DURATHERM
EXTENDED LIFE FLUIDS

TECHNICAL PAPER

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

The intent of this paper is to provide basic industry information so that an educated decision can be made when selecting a heat transfer fluid. While each application is different this guide will provide enough background to make fluid selection for your specific application easier.

There are numerous high temperature heat transfer fluids on the market today, some are recommended for open to atmosphere systems, some are not, some are rated for use as high as 750˚F some as low as only 450˚F. All claim to transfer heat efficiently but what other criteria should be considered?

For systems with a capacity under a few hundred gallons it is typical to find they are open to atmosphere, in that there is no inert buffer (nitrogen blanket) between the fluid and the atmosphere (usually at the reservoir or expansion tank). These types of systems have unique considerations for fluid selection.

To begin with there are basically 4 general types of high temperature heat transfer fluids:

MINERAL OILS

Generally available from major refineries they tend to be low in cost and multi-purpose with no or very little additives for ‘extra’ protection. These products are usually lightly refined and as a result often retain petroleum distillates or aromatic hydro-carbons like naphthalene, xylene, toluene, and benzene. These fluids can also retain sulfur, waxes and other components all which contribute to an overall 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. Furthermore a few companies have specifically engineered blends of these base stocks with additives to provide enhanced protection and life expectancy in heat transfer applications.

SYNTHETICS (PAO’s and Silicones)

Generally of the highest costing fluids, PAO’s (similar to those used in synthetic motor oils) have been shown to inherently 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; although costly they do exhibit extreme resistance to thermal and oxidative degradation. The use of silicones in some manufacturing environments however may cause issue with product finishing, such as painting or coating, if silicone or its vapors are introduced to the surface.

CHEMICAL AROMATICS

Typically comprised of benzene based chemical structures, they have wide ranging temperature characteristics and can often be used up to 750F (398˚C). While they offer good thermal characteristics they tend to be costly and less friendly to both the environment and work health and safety. They are often also not recommended for use in open systems.

Then there are also a few things to understand with respect to how typically a fluid will degrade. This can effectively be summed up in two categories:

OXIDATIVE DEGRADATION (Most common)

The scientific definition of oxidative degradation is the reaction of oxygen (in air) with the fluid by a free radical mechanism to form larger molecules which end up as polymers or solids. These thicken the fluid increasing its viscosity. A more viscous fluid will be more difficult to pump, have poorer heat transfer characteristics as well as an increased chance of coke formation. Oxidation is also accompanied by an increase in the acidity (TAN) of the fluid.

As with most chemical reactions, oxidation occurs more rapidly as the temperature is increased. At room temperature the reaction rate is hardly measurable. However, at elevated temperatures the affect is exponential and can impact the fluid life in systems not utilizing oxidation reducing measures such as nitrogen blanketing the expansion tank.

In layman terms oxidation occurs 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 in the fluid molecules by heat to form smaller fragments which are free radicals. The reaction may either stop at that point, in which case smaller molecules than previously existed are formed, or, the fragments may react with each other to form polymeric molecules larger than previously existed in the fluid.

In heat transfer terminology, the two types of degradation products 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.

In layman terms, thermal degradation is overheating the oil past its boiling point. As the fluid boils, much like water, it produces a lighter component in the form of vapors. Excessive overheating or cracking can cause reduced viscosity as well as pose safety concerns with the creation of the lighter components which in turn reduces the overall flash point, fire point and auto ignition temperatures.

Now while it is critical to select a fluid that will sustain operation in your required temperature ranges there are many factors that should also be considered.

1. Cost of fluid vs. Service Life
2. Oxidative stability and affects of service life
3. Thermal stability and affects of service life
4. Environmental / Worker Safety

COST

While cost can be a strong motivating factor, with heat transfer fluids the old adage “you get what you pay for” does often hold true. Heat transfer fluids can be found for prices ranging from under $8 US per gallon to upwards of $50 US per gallon. What makes them different?

Lower Cost Fluids (Under $8 To $10 Per Gallon) generally are lightly refined mineral oil based and offer very little in the way of added protection through the use of additives. While these fluids have a place in systems that are protected from elements such as oxidation, open to atmosphere applications should carefully consider their use as the downside is not only shortened fluid life but also sludge and carbon that can form and ultimately cause system failure.

(COST continued)

These fluids do however have a place in open systems that lose fluid by attrition through ongoing mold or die changes (or leaks) and of course systems running lower temperatures and/or closed to the atmosphere.

