

Mechanical Feature

Engine Coolant Testing

Posted 2/7/2001

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Why use a refractometer?



In the battle for engine coolant/ antifreeze concentration and freeze point protection level testers, the hydrometer accounts for roughly 75 percent of all units sold. Refractometers and test strips round out the field. When service personnel are asked if they believe that their engine coolant tester is performing adequately, more than 95 percent feel satisfied; 35 percent feel extremely satisfied. The significance of this is that three-quarters of these service providers believe that their engine coolant tester must be accurate to plus or minus 5 degrees Fahrenheit. Less than one-tenth of those surveyed felt that an inaccuracy of plus or minus 10 degrees F was acceptable.

The curious fact about this is that even a high-precision, laboratory hydrometer (which costs more than \$60) used by a trained laboratory technician in a controlled environment, using readings that have been mathematically corrected for fluid temperature, can't obtain that accuracy. According to American Society for Testing and Materials (ASTM) Method D1124, the best accuracy that is achievable with a hydrometer used under these specific conditions is plus or minus 8 degrees F. So, how can we reconcile this fact with the overwhelming feeling of satisfaction that service personnel have regarding their hydrometers? The truth of the matter is, they simply do not realize just how inaccurate hydrometers can be.

Hydrometers and Refractometers: The Ins and Outs

Hydrometers measure specific gravity. Specific gravity is extremely temperature dependent. The same sample that is read at 150 degrees F will read as having a 30 degree F better freeze point protection level if it is read at a temperature of 100 degrees F. Temperature effects must be calculated.

Hydrometers only work for ethylene glycol-based coolants/antifreeze. Propylene glycol cannot be read with a hydrometer due to the fact that up to 70 percent concentration specific gravity increases, but above 70 percent specific gravity decreases. A 100 percent solution reads identical to a 40 percent solution.

Sampling technique is critical in hydrometer use. Air bubbles in the sample will cause inaccurate readings. The float must be kept free from the wall of the hydrometer.

Refractometers can measure both ethylene and propylene glycol-based coolant/antifreeze accurately.

Automatic temperature compensation (ATC) is very beneficial. Without it, refractometers can easily be inaccurate by more than plus or minus 16 degrees F.

There are numerous reasons why it is difficult to obtain an accurate engine coolant concentration reading with a hydrometer, but first let us try to understand why they are so popular. Probably the most important reason for the widespread use of these instruments is that they are inexpensive. A hydrometer is simply a container with a weighted float device. An applicable scale is displayed either on the cylinder of the container or on the float, which correlates the specific gravity (which is measured by how much of the float remains above the fluid level) and the particular concentration of interest. There are several different styles of hydrometers, but they all work off this same principle.

Hydrometers are also popular among service technicians because they are a visual indicator of fluid quality. When a vehicle is in the facility for service, the shop wants to perform as many extra services as possible. Not only does it promote proper maintenance of the vehicle, it is also a source of revenue for the shop. Typically, a technician will check the air filter element and the transmission, engine coolant and brake fluids. For the engine coolant, the technician can take a sample with the hydrometer and show this to the customer. This gives the customer the feeling that he is informed enough to make a qualified decision of whether or not to purchase the extra service of flushing out the cooling system. An informed customer is a happy customer.

Now that we know why someone would want to use a hydrometer, let's turn our attention to why someone would not want to rely on one. For starters, hydrometers are actually far more difficult to use accurately than they would appear. When you purchase a hydrometer, the instructions are very basic. Take a sample and read how many discs or balls are floating or how high a float sits in the sample, etc. Then take this number of floating discs or balls, or height of the float, and refer to a chart that converts this number into a useful measure of concentration and freeze point protection.

That's it! In reality, there is a lot more to it than that. Here is what they do not tell you:

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Remember that a hydrometer is actually measuring specific gravity of a solution. How it accomplishes this is to take a substance with a known specific gravity (a standard) and see if it floats in the unknown sample. If it floats, the specific gravity of the sample is greater than the specific gravity of the standard.

Disc- and ball-type hydrometers have discs (or balls) of increasing specific gravity. The more discs or balls that float, the higher the specific gravity of the unknown. A single float hydrometer has a float, which has a weighted bottom and a hollow top. This will sink into the solution until the specific gravity of the unknown sample and the float are equivalent. The amount of the float that is submerged is an indicator of the specific gravity.

Probably the most important factor in the use of a hydrometer is the temperature relationship between the sample, the instrument and the standard reference temperature. To obtain an accurate specific gravity reading, it is imperative that the sample and the instrument temperatures be at equilibrium. Readings must be taken at a specific, stable temperature. This temperature must be noted for each reading. If this temperature differs from the standard reference temperature (which is typically 60 degrees F for most hydrometers) the specific gravity reading must be mathematically converted to its equivalent value for the standard reference temperature.

For most substances, as temperature increases, specific gravity decreases. In other words the sample “thins out” as it is heated. This shift can be mathematically modeled. A reading for a 50 percent ethylene glycol solution at 100 degrees F would give a specific gravity of 1.056. This same 50 percent solution at 150 degrees F would read 1.038 specific gravity. If that hydrometer were calibrated for 100 degrees F, it would read as 50 percent only if the reading were taken at a fluid/instrument temperature of 100 degrees F. If the reading were taken at a fluid/instrument temperature of 150 degrees F, the instrument would measure the specific gravity as 1.038, which at the instrument's standard reference temperature of 100 degrees F corresponds to a 35 percent concentration. The person taking the reading would think that the solution was 35 percent ethylene glycol. As a

reference, the freeze point protection level for a 50 percent mixture is -32 degrees F. The freeze point protection for a 35 percent mixture is approximately -2 degrees F. This is a significant error.

