Assessing the Longevity of Heat Transfer Fluids for High Performance Applications

Introduction

It is widely understood that different types of inhibitor packages can have an impact on the performance and longevity of heat transfer fluid. However, the type of glycol used can also have an impact on fluid performance in certain types of applications. Recently, DuPont Tate & Lyle and worked first with Penray and subsequently with Amalgatech Laboratories to conduct testing to predict the performance of fluids used in a variety of environments found in common heating applications. The tests were designed to evaluate and compare the performance propylene glycol (PG) and 1,3 propanediol (PDO) when used as a glycol in a low-toxicity fluid and as a glycol in a heavy-duty fluid formulation.

Low-Toxicity Fluid Comparison

Low-toxicity (sometimes referred to as "food grade") fluids are the HVAC industry standard, and this experiment compared the performance of a propylene glycol (PG) based fluid against a 1,3 propanediol (PDO) based fluid. Both fluids were made using a 50/50 dilution of glycol and water, and both were inhibited with a low-toxicity phosphate-based inhibitor package and started the experiment with a pH of 7.5. The objective of performing this research is to document how HVAC fluid behaves over time, and especially how it protects against corrosion of various metals in HVAC systems. The RPVOT was used because it is a very severe test that greatly accelerates aging behaviors.

The RPVOT test method evaluates the oxidation stability of fluids in the presence of two environments, air and oxygen, and introduces metals commonly found in HVAC systems. The first environment air is severe because it provides only 55 ml of fluid to protect a semi-submerged, rotating bundle of six metals commonly found in HVAC systems, assembled per ASTM D1384. Air is available at 90 psig pressure, the bundle is rotated at an angle in the fluid and the temperature is maintained at 115 degrees C (about 239 F).

In the second environment the severity is increased by changing the atmosphere to pure oxygen and increasing the temperature to 150 degrees C (about 300 F). The second environment is useful because it presents a "worst case" scenario, and the test method will help generally distinguish between fluids that are definitely unstable and deleterious from the corrosion standpoint and those that are suitable for further evaluation as extended life ("ELC") formulations.

In addition to measuring the weight loss of each metal specimen, an analysis of the exposed fluid was performed. The condition of the used fluid may be compared to the typical values of the unused fluid to assist in understanding the aging mechanisms and behaviors of the fluid formulation being tested. This test method greatly accelerates the oxidation aging of both the base fluid (i.e. glycol) and corrosion inhibition components. The analysis performed is appropriate to the inhibitor package, it is not necessary to analyze for components that are not used in the sample tested.

Low-Toxicity Fluid Comparison Results

In the pressurized air environment (115 C), there was little difference in the performance between the PG-based low-toxicity fluid and the PDO-based low-toxicity fluids, which appeared clear and had a pH of 7.5 prior to testing. After being tested in the oxygenated, high-temperature environments, both fluids became acidic and neither fluid provided strong protection against corrosion of copper.

However, after exposure to the pressurized oxygen environment the PG-based fluid exhibited a much lower pH level and had higher levels of organic acids than the PDO-based fluid. Interestingly, the pathway for PDO breakdown is different than that of PG, which was demonstrated by the lower levels of glycolate and formate found in the PDO-based fluid. Lower levels of organic acids in the PDO-based fluid offer an explanation as to why, though the fluid didn’t fully protect against corrosion, the PDO-based fluid demonstrated lower levels of copper and zinc after oxidization.

Heavy-Duty Fluid Comparison

Heavy-duty fluids are used in a variety of applications, including but not limited to solar thermal equipment for producing hot water and heat, industrial generators, and oil and gas processing equipment. This experiment compared the performance of propylene glycol (PG) based heavy-duty fluids against 1,3 propanediol (PDO) based heavy-duty fluids.

For the first test method, both fluids were made using a 50/50 dilution of glycol and deionized water, and both were inhibited with a heavy-duty OAT inhibitor package. Per ASTM D-1384, metals typically present in engine cooling systems are totally immersed in aerated fluids for 336 h at 88°C (190°F). The objective of performing this research is to document how heavy-duty heat transfer fluid behaves over time at high temperatures. Doing so assists in determining whether or not the fluids are suitable for heavy-duty heat transfer fluid applications.

For the second test method, both fluids were made using a 50/50 dilution of glycol and deionized water, and both were inhibited with a low-silicate, phosphate-free inhibitor package made by Penray (#2792).
The fluids were boiled in a reflux system for 16 hours at 192 ± 10°C. This period of reflux was intended to simulate a stagnant high thermal event for a semi-closed loop heat transfer system.

Heavy-Duty Fluid Comparison Results

There was not a significant difference in fluid performance between PG-based fluids and PDO-based fluids with heavy-duty OAT inhibitors at 88C for 336h. The OAT inhibitor package successfully prevented corrosion of metal specimens, including copper, regardless of whether the glycol used in the fluid was PDO-based or PG-based.

However, there was a significant difference in the performance of the two fluids in the 192C reflux system for 16 hours. The PDO-containing heat transfer fluid was shown to have improved stability to thermal decomposition when compared to the PG-containing heat transfer fluid, exhibited by lower levels of acids in the PDO-based fluid after testing.

Conclusion

For heating applications that do not demand a high-performance heat transfer fluid, the type of glycol used in the fluid formulation is likely not the primary point of consideration when choosing a product. However, for applications in which a heat transfer fluid is exposed to high temperatures, the type of glycol used in the formulation can have a significant impact on the performance of the fluid and should be taken into consideration when filling a system. The performance of the glycol was shown to have the most significant impact in both the low-toxicity fluid at 150C and in the heavy-duty fluid in the solar-thermal simulated environment at 192C. After being exposed to both of those testing environments, the PDO-based fluids exhibited lower levels of organic acids and demonstrated better thermal stability than the PG-based fluids.

Metal Specimens Used in Analyses (1 by 2 inches in size):

1. ***Steel***, UNS G10200 (SAE 1020), Chemical composition of the carbon steel is as follows: carbon, 0.17 to 0.23 %; manganese, 0.30 to 0.60 %; phosphorus, 0.040 % maximum; sulfur, 0.050 % maximum.
2. ***Copper***, conforming to UNS C11000 (SAE CA110) or UNS C11300 (SAE CA113). Cold-rolled.
3. ***Brass***, conforming to Alloy UNS C26000 (SAE CA 260).
4. ***Solder***—A brass specimen as described in 6.1.3, coated with solder conforming to Alloy Grade 30A (SAE 3A)
5. ***Cast Aluminum***, conforming to Alloy UNS A23190 (SAE 329).
6. ***Cast Iron***, conforming to Alloy UNS F10007 (SAE G3500).

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