Technical Brief

Thermal Heat Transfer Systems
GulfSea HT OIL 32

Introduction

This Technical Brief provides vessel operators with the requisite information for safe and reliable management of thermal systems using GulfSea HT Oil 32.

GulfSea HT Oil 32 is a premium heat transfer oil, recommended for most thermal oil systems.

Traditionally, steam has been the common medium used to provide thermal transfer for the heating processes on board ships. However, this medium carries a number of maintenance requirements and safety hazards. Mineral oil-based heat transfer systems provide several advantages over steam, including lower operating temperatures / pressures, and easily regulated fluid temperature. This has led to the growing popularity of thermal oil heating systems and their widespread application in vessels with high heating coil load requirements, such as Product Tankers and Chemical Carriers.

Key features of GulfSea HT Oil 32: Required Functionality of Heat Transfer Fluids

- High thermal stability
- Excellent heat transfer characteristics
- Low viscosity over the total temperature range
- High boiling point at atmospheric pressure
- Low solidification temperature
- High oxidation stability
- Compatibility with vessel heat transfer systems materials; low corrosion tendency
- Non-toxic, odourless, non-corrosive – safe handling by personnel
- Low danger of fire
- Easy disposal
- Low initial cost

Heat Transfer Fluids - Modes of Failure:

Heat transfer fluids are extremely durable in well-designed systems; when operated with the necessary controls, the common causes of heat transfer oil degradation can largely be avoided. The two failure modes for heat transfer oils are thermal degradation and oxidation.

Thermal degradation or “cracking” occurs when the oil is overheated and the molecules in the fluid break up, releasing some of the hydrogen and short-chain hydrogen-carbon molecules as gases. The remaining oil becomes carbon rich and will undergo further reactions creating a high viscosity product with tar-like “sticky” characteristics.

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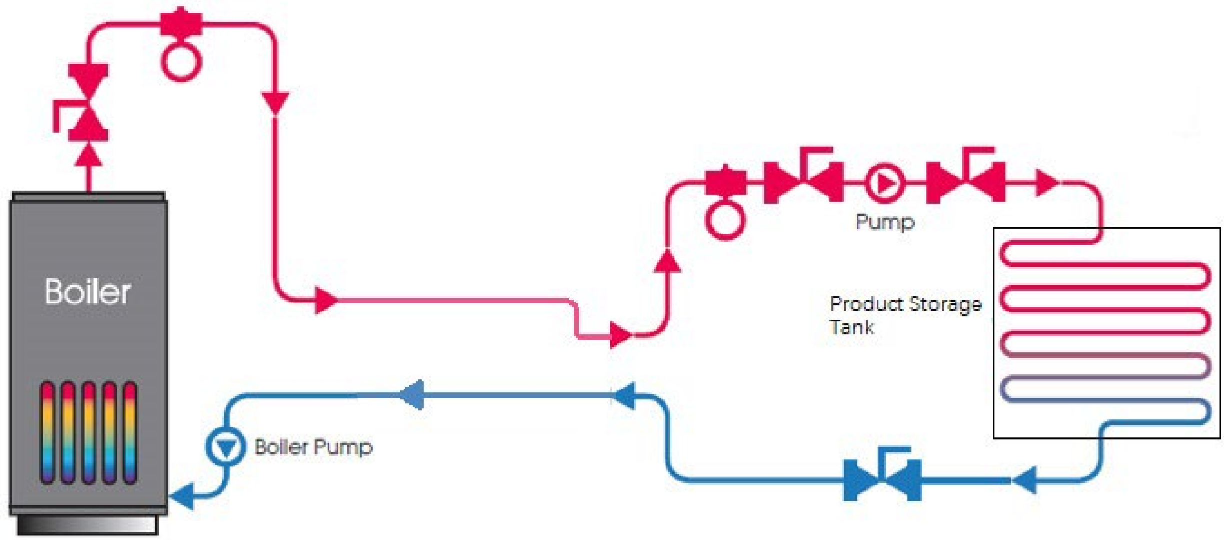
If overheating continues, the inevitable consequence is further break-down of the fluid, deposition on hot surfaces causing lower heat transfer rates, and subsequent higher surface temperatures. If the causes of the degradation are not arrested and corrected, the system can quickly degenerate, resulting in a total loss of the heat transfer fluid and the need for an internal cleaning of the thermal oil system.

