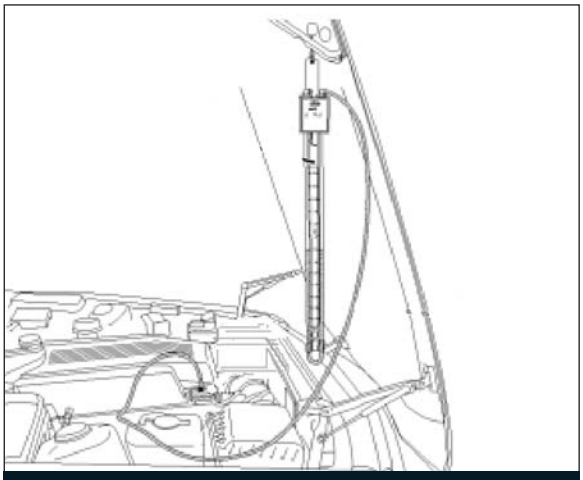
Early ('96-'99) Siemens systems would set fuel trim codes when the multiplicative value exceeded 8% in either direction, rich correction or lean correction. Bosch systems could run the values as high as 25% before setting a code for rich or lean limit. Multiplicative numbers are the rough equivalent of what is called in SAE standardized terminology LFT (Long Term Fuel Trim). Some techs report that multiplicative fuel trim is based on memory cells that are not adapted at idle because they are biased according the engine load, but we were not able to confirm this. So, use your own powers of observation to check it for yourself. Create a vacuum leak at idle and observe whether multiplicative numbers move, or only additive numbers. Additive fuel trim is the equivalent of the SAE term SFT (Short Term Fuel Trim). This number is given in tenths of a millisecond, either plus or minus, and relates directly to the actual injector pulse width as it would be measured with a lab scope.



Over the years, numerous versions of the BMW oil separator PCV have been used.

Positive numbers on both additive and multiplicative at idle are usually a good indication of an air leak. One spot of common trouble is the positive crankcase ventilation valve found at the rear of the intake manifold on BMW V8s and the bottom of the intake on sixes. The diaphragm will fail and apply excessive vacuum to the crankcase. BMW procedures (Bulletin #11 05 98) call for the use of an inches-of-water manometer to check crankcase vacuum. The spec is three inches to six inches of water, which is very little vacuum. The complaints listed in the service bulletin include rough running, a whistling noise, and MIL illuminated. The codes set may include O2 sensor codes 12 and 13 in OBD I, but the system should not set those codes from 1996 onwards.

Intake manifold and throttle body gaskets are other possible vacuum leak locations. We often find these by feel, but smoke testing is becoming popular. Techs who don't have a smoke machine can use a wand-type propane nozzle. Feed small amounts of propane to the suspected area while watching O2 and additive trim numbers for a reaction to an induced rich condition. If there is a leak, the O2 voltage should swing high while the additive trim starts subtracting pulse width. Another vacuum leak we occasionally encounter is inside the brake booster.



This inexpensive slack-tube manometer is sensitive enough to measure the low vacuum the PCV system is supposed to be operating under.

Positive and negative

Multiplicative numbers that are positive (greater than 10%) with adaptive numbers that are negative at idle are often a good tip-off that the air mass meter has drifted out of calibration. One diagnostic strategy is to clear the adaptive values (this requires a scan tool capable of this function; disconnecting the battery will not work on most OBD II BMWs). After clearing, drive the vehicle and see how it performs. Without the multiplicative fuel, the car will run terribly if the AAM is bad, often refusing to rev over 4,000 rpm, until the computer can re-adapt by adding back in the additional pulse width.

Adaptive numbers that are negative indicate an excess of fuel. This seems to be considerably less common than positive numbers, but when it occurs the place to look would be toward other factors that would cause a rich condition. Among these would be excess fuel pressure caused by a faulty regulator, or, on a return-type system, a pinched fuel return hose (we once removed a pair of Vice Grips from the return hose of a vehicle, apparently the result of someone's effort to "increase horsepower")! Other likely causes would be gas contaminated engine oil, dripping fuel injectors, or injectors that are stuck open.

