GUIDE TO FLUID SELECTION FOR SYSTEMS OVER 250 GALLON AND/OR ELECTRICALLY HEATED

The intent of this paper is to help you make an educated decision when selecting a heat transfer fluid. While most applications are unique, this guide should provide enough background to make choosing a fluid for your application much easier.

There is a wide selection of high-temperature heat transfer fluids on the market today, so you have a lot of options. Some of these fluids are recommended for open-to-atmosphere systems and some are not. Some are rated for use as high as 750˚F (398˚C), while some are only recommended for temperatures as low as 450˚F (232˚C).

All claim to transfer heat efficiently, but what other factors should be considered?

Most systems over 250 gallons are designed to protect fluid from elements such as oxidation and thermal degradation. Expansion tanks are often blanketed with a buffer or inert gas to help reduce oxidation. Often there are numerous other safety measures like low flow or level shutoffs that will further help protect the fluid from thermal degradation.

So how do fluids break down?

OXIDATION

Scientifically speaking, oxidative degradation is the reaction of oxygen (in air) with the fluid by a free radical mechanism. This process forms larger molecules which end up as polymers or solids. These elements can then thicken the fluid, thereby increasing its viscosity.

The more viscous a fluid becomes, the more difficult it will be to pump. Its heat transfer characteristics will also be compromised, and the acidity (TAN) of the fluid will increase. This also means there will be a greater risk of coke formation.

As with a lot of chemical reactions, oxidation occurs more rapidly as temperatures increase. The reaction rate is hardly measurable at room temperature, but as a temperature rises, the risk of oxidative degradation increases exponentially in the absence of special measures such as inert blanketing of expansion tanks.

Put simply, oxidation happens when hot fluid comes in contact with air. Signs of fluid oxidation are seen most evident as sludge formation within the system especially in low flow areas such as reservoirs or expansion tanks.

THERMAL DEGRADATION

Thermal degradation, or thermal cracking, is the breaking of carbon - carbon bonds by heat in the fluid molecules. This forms smaller fragments called “free radicals”. In some cases, this is as far as the reaction goes. In others, the fragments may react with each other to form larger polymeric molecules.

In heat transfer terminology, these outcomes are known as “low boilers” and “high boilers”.

Low Boilers: The effect of the low boilers is to decrease the flash point and viscosity of the fluid as well as to increase its vapor pressure. The increased vapor pressure can affect overall system efficiency and can cause pump cavitation. The reduction in the flash point could also be cause for safety concerns.

High Boilers: If thermal degradation occurs at extreme temperatures greater than 400˚C (752˚F), the effect is not only to break carbon - carbon bonds but to separate hydrogen atoms from carbon atoms and form coke. The effect of the high boilers is to increase the viscosity of the fluid as long as they remain in solution. However, once their solubility limit is exceeded, they begin to form solids which can foul the heat transfer surfaces. In this case, fouling of the heat transfer surfaces is very rapid and the system will soon cease to operate.

High boilers increase the viscosity of the fluid as long as they remain in solution. Once their solubility limit is exceeded, however, they begin to form solids which can quickly foul the heat transfer surfaces. In this case, fouling of the heat transfer surface is rapid and the system may soon cease to operate.

In essence, thermal degradation is overheating the oil past its boiling point. As the fluid boils, it produces a lighter component usually in the form of vapors. Continual overheating or cracking can cause reduced viscosity. It can also pose safety concerns with the creation of the lighter components. This in turn reduces the overall flash point, fire point and auto-ignition temperatures.

FOUR FLUID GROUPS

Mineral oils: Generally available from major refineries, mineral oils are usually low-cost and multi- purpose with very few or no additives for extra protection. These oils are lightly refined, which means they often retain petroleum distillates or aromatic hydro-carbons like naphthalene, xylene or toluene.

Mineral oils can also retain sulfur, waxes and other components. All of these contribute to shorter fluid life, particularly at higher temperatures.

White/ Paraffinic Oils: In the past 20 years the crude oil refining process has advanced significantly to offer highly refined white and virtually pure paraffinic base oils free of aromatic hydro carbons. While there are numerous grades or “cuts”, some of these base stocks have shown to be well-suited for heat transfer applications. Some speciality companies have also engineered blends of these base stocks with additives that provide enhanced protection and life expectancy in heat transfer applications.

Synthetics (PAOs and Silicones): Generally of the more expensive fluids, PAOs (similar to those used in synthetic motor oils) provide oxidative and thermal stability (up to about 550˚F/287˚C) in heat transfer applications.

Silicones are relatively new to the heat transfer market. Though costly, they do offer extreme resistance to thermal and oxidative degradation. In applications that involve product finishing, care should be taken because silicones and its vapors can cause problems if they come into contact with surfaces that will be painted or coated.

