CHEMICAL ENGINEERING
3 CORROSION • HEAT TRANSFER FLUID
VOL. 120 NO. 3 MARCH 2013

CHEMICAL ENGINEERING

March 2013
www.che.com

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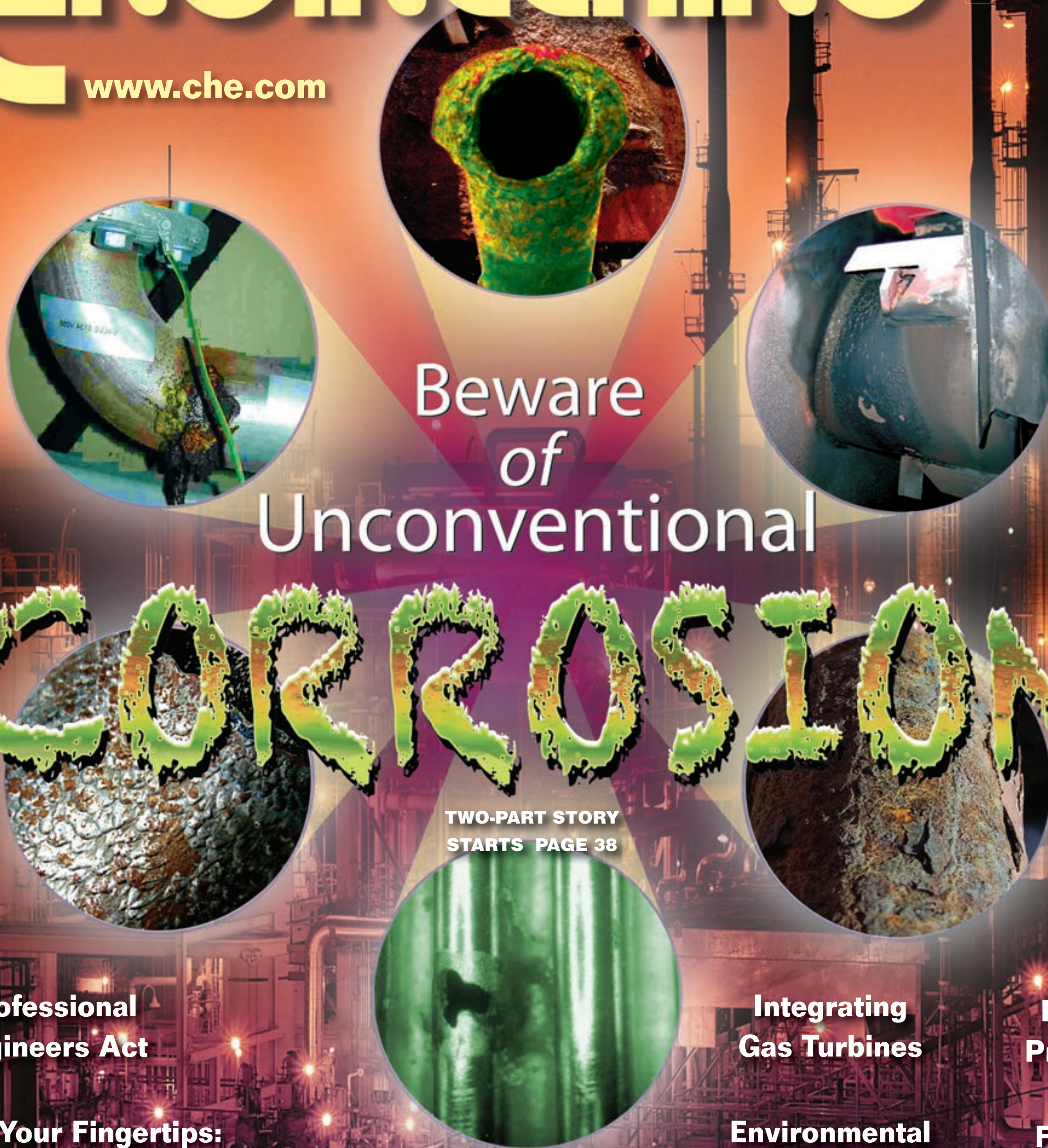

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Five Steps to Replacing Aged Heat-Transfer Fluid

Follow these guidelines to help ensure efficient operation of heat transfer systems, and proper exchange and disposal of aged fluids

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Solutia Inc.

