DURATHERM
Heat Transfer Fluids

FLUID SELECTION: SMALL SYSTEMS

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, while others are not. Some are rated for use at operating temperatures as high as 398°C (750°F) and some as low as only 232°C (450°F). All 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 and 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, mineral oils tend to be low in cost and multi-purpose with no or very little additives blended in for 'extra' protection. These products are usually lightly refined and as a result, often retain petroleum distillates or aromatic hydrocarbons like naphthalene, xylene, toluene, and benzene. These fluids can also retain sulfur, waxes and other components, all of 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 hydrocarbons. 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 an extended service life in today's demanding heat transfer applications.

Synthetics (PAO's and Silicones)

Generally 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 287°C, 550°F) 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 prior to or during finishing.

Chemical Aromatics

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

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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)

Scientifically speaking, oxidative degradation is the reaction of oxygen (in air) with the fluid by a free radical mechanism. This process forms larger molecules that 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 or TAN (Total Acid Number) of the fluid will increase and there will be a greater risk of coke formation within the system.

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 the 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 become evident with the formation of sludge 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 the fluid's carbon–carbon bonds at the molecular level through overheating. This forms smaller fragments called "free radicals" and 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 presence of low boilers is evident with a measured decrease in the flash point and viscosity of the thermal fluid as well as an increase in vapor pressure. The increased vapor pressure can affect overall system efficiency and can cause pump cavitation leading to premature failure. The reduction in the flash point could also be cause for serious safety and operating concerns.

High Boilers: If thermal degradation occurs at extreme temperatures – greater than 400°C (752°F), the overall effect is it not only leads to the break down of the carbon¬–carbon bonds but it also causes the hydrogen atoms to separate from their carbon atoms – leading to the formation of coke. High boilers result in an increase in the viscosity of the fluid for as long as they remain in solution. However, once their solubility limit is exceeded, they begin to form solids that 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.

Simply put, thermal degradation is the result of 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 of the fluid – which can pose a serious safety concern.

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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 its Affect on Service Life
3. Thermal Stability and its Affect on Service Life
4. Environmental & Workplace 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. From the lowest priced, lightly refined mineral oils to the significantly higher cost silicones, the price range and in-service performance varies.

So What Makes Them Different?

Low Cost Fluids

Generally these fluids 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 with the downsides not only being a shortened in-service life but also the tendency for them to produce sludge and carbon that can ultimately cause system failure.

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

Moderately Priced Petroleum-Based Fluids

The mid price category of fluids 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 low cost, mineral oil based fluid.

Higher Priced Synthetic Oils

Synthetic oils 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.

Premium Priced Silicones

Silicones are now being formulated for use in a variety of heat transfer applications. These fluids tend to be high in cost but if used in systems designed for silicones specifically, can often offer an extremely long life cycle as they are virtually impervious to oxidation and thermal degradation.

Moderately Priced Chemical Aromatic Fluids

These are not typically recommended for use in open to atmosphere applications for two main reasons; environmental exposure and higher vapor pressures (read more below).

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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 93°C (200°F). However, for every 8C° (15F°) rise above 93°C (200°F), the rate of oxidation effectively 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, as 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, tend to offer very little in the way of 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 332°C (630°F), the effects of high heat should be considered – especially with smaller electrically heated systems. It's 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.

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

While PAO fluids offer good stability, they generally have a lower maximum use temperature than their petroleum counterparts and therefore, at temperature above 260°C to 288°C (500°F to 550°F), they are not recommended.

Silicones can offer extremely high upper temperature limits. However, in some cases, they provide inferior heat transfer characteristics due to their naturally high viscosity index – meaning that they don't thin out as much with an increase in temperature.

While the high maximum temperature of chemical aromatics can be attractive, the other concerns outlined in this document should be weighed before committing to their use as an option.

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 are easy to dispose of. They generally don't require special handling and can be disposed of with other waste oils.

Synthetic (PAO's) offer similar environmental properties as to those of their petroleum counterparts; however, disposal with other mixed waste oils should be investigated with your service as segregation may be required.

Chemical aromatics can be comprised of chemical components that, when exposed to high temperatures, can produce carcinogenic or cancer causing compounds. Leaks and disposal can also be of concern in the workplace 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 15 psia. In an open system that does not contain these vapors internally, fluid loss can be excessive and put worker safety at risk of exposure. Vapor loss also requires proportional fresh fluid makeup.