In conclusion, diagnosing BMW air mass meter sensing systems should not overly tax your troubleshooting abilities if you have the GT-1, MODIC, or the best among the aftermarket scan tools available. Sure, you'll have to engage your reasoning powers, your experience and the most intellectual discipline you can muster in order to be sure of your diagnosis before buying a new part. But that's what makes you a top tech.

BMW's Tech Information Site

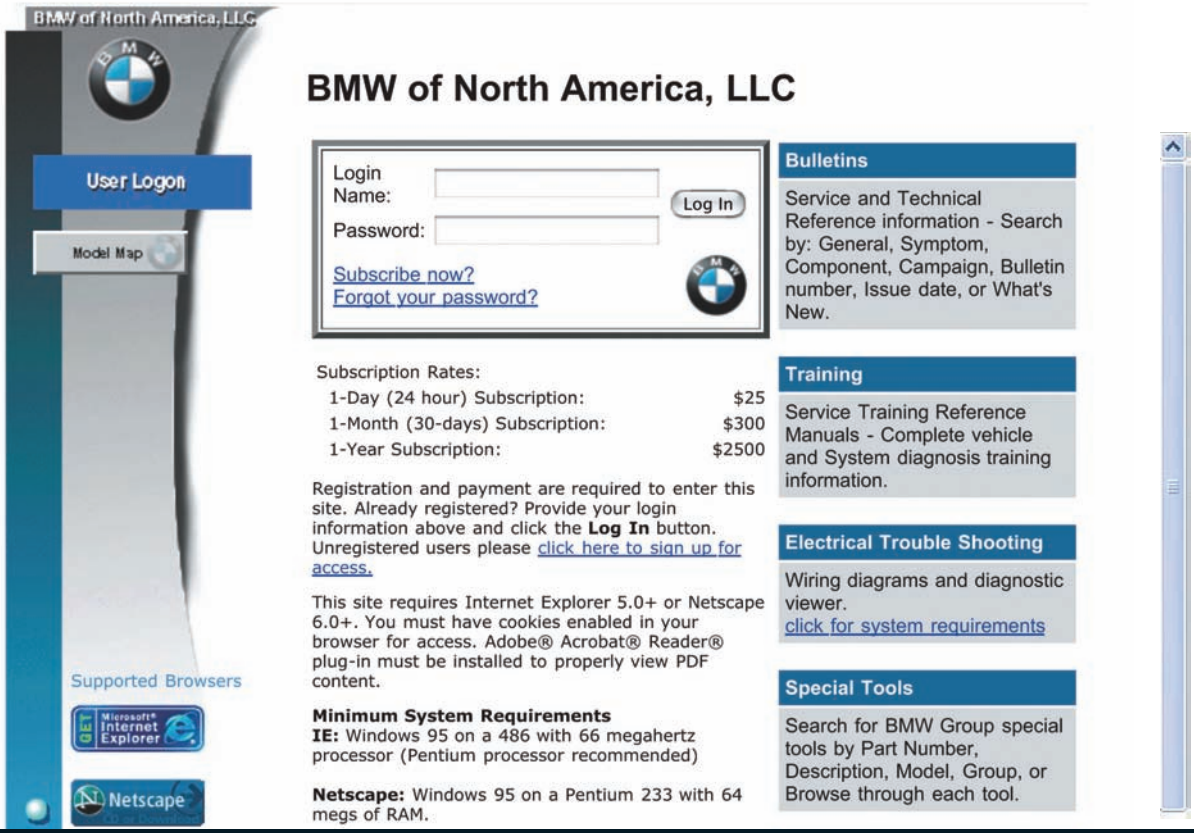
If you work on these great cars, you'll find www.bmwtechinfo.com to be a fabulous online resource

Those of us who've been in the auto service business for many years first got used to finding our specific service information in printed manuals -- a huge, ponderous and clumsy mountain of paper. There was a period back about a quarter of a century ago when it looked like microfiche data systems would become the answer to the problems of storaging and organizing tech info. Very quickly, however, it was generally realized that the power of the personal computer could vastly improve on that, even adding a search function. So, we got the CD, then DVD, service information sys tems that have been evolving and improving all along.