Degradation by oxidation occurs when the system design enables frequent air ingress, usually via an open expansion tank. In a well-designed system, the temperature in the expansion tank should not exceed 60°C and should contain an inert gas blanket in the head space. It is usually the loss of the inert gas blanket, or a frequent change in the volume of the head space in the expansion tank, that enables air exchange, introducing fresh oxygen to the system. Heat transfer oil can contain about 10% dissolved air by volume. The additives in the heat transfer fluid will react with the oxygen and prevent reaction with the fluid. However, repeated air exchanges will introduce more oxygen and eventually deplete the oxygen handling additives, after which the oxygen will start to react with the heat transfer oil, creating thickening, which increases the viscosity of the fluid leading to poor fluid flow and heat transfer as well as thermal degradation as described in the paragraph above.

Applications:

GulfSea HT Oil 32 is recommended for non-pressurized, closed liquid-phase, heating systems operating at bulk-fluid temperatures from -10°C up to 320°C, and a maximum film temperature of 320°C. Such systems are used in a variety of applications ranging from, maintaining the temperature of oil cargoes / storage tanks (see diagram below), to providing complete shipboard heating services - including main-engine fuel and lubricating oil - through to unfired steam.



An Application of a Thermal Oil System: Maintaining the Temperature of Product Storage Tanks

System Design:

Classification rules require the avoidance of contamination of the heat transfer fluid by liquid cargoes and other heated liquids. This can be achieved by ensuring there is permanent static head pressure on the thermal oil system that is higher than the maximum head pressure of the heated liquids (heated liquid cargo or fuel tanks, etc.).

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Where thermal fluid is also used for lubricating oil heater systems, it is recommended that the 220°C bulk fluid temperature limit applied for fuel oil heaters is also applied for lubricating oil heaters. This is desirable to limit the risk of fouling on the lubricating oil-side tube surfaces.

Commissioning:

When commissioning new installations, or where there has been major maintenance or thermal oil system containment renewal, it is recommended that the thermal oil system is filled with GulfSea HT Oil 32 and pressure tested to check for leaks. Water **should never be used** for this application, under any circumstances. It is also recommended that the system is then thoroughly circulated for several hours with a temporary fine filter installed in the system, using GulfSea HT Oil 32 as the flushing fluid. Flushing should only cease once the fine filter is no longer collecting debris.

System filling is complete when the oil level in the expansion tank is at 30-45% of the level expected at operating temperature. This will allow sufficient head space once the oil has expanded when heated. The ullage or head space should then be filled with an inert gas blanket. The expansion tank is the only location where the oil is likely to be in contact with the atmosphere and thus where air and oxygen can enter the system. Once the system is filled, and prior to commencing heating, all air must be completely expelled from the system, to prevent circulation problems and oxidation. This can be achieved by venting any dead-legs out of direct circulation (such as pipes that may be used for sensor connections, filling, sampling and other duties), and venting any vessels, heating-coil headers, etc.

The system should be circulated cold for at least one hour to ensure that all lines are filled with heat transfer oil. During circulation, all venting points should be vented periodically and just prior to completion of cold circulation. The use of auto vents is not recommended, unless it includes a manual shut-off valve, which should be closed before the system is entered into service.

Ideally, there should be sufficient distance between the header tank / expansion tank and the thermal oil circulation such that the fluid in the tank does not become hot. If the system design results in the temperature of the fluid in the header tank / expansion tank exceeding 50 °C, it is often a better option to fit a floating cover: this serves the purpose of eliminating the head space making contact with air and oxygen.

Service Life:

GulfSea HT Oil 32, when used in a well-designed and well-operated system, will provide a long service life. It is possible for the thermal oil to operate for many years before requiring part or full replacement.

Listed below are design and operating conditions which can significantly shorten the fluid life:

- **Excessive & repeated exposure to air and moisture:**
  This is often due to the lack of an inert gas blanket, poor maintenance of the inert gas blanket, or the alternate option of fitting a floating cover. The change in volume of the head space will then result in air and, possibly, moisture being expelled and drawn in as the head space ullage reduces and increases with changing system temperatures (typically most significant when the system is in use for a period and then is off for a period and the system cools down).

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- **Thermal shocking, due to overheating of the thermal fluid:**
  This can be caused by raising the fluid temperature too rapidly, by too high a firing rate, or by poor heat transfer caused by a number of factors such as fluid flow rate, fluid viscosity, carbon deposits, and/or incorrect burner adjustment resulting in flame impingement on the fired heat-exchanger surfaces.