Changing out used heat-transfer fluid is critical to the efficiency of a heat-transfer fluid system. A well-operated heat-transfer-fluid system can enable efficient production, fewer shut-downs, less maintenance time and lower costs. In order to maintain a sound heat-transfer system, it is critical that the fluid is well cared for and, when the fluid reaches the end of its life, that it is efficiently changed out for new fluid. As fluid is used and ages, it can degrade to a point where it is no longer providing sufficient heat transfer for the process. When this occurs, the fluid must be evaluated and potentially changed out to restore the system to maximum efficiency. This article presents the general steps involved in determining: when a fluid should be replaced; draining the system; flushing and cleaning; complying with regulatory requirements for disposal of the used fluid; and refilling the system.

Step 1: Fluid quality

As organic heat-transfer fluids begin to age, they can break down into degradation products, begin to form solids and experience an increase in viscosity as shown in Figure 1. Process contamination, oxidation and overheating can also cause deterioration of fluid quality at an accelerated rate as described in Table 1. As these fluids experience higher viscosities and solid begin to form, the overall heat-transfer performance of the system can become less efficient.

In addition, the elevated viscosity and solids content will result in accelerated fluid degradation. This occurs because as the fluid moves through the heater or user, the turbulence is reduced with increasing viscosity and solids concentrations. This results in reduced fluid-side heat-transfer coefficients, increased retention time of the fluid within the coil, along with increasing film thickness adjacent to the heater-coil wall. The increased film thickness at the highest temperatures the fluid will experience leads to increased overall thermal stress to the fluid, and ultimately greater rates of thermal degradation. Generally, the result will be overheating of the fluid causing further degradation and potential coking. The consequences could be increased batch times, poor performance of the process and increased or unplanned maintenance time.

If the heat transfer system is not performing as expected, an initial review should be done to determine the cause behind the poor performance. This review should include sampling and analysis of the heat transfer fluid [*1*]. The quality of the fluid in the system can be telling in determining the cause for inadequate performance. For example, analysis may indicate that the acidity of the fluid is elevated above the standard range for organic heat-transfer fluids. This will most likely indicate that hot fluid oxidation or process contamination is occurring. This examination of fluid condition will allow the potential causes with the system to be narrowed down dramatically, making it easier to pinpoint the problem. In instances such as these, it is essential that the cause of the issue be determined and remedied before diluting or replacing the fluid. If the initial problem is not corrected, any additional fluid added to the system may be vulnerable to the same harmful influence. Analysis may also show that multiple parameters are elevated, indicating the fluid is simply reaching the end of its life. Fluid that has become severely degraded through age, or prematurely degraded through other factors, such as those listed in Table 1, will most likely require replacement to improve the system performance.

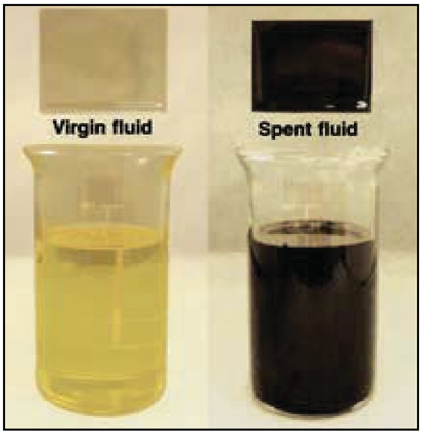

FIGURE 1. Virgin fluid (left) versus aged fluid (right) are shown here. Residue on the glass slides illustrate the deteriorated condition of aged fluid

Step 2: Draining

Once the fluid quality has been analyzed and found to be compromised, the system will most likely need to be drained. The initial action is to decrease the temperature of the heat-transfer system to 200°F and shut off the heater. The fluid should be allowed to continue to circulate in order to dissipate as much heat as possible [*2*]. One of the most common injuries sustained when working with heat trans-