They had a couple of drawbacks, however. First, you had to make sure you kept your discs updated. And, shuffling through piles of discs for exactly the right one takes time.

Enter the Internet. Here, a site can be maintained by a company -- BMW in this case, of course -- so that it always contains the most up-to-date content possible. No messing with stacks of CDs/DVDs, either.

This is such an important aid to all people who work on cars, dealers and independents alike, that there's now a law making it a requirement that, *where emissions-related*



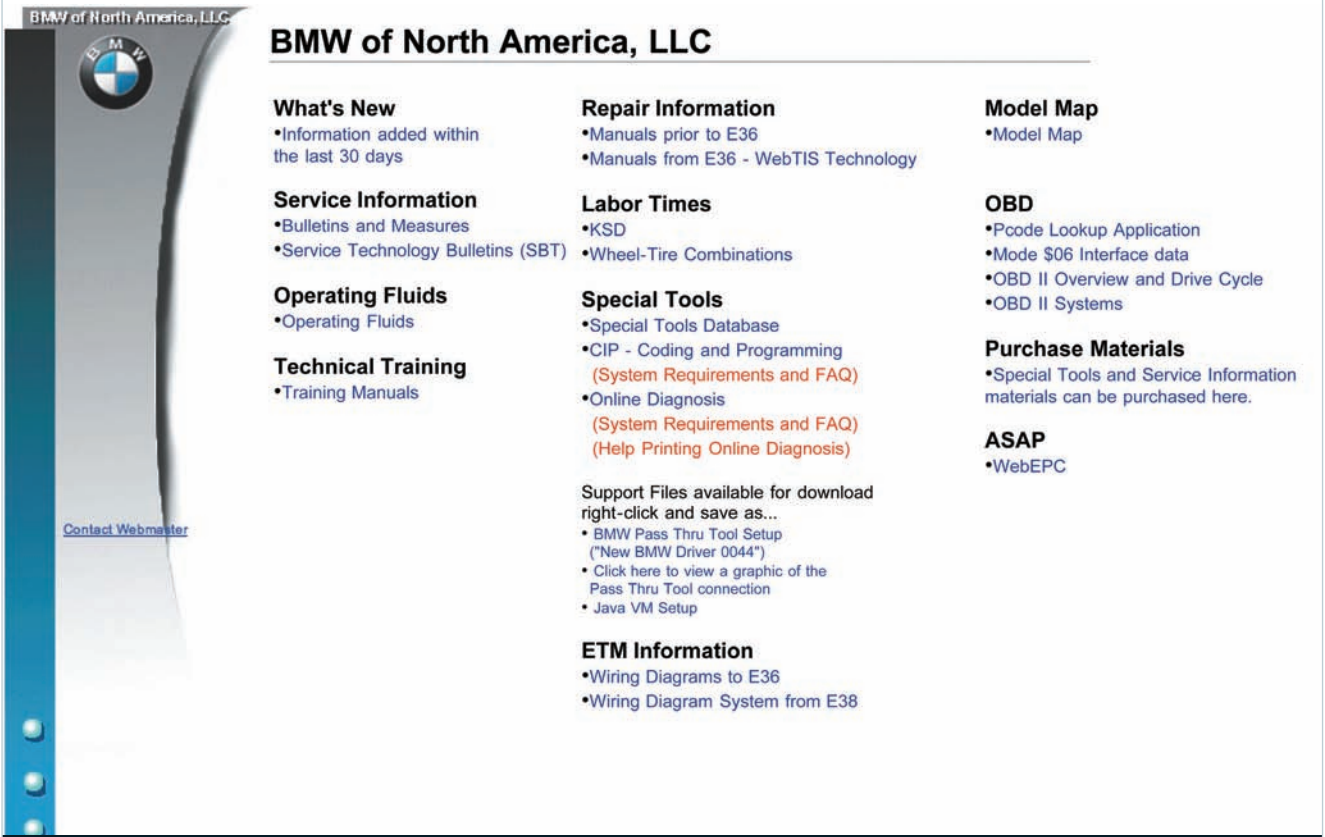
Take a minute to subscribe . . .

subjects are concerned, all carmakers provide access to such a site at a reasonable cost. But BMW has gone way beyond that, providing comprehensive information on the whole car. This can be had on a daily, monthly or yearly subscription basis at $25, $300, and $2,500, respectively. That's a good value, and, in any case, it can be charged to the customer.

