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Cover Story Part 2: Heat Transfer Fluids: Maintaining the System

Use cost-effective techniques to find a solution for coke, sludge, high viscosity and deposits in your thermal fluid process

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Organic-based thermal fluids provide relatively trouble-free service for significant periods of time. However, there comes a time when any fluid (either aromatic- or aliphatic-based) needs to be replaced. Since aromatic-based fluids generally cost more and are complicated to dispose of, they receive far more attention than aliphatic-based fluids when the time comes for replacement. Aliphatic-based fluids (manufactured with mineral oil, petroleum or poly alpha-olefins) are viewed less critically, since they are historically less expensive to purchase and are more easily handled as waste. As a result, these fluids are replaced more frequently than may be required. However, the recently rising costs of petroleum feedstocks have made these relatively low-cost hot oils more expensive to replace. To minimize the waste of good product, this article provides guidance on when to replace thermal fluids and how to achieve this using the most cost-effective method. (Part 1 of this report, p. 34, describes important considerations for avoiding overheating.)

FIGURE 1.
Use this simple test to find the degree of carbon contamination in your thermal fluid

Analyze your fluid

There is a tendency to blame every process problem, whether it be perceived or real, on the thermal fluid. For example, it is possible that a buildup of sludge or high viscosity can cause a decrease in heat-exchanger performance. More often, however, this reduced performance is caused by a drop in flowrate due to a plugged strainer, a malfunctioning control valve, or an improperly set bypass valve. Similarly, repeated pump-seal failures are often blamed on a thermal fluid breakdown, but carbon depositing around a leaking flange does not necessarily indicate elemental carbon in the fluid. Carbon will form even when new fluid leaks past a gasket while it is hot. In both instances, replacing the heat transfer fluid will not solve the problems.

The best method to determine if a thermal fluid needs to be changed is to test it. Samples should be taken from a live part of the system while the fluid is circulating at a temperature no less than 180°F. It is important that the sample be taken directly into the sample container — a clean-metal can may be used if necessary, although a glass jar is preferred so that the carbon loading can be visually evaluated (Figure 1). Once the sample has cooled, tilt the jar. If the fluid doesn't flow, keep the system hot until a charge of new fluid is onsite. Replacing a section of pipe that has solidified heat-exchanger fluid in it is a very time consuming and expensive way of draining the system.

Three tests can be done on any aliphatic-based fluid (regardless of manufacturer) that will indicate whether the fluid should be replaced. While the acid number test may be the most significant, it is strongly suggested that all of these tests be performed to develop the correct solution for the heat transfer system (Figure 2).

Acid number. When thermal fluid reacts with oxygen, organic acids are produced and oxidation occurs. Coke deposits, sludge and high viscosity are all symptoms of oxidation and are the most common reasons for severe fluid degradation. Unless water is present, however, these acids are not corrosive in the traditional sense. The problem occurs as the acids, which have poor thermal stability, break down inside the heater. One of the consequences of this acid deterioration is the extremely fine carbon particles (soot) that can agglomerate to form sludge deposits.

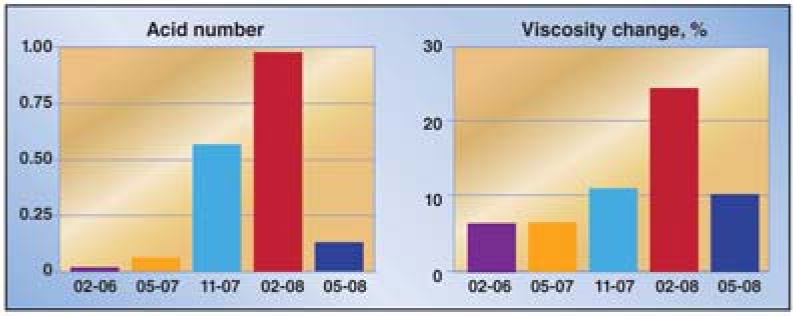

FIGURE 2. Key fluid parameters, such as acid number and the change in viscosity, should be consistently recorded to track discrepancies and overall trends in fluid behavior over time

Another way that acids cause problems in heat transfer systems is that they increase the viscosity of the thermal fluid when they polymerize. If localized hot surfaces exist inside the heater tubes or on electrical elements, high acid levels will cause hard deposits (coke) to form on the hot spot.

The acid number is found by determining the amount of potassium hydroxide (KOH), in milligrams, that is required to neutralize one gram of the sample. Generally, acid number guidelines are as follows:

- < 0.05: The fluid is new
- > 0.2: Investigate the fluid using more parameters, especially if there is a presence of carbon
- > 0.5: The fluid may have to be replaced

Viscosity. A change in viscosity may indicate that a fluid has been overheated, contaminated or oxidized. Theoretically, any changes in viscosity can indicate changes in the fluid composition because the viscosity of an organic liquid is related to the average molecular weight. In practice, however, only extreme changes are significant.