Mid priced petroleum based fluids ($10 to $15 per gallon) generally are comprised of more highly refined or even severely hydro treated white or paraffinic oils. These fluids for the most part offer an inherent level of protection however some are further enhanced with the use of additives such as anti-oxidants.

These fluids are all well suited for closed applications; however some are specifically engineered to be used in open applications through the use of additives. While these fluids are not all created equal they tend, in general to run cleaner and longer than a mineral oil based fluid.

Synthetic fluids (generally over $35 per gallon) are similar to the bases used to make today's popular synthetic motor oils (PAO's). While very stable at lower temperatures, synthetic heat transfer fluids generally will have a lower operating temperature range over their non synthetic counter parts (paraffinic oils).

While offering good resistance to oxidative breakdown the cost of these fluids can be a limiting factor in applications prone to leaks (plastic processing, die casting etc.). As well it has been shown that the more economical paraffinic based fluids with specific additive packages can perform in some cases better than PAO based fluids.

Silicones are now being formulated for heat transfer applications. These fluids tend to be high in cost ($35 to $50 per gallon) but if used systems designed for silicones can often offer extremely long life cycles as they are virtually impervious to oxidation and thermal degradation.

Chemical Aromatic Fluids (generally over $25 per gallon) are not typically recommended for use in open to atmosphere applications for two main reasons, environmental and vapor pressures (read more below).

OXIDATIVE STABILITY

This is probably one of the most important considerations for systems that are open to the atmosphere. With any open system there is always a point at which the fluid will come in contact with air. The higher the temperature at which this happens the higher the rate of oxidation.

Oxidation will result in sludge and carbon formations within the system that if left unchecked can cause complete system failure due to blocked lines, sludged heaters, or insufficient flow.

Heat transfer fluids are generally unaffected by oxidation at temperatures under 200F. However, for every 15 degrees above 200˚F the rate of oxidation doubles. The higher the temperature the more protection is needed. It is therefore extremely important to consider your system design and exposure conditions when selecting a heat transfer fluid.

Petroleum based fluids offer some inherent protection from oxidation. However they are not all equal, some fluids will last longer and run cleaner than others. The use of additives in recent years has helped significantly improve fluid longevity and cleanliness.

Synthetic PAO fluids also provide good protection from oxidation similar to well engineered petroleum fluids.

Silicone fluids can if properly utilized offer almost impervious protection from oxidation.

Chemical Aromatics are recommended for closed systems and for the most part therefore offer very little protection from oxidation.

THERMAL STABILITY

It is critical to always select a fluid with the maximum use temperature rated higher than your operating temperature.

While petroleum based fluids can operate as high as 630˚F the effects of high heat should be considered especially with smaller electrically heated systems. Its important to remember that while your operating temperature might be comfortably below the maximum use temperature of your fluid with an electric heater the impingement point can be several hundred degrees hotter than your operating temperature.

(THERMAL STABILITY continued)

Petroleum based fluids will thermally degrade (crack or boil) if exposed to excessive temperature and form a lighter component. Generally for incidental causes this is not of concern and any light ends will be vented from the system. Longer term effects of ongoing overheating should be considered.

While PAO offer good stability they generally have a lower maximum use temperature than their petroleum counterparts and therefore at temperature above 500˚F to 550˚F they are not recommended.

Silicones can offer extremely high upper temperature limits. However can in some cases provide inferior heat transfer characteristics due to their naturally high viscosity index (they don't thin out with temperature)

While the high maximum temperature of Chemical Aromatics can be attractive the other concerns outlined in this document should be weighed.

ENVIRONMENTAL IMPACT/ WORKER SAFETY

Petroleum based (mineral, white or paraffinic) fluids generally are the 'cleanest' of all heat transfer fluids and provide ease of use and disposal. They generally don't require special handling and can be disposed of with other waste oils.

Synthetic (PAO's) offer similar environmental properties to their petroleum counterparts. However disposal with other mixed waste oils should be investigated with your service (segregation may be needed)

Chemical Aromatic - these fluids can be comprised of chemical components that when exposed to high temperatures can produce carcinogenic compounds. Leaks and disposal can also be of concern from a reportability and cost aspect.

Another concern with Chemical Aromatic fluids is their high vapor pressures. These fluids at temperature produce vapors sometimes as high as 15Psi. In an open system that does not contain these vapors fluid loss can be excessive and put worker safety at risk of exposure. Vapor loss also requires proportional fresh fluid makeup.