- **Continuous running above the maximum recommended operating temperatures:**
  Overheating of the heat transfer oil will result in thermal cracking and the production of light ends in the system. These, lower molecular weight, compounds will reduce both the flash point and viscosity of the fluid. There will also be a resultant increase in the fluid's vapour pressure.

A high concentration of light ends in the heat transfer fluid may result in the "vapour locking" of centrifugal type circulating pumps.

The normal method of removing light ends is to vent the expansion tank along with any inert gas that may be in use as a blanket. The tank must then be topped up with inert gas to prevent air and moisture contact.

Fluid Maintenance:

Where a system has been in service for a number of years, it is advisable to undertake a system flushing in order to remove particles and other solid debris. The flushing and internal cleaning process can be enhanced by the application of proprietary detergent cleaning fluids. These fluids will help coagulate particles for easier filtration and removal, and will soften and release lacquers and gums that may be adhering to the system internal surfaces. These cleaning fluids are often effective in the removal of deposits that accumulate on heat transfer surfaces after long or unusually severe service. The released deposits will enter into circulation; large particles are removed by filters, but small particles may remain in circulation until an oil change is carried out.

Following excessive heat transfer fluid degradation, it is recommended that prior to any system change, a suitable system cleaner is added, and allowed to circulate for a period of 10 to 15 days, before draining – please follow system cleaner manufacturer's instructions on treat-rates. During this period, the system can be left to operate normally. Filters must be checked more frequently in case they begin to choke with collected debris and particles.

It should be noted that where there are hot spots, or where the system has been severely thermally stressed, carbon build-up can be so heavy that a system cleaner will not remove it.

To monitor the heat transfer oil condition, samples should be taken on a six-monthly *basis* and submitted for analysis. In cases where system maintenance has been undertaken, a sample should be submitted after any work or cleaning and, once the system is up to operating temperature. This should be followed by a second sample after three months. If both sample analyses indicate that the fluid is suitable for further use, and there is no significant deterioration, then sampling can revert to every six months.

Operational Safety:

In a heat transfer system, it is quite normal for the fluid bulk temperature to be above the Flash Point, and in some cases above the Fire Point, of the system fluid. This means that it is particularly important to ensure that the heat transfer systems are operated and maintained to high standards, with particular care taken to avoid systems fluid

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leakage and ignition sources within the vicinity of the system. To avoid the risk of fires or explosion, the following is recommended during system maintenance operations:

- Allow the system to continue circulating until the heat transfer oil bulk temperature is below 50 °C.
- Do not empty the system while the fluid is hot.
- During system filling and venting operations, care should be taken to avoid the possibility of hot oil entering the expansion tank, which could present a flammability hazard.
- Any part of the system that has been emptied of fluid must be thoroughly purged to expel air before being returned to operation.
- Inert gas blanket systems should be regularly checked to ensure auto-venting is still taking place.

It is particularly important to ensure that thermal oil heat transfer systems retain oil tightness. Special care is necessary to avoid oil leaking into pipe lagging, as pipe surfaces may operate at temperatures within the range in which it is possible for oil-wetted lagging to self-ignite.

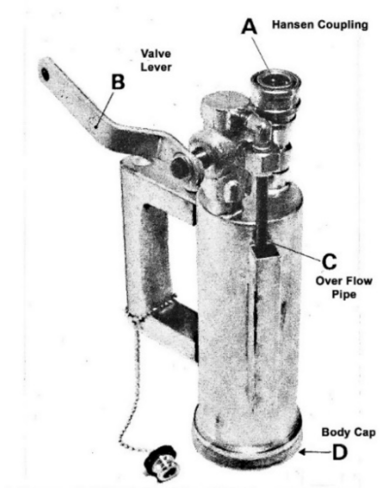
Lagging fires are largely preventable if porous type insulation is protected by an impermeable covering, such as aluminium. All flange joints, valves, and similar parts should preferably be boxed-in separately and provided with a means of draining any leaked fluid. Good housekeeping and effective maintenance procedures should ensure a safe and reliable system.

Sampling & Monitoring:

The in-service heat transfer fluid should be periodically sampled and analysed to assess the fluid's suitability for continued use. The sample analysis will assess fluid degradation, including oxidation, thickening, and thermal cracking.