In common situations where more than one fluid is present or there is no record of what has been added to the system over time, several rules of thumb can be applied. Most commercial aliphatic-based heat-transfer fluids have a viscosity of 35 – 60 cSt at 104°F when new. Any fluid with a viscosity over 100 cSt (when new) is most likely a lubricating oil. While high viscosity may be desirable for lubrication, it can prolong the startup time of a cold heat-transfer system. Replace any fluid that has a viscosity less than 15 cSt or greater than 100 cSt at 104°F.

If the viscosity of the original fluid is known, then the change in viscosity can be easily determined by using ratios to find the relative amount of change as a percentage. In fired heaters, the following rules of thumb apply:

- A decrease of 15% falls within the normal range. Some thermal cracking can occur, particularly where the operating temperature is within 20 – 50°F of the fluid's maximum operating temperature
- A large decrease of 30% indicates that overheating has occurred
- An increase of 10% can be the result of oxidation or contamination with a less thermally stable fluid (like a lubricating oil or even worse, hydraulic fluid)

Carbon loading. Fine carbon particles (similar to soot in appearance) are formed when acids produced by oxidation breakdown inside the heater at normal operating temperatures. These particles will remain suspended in the fluid while it is flowing, but can stick together and form blockages where excessive turbulence will pack the particles together. These carbon particles will also drop out of suspension and form sediment when the fluid is stagnant and cool. Expansion tanks are at the highest risk for this type of sludge formation.

A quick and practical test to determine the amount of carbon in the fluid is to turn a sample upside down after 24 hours and look for soot settled on the bottom of the container. Since acids are the raw material for sludge, even a low acid number (less than 0.2) should not be ignored if there is carbon present.

Additional tests. More in-depth information about the condition of the fluid can be determined through additional testing. However, it should be noted that the following tests are the most useful if new-fluid data is available for comparison and analysis.

1. The Cleveland Open Cup (COC) flashpoint test is very common, but can also be misused and misunderstood. There is no standard or regulation that covers the permissible flashpoint change in a

thermal fluid. However, the test does indicate the overall amount of vapor generated by the fluid. A severely overheated fluid will have a higher concentration of low-boiling-point molecules than a new fluid and will therefore have a lower flashpoint. Significant decreases in the test results (a change greater than 150°F) can indicate that degradation has occurred.

2. Distillation-range tests measure the boiling profile of the fluid. If the brand of fluid is known, the test results can be compared to the new-fluid specifications and will accurately determine whether the fluid has been contaminated (Figure 3).

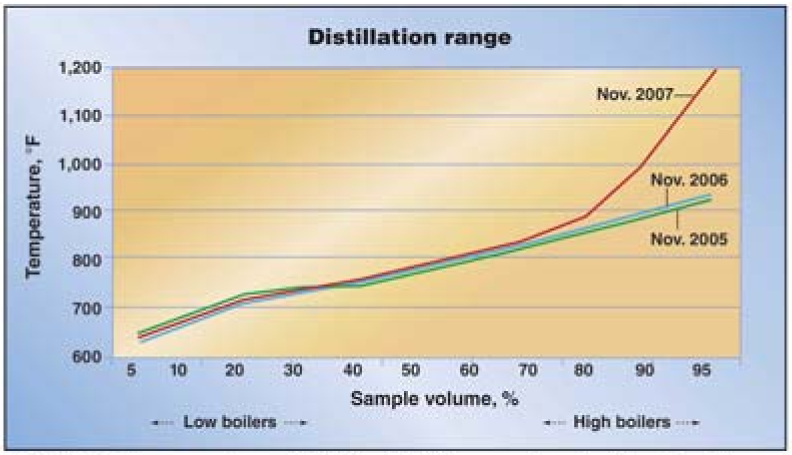

FIGURE 3. The second annual test (Nov. 2007) shows why periodic testing is important; contamination or oxidation resulted in a dramatic increase in high boilers

Because they are inexpensive to run, lube-oil-test results are sometimes used for establishing the condition of the thermal fluid. The problem with these test results — which include trace metals and particle count — is that they measure properties that are important for lubrication and not heat transfer. Thermal fluid systems do not have the close mechanical tolerances that can be affected by particles. Nor is there extensive metal wear that requires a metal analysis. Thermal fluids don't, or shouldn't, contain lubricant additives that may have depleted over time and use. The test results necessary for thermal fluids — acid number and viscosity — may be included in a lube-oil test, but may not have been run using a standard method. So when choosing where to have the testing done, users are urged to remember the total cost of a potential change-out and choose the testing location that will give the most accurate data.