We've been using BMW's tech info site for over a year, and have had great success finding exactly what we were looking for. The menus make sense, and the searches are easy to use and highly productive. As a matter of fact, we've tried other automakers' technical sites, and have found them to be much less convenient to use.

On the BMW site, which is affectionately known as TIS for Technical Information System, the menu page that opens up after you log on couldn't be any easier to understand or work with. We always check the "What's New" section, which contains info added within the last 30 days. Then, we usually go to "Service Information" and do a search under "Bulletins & Measures" (very simple and effective).

There's much more here that you'll appreciate, such as repair manuals new and old (and we mean old!), labor times, special tools, a model map that gives you series, engine, and code, and OBD II Mode $06 interface data. We can't think of anything you'd need that you won't find on this site. You'll wonder how you ever got along without it.



. . . and the whole world of BMW service technical information will open up to you with this menu, which we hope most of you are familiar with.

This test bench engine should give you an idea of how much heat is released inside the cylinders.

BMW Cooling System Service: Adventures in the Temperate Zone

Neglected cooling system problems and maintenance can lead to the biggest repair bill your customer has ever seen.

As winter approaches, it's time for you to start promoting cooling system service.

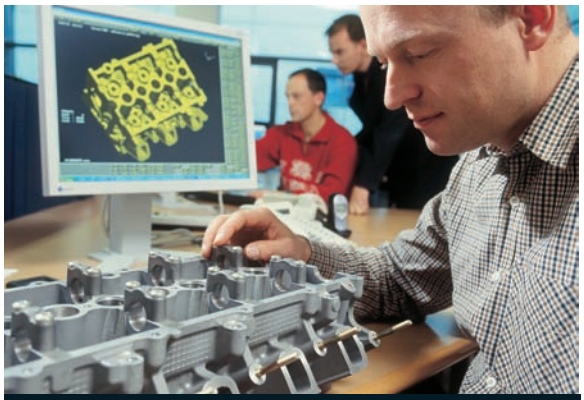
You've certainly noticed that cars in general, and BMWs in particular, just keep getting better and better, and last longer and longer. Given good maintenance, engines and transmissions can go hundreds of thousands of miles without major repairs, steering and suspension components take seemingly forever to wear out, serpentine belts run much longer than the V-type they replaced, electrical systems rarely give any trouble, and the electronics that control everything these days are practically bulletproof.

There are a couple of areas, however, that require about the same amount of care as they always have. Brakes, of course. And what keeps that terrific engine from melting itself down in an orgy of self-destruction? The cooling system, our subject here. Although some other automakers have pushed the recommended service intervals on this system to foolhardy limits, BMW maintains a sensible and conservative philosophy on this maintenance. Having seen so many ruined engines due to severe overheating, we applaud this attitude.

Fundamentals

You need a fundamental understanding of cooling system principles or you'll be apt to flub diagnosis, and you won't be able to explain the need for maintenance to your customers.

To begin with, if automotive engines were perfectly efficient, they wouldn't need a cooling system. All the energy contained in each gallon of gasoline -- about 125,000 BTUs worth -- would be converted into useful mechanical work.



Even high-efficiency diesels, such as this one being developed at BMW's Steyr plant, still can't convert enough heat into mechanical work to be able to do without a cooling system.

Alas, something is lost when the theories of physics and thermodynamics are translated into the reality. If we're lucky, we can get maybe 30% fuel efficiency. There are experimental adiabatic (that means no heat loss) diesels that are striving for a much higher level, but don't hold your breath.

So, 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 remnant that has to be forcibly extracted. Hence, the cooling system, which amounts to a heat sink. If everything is working as designed, this carries away the excess heat, thus keeping the engine below the point at which its parts would start to melt, warp, scuff and seize.

