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Special Report

BETTER MANAGE YOUR THERMAL FLUIDS

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Optimize Your Thermal Fluid Experience

Recognize the impact of heat transfer fluid operations and make informed value-added decisions

By Ryan Ritz, Paratherm Heat Transfer Fluids

WHETHER YOU call them heat transfer fluids, thermal fluids, thermal oils, heating and cooling fluids or simply hot oils, their key advantage is the ability to generate high operating temperatures at low system pressures. This is an important benefit over more traditional models such as steam heating or direct fire heat. When compared to those technologies, heat transfer fluid systems offer greater safety, lower maintenance, and extended operating lifetimes of both the systems and the fluid. All the while heat transfer fluid systems sustain a highly efficient, non-corrosive operation which allows for accurate temperature regulation and uniformity of your entire process.

Thermal fluids have the potential to directly affect the safety, maintenance, efficiency and reliability of overall plant operations. Therefore, these fluids deserve dedicated considerations on how they can impact the safety of your plant personnel, the protection of your equipment investment, the ability to run an efficient operation in terms of energy cost and scheduling, and the avoidance of production downtime associated with unscheduled maintenance activities.

An optimized thermal fluid experience starts with recognizing those impacts that heat transfer products ultimately have on your operation. From there, proper attention to the essential considerations associated with the fluids/systems will become more consequential amongst key decision makers and facilitators. This level of buy-in is necessary to ensure that adequate research, investment, training, maintenance, etc. are dedicated throughout the entire fluid lifecycle (design → selection → operation → maintenance → change out). The purpose of optimizing the thermal fluid experience is to extend that lifecycle to its maximum potential while benefitting from the positive impacts that the technology is designed to offer.

CONSIDER THE CONSEQUENCES

When run properly with the correct fluid, heat transfer systems are safe and low maintenance by design. The inherent dangers of any high-temperature operation increase exponentially when these factors are taken for granted. It requires a series of fluid and equipment failures compounded over time to yield a catastrophic outcome such as a fire or major leak. A system utilizing an under-designed fluid and operating outside of its designed limitations is the start of that series of failures.

Using the proper heat transfer fluid is paramount. The wrong fluid will likely lead to accelerated degradation, equipment failures associated with those degradation products, fouling of the fluid onto the surface elements of equipment, increased maintenance activities and decreased efficiency of both heat transfer and overall system operation. Equally important are maintenance and operating procedures. Operating outside of your design specifications such as temperature limitations and flow rates, and failing to adhere to basic preventive maintenance practices, can lead to irreversible damages to both the fluid and equipment.

To help mitigate problems, a reputable specialty supplier can assist in selecting a high quality, specifically engineered specialty heat transfer fluid. Your supplier should be able to co-develop an operation-specific preventive maintenance plan for your plant. They should be proactive in helping to manage and facilitate this plan on an ongoing basis by providing consultation and a comprehensive service offering. This level of support will lead to prolonged fluid life as well as decreased potential for equipment fouling, operating issues and unscheduled change outs.

UNDERSTANDING FLUID OPTIONS

Traditional heat transfer fluids can be grouped into three general classifications: aqueous-based solutions, natural

FLUID CLASSIFICATIONS

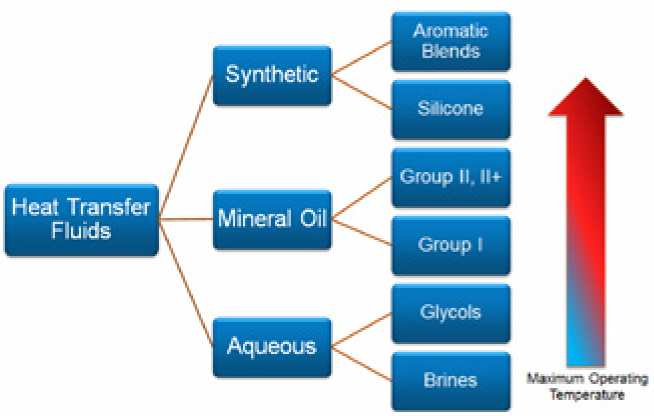

Figure 1. Heat transfer fluids have three classifications: Synthetic, Mineral Oil and Aqueous. *Source: Paratherm Heat Transfer Fluids.*

organic hydrocarbons and synthetic hydrocarbons/silicones. The preliminary specification used to determine which fluid classification you should consider is your system operating temperature range. This factor alone will almost always eliminate at least one of the fluid groups from consideration and typically provides adequate justification for narrowing the options down even further.

Starting at the low-end of the temperature range (Figure 1) are aqueous-based fluids that use water as the heat transfer medium. There are various means of extending the temperature range of water beyond its freezing point and boiling point including the use of brines or glycol solutions (propylene and ethylene are most common) as aqueous heat transfer fluid additives. Natural organic hydrocarbon-based fluids, often generalized as mineral oils, offer a capable cost-effective option for use at moderate-to-high operating temperatures. To reach the highest temperature capabilities of traditional heat transfer fluids, users are limited to considering synthetic product options. Specialized silicone-based fluids and synthetic aromatic blends offer higher thermal stability performance at those elevated temperature extremes.

In this special report, we limit our focus to hydrocarbon-based heat transfer fluids, or more specifically natural organic hydrocarbons (mineral oils) versus synthetic organic hydrocarbons (synthetics/aromatics). These are the two most widely used heat transfer fluid classifications for process heating operations in industry today. Furthermore, there are a range of applications that could potentially use either type of fluid, which requires a more in-depth evaluation of the tradeoffs associated with each. For these reasons, it is important to understand the differences between them.