How to restore efficiency

Once the proper parameters are obtained to analyze the fluid quality; full efficiency in a poorly performing system can be recovered using the following procedures (Figure 4).

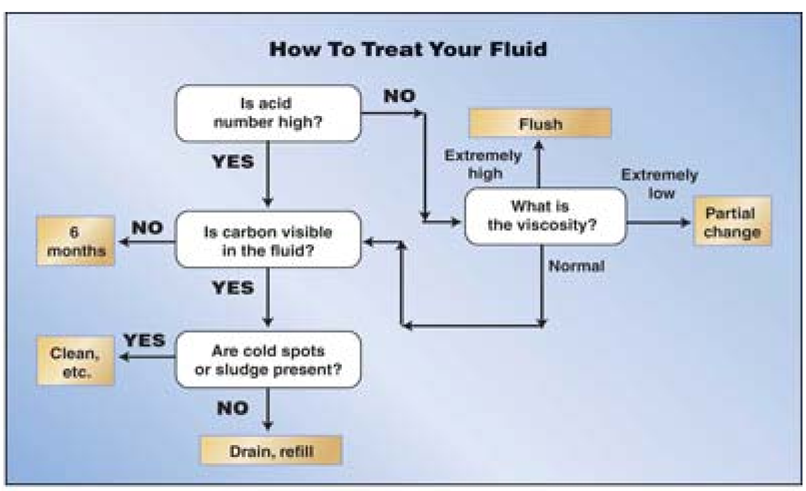

FIGURE 4. Solutions to common thermal fluid problems can be found by analyzing the results of a few simple tests

Retest in six months. Retesting is recommended if the acid number is high, but no carbon is present. This can occur in systems where the operating temperature is low enough (less than 300°F) that the secondary reactions (carbon formation and increasing viscosity) are not occurring quickly. It can also occur if the high acid number is due to a recent operating error. If there is any noticeable change in the system operation (such as sudden and repeated screen plugging or a necessary increase in operating temperature) another sample should be taken immediately.

Partial change-out. This procedure is recommended where there is a decrease in viscosity with no increase in acid number. Overheating can occur if there is a flame impingement due to burner malfunction or if there is insufficient flow through the heater. Since the rapid degradation will stop once the equipment problems have been addressed, replacement of a portion of the fluid to raise the viscosity is cost-effective. The fluid supplier should be able to provide the suggested replacement level.

Drain, fill and restart. This method is effective when there is carbon in the fluid and the acid number is high but there are no cold spots or any other indicators that sludge deposits are present. While there have been problems when different fluid types are interchanged in heat transfer systems, the two main types of thermal fluid (aromatic and aliphatic) are chemically compatible. Residue levels reaching 10% will not produce any abnormal degradation in the new charge.

Drain, flush, fill and restart. Flushing the system to minimize residue may be necessary if the viscosity is extremely high or if the new fluid will be operating above the maximum operating temperature of the old fluid. The options are to flush with a spare charge of the new fluid or use a dedicated flushing fluid. The advantage of a true flushing fluid is that it does not have to be heated to dissolve the residual thermal fluid. However, the fluid is formulated for solvency and not thermal stability, and has to be rinsed from the system with a spare charge of new thermal fluid. This adds an extra step to the change-out and generates more waste fluids. An advantage of using a spare charge of the thermal fluid to flush the system is that the fluid can be left in the system and drained at a later date. Testing this new fluid may prove that the residue is low enough that it may not have to be drained.

Clean, drain, fill and restart. Cleaners can be useful if a significant amount of carbon sediment is visible in the sample or there is any evidence of sludge buildup in the process, such as cold spots. Cleaners work by dissolving the glue that holds carbon particles together. The freed particles go back into suspension in the fluid and can be drained or filtered out.

The additive type of cleaner is more suitable for large heat-transfer systems where production cannot be interrupted and complete draining would be difficult. Additive cleaners should be removed only when all parts of the system have regained operating temperature (or as instructed by the manufacturer of the cleaner). The cleaner will not be effective in the expansion tank unless there is a boilout or warm-up line into the tank. Note that only water-based caustic cleaning compounds can dissolve hard coke deposits in heater tubes. The organic-based system cleaners described above will have no effect on these deposits.

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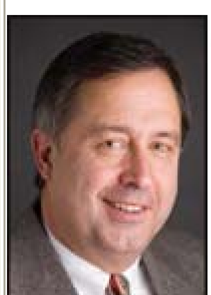

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