Actually, it's this way for nearly all mechanical systems -- especially those that generate usable power. We have no

(Continued on page 18)

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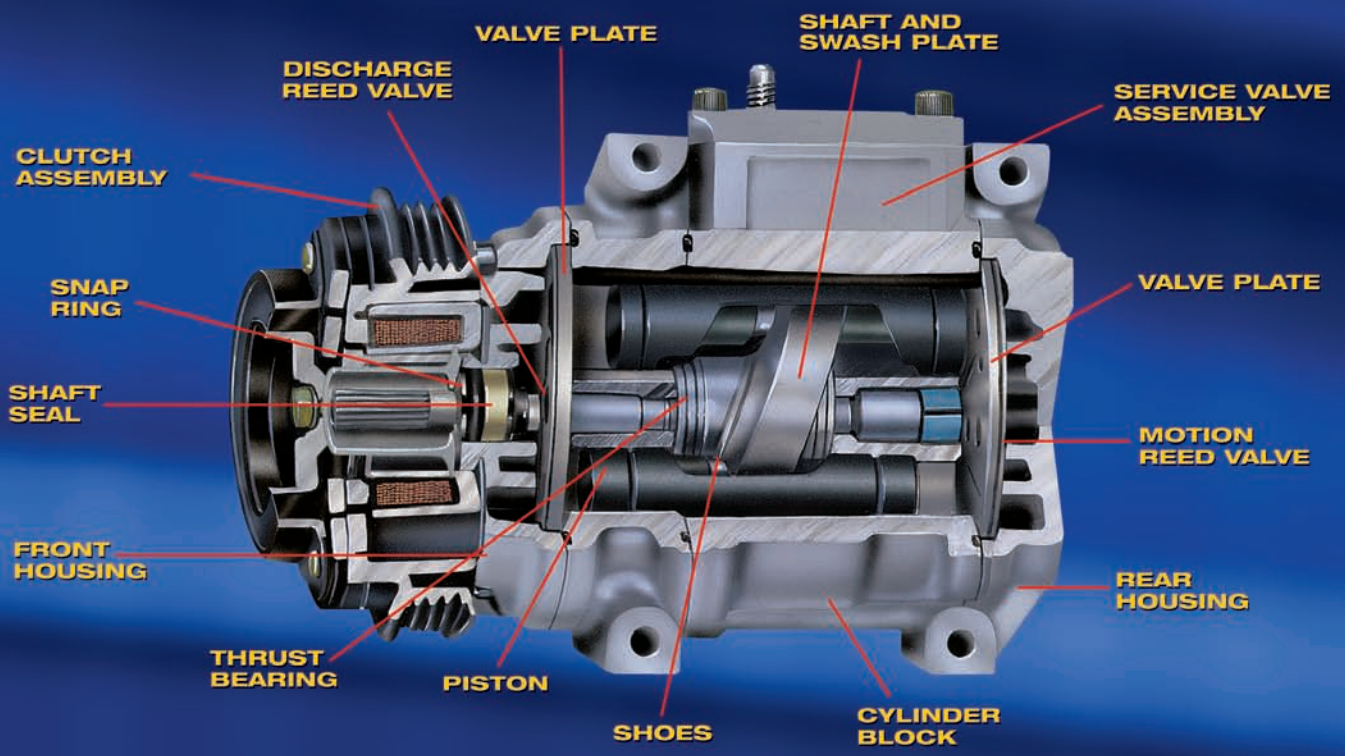

CYLINDER BLOCK & FRONT/REAR HOUSING
Cleaned, inspected and brought to O.E. specifications, or replaced with new components if necessary, to insure proper fit.

DISCHARGE REED VALVE
Inspected, cleaned, and polished, or replaced by new components as necessary, to insure compressor performs as "new."

STEEL GASKET
Replaced 100% with new components to insure compressor performs as "new."

O-RINGS & SEALS
Replaced 100% with O-Rings compatible with both R12 & R134a refrigerant to achieve O.E. performance and maximum service life regardless of which refrigerant is utilized.

OIL
Replaced 100% with R134a compatible oil to insure long service life.

PISTON
Inspected and cleaned, or replaced by new if Teflon surface is damaged, to insure compressor performs as "new."

SHAFT & SWASH PLATE
Cleaned, polished, and inspected, or replaced with new components if necessary, to insure compressor performs as "new."

