

Improving production of heat transfer fluid systems with solvency enhancers.

Jo Ameye

Fluitec NV, Brussels, Belgium

j.ameye@fluitec.com

Greg Livingstone

Fluitec International, Bayonne NJ, USA

1. Introduction

Heat transfer systems (HTS) can be simple in design but complex when we think about the stress the oil undergoes.

Understanding the bulk oil temperature can help estimate the thermal stress placed on the oil, however there are also higher thermal loads placed on the fluid at the interface of the piping as the oil flows are lower in this region causing accelerated oil degradation. Supplemental pressurized oil systems, added to the system to increase the cooling capacity of the fluid, can be a further oxidative stress factor.

Due to this thermal and oxidative degradation, contamination levels in the heat transfer fluid will quickly buildup and result in production and quality issues for example in the wooden plant manufacturing industry. Usually, the only solution for high contamination levels on heat transfer fluids, is the total exchange of the fluid, which is costly but not sustainable.

Solubility enhancement of fluids can be the way forward to improve and control deposit formation. These can provide a possible way to avoid maintenance issues such as pump failures, premature filter clogging etc.. With this paper we will go in more depth on the effect of solvency enhancement with heat transfer fluids as part of possible suggested maintenance actions.

2. HTS Common industrial applications

Industrial heat transfer systems are designed to circulate heat transfer fluids (HTFs) through a closed loop or open-loop system to manage process temperatures in a wide range of industrial operations. HTS are simple in design and consist of a heater, pump, expansion tank and

process vessel. The components can be viewed in Fig. 1 below.

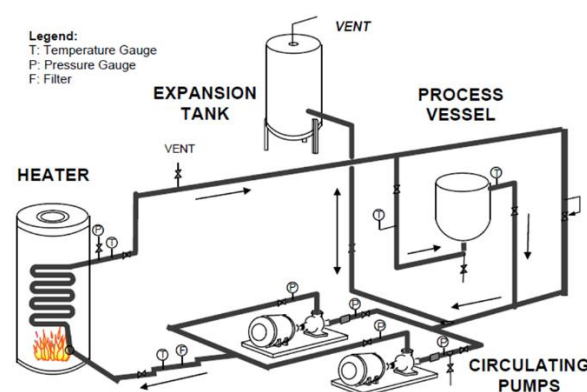


Fig.1: typical Heat Transfer Fluid System

These fluids must maintain stable thermal properties, chemical compatibility, and minimal degradation over time. Heat transfer fluids can typically be used on the industrial applications below:

- **Chemical Processing:** Reaction vessels and polymerization reactors rely on stable HTFs to maintain precise temperature control for consistent product quality.
- **Plastics and Rubber Manufacturing:** Injection molding machines and extruders use heat transfer systems for temperature regulation of molds and barrels.
- **Pharmaceutical and Food Processing:** Cleanliness and tight temperature tolerances are essential, requiring fluids with low toxicity and robust thermal stability.
- **Petrochemical and Refining:** Process heaters and reformers employ high-temperature heat transfer fluids to transfer heat efficiently and reduce the risk of thermal cracking in feedstocks.

- **Power Generation (Thermal Solar, Geothermal, CSP Plants):** fluids are used to harness and transfer heat from solar concentrators or geothermal sources.
- **HVAC and District Heating Systems:** Large-scale HVAC systems in commercial or municipal settings rely on water, water-glycol mixtures, or specialized HTFs for efficient heat distribution.

3. Heat transfer system fluid failure modes

Heat transfer fluids in heat transfer systems (HTS) are subject to several degradation pathways, each of which can lead to deposits and reduced system efficiency. In a properly functioning HTS utilizing hydrocarbon oil heat transfer fluids, the oil film is typically 14-28°C (25-50°F) higher than the bulk oil temperature. However, if the oil velocity is reduced, film temperatures can be more than 40°C (104°F) causing accelerated oil degradation. There are well established calculations used to estimate film temperature based on oil flow, pipe diameter, and heater capacity. Fig.2 below shows the fluid at the interface of the piping as the oil flows are lower in this region.

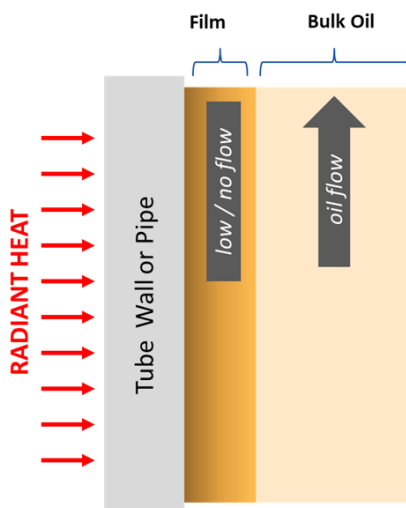


Fig. 2: Fluid film temperature is higher than the bulk oil temperature due to lower flow rates.

The first degradation mechanism is oxidation which by the elevated temperature and oxygen exposure can cause chemical reactions in the fluid, forming acidic by-products and sludge.

These HTS typically also suffer from thermal degradation (thermal cracking), based on overheating conditions beyond the fluid's recommended maximum temperature that will break down its molecular structure, producing lighter components (potentially volatile) and heavier tar-like materials (polymers from high molecular weight deposits).