The location and type of the sampling point is very important in a heat transfer system. To ensure a representative sample, the sampling point should be located in the primary circuit. A truly representative sample can only be taken when the fluid is hot and circulating. As the operational temperature will exceed 100°C and can be as high as 300°C, the use of a special sampling device is essential.

The device, often known as a Fluid Sampling Bomb, is a specially-designed, heat-resistant and pressure-tight, pot that enables samples to be drawn hot without exposing the operator to the risk of burns, but without the loss of volatile light ends from the sample. The use of a fluid sampling bomb connected into the thermal fluid system, using a pre-installed and tested instant coupling such as a Hanson coupling, is a safe method for which a representative sample is assured. When drawing a sample, the first 5 litres should be flushed through the fluid sampling bomb taking the representative sample. Once the sample is taken it MUST be allowed to cool down before transferring the sample from the fluid sampling bomb to a sample bottle.



Thermal Oil Sampling Device

The practice of running a sample into open containers is dangerous, and the oil will oxidise immediately, light ends will "flash off," and the sample will no longer be representative of the fluid in the system. It is also unsafe to draw a

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hot oil sample directly into a glass or plastic sample bottle. There have been several recorded incidents, of shattered glass bottles, or melted plastic bottles, respectively.

Laboratory Analysis of GulfSea HT Oil 32:

Thermal and oxidative degradation of heat transfer fluid is easy to detect and monitor through routine fluid analysis. Most Class Societies require a minimum of one sample analysis every year. There are a number of tests that are undertaken. These include:

Flash Point & Fire Point:

In many heat transfer systems it is quite normal for the oil working temperature to be higher than its flash and fire points. Flash point is used as an indicator to determine the extent of light end formation. Because light ends reduce the viscosity of the fluid, they can mask an increase in polymers and sludge build-up.

Viscosity:

Viscosity in a heat transfer system is another important characteristic for two reasons; it affects velocity and turbulence, and hence the rates of heat transfer. Any excessive change in viscosity in service is an indication of thermal stress and/or oxidation.

Acid Number (AN):

The Acid Number (AN) is a measure of the organic acid concentration in the fluid. A new fluid has an AN of 0.01. Complete fluid replacement is recommended at an AN of 3.0.

To distinguish between, degradation caused by thermal cracking, and that caused by oxidation, an assessment is made between measured flash point and AN level of the sample.

- Thermal Cracking has taken place when the flash point decreases and the AN remains stable.
- Oxidation has occurred when the flash point remains stable and the AN increases.
- Simultaneous degradation by thermal cracking and oxidation is indicated by a simultaneous decrease in flash point and an increase in AN.

Strong Acid Number (SAN):

The Strong Acid Number (SAN) is a measure of the inorganic acids present in the sample. Strong acids may cause system corrosion and damage to metallic components such as impellors, wear rings, valve spindles, etc. If there is presence of strong acid, the fluid must be changed immediately and the system thoroughly flushed to remove any traces of inorganic acids.

Insolubles & Ramsbottom Carbon Residue:

The insoluble and Ramsbottom Carbon Residue analysis provides additional information on the condition of the fluid, including the extent of thermal cracking and the presence of particles and carbon in the system.

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Typical Limits for GulfSea HT Oil 32:

GulfSea HT Oil 32 is suitable for continued use if the following analysis limits are achieved:

- Kinematic Viscosity @ 40 °C ± 20% of nominal
- Neutralisation Value < 0.6 mg KOH/g
- Flash Point (PMCC) > 150°C

GulfSea HT Oil 32 Typical Characteristics:

The values below are typical of those obtained with normal production tolerances and do not constitute a specification.

Characteristic	Units	Test Method	Value
Density @ 15°C	Kg/l	ASTM D1298	0.868
Closed Flash Point (PMC)	°C	ASTM D93	>180
Open Flash Point (COC)	°C	ASTM D92	230
Fire Point	°C	ASTM D92	255
Kinematic Viscosity @ 40°C	cSt	ASTM D445	31
Kinematic Viscosity @ 100°C	cSt	ASTM D445	5.2
Pour Point	°C	ASTM D97	-12
Auto Ignition Temperature	°C	ASTM D2155	350
Maximum Operating Temp	°C		315
Neutralisation Value	mg KOH/g	ASTM D664	< 0.05
Carbon Residue (Conradson)	%wt	ASTM D524	<0.01
Coefficient of Thermal Expansion Per °C			0.0008

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