TABLE 1. COMMON CAUSES OF ACCELERATED FLUID DEGRADATION		
Cause	**Description**	**Result**
Contamination	Often occurs through heat-exchanger breach in the system resulting in the process-side material being released into the heat-transfer fluid. May also occur through accidental addition of incorrect material to the system during top up	The severity of the damage to the heat-transfer fluid will depend heavily on the type of process fluid. Generally process contamination can cause an increase in acidity resulting in potential corrosion, formation of solids and sludge, increase in viscosity and overall an increase in fluid degradation
Oxidation	Occurs when organic fluids are exposed to oxygen at elevated temperature. This reaction causes weak organic acids and other byproducts to form	Will cause an increase in the fluid's acidity, which may result in corrosion of carbon-steel surfaces. Over time it can result in high-viscosity fluid and an increase in solids formation
Overheating	Normally occurs when the velocity through the heater or user is below the design requirements, system upsets where the fluid becomes stagnant, or the temperature of the heater/process is elevated above design	Will cause the fluid to break down at an accelerated rate and form degradation products. Can result in coke forming on the heating coils or users. May also result in increased solids and sludge formation

fer systems is thermal burn. Cooling the system to below 200°F can minimize the risk of injury.

Once the fluid has been cooled to below 200°F, it can safely be drained through the use of appropriate procedures and personal protective equipment (PPE) from the system into drums, bulk containers or storage tanks for disposal. Seriously degraded fluids can have significantly elevated viscosities, which can impede effective draining if allowed to cool to lower temperatures. It is important to remove as much of the used fluid as possible to ensure minimal contamination of the new charge of fluid. Blowing the lines with nitrogen can assist in moving residual fluid to low points in the system where it can be safely drained and removed. The fluid manufacturer should always be consulted for specific guidance when draining a particular fluid.

The proper PPE should be worn whenever exposure to the fluid is possible. Suitable PPE for handling most heat-transfer fluids will be similar to what is expected in most plant environments. Chemical goggles, splash protective clothing and a face shield should always be worn when there is the potential for splashing of the fluid. Clothing that fully covers both arms and legs, closed-toed shoes and chemically resistant gloves are preferable.

Depending on the type of fluid being used, there may be vapor generation. In cases where the airborne exposure limit can be exceeded, such as in poorly ventilated spaces or during excessive vapor generation, the use of a respirator may be necessary. For most organic heat-transfer fluids, an organic mist cartridge should be adequate; however, the respirator manufacturer should always be contacted to confirm the appropriate type of cartridge. Despite the use of proper PPE, exposure to the heat-transfer fluid may occur.

In general, most heat-transfer fluids tend to be moderately irritating when exposed through skin or eye contact. When contact does occur, it is important to thoroughly flush the affected area with water immediately in order to prevent extended exposure and potentially worse irritation. It is also essential to ensure that employees working with a fluid are aware of its potential health effects, especially in cases of fluids with more harmful characteristics, and know appropriate actions should they come in contact with the fluid. Fluid suppliers typically include information on hazards and handling in the product's Material Safety Data Sheet (MSDS). The MSDS should always be consulted prior to draining the used fluid.

During the removal of the fluid from the system, there may also be leaks and spills around the system. It is important to immediately clean up any spilled heat-transfer fluid to avoid accidental contact or release into the environment. If the leak is significant enough to cause standing liquid, any free liquid should be pumped into a suitable container. Residual fluid can then be removed using absorbent material, such as mats or loose media. Once any remaining fluid has been absorbed, this material should be removed for appropriate disposal. Once again, the product's MSDS should be consulted to ensure that the fluid is handled properly and safely.

Step 3: Flushing and cleaning

Flushing the heat-transfer system prior to refilling with new fluid may be required if the system contained a severely degraded fluid that generated a large amount of sludge and solids. While sample analysis can offer a good indication on whether the system needs to be flushed, system indicators may also be helpful in determining if flushing is necessary. Symptoms such as increased batch times, temperature changes across heat exchangers, progressively longer heat-up times and higher fuel usage may indicate that the system requires flushing or additional cleaning.

Flushing the system will usually include filling the entire system with an organic flushing fluid and circulating this fluid at elevated temperature for a period of time. This process will allow excess residual material to be removed from piping and vessel walls and be swept out of the system by the flushing fluid. The flush fluid should then be thoroughly drained and disposed of properly before refilling the system with a fresh charge of heat-transfer fluid. When utilizing flush fluid, the specific guidance by the flush-fluid manufacturer should be followed closely. In addition, the manufacturer should be consulted on material compatibility with the system components and the replacement heat-transfer fluid.

