

Heading Off Corrosion

Your water or water/glycol heat transfer fluid may be perfect for your application, but corrosion still could rear its ugly head, interfering with production and your final product.

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Corrosion of metallic components is an inherent problem for water and water/glycol cooling systems because metals naturally tend to oxidize in the presence of water. Rust is one example of iron oxidation.

The various forms of corrosion usually are grouped as either general or localized. General corrosion, also known as uniform corrosion, is described as loss of metal over the entire surface area. While general corrosion results in large amounts of corrosion products, it typically does not lead to rapid system failure because the rate at which the metal thins is slow enough that the corrosion is identified before the metal ruptures.

Localized corrosion most often is in the form of pitting. Pitting corrosion does not release large amounts of corrosion products into the coolant but results in more rapid perforation of the metal part compared to general corrosion. Aluminum tends to undergo pitting corrosion when the passive film is locally disrupted by chloride.

Cavitation, a special type of localized corrosion, occurs when the coolant is cavitated near the metal surface. Cavitation occurs when the pressure near a solid surface drops below the vapor pressure of the coolant. This can occur if the metal component rapidly pulls away from the coolant such as

during cylinder-liner vibration. It also can happen under conditions of rapid coolant flow, which often occurs past the impeller blades of the coolant pump. The coolant forms vapor bubbles that undergo rapid implosion that can produce severe pitting of the metal surfaces.

Corrosion Inhibitors

Corrosion is usually minimized through pH control and corrosion inhibitor use.

Dissolved oxygen accelerates most corrosion processes. In closed coolant systems, the dissolved oxygen is consumed over time and no longer poses a corrosion risk. For open systems, however, the continued exposure to air allows oxygen to dissolve into the coolant. Open systems often suffer more corrosion problems compared to closed units.

The measure of a liquid's acidity or alkalinity is pH, with a pH of 7 being the neutral value for water. Under acidic conditions, corrosion is accelerated due to the reduction of hydrogen ions: the lower the pH, the greater the corrosion problem.

For aluminum, high pH also is bad. At pH values greater than 10, the oxide film starts to dissolve, resulting in rapid corrosion unless controlled by inhibitors. However, aluminum tends to be resistant to corrosion at pH values of 7 to 10.

Iron corrosion is decreased in severity at higher pH, and pH values of 9 to 11 commonly are used to minimize the corrosion of iron, carbon steel and low-alloy steels. Without inhibitors, however, iron corrodes at neutral pH values of 7 to 9.

Copper and brass are more resistant to corrosion compared to iron and aluminum. These metals will corrode, however, if oxygen is present or if a corrosive chemical is present. Ammonia is very corrosive to copper.

The pH of coolants is controlled by the use of buffers; the most common are phosphate and borate. The buffering action helps keep the pH within desired limits to minimize corrosion. Reserve alkalinity is the term used in the measurement of a coolant's ability to tolerate contamination by acids.

Corrosion Problems

One of the more significant corrosion-induced problems in a cooling system is perforation leading to coolant leakage. However, other problems include reduced heat transfer and plugging of cooling system passages.

As corrosion occurs, the metal begins to dissolve into the coolant, reacting with the liquid's oxygen, chloride and/or corrosion inhibitors and precipitating back onto the metal surface. This surface scale might slow further corrosion to a small degree, but it

does not eliminate it. Meanwhile, the scale acts as a barrier to heat transfer, such that cylinder heads, liners and blocks operate at a higher temperature than for which they were designed.

Further, as the scale comes off the metal surfaces, it causes other problems. If scale accumulates into large particles or deposits in cooler areas, it tends to block cooling-system passages. Small particles are carried with the coolant and act as an abrasive, causing erosion and more corrosion.

Formulated coolants contain carefully matched corrosion inhibitors. These inhibitors act by attaching to the metal surfaces to passivate them and prevent corrosion.

There are several common corrosion inhibitors, each with its advantages and disadvantages.