Natural organic hydrocarbons feature a base chemistry consisting of a selected mixture of molecules generated during crude oil refining processes (Figure 2). Fluids formulated using these mineral oils typically feature nontoxic, efficient performance at process temperatures up to a maximum of 550° to 600°F. Because of their refined petroleum origins, natural organic hydrocarbons are available in a variety of options. API base oil groups can be used to further categorize these

HYDROCARBON-BASED HTFs: NATURAL VS. SYNTHETIC

Natural Organic Hydrocarbons

- Base chemistry consists of selected mixture of molecules generated during crude oil refining processes.
- "Mineral oils" featured for non-toxic, efficient, cost-effective performance at moderate/high temperatures:
  - 550°-600° F Max Operating Temp
- Quality and purification levels are crucial with natural organics. Color is important, impurities foul equipment. Highly refined, specialty engineered options are well worth the added cost due to higher stability and performance.

Synthetic Organic Hydrocarbons

- Base Chemistry produced from specifically formulated chemical synthesis.
- "Aromatics" display very high thermal stability at elevated temperatures and offer lower start-up temperatures.
  - >650° F Max Operating Temp
- Typically benzene-based; ring structure and double-bonding yield superior stability. Trade off considerations with cost and toxicity issues (environment, shipping/disposal and process limitations need to be evaluated)

Figure 2. Consider which heat transfer fluid, natural or synthetic, best suits your process specifications. *Source: Paratherm Heat Transfer Fluids.*

Degree of decomposition reflects the overall thermal degradation of the stressed fluid. The lower the degree of decomposition, the better the thermal stability of the heat transfer fluid relative to other fluids tested under the same conditions.

options. Group I base oils are solvent refined whereas Group II base oils are manufactured by hydrocracking – resulting in greater purity and better anti-oxidation properties. Further processing of the oils beyond these sub-groups produces the highest levels of purification and can provide added enhancements to performance of the formulated thermal fluids.

Knowing there are different grades available based on how far the refining process went is important. Lower grade base oils (Group I) are going to yield less consistency, more fouling potential and lower stability at high temperatures (max operating temperatures <500°F). Considering those limitations, when choosing a natural organic hydrocarbon based heat transfer fluid, limit your options to products formulated using Group II or higher quality standards as the base chemistry. Color can serve as a useful initial indicator. Darker colored fluids typically indicate the presence of impurities that will eventually break out of the fluid and foul up your equipment. It's best to avoid anything with a dark amber, yellow-orange type tint to it. Focus on something water white or clear in appearance. Additionally, seek out a highly refined, specialty engineered option that takes more than just the purification into account. These fluids are going to be well worth any added upfront costs relative to the lower quality products as they offer higher stability and performance.

As for synthetic organic hydrocarbons, base chemistries are produced from formulated chemical synthesis of either benzene derivatives (aromatic synthetics) or specialized reactions of isolated hydrocarbon groups (non-aromatic synthetics). This level of controlled production allows for selective molecular make-up and targeted product capabilities. For example, synthetic aromatic fluids are designed to feature double-bonded ring shaped molecular structures that inherently provide superior thermal stability at elevated temperatures and offer lower startup capability. Most common synthetic aromatics can be used at operating temperatures of 650°F or higher depending on the fluid/system design.

There are some important tradeoffs to consider before choosing an aromatic based thermal fluid. The same benzene-derived chemistry that delivers the advantage of higher thermal stability also carries the stigma of associated toxic/carcinogenic/ environmentally hazardous concerns. While most standard aromatic thermal fluids offered today are formulated to minimize these hazards, care still needs to be taken to evaluate the potential for any issues related to environmental regulations, shipping/storage restrictions, special handling precautions, and process-specific limitations at your facility. Along with those potential material-related concerns, the fact that synthetic aromatics typically demand a much higher upfront cost (up to 4x the cost of standard mineral oil-based options) should substantiate the importance of understanding all available options prior to making a purchase.

CHOOSING SUPERIOR FLUID

At this point you are able to make a decision on which general type of heat transfer fluid is going to best suit your process specifications. You've verified your operating temperatures, determined the environmental implications that your plant is able to take on, and reviewed the budget to see how much you're willing to spend on these products. Based on that evaluation, you've decided on either A: a natural organic mineral-oil-based product that's going to offer great stability and performance up to a certain temperature limitation, or B: you need to move to a higher-temperature synthetic-aromatic-based product that's going to extend your range and give you higher thermal stability capabilities but also comes along with the tradeoffs of greater initial investment and potential environmental and health-related issues.

Now comes the time to navigate through the details and actually purchase a specific product. Due diligence in researching the best finished products requires entering the world of advertisements, manufacturers claims, data comparisons, product/safety data sheets, sales reps, competitive quotes, colorful ads, technical presentations and clever tag lines. At the end of the day, technical superiority of a product should speak for itself, but you are best served by taking all available information into account. Don't automatically dismiss a well-designed ad or high quality branding as just mere marketing tricks. In a specialized field such as heat transfer fluids, a supplier that is highly invested in the industry prob-

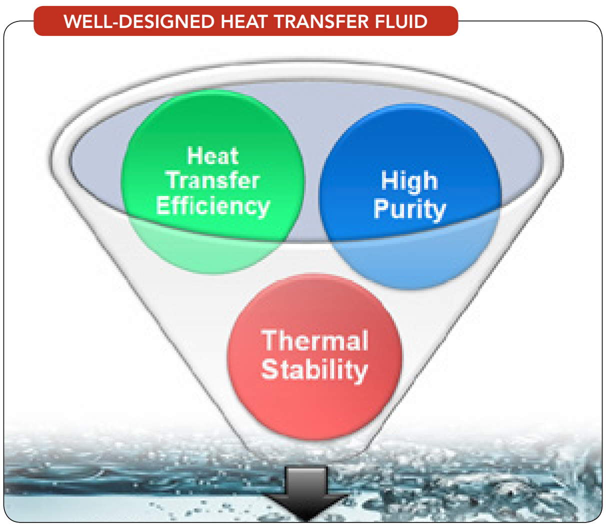

Figure 3. There are three key factors of a well-designed heat transfer fluid. *Source: Paratherm Heat Transfer Fluids.*

INSIDE FILM COEFFICIENT

- Fluid Inside Film Coefficient (hi) is used to represent the heat transfer efficiencies of each fluid at a given set of operating conditions (fluid temp, flow dynamics, etc).
- Considering all other operating conditions to be equal, the heat transfer efficiency of each fluid can be directly related to any other product at any given temperature by comparing calculated Inside Film Coefficients.
- The higher the Inside Film Coefficient, the more efficient the heat transfer fluid at the given set of operating parameters.
- Calculated using established correlations between thermophysical properties and process-specific flow dynamics (pipe size, fluid velocity, etc.)