In more aggressive cases where coking of the fluid has occurred, mechanical or chemical cleaning may be necessary. Coking generally occurs in systems where the fluid has been severely overheated. Mechanical cleaning involves physically removing coked material and solids from the system, by using methods such as hydro-blasting heat exchanger tubes or using a pipeline inspection gage (PIG) to clear blocked piping. Chemical cleaning may also be used instead of flushing or mechanical cleaning. This method tends to be more time-consuming, frequently includes multiple washes or treatments, and can generate a significant amount of waste that will require proper disposal.

While chemical cleaning can be effective in many systems, it is not a foolproof method of removing coke-like deposits. Before considering chemical cleaning, bench-scale analysis should be done with deposit samples from the specific system. This will help ensure that the coke material can be effectively removed, and avoid potentially costly procedures that do not sufficiently clean the system.

Once the system has been thoroughly cleaned, a visual inspection should be performed before refilling with fresh fluid. This inspection should confirm that residual material — especially in low-flow areas, such as storage and expansion tanks — has been thoroughly removed and that the new charge of fluid will not be significantly affected.

Step 4: Regulatory requirements

Synthetic heat-transfer fluids can be categorized as a hazardous waste under the Resources Conservation and Recovery Act (RCRA) when sent for disposal. A hazardous waste, as defined by the U.S. Environmental Protection Agency (EPA), is a solid waste that has been identified to be ignitable, corrosive, reactive or has toxicity characteristics [*3*]. Synthetic heat-transfer fluids may be identified as hazardous waste due to the toxicity characteristics category, unless contaminated by another material that meets one of the other qualifications. One compound that could qualify heat-transfer fluids as hazardous is benzene, which the EPA sets at a regulatory level of 0.5 mg/L [*4*]. These regulations are implemented by the EPA, however individual states may have more rigid regulations.

Used heat-transfer fluids may qualify under the EPA Standards for the Management of Used Oil (40 CFR 279). Used oil regulations are an amendment to RCRA that allow "on-spec" used oil that could potentially be characterized as hazardous waste to be recycled or used for fuel instead of disposed of [*5*]. The cost of disposing of a fluid as a used oil instead of a hazardous waste can be significantly less and, in many cases, the used-oil dealers will purchase the used oil. Used-oil dealers must comply with the EPA used-oil regulations and ensure that the fluid to be reclaimed meets the used-oil criteria. The requirements for a fluid to meet the specification for "on-spec" used oil are listed in Table 2 [*6*].

TABLE 2. EPA REQUIREMENTS FOR USED OIL

Constituent or property	Allowable level
Arsenic	5 ppm maximum
Cadmium	2 ppm maximum
Chromium	10 ppm maximum
Lead	100 ppm maximum
Flashpoint	100°F minimum
Total halogens	1,000 ppm maximum

In addition to meeting these requirements, the oil must be synthetic or refined from crude oil and it must have been used [7]. A fluid that has been operated in a heat-transfer-fluid system will typically qualify by the EPA as being used. As indicated above, individual states may have more stringent requirements when it comes to qualifying fluid as used oil. In addition, it is up to each state whether or not to adopt the EPA used-oil regulation. Before considering used-oil generation or disposal, it is advisable to consult a state authority to learn the specific state requirements for used-oil generation and disposal.

The disposal of absorbent material used during cleanup of small spills or releases of used oil may also qualify under the used oil regulation. If the material is to be burned for energy recovery it can be disposed of as used oil. If the material is not to be disposed of as a used oil, it should be completely drained and then undergo a hazardous waste evaluation [*5*].

If used oil is stored at a facility before being transported to a used-oil dealer, it must be stored in a structurally sound container and labeled appropriately. Each drum or container must be clearly labeled as "used oil" as shown in Figure 2 [*8*]. Once ready for disposal, the fluid must be transported by an operator that has an EPA Identification Number to transport used oil [*9*].