- ▶ **Phosphate** is effective as a corrosion inhibitor for iron, steel, lead/tin solder, and most aluminum components. It is also a very good buffer for pH control. One drawback of phosphate is precipitation with calcium in hard water, which is one reason that deionized water is preferred for diluting the coolant.
- ▶ **Tolytriazole** is a common and highly effective corrosion inhibitor for copper and brass.
- ▶ **Mercaptobenzothiazole** also works for copper and brass, but it is not as stable as tolytriazole for long-term use.
- ▶ **Nitrite**, an excellent corrosion inhibitor for iron, is the primary inhibitor used to combat cavitation corrosion of cylinder liners. However, it gets used up rapidly in the process. Also, at high concentrations, nitrite becomes corrosive to lead/tin solder. When used for combating cavitation corrosion in heavy-duty engines, nitrite should be maintained between 800 and 2,500 ppm.
- ▶ **Silicate** is an effective inhibitor for most metals but shows a tendency to form thick deposits inside the cooling system. Even more important is silicate's tendency to polymerize and form gel. For this reason, coolants containing silicate should not be used in large volume systems of more than 50 gal.
- ▶ **Chromate and soluble oils** have been in used in the past, but their use has greatly

Taking the Measure of Reserve Alkalinity

Reserve alkalinity pertaining to heat transfer fluids and engine coolants is a measure of the buffering ability to absorb acid. Another common term for reserve alkalinity is buffering capacity. It is the ability of the coolant to remain within a desired pH range even when contaminated by acids, which can occur from a process fluid leak or engine head-gasket blow-by.

Should the coolant be contaminated by acids, buffering ability is desired to delay the onset of low pH values (below 7) that would result in increasing corrosion rates and faster glycol degradation. Reserve alkalinity, in combination with corrosion inhibitors, helps to minimize corrosion and glycol degradation.

How much reserve alkalinity (RA) is needed? Most industrial heat transfer fluids and engine coolants have reserve alkalinities in the range of 10 to 14. Some new coolants for both light- and heavy-duty engines have values of 6 to 8. A few coolants have values of 18 to 20. Higher value coolants were designed for systems that tend to suffer substantial acid contamination. The objective is to have enough reserve alkalinity to provide a stable pH reading for the life of the coolant.

Very high reserve-alkalinity values are not necessarily good because the high buffering comes from addition of extra salts that contribute to high total dissolved solids (TDS). High TDS can lead to rapid wear of seals and inhibitor dropout. The important thing is to have a properly designed and balanced corrosion-inhibitor package that includes sufficient buffering for the intended application.

ASTM D1121 specifies the method for measuring reserve alkalinity of glycol-based coolants and heat transfer fluids. The RA value is the number of milliliters of dilute, 0.1 N hydrochloric acid used to change the pH of 10 milliliters of coolant to 5.5.

Because the ASTM procedure calls for using 10 ml of coolant, the more dilute a coolant is, the lower the RA value will be. As a minimum, the RA value for diluted coolant should be 2 or greater. A coolant that provides an RA of 10 when undiluted will produce an RA of 5 when diluted to 50 percent. Therefore, RA values for diluted coolants of 2 to 5 are considered normal.

Some coolant test labs modify the RA values to convert to 100 percent glycol. A coolant with a 40 percent glycol concentration that has an RA of 3 would be reported as 7.5. While this method provides a number that is more comparable with fresh, undiluted coolant, it does not provide the actual buffering capacity of the coolant. It is important to identify whether the RA values being reported to you are determined according to the ASTM 10 ml volume method or are converted to 100 percent glycol basis.

diminished. Chromate is toxic and has been replaced by modern inhibitors. Soluble oils were effective in older, low flow-rate cooling systems but are not effective in the more efficient, high flow-rate systems currently used.

Glycol Choices

While traditional coolants contain ethylene glycol, newer coolants based on propylene glycol have the primary advantage of much lower toxicity if ingested by mammals. There also may be some advantage for control of cavitation corrosion. In either case, both glycols are biodegradable and have similar performance for heat transfer and freeze protection. When propylene glycol is used, the concentration needs to be 2 percent to 5 percent higher than ethylene glycol to obtain the same freeze protection. A refractometer specific to propylene glycol should be used because its refractive index is different than for ethylene glycol.

All coolants tend to pick up some metals due to corrosion. Therefore, both ethylene glycol and propylene glycol coolants must

be disposed of properly in accordance with local regulations.

At different locations, the properties of tap water vary considerably in hardness and chloride content. Chloride is corrosive and use of tap water should be minimized or avoided if it contains more than 100 ppm chloride. Hardness of tap water also needs to be considered, as it introduces calcium and magnesium, which form scale on the surfaces of cooling system walls, significantly impeding heat transfer. Deionized water is strongly recommended in order to avoid chloride and scale buildup. **PCE**

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