SHAFT KEYS
Replaced 100% with new components to insure new OEM spec. tolerances.

SHOES
Inspected for deterioration and cleaned to eliminate contaminants, or replaced by new components. Gauged and sized for noise reduction.

SNAP RINGS
Replaced 100% with new components to insure compressor performs as "new."

SUCTION REED VALVE
Inspected, cleaned, and polished, or replaced by new components, to insure compressor performs as "new."

THRUST BEARING
Inspected for deterioration and cleaned to eliminate contaminants, or replaced by new components if necessary.

VALVE PLATES
Inspected, cleaned, and polished, or replaced by new components, to insure compressor performs as "new."

DENSO

 (Continued from page 15)

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.

Move it

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.

You may have noticed that water pumps tend to start leaking shortly after an overheating incident. That's because the rubber components are subjected to temperatures far beyond what they can tolerate, and

This V10 water pump may be highly-evolved, but it's still vulnerable to seal damage if the engine should overheat.

they harden and crack. Naturally, lack of coolant makes the whole engine red hot, but it also results in dry contact between the rings, which adds friction to the equation. This can cause another failure: warpage of the sealing elements.

We've heard it said that hard particles, such as a collection of the silicates and phosphates from anti-freeze, or core sand, can score and fracture those precisely-made rings, but engineers tell us that the space between the sealing faces is too small to allow those particles to enter. There is the possibility, however, that using plain water instead of a 50/50 blend of H2O and anti-freeze will deprive the seal of the lubrication it needs to survive.

Hot, hotter, hottest

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

Plenty of pressure and unimpeded flow is needed to achieve even cooling throughout all those passages.

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.

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 the metal pocked with ruts and holes, or even rotted through.

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 soft materials can literally "sand blast" its way through. There's also corrosion, the result of a chemical attack on the metals or rubber, much as 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 (see the sidebar).

Modern maladies

To find out what problems are prevalent out there in the real world these days, we talked to seasoned service experts. A few of the more common items mentioned:

- Hot spots inside the engine, which can cause serious damage such as galled or even seized pistons. The major culprit is deposits.
- Head gaskets that have rotted out to the point that they leak.
- Restrictions in head gasket coolant holes.
- The formation of heavy, hard deposits ("Like stalactites," one shop owner said).

- Restricted airflow through the radiator due to leaves, fast food wrappers, unfortunate birds, etc.

For the most part, these troubles can be attributed to – surprise! – Poor maintenance.

But there are other cooling system maladies that are rarely talked about. Don't underestimate the importance of bleeding the air out of convoluted modern cooling systems. Not only will trapped air ruin the intended flow pattern, thus causing hot spots, but it'll increase corrosion dramatically. Streamlining cars to reduce drag is great, but it means that airflow through the radiator and over the engine is a controlled matter in most late models. Make sure all shrouds, belly pans, and deflectors are present and properly secured.

The big buzzword in the cooling system hose business today is ECD (Electro-Chemical Degradation). It refers to the fact that every place in the system where dissimilar materials are joined actually acts as a kind of weak electrical cell. The rubber companies tell us this kind of damage can happen in as few as four years.

Eye exam

When it comes to diagnosis and service, you need a logical procedure that both streamlines the work and helps you avoid missing any opportunities. The following is intended to give you just that.

Begin with a thorough visual exam. Does the coolant resemble raw sewage? Is the radiator plugged or ready to burst a tube? Are the hoses biodegrading into their basic elements? Do the belts look like they've tangled with a chain saw? Is there seepage at the radiator, heater core, freeze plugs, water pump vent hole, hose connections, or the trans cooler lines? Is that declutching fan permanently declutched? Grab the fan and rock it from side to side. If there's excessive play in the water pump bearings, you may have just saved your customer the cost of a new radiator, fan, etc. because things really get chewed up when a pump shaft snaps.

If the coolant looks bad, chances are it's been in there too long (the adjective "permanent" when applied to antifreeze just means it won't boil off like the plain alcohol that was used in the old days). Right on the back of the jug of original BMW antifreeze/coolant, it says, "Change coolant every three years for maximum protection," and we agree. There's no reason to be asking for trouble by trying to get every last month out of a load of coolant, especially when this amounts to relatively inexpensive maintenance.