Finally particulates, water, or process contaminants can interact with the fluid or consume stabilizing additives, leading to instability and deposit formation.

4. Effects of sludge, varnish, and coke deposits on HTS's

When heat transfer fluids degrade, the by-products that are formed may appear under the following chemical forms.

- **Sludge:** Typically formed by oxidation and partial polymerization. The sludge is either present as suspended or deposited sludge, which will restrict fluid flow, potentially causing hot spots and reducing heat transfer efficiency.
- **Varnish:** The varnish deposits (as a film) can coat internal surfaces such as piping, heat exchangers, and temperature control valves. Typically when heat exchangers are affected by the varnish film, it will reduce the heat exchanger efficiency by adding a thermal barrier and can impede flow or cause valve-sticking issues.
- **Coke:** Is different from the aforementioned 2 categories, as the deposit is hard, and carbon-rich. The coke formation is caused thermal stress or "cracking." Coke deposits are highly insulating, leading to hotspots, corrosion under deposits, and overall loss of thermal efficiency.

4.1. Impact on Efficiency and Equipment Life

Deposits formed by the above reaction will act as insulating layers. As a result, more energy is required to achieve the same heat exchange, decreasing system efficiency as a result of reduced heat transfer coefficients. Additionally the sludge and coke deposits will impede fluid circulation, and trap heat in specific areas, accelerating further fluid degradation and damaging equipment. Field experiences have taught us how pumps are affected by these deposits and cannot achieve the required hydraulic pressure.



Fig.3: HTS contamination example

Systems fouled with varnish and coke often require shutdown for cleaning or part replacement, resulting in increased maintenance and downtime. In a production environment this leads also to increased costs associated with production and operation.

4.2. Monitoring the condition of HTF's

Even though the two oil degradation mechanisms occur due to high temperatures, the impact on the oil is different depending on which pathway is involved. Table 1 illustrates the differences between the two phenomena.

Table 1: A comparison between thermal cracking and oxidation

	Thermal Cracking	Oxidation
Degradation Influence	Severe Temperatures	Contamination with Air
Changes in Viscosity	Decreases	Increases
Flash Point	Flash Point Decreases	No change
Acid Number	No change	Increases
Deposits	Conradson Carbon Residue (CCR) Increases	Insolubles Increase

To determine the condition of in-service heat transfer fluids, Mobil™ has developed an oil analysis package that includes the following tests:

- Viscosity
- Water volume % Karl Fischer (KF)
- Oxidation
- Total Acid Number (TAN)
- Particle Quantifier (PQ) Index
- Metals
- Flash Point (Cleveland Open Cup)
- Micro Carbon Residue (MCR)

Other tests may include Flash Point (Penske Martin Closed Cup), Conradson Carbon Residue, Pentane Insolubles, or Simulated Distillation by Gas Chromatography.

5. Mitigating deposit formation

5.1. Online remediation of thermal fluids in heat transfer systems is also challenging, stemming

from the need to maintain system efficiency, safety, and integrity without disrupting the production process. Here are some of the key challenges:

- **Safety Concerns:** Handling hot thermal fluids poses significant safety risks, including burns, fires, and explosions. Performing online remediation requires stringent safety protocols to protect personnel from the hazards associated with high temperatures and potentially reactive or flammable fluids.
- **Decontamination:** Advancements in chemical filtration technologies to remove oil degradation products in other industrial lubricant applications are not suitable for heat transfer fluids due to the high temperatures.
- **Detergent-based oil cleaners:** Adding chemical cleaners to heat transfer fluids may be a suitable strategy when part of a turnkey flushing procedure but introduces operational risks when added to an operating system, including rapid deposit accumulation and decreased flash points.

5.2. Use of Solvency Enhancers

DECON™, as a Solvency Enhancer and part of the Fluitec Solvancer® product range, is a full synthetic, API Group V, oil soluble cleaner designed to be safely added to in-service oils with no measurable impact to fluid quality or system performance. It dramatically increases the solubility of an in-service oil allowing deposits to be dissolved. It also minimizes further deposits from being generated. By adding DECON, it helps to eliminate carbon deposits from heat transfer systems, making heat exchangers, pipes and pumps cleaner. Fig. 3 presents the effect of solubility increase on an in-service fluid, before and after treatment.



Fig.3: in-service fluid treatment with DECON (Source: OptiOil Germany and University of Rostock)

DECON is an effective solution to increase system efficiency in HTS by tackling carbon deposits.

6. Conclusions

Large industrial heat transfer systems are critical to many manufacturing and processing applications. While heat transfer fluids are formulated to endure high temperatures and challenging environments, they are still subject to oxidation, thermal cracking, and contamination. Sludge, varnish, and coke deposits resulting from these failure modes can significantly compromise heat transfer efficiency, increase operational costs, and lead to equipment failure.

To prevent reliability issues, the proper fluid selection in combination with regular condition monitoring, and proactive maintenance strategies, will help mitigate these issues and extend the life of both the fluid and the equipment. The use of solubility enhancers will help end-users to keep deposits and varnish into solution and optimize the availability of heat transfer systems.