Figure 4. Heat transfer efficiency can be represented by the inside film coefficient. *Source: Paratherm Heat Transfer Fluids.*

ably means that they have products that they are proud of and confident in. That level of confidence should mean they are willing to provide technical evidence to prove superior capability to their users. We will spend time later on how to further evaluate suppliers themselves; for now, let's discuss the key factors that you should expect them to provide in proving the value of their products.

KEY FACTORS FOR SUPERIOR FLUID

High purification is the first key factor of a well-designed heat transfer fluid (Figure 3). The level of thermal fluid purification goes well beyond just toxicity considerations. The primary goal is to remove impurities that catalyze fluid degradation and foul out on equipment surfaces when the fluid is continuously exposed to high operating temperatures.

The highest quality products that go through the most rigorous refinement processes have a clear, bright water-white appearance. Typically, the darker the fluid is the more crude impurities it contains. This is a great first-glance evaluation of fluid quality that is most relevant for natural organic based fluids. With synthetic based products, the color scale is not as prominent due to the nature of chemical synthesis vs. petroleum refinement; however, you typically want to find the clearest lightest color regardless.

The benefits of higher purification levels include extended fluid service life and reduction in the maintenance activities associated with premature degradation. There is also a lower risk of equipment failure for the same reasons. If you have degradation products accumulating in the system, there's a higher chance that they can build up and start affecting the performance of the equipment. A more highly refined fluid will also give you greater consistency in performance. Beyond just the color of the products, you're looking for keywords that are descriptors of the product themselves, for instance "hydro-treated" or "hydro-cracked" oils. "Highly refined" is a broad term and is typically applied to products that don't meet technical criteria of the more advanced processing steps. You want a specific indication which ensures you that the fluid has gone through the most rigorous refinement steps possible.

Heat transfer efficiency is the next key fluid design criteria which we will examine. This is represented by the inside film coefficient, hi. (Figure 4). The film coefficient is used to calculate the heat transfer efficiency of any given fluid under a certain set of operating conditions. By using established correlations, the relative efficiency of a fluid can be calculated using basic system parameters along with fluid temperature, flow dynamics, and the thermo-physical properties of that fluid at those temperatures and conditions. A comparative calculation allows for multiple fluids to be evaluated at the same conditions to determine which fluid, based on its properties alone, will offer better heat transfer efficiency.

The higher the value of the inside film coefficient the more efficient the heat transfer fluid at that given set of con-

Thermal stability measures resistance to the irreversible damages to fluid properties that are caused by long term exposure to heat.

ditions. There are multiple correlations that can be applied depending on specific scenarios, so you should be sure that your thermal fluid supplier can justify the formulas that they use to calculate these values. While specifics may vary, any acceptable correlation is ultimately trying to model what is occurring at the inside of the pipe wall, where the fluid is coming in contact and pulling heat energy away from the heat source.

Let's take a deeper look at heat transfer efficiency and what it means in relation to superior thermal fluid. The key point is that there is an ability to engineer fluid performance (Figure 5). A good specialty manufacturer understands the properties that contribute to an efficient fluid and makes an effort to balance these factors when formulating a product. In general, the ideal combination of low viscosity, high density, high thermal conductivity and high specific heat capacity will yield better heat transfer efficiency characteristics. Make no mistake about it; those are controllable aspects of a product during the formulation stages. There

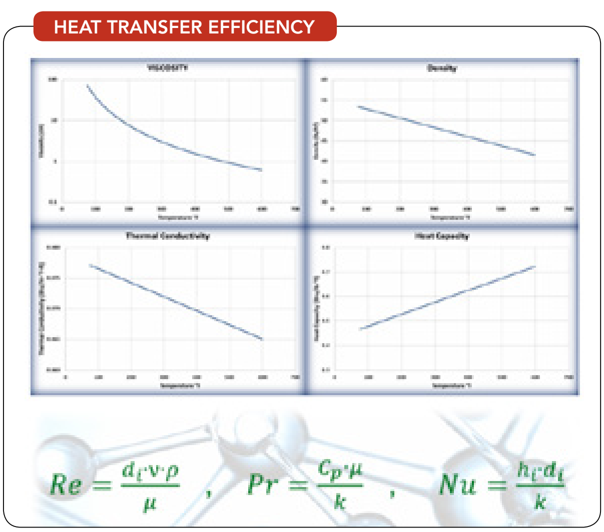

Figure 5. Efficiency (h_i) is determined by ideal combination of: low viscosity (μ) , high density (ρ), high thermal conductivity (κ) and high specific heat capacity (Cp). Considerable advantages in viscosity, density, thermal conductivity and specific heat capacity will result in better heat transfer efficiency characteristics at any proposed operating temperatures and flow conditions. Quality thermal fluid manufacturers take great care in engineering fluids that balance the most effective ratio of these key characteristics.

are tradeoffs in performance versus cost, but you want to ensure the time was taken to actually engineer a fluid that's going to be value added and result in great efficiency and superior performance.

At this point we've introduced purification levels and heat transfer efficiency as two criteria that can be used when considering the value of a heat transfer fluid. Let's move on to the third key factor: thermal stability. Thermal stability measures a fluid's resistance to the irreversible damages to fluid properties that are caused by long-term exposure to heat. This is key considering that by design, a thermal fluid system is exposing the fluid to high temperatures over long process times, so it's important to choose a fluid that can stand up to those conditions and give you longer fluid life and less wear on your equipment over time.

It's also important to realize that damages caused by exposure to high temperatures are essentially irreversible, as they occur at the molecular level of the fluid; you're actually changing the molecular makeup and the chemistry of the fluid itself. Of course, alterations at this level will have an effect on the fluid properties. As we discussed before, the fluid properties are the primary aspect of the heat transfer fluid efficiency calculation. If you're negatively impacting the fluid properties, those impacts are going to have a negative effect on the heat transfer efficiency.