In inspection situations where fresh coolant isn't necessarily included, at least use your hydrometer or refractometer to determine the amount of anti freeze present. The traditional 50/50 blend is still correct whether you live in Florida or Alaska, and this is one place where more isn't better. Too low a percentage of water will reduce the system's ability to move those BTUs, and the silicates that protect aluminum from corrosion can fall out and plug passages if the concentration becomes too high from adding straight antifreeze to maintain the level, something do it yourselfers are famous for.

(Continued on page 22)

You promised the car by 5, so he could start his trip

...but that knock off part won't fit and it's 4:30.

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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.

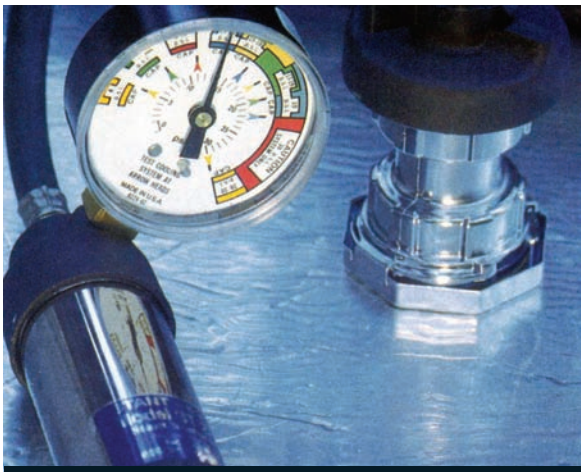
But perhaps you live in a really frigid climate where the -34 deg. F. (-37 deg. C) protection a 50/50 mix provides is marginal. In that case, BMW says it's okay to go to a blend of 60% antifreeze, which will take protection down to -62 deg. F. (-52 deg. C). If you live where it gets colder than that, move.

Seek the leak

Hook up your pressure tester to make sure the system will hold its specified psi for at least two minutes. While you're at it, find out if the cap blows off at the correct pressure. Sometimes it's difficult to zero in on a leak. One good way is to add fluorescent dye to the radiator, run the engine for a sufficient time (this can take a while it might even make sense to have the customer bring the car back the next day), then have a look with your UV/black light. Seepage will jump out at you in bright yellow.

But, according to a couple of experts, some leaks need yet another procedure: Keep 16-20 psi in the system with shop air and a pressure regulator (as you'll find in the analyzer shown in the accompanying photos) from warmed up to totally cool. That way, the seepage will give itself away regardless of when in the engine's temperature range it appears.

You can use your exhaust analyzer to find compression/combustion leaks into the cooling system by picking up a sample above the radiator neck on those models where that's possible. But it's easy to go too close and get coolant in the probe. A better way is to secure a large plastic bag around the neck with a rubber band, then punch a hole in the bag and insert the probe, keeping it a safe distance from the liquid. The bag trick can be used in another way: Clamp off the hose to the reservoir, put the bag over the neck as above, then start the engine and see if the bag inflates. There are also inexpensive leak detectors that you fill with water, then plug into the top of the radiator (again, where possible). If a stream of bubbles appears, the most likely cause is a gap in the head gasket.



If a visual inspection doesn't uncover the source of a leak, the next step is to hook up your pressure tester. You'll need the right adapter for BMWs that have the pressure cap on the overflow jug.

This late-model BMW overflow set-up uses a pressurized jug. It works fine, but you can't look down into the radiator during troubleshooting. So, you'll be using other means.

Whether from a bad pump impeller or, more likely, a plugged radiator, a low flow situation can be hard to diagnose. 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. On older BMWs that have a regular cap on top of the radiator, take the coolant level down until it's just above the 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. The trouble is, late model BMWs have their pressure cap on the overflow reservoir, so you can't see into the radiator. In these cases, remove a heater hose, stick the end in a bucket and start the engine. Finally, clear tubes are available that you attach in series with the upper radiator hose that allow you to see the flow.

Consider the Water

The quality of the coolant's other ingredient is important, too

Anti-freeze formulas are a hot topic among all kinds of experts in automotive technology and service. They've been the subject of numerous industry association committees, SAE meetings, and, frequently, heated discussions.