A hydrometer cannot be used for measuring propylene glycol-based coolant/antifreeze solutions. As concentration increases to around 70 percent, specific gravity also increases. Above 70 percent, however, specific gravity actually decreases with increasing concentration. For instance, at 100 degrees F, a 100 percent propylene glycol solution has the same specific gravity as a 45 percent solution. There is no way for a hydrometer to differentiate these two dramatically different solutions.

Sampling technique is also critical in specific gravity measurement. Any air bubbles present in the sample can attach themselves to the float device and thus affect the readings. For both types of hydrometer, the specific gravity of the float will be reduced if an air bubble attaches itself to the float. In other words, the buoyancy of the float will increase.

Another important sampling technique is to be certain that the float does not touch the walls of the container. The friction causes the float to sit lower in the sample and thus will cause the reading to appear greater than it actually is. In essence, the friction decreases the buoyancy of the float. This is more important with single-float style hydrometers because their float is prone to lean into the wall. In disc- and ball-type hydrometers, the floats are entirely submerged and thus virtually free from friction.

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Now let's look at the refractometer. Refractive index is, basically, the relative speed of light through a substance vs. the speed of light through a standard, typically air. Another way to think of it is the bending of light as it passes through a substance. As light is transmitted into and through a substance, it will slow down. If that light is passed through at an angle, the substance will "bend" the light. The angle at which this light is "bent" can be measured and converted into a refractive index number, which can then be converted into a percentage of concentration number (or virtually any units, which are applicable). This is exactly what a refractometer does; it simply passes light through a sample, a prism and optical system, a reticle (printed scale), and an eyepiece. The optical system and prism capture the bent light and pass it on to the reticle and eyepiece, producing a shadow line intersect on the reticle, which is a visual indicator of the refractive index of the solution.

Both ethylene glycol and propylene glycol may be measured accurately by refractive index. Both these solutions have a nearly linear relationship between concentration and refractive index. As concentration increases, refractive index increases. Propylene glycol, which cannot be measured on a hydrometer, can easily be measured on a refractometer.

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Sounds nice and simple. Unfortunately, refractive index is also temperature dependent. As temperature increases, refractive index decreases. That is why you must also reference the temperature at which refractive index measurements are taken or converted to. Most refractometers use the standard reference temperature of 68 degrees F.

For refractometers, the temperature of the instrument is the critical factor. This is due to the fact that for refractive measurements, only a drop of sample is required. The mass of this amount of the sample is so small that it will almost immediately assume the temperature of the instrument. The temperature of the instrument is directly dependent upon the temperature of the environment in which it is used. If the temperature is changing fairly regularly, such as a garage with vehicles pulling in and out, the refractometer needs to be made out of a material that will quickly equilibrate with these changes. Heavy metal bodies act as a heat sink; therefore, lighter polycarbonate bodies that respond more rapidly to these temperature shifts are preferred.

As an example of this temperature dependence, suppose we had a 50 percent propylene glycol solution. The refractive index for this solution when measured at 68 degrees F would be 1.38908. If this solution were to be measured at 20 degrees F instead of the standard 68 degrees F, the change in refractive index would be 0.006, thus the refractive index would be 1.39508. This refractive index, if not temperature corrected, would correspond to a concentration reading of 55.74 percent propylene glycol on a refractometer, which is referenced at 68 degrees F. A 50 percent propylene glycol solution will freeze at roughly -29 degrees F, whereas a 55.74 percent solution will freeze at roughly -45 degrees F. Therefore, a service technician using a non-temperature compensated refractometer under these conditions will believe he has far greater freeze point protection than he actually does. A refractometer with automatic temperature compensation automatically corrects all readings back to the standard of 20 degrees C. Thus the user need not worry about what temperature his readings are taken. The Leica Duo-Chek with automatic temperature compensation is accurate to plus or minus 1 degree F, according to ASTM Method D3321, which is the standard practice for use of a refractometer for determining the freezing point of aqueous engine coolants.

The Problem With Inaccuracy

Increasing concentrations to roughly 60 percent improves freeze point protection level. Above 70 percent, freeze point protection level becomes progressively worse. In this case more is not better.

Cavitation corrosion, water pump failure, scale formation, gelation, inefficient heat transfer, boil over, freezing and cracking engine blocks, solder bloom - all are problems defined by the Society of Automotive Engineers (SAE) for over and under concentration of engine coolant/ antifreeze.

Emissions control is impossible without proper concentration. Catalytic converters are fickle at best. **More than 26 percent of all repair costs can be directly attributed to cooling system maintenance issues.**

“Emissions control is impossible without proper concentration.”

There are other problems associated with higher concentrations as well. Water pumps are designed to work with a specific viscosity of fluid. Increasing concentration increases the viscosity of the fluid, thus water pumps have to work harder, potentially reducing life of the water pump. There is also a phenomenon known as cavitation corrosion associated with concentrations exceeding 70 percent. This is the formation of microscopic bubbles within the coolant/antifreeze. These bubbles and the silicate particles from the additives contained in many coolant/ antifreezes act almost like sandpaper. They can rapidly wear away at the cylinder heads, liners, head gaskets, water pump impeller and even the radiator.

Most customers expect their repair facility will protect them from these problems. One dollar spent on maintenance will save \$10 in repairs. Service personnel have the opportunity to perform the maintenance, but once the repair is needed customers may not be willing to patronize a facility that cost them substantial amounts in repairs. The only real way for service personnel to perform effectively for their customers is to use a reliable tool. The refractometer is such a tool. A hydrometer is definitely not.

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