Thermal stability can be tested by ASTM method D6743, which is essentially a lab scale simulation of the thermal stress a fluid is subjected to at the inside film layer of a pipe coil in a fired heater. The test is run with at least two side-by-side products heated continuously at the maximum defined film temperature of the fluids over a set time-period. Physical condition data is evaluated before and after the heating period to determine the relative level of thermal degradation that occurs as a result of the high stress application. Comparing the levels measured after heating to those of the unstressed fluid reveals how much the fluids have changed, thereby indicating the degree of decomposition. When comparing two fluids run side-by-side under the same test, the product with the lower degree of decomposition will have a higher thermal stability value.

Superior fluids will feature the most effective combination of:

- **High purification**
- **Heat transfer efficiency**
- **Thermal stability**

CHOOSING A SUPPLIER

Hopefully, by now you have fully realized the importance of heat transfer fluid related elements of your process and the extent to which they can impact your operation. You know what to look for when making an investment in a well-engineered thermal fluid and you should demand excellence from the supplier that ultimately earns the right to provide you with that product. A supplier team should constitute a group of highly-trained technical individuals that are well tenured in the science heat transfer. It should feature chemical engineers, chemists or other engineers along with technical sales representatives to guide you through the decision making process, not only commercially, but also on the technical level. Your supplier should feature process control experts that can help you with equipment decisions and specification levels and be well networked with the equipment suppliers and other key industry players.

A good indication of a high caliber supplier is their footprint on the industry in the form of technical documentation, published trade articles, presence at key industry events and investment in the recognition of their brand. That being said, the supplier's primary focus should be on engineering and supporting quality heat transfer fluids and system cleaners at the user level, and their product line capabilities will serve as evidence of this. Any reputable thermal fluid supplier should have facilities that evoke a commitment to innovation and technology and they should be proud to showcase these capabilities to their prospective partners. As a minimum, they should feature an onsite fluid analysis/research and development lab with full-time fluid monitoring technicians.

Investment in a supply partner should extend well beyond the fluid sale. Inventory levels should be reviewed regularly and the products you need should be stocked strategically. As a supplement to this, they should offer 24-hour emergency shipping and direct access to commercial/technical support to back this level of availability. Your thermal fluid supplier should proactively stress the importance of ongoing support and will have the ability to plan key aspects of a comprehensive service offering with you.

MAINTAINING THE INVESTMENT

Having confidence in products and capabilities means that a supplier's focus should not be on the next fluid sale, but on working with the user to prolong fluid life and prove the value of their brand. Fluid degradation either reduces the safety margin or increases the amount of maintenance required. Fluid degradation over time is inevitable. The goal is to minimize the rate at which it happens. No matter how high of a quality fluid you have with great thermal stability, purity and efficiency, the opportunity for fluid degradation is always there.

As a minimum preventive maintenance practice, your supply partner should highly recommend performing an annual fluid analysis. Furthermore, they should offer to proactively manage this program for you. The tests should be specific to heat transfer fluids and shouldn't be lumped in with any lube oil or hydraulic fluid analyses. The supplier should provide a full report of your fluid condition, giving you expert recommendations and verbal review on the results and best practices for controlling any degradation that could be happening. This has to go beyond results. They should be offering you a plan of action based on those results. Any unanticipated or premature degradation should not just be addressed with action on the fluid, but also with maintenance suggestions or operating adjustments to avoid similar results in the future.

Heat transfer fluids and thermal fluid systems play an integral role in processing operations. In order to fully optimize the user experience, the importance of the technology needs to be realized and dedicated considerations need to be made in the investments surrounding it. Selecting the proper fluid for your operation is crucial. You should be choosing the right fluid to optimize your operating specifications, your equipment design features, the budget and any other key elements that are specific to your plan. Look for superior fluids that will feature the most effective combination of high purification, high heat transfer efficiency and superior thermal stability in comparison to competitive options. The decision to purchase a high quality thermal fluid should be complimented by choosing a high caliber supplier to protect that investment: a highly qualified and capable partner that will help maximize fluid value and minimize any potential negative outcomes.

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Understand Fluid Degradation

Proper fluid management is key to maintaining a safe and efficient thermal fluid operation

By Ryan Ritz, Paratherm Heat Transfer Fluids

LET'S PLAY a game of word association:

"Thermal Fluid Heating" ⟷ "Impact"

Perhaps your initial reaction was to consider a list of safety hazards, maintenance issues and various other potential problems that can be linked to this widely used process heating technology. In reality, thermal fluid systems are inherently safer and easier to operate than alternative options. Because of this, they are often misunderstood and commonly overlooked until something goes wrong with them. At that point the impact is not only negative, but also significant. Cracked heater tubes. Pipes full of "gelled up" oil. Unscheduled maintenance. Downtime. Loss of production. Equipment replacement. Unbudgeted funds. Leaks. Fires. Accidents. The list goes on.

Our goal is to understand the circumstances that lead to such harsh outcomes and to learn how to prevent them. Change the culture surrounding thermal fluid operations and recognize that the *impact* should ultimately be a positive one. After all, heat transfer fluid technology was designed to be a safer, lower maintenance alternative to traditional process heating methods; considering that systems are run properly and are well maintained. The inherent challenges of any high temperature operation increase exponentially when those considerations are taken for granted.

THE PERFECT STORM

The good news is that such negative outcomes don't happen overnight. It takes a series of fluid and equipment failures compounded over time to yield a catastrophic event such as a major leak or thermal fluid fire. A well-informed user conscious of these potential impacts can easily avoid these situations. The combination of a few ill-advised shortcuts coupled with the failure to adhere to basic maintenance practices provides a formula for major failures.

At the most basic level, the two controls an operator has over the thermal fluid system are the heater outlet temperature (set point) and the fluid flow. In theory this is an easy process without much potential for disturbance or error. In practice, there are a number of additional factors that can occur throughout the system to complicate things and adversely affect the performance of the fluid and lead to expedited degradation. As the fluid degrades over time (Figure 1), these complications tend to escalate undetected until it is too late.