Chemical/Synthetic Aromatics: Typically made up of modified benzene-based chemical structures, they have wide-ranging temperature characteristics and can often be used up to 750˚F (398˚C). While chemical aromatics offer good thermal characteristics, they tend to be costly and can have negative implications for the environment and for health and safety.

They are often not recommended for use in open systems.

I’m ready to choose. Where do I start?

The first thing to consider in selecting a heat transfer fluid is the required operating temperature. This should include the maximum operating temperature, as well as any low temperature considerations for processing or pumping ability at ambient temperatures.

Systems operating below 600˚F (315˚C) have a much wider range of fluids to choose from. Systems operating between 600˚F to 630˚F (315˚C to 332˚C) have fewer options and those over 650˚F (343˚C) are even more limited. In general, the higher your temperature is, the fewer options you have and the more costly the fluid will be.

Petroleum-based heat transfer fluids are often best-suited for applications requiring fluid temperatures below 600˚F (315˚C) for reasons of cost, environmental impact and performance.

(Where do I start? continued)

If your system runs between 600˚F (315˚C) and 630˚F (332˚C), fluid options are limited to some high-end petroleum fluids, chemical aromatics and some silicones.

Systems needing a fluid to run above 630°F (332°C) are basically limited to chemical aromatic fluids and a few silicone fluids.

Note - it is quite common to see a high temperature fluid (650°F/343°C) used in applications as low as 400°F (204°C). While a temperature buffer is not a bad idea, over-specifying a fluid can come at the expense of better choices for performance, economic or environmental reasons.

I've established my operating temperature range. Is there anything else I should consider?

How long is your process or system's life expectancy?

If a system is being commissioned for only a short period of time (a few years, say), then the life expectancy of a heat transfer fluid is obviously less critical and cost becomes the biggest factor in your decision.

If you are expecting to maintain and run your system for a number of years, then a fluid's life expectancy and the costs associated with that should become the overriding factor.

For example, chemical aromatic fluids often have higher vapor pressures, especially as they come closer to the maximum use temperature. If a system is not inertly 'sealed' or pressurized, these vapors will escape through the expansion tank. Any vapor loss will then require fresh fluid top-up to maintain sufficient levels.

Mineral oils generally don't hold up very well when they reach their maximum use temperatures. When used at or close to their limits, they tend to thermally degrade and if not sealed from the atmosphere, they will oxidize rapidly. This is a result of some of the distillates left in the fluid after refining, and often a lack of additives.

White oils and especially pure paraffinic-based fluids are still effective right up to their maximum recommended temperatures. If the maximum temperatures are exceeded, these fluids will thermally degrade as well. The resulting light ends will need to be vented from the system which could have similar issues as with the chemical aromatics with respect to fluid make up. These fluids also have varying degrees of susceptibility to oxidation, which should be considered if your system is not nitrogen-sealed.

Does your process require a food-grade fluid?

Of all the heat transfer fluids on the market there are only a few that are rated as food grade (USDA, USP, H1 etc.). This can make the selection process a little easier, but it is important to understand there are some restrictions placed on the manufacturing components of a food grade heat transfer fluid. Oftentimes this limits the product's performance.

Closer examination of a food-grade fluid should be conducted with respect to its resistance to degradation, particularly oxidation.

Also worth noting is that food grade fluids are often specified where in fact they are not required. Careful examination of the application should be conducted given the fact that manufacturing a food grade fluid often results in limitations to the fluids performance and/or longevity.

Do you have environmental concerns?

When selecting a fluid, it's important to consider its environment impact, as well as any health and safety implications.

The EPA, OSHA or other local agencies governing the use, disposal and leak reporting of fluids should also be investigated with any fluid or application. If your system is open to the atmosphere or of the type that requires plant personnel to regularly expose themselves to the fluid or could have a probability for leaks, potential environmental issues should be addressed before committing to a heat transfer fluid.

Chemical aromatic fluids often have foul odors associated with them as well as clear and distinct health risks.

(environmental concerns continued)

White oil or paraffinic based fluids (and most mineral oils) are generally the ‘cleanest’ of all heat transfer fluids and offer ease of use and disposal.

Synthetics (PAO and silicones) are also generally considered to be ‘environmentally friendly’.

Don’t forget about disposal

Regardless of the heat transfer fluid you select, there will always come a day when you need to dispose of either small amounts of it (if the system leaks or during maintenance), or all of it when the fluid has reached the end of its service life. It is therefore important to consider the costs associated with fluid disposal.

Chemical aromatics generally need to be segregated from other spent fluids and may have to be disposed of as hazardous waste.

Silicones may also require segregation but should not be considered hazardous. PAOs as well as petroleum-based fluids can generally be mixed with other waste ‘oils’ and are, in most areas, the easiest and most economical to dispose of.