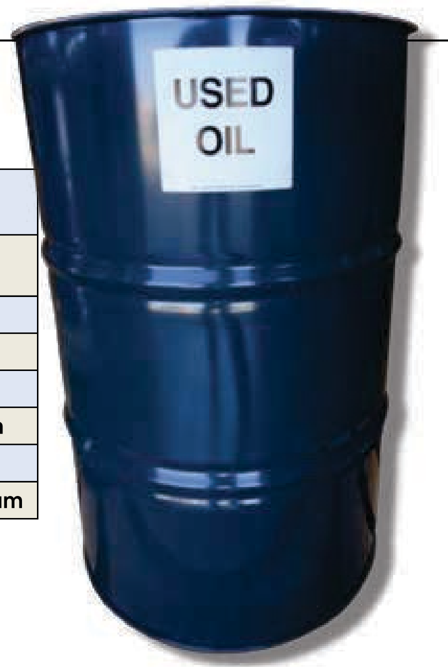

FIGURE 2:. Used oil should be stored in clearly labeled drums

If used oil is being stored at a facility, it is also important to follow the EPA standard for dilution or mixing of waste material. The EPA prohibits the use of dilution as a means to lessen the components in a waste that would characterize it as hazardous. In other words, if any amount of a listed hazardous waste is combined with a non-hazardous waste then the entire mixture becomes hazardous. Fortunately, this should not apply to most used heat-transfer fluids, as they are generally not listed hazardous wastes. However, if there is a listed hazardous waste generated at the manufacturing site, it is important that it not be disposed of in the same container as the used oil, since this would then classify the entire volume as a hazardous waste [*5*].

The storage of used oil will also fall under the Spill Prevention, Control, and Countermeasures (SPCC) rule as regulated by the EPA (40 CFR 112). This rule requires facilities to put in place appropriate procedures to prevent oil spills, as well as measures to contain and respond to a spill should one occur [*10*]. The ultimate goal of the SPCC is to minimize oil release into the navigable waters or adjoining shorelines of the U.S. If a facility has the potential to release a significant

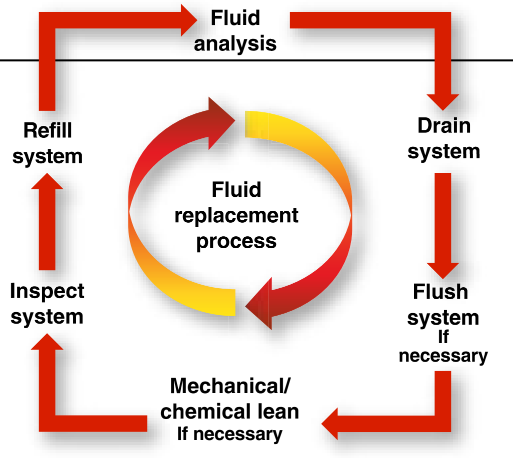

FIGURE 3. Common steps involved in replacing aged heat-transfer fluid

amount of oil into navigable waters it will most likely need a SPCC plan in place to be in compliance with the EPA regulation [*11*].

If used oil is not sent to a used-oil dealer for recycling, or burned for energy recovery, it must be disposed of as a hazardous or nonhazardous waste depending on the material. If the used fluid meets the definition of a hazardous waste under the applicable regulation, then it must be disposed of as such. If the used fluid does not meet the definition of a hazardous waste, then it may be disposed of as a solid waste in accordance with the EPA regulation. Due to the cost of these disposal methods, it is advantageous to dispose of used heat-transfer fluid as "on-spec" used oil when possible.

Step 5: Refilling

Once the used fluid has been removed from the system, and the system has been cleaned if necessary, the new charge of fluid can be added. Before adding the new fluid, it is important to ensure that all drain valves have been closed, that any maintenance on the system has been completed, and that the system has been restored to normal operational readiness. The fluid can then be added to the system. The system should be filled from the bottom to effectively expel any air or gas bubbles and to avoid splashing and aerating the fluid. Once the system is fully filled, the fluid can begin to be circulated and the heater can be turned on. The system should be slowly heated and then held at just above 100°C to dispel any residual moisture that may have been introduced during the system fill. Any excess moisture present in the system should be vented, typically from the expansion tank, then the temperature can be elevated to operating conditions. The standard process for replacing aged heat-transfer fluid is illustrated in Figure 3.

It is important that proper care is taken when removing used fluid from a system, through the disposal process and when refilling with fresh heat-transfer fluid. Effective management of heat-transfer-fluid replacement can minimize turnaround time, system downtime and the occurrence of unexpected incidents. ■

Edited by Gerald Ondrey

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