IMPACT OF FLUID DEGRADATION

Figure 1. Fluid degradation either reduces the safety margin or increases the amount of maintenance required. Fluid degradation over time is inevitable; the goal is to minimize the rate at which it happens.

FIRE HAZARD

Figure 2. Serious fires can occur as an ultimate result of compounded thermal fluid failures over time.

Let's propose a potential scenario as an example. The plant engineer determines that raising the heater outlet 15°C will result in a more efficient product yield. The established rule is that for every 10°C rise in temperature, the rate of fluid degradation doubles. To stay under budget, the fluid selected for this particular operation was a moderately priced local oil that was advertised to have a maximum operating temperature 20°C above the original designed system requirement. As the fluid degrades at a much higher rate, unbeknownst to the operator, carbon particles build up in the expansion tank and eventually block the low-level alarm switch. At the same time, the fluid properties have been affected to the point of decreased thermal efficiency and reduced flow turbulence. The consequence is increased fluid fouling and varnishing on the inside of the heater tube walls. That varnish buildup further inhibits effective heat transfer in the heater, and the fluid outlet temperature slowly fades away from the set point. Naturally, the operator then increases the set point another 10°C to compensate for the lag; and the downward spiral continues to get deeper as the degradation doubles yet again. The low flow alarms would eventually indicate an issue going through the heater, but remember, carbon buildup is blocking that switch. Pressure builds up, temperatures rise, the integrity of the metal is compromised and the heater tube cracks. Hopefully the fire that results from degraded thermal fluid spraying into the flames doesn't result in injury or death, seeing as the entire situation could have been easily avoided.

This is not some far-fetched story meant to provide "what-ifs." This is a very feasible situation that unfortunately has multiple real-life inspirations (Figure 2). Assuming that the proper fluid is selected at the onset and that due diligence was practiced in designing and building the system, the major culprit initiating these outcomes is fluid degradation. Therefore, it is necessary to understand how the fluid degrades, where the degradation originates, and how the operation of the system can be altered to avoid the ultimate problems.

KNOWING YOUR BREAKING POINTS

There are two primary ways in which heat transfer fluids degrade: overheating and oxidation.

Overheating, or thermal cracking, occurs when a fluid is exposed to film temperatures that exceed the manufacturer's maximum recommended limits. This exposure at the inside walls of the heater tube causes the fluid molecules to break-down or crack. Severely cracking the fluid can result in decreased heat capacity, excess low boilers, pump cavitation and eventually the formation of solid carbon particles (Figure 3).

Overheating takes place at the heat source and is caused by either improper control of heat input (flame impingement/localized heating, controller inconsistencies, power failures, ill-advised startup and shutdown practices) or reduction in flowrate through the heater (plugged lines, inadequate fluid volume, circulating pump issues, faulty bypass valves, increased fluid viscosity). As flowrate decreases, the fluid becomes less turbulent and will not effectively transfer heat from the walls of the heater tube to the bulk of the fluid. The result of either path is continually and dramatically increasing film temperatures that will severely degrade the fluid and compound issues if not detected early on.

Oxidation occurs when hot fluid is in continuous contact with a fresh supply of oxygen from air. As the oxygen

CARBON CATASTROPHE

Figure 3. Severe carbon buildup in a strainer basket resulting from unmonitored thermal degradation.

SLUDGE ISSUES

Figure 4. Sludge accumulation as a result of oxidation can cause low-flow zones, plugged lines and cold-spots.

molecules react with the oil molecules and the fluid oxidizes, it begins to produce acids that will eventually lead to increased high boilers, elevated fluid viscosity and sludge formation. Sludge will begin to accumulate at low-flow areas and around fittings, significantly altering the flow dynamics of the system (Figure 4). The source of oxidation is almost always at the system expansion tank (reservoir), which is typically the only portion of a closed-loop thermal fluid system that is vented to atmosphere. Under normal operating conditions, the temperature of the fluid in the expansion tank should never exceed 180°F. This is the temperature at which the oxidation reaction mechanism is initiated. "Warm-up" or "boil-out" valves that convert flow of hot oil directly into the expansion tank are designed to be used only for the removal of moisture in the system and should always remain closed during normal operation.

Being aware of these paths to degradation, how to detect them before they progress too far and what to do to correct the underlying problems will allow operating personnel to run efficient heating processes with minimal downtime and maintenance problems.

BEWARE: FLUID TRESPASSERS

Contamination of thermal fluid can come in many forms, and is almost always user-inflicted. The most common contaminant is some other industrial liquid that is accidentally (or purposely as the result of an ill-advised decision) added into the existing heat transfer fluid loop. These are commonly products dedicated to lubricating or hydraulic operations elsewhere in the plant. Most of these "infiltrating" products contain specific additive packages or incompatible base fluids that will quickly foul out at elevated temperatures. Other common results of contamination are pump cavitation, pressure fluctuations and plugging of filters/strainers.

Preventing user-inflicted contamination is easily accomplished by properly labeling all containers and enhanced by clearly indicating the fluid-type and even the exact brand name on a label near any fill points. Also, transfer pumps and filling hoses should be dedicated to a single system and clearly marked as such.

MAKING THE RIGHT MOVES

While the control of a thermal fluid system during normal operation is relatively straightforward, there are certain steps that should be followed to prolong the life of the fluid and prevent disruptive maintenance problems from occurring when least expected. As previously discussed, fluid degradation occurs gradually over time and when overlooked can lead to any number of costly setbacks. The primary culprit for this degradation is improper operation of the system in the form of faulty equipment, inherent design flaws and ill-advised operating practices. The combination of having a basic education on how the system is meant to operate and adhering to periodic monitoring of key components is the primary defense against continuous fluid degradation.