Yet, everybody seems to forget that the anti-freeze is only half of what goes into a cooling system. The other half is, of course, water. Do you know what you're putting in there? Are you just using tap water on the assumption that it'll be fine? Have you ever taken the time to research, or even think about, what the ramifications of using unsatisfactory water might be? No? Well, hardly anybody else has, either, but we at *TECHDRIVE* believe you need to know the whole truth.

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. Not surprising since it comes from an aquifer, which is underground. This is measured in parts per million, or in grains (17.1 ppm equals one grain). Water with over 120 ppm, or seven grains, is considered hard, but in some areas it may be as high as 850 ppm – 50 grains! You sure don't want to pour anything like that into a cooling system.

Besides the possibility of clogging heat-exchanging components, the metallic particles in very hard water may contribute to electrolysis failure of those same parts. Virtually all coolant is at least slightly conductive. If you ground a digital voltmeter and insert the positive probe into the coolant, you'll find a small voltage, typically under 0.1 V. Metallic particles add to the current-carrying ability of the coolant, which equals higher voltage that forces current through the heater and/or radiator to electrical ground to complete the circuit. This electrical activity causes corrosion to form and the corrosive deposits may restrict either or both heat exchangers

If your water comes from a municipal water supply system, there's also the distinct possibility that considerable amounts of chlorine and fluoride have been added, neither of which will do that engine, water pump, radiator, thermostat, etc. any good.

BMW is the only auto maker we've seen that actually publishes standards for the water in the 50/50 mix:

- **Appearance: colorless/clear**
- **Residue: no suspended particles**
- **pH value: 6.5-8.0**
- **Total hardness: maximum 357 ppm calcium carbonate**
- **Chlorine content: maximum 100 mg per liter**
- **Sulfate content: maximum 100 mg per liter**

You can buy a home water quality test kit at your local full-line lumber yard for about $10. This will tell you the levels of hardness, chlorine, pH, alkalinity, nitrate/nitrites, iron and copper. If your water's unacceptable, you could install a water softener, then retest. It's probably easier just to buy the good stuff, though, as we'll explain.

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. Also, you can distinguish yourself from your competitors by advertising that you use only distilled, or deionized, water to fill your customers' cooling systems.

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. 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.

Instituting 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, and make sure you let all your customers know how conscientious you are about maintaining their cars.

Don't Risk Your Reputation on Generic Antifreeze

Give your customers the right stuff

You may work exclusively on BMWs, but we'll bet you've heard horror stories about long-life antifreeze, especially the change interval and formula embraced by the largest domestic auto manufacturer. Indeed, it can last a long time. The trouble is, its anti-corrosion properties are often defeated by one simple thing: air. If the coolant level in the system is allowed to drop so that all surfaces aren't continually immersed, oxidation occurs rapidly. The dusty deposits that form accumulate into crunchy glop that clogs up the works. And this situation is much more likely to happen given the over-100K replacement interval that particular carmaker advises.

This becomes a risk for you because now some aftermarket manufacturers are selling generic antifreeze with essentially the same formula, and making the same claims about extended change intervals.

The exclusively-formulated antifreeze that BMW specifies and makes available through its dealerships' parts departments is a different story. It's an ethylene glycol-based silicated OAT (Organic Acid Technology) formula, which contains no nitrates or phosphates, and has been chemically designed to prevent excessive silicate dropout. Also, the silicates leave an anti-corrosive coating on metal that remains even if the coolant level should be allowed to drop.

While genuine BMW antifreeze doesn't say "Long Life" anywhere on the jug, the fact is 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.

BMW's engineers are more prudent where maintenance is concerned than those of some other carmakers we can think of, and they want people to enjoy their cars for a long, long time without encountering expensive and inconvenient problems. So, they're sticking with the sensible recommendation that the coolant be changed every three years for maximum protection. Sound wisdom in our opinion, and something you can easily justify to your customers. The one-gallon container carries Part Number 82 14 1 467 704.

Will aftermarket parts really perform properly on that BMW repair?

Keep your fingers crossed!

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