Proper system start-up and shut-down are key operating practices that should always be followed. Cold fluid is more viscous and does not provide turbulent flow necessary to transfer energy out of the heat source. Instead, cold thermal oil will absorb heat energy instead of moving it out, which results in broken molecular bonds and premature cracking. If this occurs on a regular cycled basis, the fluid will be prematurely damaged in a short time. To avoid overheating cold fluid, start the system up slowly until the fluid reaches about 10 cP viscosity which is typically low enough to promote turbulent flow. Conversely, never shut the entire system down all at once as the fluid will be stagnant in a very hot, insulated heater box. This is an easy way to essentially bake the fluid inside of the heater tubes. Be sure to keep the main circulating pump active after shutting the heater off until the fluid has cooled below 250°F at the outlet.

KEEPING TABS

Periodic monitoring of the key elements of your thermal fluid system are essential to prolonging a safe and predictable system. Take the time to know the standard characteristics of your operation. Walk through the system on a routine basis; look, listen, smell, observe, and record (Figure 5). Normal operat-

Figure 5. Periodic monitoring, including a walk through, of your thermal fluid system are essential to prolonging a safe and predictable system.

Figure 6. A properly performed fluid analysis is the most fundamental aspect of any routine maintenance plan for a thermal fluid system.

ing values, such as heater set point, actual outlet and return temperatures, pressure readings at key locations (pump suction, feed/return differential, etc), exhaust stack temperature, expansion tank temperature, etc. should be recorded and any discrepancies should be evaluated. Any drastic changes in these performance criteria can often be traced back to an issue that may lead to degradation. Any out of the ordinary sounds, visual leaks or evidence of smoke or vapor may be key indicators of a problem that can be easily fixed if noticed early enough. These basic monitoring steps, in conjunction with a good routine fluid analysis program, go a long way in prolonging the life of the fluid and keeping the system up and running.

A proper *fluid analysis* is the most fundamental aspect of any routine maintenance plan for a thermal fluid system (Figure 6). Proper testing of the fluid not only indicates the current condition, it establishes a history of the system and can raise red flags for problems that will eventually damage the fluid and system. As recommended by all thermal fluid and equipment manufactures, a professional analysis of the fluid should be conducted at least annually. The analysis should be specific to the operating criteria that are unique to thermal fluids, and should not be substituted by common lubrication oil testing. A combination of visual inspection, laboratory testing and professional evaluation of the results is essential for capturing all of the information necessary for an effective analysis. Just as important as the frequency and specific type of testing is the proper collection of the fluid sample. The sample should be taken at a minimum temperature of 180°F from an active section of the system and protected from any contamination. This ensures that the sample is providing an accurate representation of the bulk operating fluid within the system.

There are three basic laboratory tests that should be run to accurately determine the condition of a thermal fluid sample. *Total Acid Number* (ASTM D-664) is the most telling and directly relevant test. This measures the level of acids present in the fluid as a result of oxidation. These acids are the raw material responsible for the formation of sludge, fluid “gelling” and system cold spots. The higher the Acid Number, the greater the extent of oxidation. *Kinematic Viscosity* (ASTM D-445) is a measurement of how easily a fluid flows at a certain temperature (40°C is the most common test temperature). Fluids with extremely high viscosities will typically display poor heat transfer efficiency and may also cause problems with low temperature startup. Significant increases or decreases in fluid viscosity over time are strong indicators of thermal degradation or the possibility of contamination. Finally, the *Distillation Range* (ASTM D-2887) can be used to track changes in the make-up of the fluid over time to determine whether a fluid has degraded or has been contaminated. When analyzed by an expert, the results of these tests, especially when conducted at routine intervals, can be interpreted to indentify degradation problems as well as the likely source of the degradation.

GO WITH THE FLOW

Thermal fluid systems can be utilized as efficient, safe, and low maintenance alternatives to traditional high pressure steam and direct-heating systems. By recognizing the positive impacts that they bring to your operation, avoiding the negatives and then following a few simple steps to monitor key components and keeping up on basic routine maintenance practices, a thermal fluid user can benefit from uniform, precise temperature control in a predictable, value added and trouble free process.

Get to know your equipment manufacturer and service reps along with the provider of your heat transfer fluid. Pick up tips. Follow advice, recommendations and corrective actions. Any costs associated with that information is well worth it in comparison to the alternative potential issues discussed throughout this guide. Taking the time to understand the equipment and how to properly maintain the fluid will not only extend the operating life but also ensure more efficient, reliable production capabilities for many years.

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Adopt These Fluid Hacks

Follow these tips to optimize your thermal fluid operations

"FLUID HACKS" is a collection of tips and practical guidelines from industry experts on thermal fluids and related operations. Below is some summarized advice intended to take the guesswork out of dealing with heat transfer fluids and to improve the overall user experience.

LEAKING SYSTEMS: CONTROL THE DRIPS, PREVENT THE GUSHES

The quickest way to detect a leak: SMOKE. When hot thermal fluid is exposed to oxygen in small quantities (like a slow leak), the fluid will immediately oxidize and produce smoke. The amount of smoke depends on the size of the leak, the temperature of the fluid and to some extent the airflow in the area.

Small leaks can produce an exaggerated amount of smoke because there isn't enough fluid to form a drop. This steady weeping smokes and then cooks onto the metal near the leak.

With larger leaks, the fluid usually cools quickly as it drips or sprays into the air. This cooling reduces the vaporization of fluid which helps lessen the amount of smoke. However, if the leak is large enough that it uses up all the fresh air — or if ventilation is insufficient — vapor can accumulate and cause a potential fire hazard.

Minimizing leaks starts with running a tight system; pun intended. As fluid temperatures cycle over time, system elements will naturally expand and contract, loosening fittings. Flanges are the most common source of leaks. Re-torque flanges on a periodic maintenance interval to decrease leak potential. Threaded fittings should be kept to a minimum; when used they should be reinforced with fluorocarbon thread sealant or Teflon tape and tightened down.

Avoid major fluid discharges by ensuring that:

- All drain valves are closed before adding fluid to the system.
- All block valves are closed before opening a line.
- Pressure valves are installed in areas where they are not exposed to "accidental forced removal" from the likes of heavy equipment. Isolating valves should be installed just in case.
- Leaking pump seals are to be replaced before they flush out the bearing grease.
- Expansion tank levels are checked before startup to prevent overflow from the vent.
- Proper procedures are followed to remove any accumulated water from the system.

SAY NO TO H_2O

Unless you are purposely using an aqueous based heat transfer fluid (glycol/brine), you want to avoid water in your thermal system at all costs. This isn't as easy as you would think; water eventually shows up in more systems than not and the source is often a mystery to the system operators. It doesn't take a high volume of water to create serious problems; a commonly used visual example is that it only takes a 12-oz can of water to generate a 55-gallon drum equivalent of volume displacement in saturated steam. Once it finds its way into your system, the dedicated removal process will make you wish you would have read this section in its entirety the first time.

Maintain a "hydrophobic" thermal fluid system by following these minimal precautions:

- Never "hydro-test" a new system with water!
- Do not store drums of fluid outside where water can collect in the drum head. The expansion/contraction

of the fluid with temperature changes can pull water in through the bungs. If storing drums outside is unavoidable, they should be laid on their sides.

- Ensure that the transfer pump used to charge fluid into the system is 100% dedicated to the thermal fluid only. Keep the pump away from anyone that is likely to “borrow” it for other purposes and clearly label the pump to identify its purpose.
- If your system is vented and located in a humid environment, give some serious thought to installing a nitrogen blanket on the expansion tank. If the tank temperature drops below the dewpoint, condensation will form on the outside and the inside of a vented expansion tank.

MAINTAINING CONTROL UNDER PRESSURE (GAUGES)

Maintaining your thermal fluid system’s design flow rate is critical for system performance. Quantitative output can be provided by flowmeters, but for a simpler and less costly method of tuning a system, users should consider the installation of pressure gauges.

While pressure gauges don’t provide the data for actual flow calculations, they can track valuable information for troubleshooting. For example, should a Y-strainer become blocked, a compound pressure/vacuum gauge installed on the pump suction could help flag the issue before it causes a major problem. Similarly, a malfunctioning control valve can be readily detected by pressure gauges installed on the inlet and outlet lines of a heat user.

Suggested pressure gauge locations:

- Inlet and outlet of the heater.
- End of the supply header, beginning of the return header.
- Pump suction and discharge.
- Before and after every heat user (between the control valve and the user).

DANGER! FLASH POINT!

Slow down!! Take some time to fully understand the purpose of this fluid property and its relevance to HTF operations before you jump up and pull that fire alarm. Systems regularly operate at temperatures well above the defined fluid flash point; in fact it is more common than not. The reason is that the factors that ultimately contribute to the determination of the flash point are never likely to occur in a properly designed thermal fluid system.

Flashpoint is defined as the exact temperature at which a fluid generates a high enough concentration of *vapor* to be ignited when put in direct contact with an *ignition source* in the presence of *fresh oxygen*. Three key elements are at play here: Concentrated thermal fluid vapor, an ignition source (flame, spark, red hot metal), and fresh oxygen. Keep in mind that the tests used to measure flash point (ie ASTM D92, D93) are performed in a controlled laboratory environment designed to specifically to achieve ignition. Thermal fluid systems are designed to avoid it.

In practice, closed-loop heat transfer fluid systems separate the heated fluid from oxygen and any potential ignition sources throughout the entire process. What about leaking fluid outside of the system? Doesn’t a processing environment inherently have a variety of potential ignition sources? The fired heater perhaps? See the previous fluid hack that talks about leaks and consider the fact that the accumulation of concentrated fluid vapor outside of the loop (where the oxygen source is) is not likely to occur in a properly ventilated environment. Even so, fluid vapor that leaks out at that temperature level will likely oxidize and immediately turn into non-combustible smoke.

Basically, it would take a series of significant failures to result in a fluid ignition; say a cracked heater tube that sprays fluid into the flame or a violent discharge of fluid out of the expansion tank directly into the heater exhaust stack. At that point, the flashpoint gets thrown out of the window; any standard fluid will ignite under those catastrophic conditions. So leave the flashpoint worries to the warehouse managers and shipping coordinators and direct your focus on selecting a fluid with properties that have a relevant impact on your operation.

TIME TO CHANGE FLUIDS?

Draining systems: Before draining your system, have the fluid analyzed by the manufacturer to determine if flushing or cleaning is actually necessary. If it is, you'll get more of the crud out by keeping the fluid as hot as possible (200°F–210°F) while draining. Also, run the pump until cavitation occurs. This keeps system contaminants from settling out.

Charging systems: Throttle the block valve on the main pump discharge for cold circulation (or cycle a gear pump on and off) to prevent pump damage. Add fluid when the pump cavitates and slowly increase the flow rate until the entire system is full. Make sure you fill all the loops.

Heater startup: Increase the system temperature slowly to between 210°F and 250°F. Pump cavitation and expansion tank "geysers" mean there is water in the system. The only way to completely remove water is to flash it to the atmosphere. System is dry when pump is stable at suction temperature of 230°F.

MORE FLUID HACKS

Charging a system: Avoid filling systems from the top-down (ie from the expansion tank) as you will effectively trap air into the loop resulting in troublesome pressure fluctuations & pump cavitations. Removing air from the system is a painstaking process. Instead, fill the system from the lowest convenient point to push the air up and out of the system in its natural progression. Open all high point vents/valves and close as the fluid reaches each point.

Removing water: Avoid flashing moisture off into concentrated steam by controlling the temperature rise slowly to just above the boiling point of water (target around 230°F at standard atmospheric pressure). Open the warm-up or boil-out valve on the bypass leg to the expansion tank. This will allow hot fluid to flow directly into the tank and raise tank headspace temperature. As water boils, steam will escape through the vented expansion tank. Continue until no further visual evidence of steam and CLOSE THE WARM UP VALVE!

To prevent rapid degradation:

- Never operate above the maximum fluid operating temperature.
- Maintain designed fluid flow rates through the heater.
- Monitor differential pressure through the heater and low level switch in the expansion tank.
- Never operate with the "warm-up" or "boil-out" valve open to allow for hot fluid flow directly into the expansion tank, unless you are actively removing water. Keep this valve CLOSED under normal operating conditions.
- Install a low pressure inert gas blanket to displace air in the headspace of the expansion tank. Nitrogen is most common.
- Follow proper start-up and shut-down procedures.

For more detailed information on these *Fluid Hacks* and other heat transfer fluid related tips, subscribe to TipSheet, Paratherm's monthly technical email series.

ADDITIONAL RESOURCES: PARATHERM BLOG

In our blog we introduce the technical content that appears in our monthly Tipsheet series that offers tips for maintaining and operating hot-oils and hot-oil systems. We also cover more general topics regarding the process industry, fluid applications and equipment, and business technology and engineering history. **www.thermal-fluids.com**

PARATHERM USER'S GUIDE FOR HOT OILS & PROCESSES

Our User's Guide to Heat Transfer Fluids/Systems is a series of technical data sheets covering the operation and maintenance of heat transfer fluids, and the systems running them. **www.paratherm.com/users-guide/**

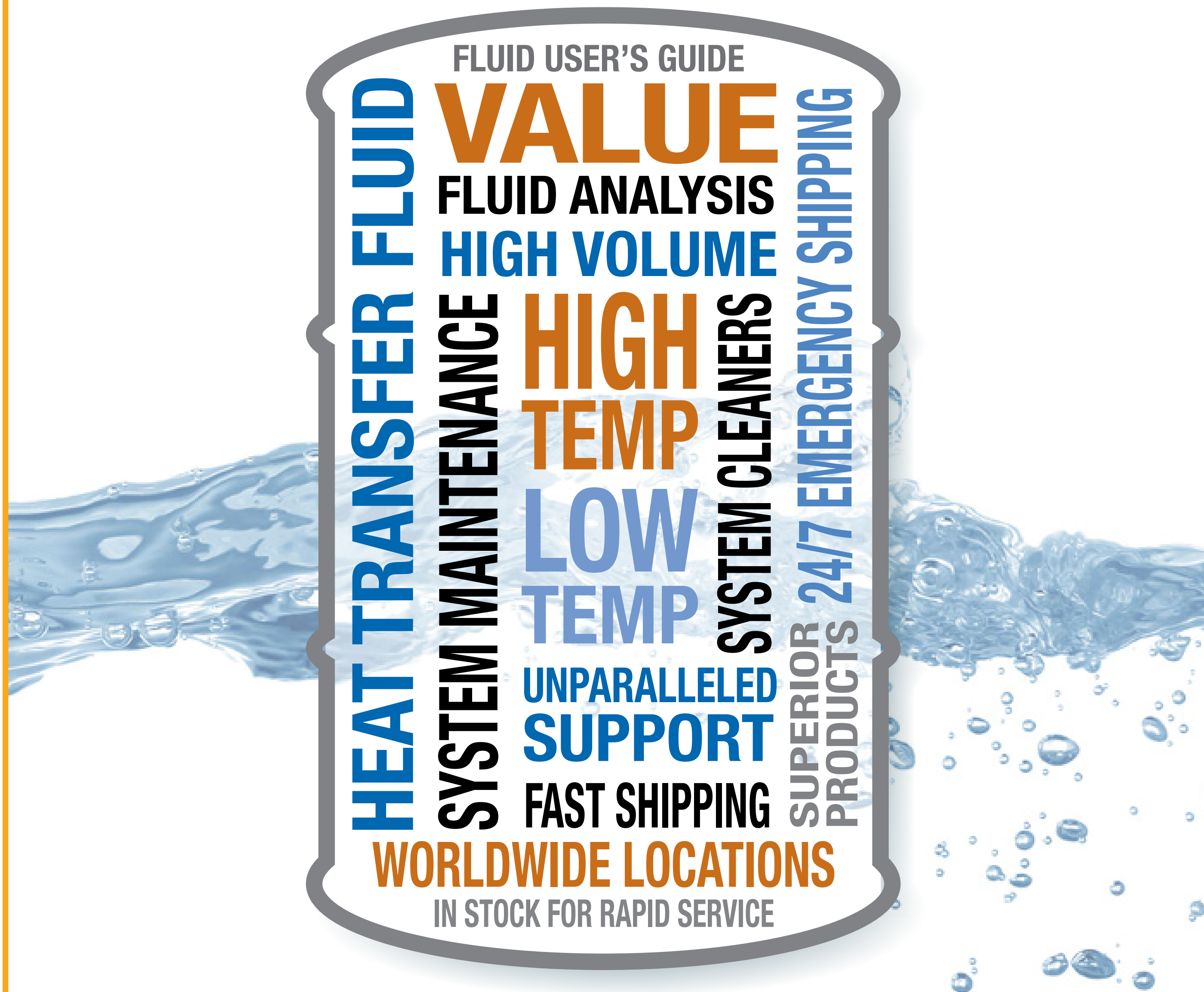
SPECIAL REPORT: MAKE THE MOST OF HEAT TRANSFER FLUIDS

Even though thermal-fluid heating systems have been used for more than 80 years, they still provoke a certain amount of fear and trepidation in users. This anxiety is reinforced by any number of horror stories that usually involve systems that suddenly develop a "problem" after years of trouble-free operation. *Chemical Processing's* Special Report: Make the Most of Heat Transfer Fluids delves in to the issues surrounding heat transfer fluids. Learn about:

- Thermal fluids – dispel common myths about hot oil systems.
- Avert oxidation – how nitrogen can serve as an inert barrier to prevent heat-transfer fluid from contacting atmospheric air through the expansion tank.
- Steam vs. hot oil – a key tradeoff complicates the choice between steam and a hot oil system to heat water.

Download: **http://goo.gl/28xxbO**

Heat Transfer Fluids...



...and a whole lot more!

Explore a clickable image where all the keywords in this drum link to details on the fluids, the cleaners, the user's guide, system maintenance, product availability, fluid analysis, and more.

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