# SAFETY IN DESIGN OF THERMAL FLUID HEAT TRANSFER SYSTEMS

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The design and operation of thermal fluid based heat transfer systems (hot oil systems) is often poorly understood and hence preventable accidents occur due to system failure. This paper discusses some of the key safety design and operational aspects of hot oil systems covering the following topics:

Properties of heat transfer fluids
Basic heat transfer systems
Natural convection
Pumped
Liquid phase
Vapour phase
Operational problems
Degradation of fluid
Corrosion
Erosion,
Overheating & hot spots
Temperature cycling
Furnace tube failures
Use of the "Hartford Loop"
Start-up and shut down
Pressure relief considerations
Cleaning and maintenance

Hot oil systems are not the same as steam systems. The properties of the thermal fluid means that there are special operational and maintenance requirements if the system is to continue in safe operation. The heat transfer system should be treated as a process unit handling a flammable material however by its' nature, it is often treated as a utility and therefore accorded reduced attention and maintenance.

## INTRODUCTION

Heat Transfer Fluid (HTF) systems, also known as "Hot Oil" systems are used for heating processes to temperatures above those which can be obtained by steam heating at reasonable pressures. Heat is usually provided to the HTF by a fired heater or furnace and typical fluid operating temperatures may be as high as 400°C in some cases.

Unfortunately, there is a tendency to view these systems as low-hazard utilities rather that as the potentially hazardous process plants that they are. The hazards of hot oil based heat transfer systems are:

Choice of an oil based system introduces fire and explosion hazards to the process that would not be present if using steam or water based systems. Although the HTFs have very high flashpoints, the system almost always operates above the flashpoint.

The vast majority of HTF systems involve the use of a fired heater or furnace thus introducing an ignition hazard to the area.

Leaks from the system can produce a potentially flammable mist if they occur at high temperature with potential vapour cloud explosion hazards.

Systems may either be atmospheric or operate under pressure. Vapour phase systems can also be used if higher temperatures and heat transfer rates are required but are generally more expensive and complex than liquid phase systems.

## SELECTION OF A HEAT TRANSFER FLUID

The principal factors which need to be considered in the selection of a heat transfer fluid are:

Good thermal stability and resistance to degradation due to excessive temperature
Suitable relationship between vapour pressure and temperature
Low freezing point/pour point to facilitate east start-up from cold
Compatibility with materials of construction of the system
Low viscosity and high specific heat capacity (for vapour systems a high latent heat capacity)
Low flammability
Low toxicity
Low environmental toxicity

The choice of fluid depends greatly upon the process requirements e.g. if a vapour phase system is required with a high process temperature, the fluid options are extremely limited (typically temperatures over 400°C). However, if a liquid phase system operating at ~300°C is required then there is a wide choice of fluids available.

Accurate predictions of fluid life in actual processing applications should not be implied from thermal stability data since theoretical data are measured under laboratory conditions which differ widely from real-world conditions. Bear in mind the heat transfer coefficient is calculated by the manufacturer based on fresh fluid properties. Fluid that has been in service for an extended period of time and has undergone thermal degradation may have a significantly lower coefficient due to fluid viscosity changes and the – presence of degradation by-products. Therefore, the HTF's thermal stability plays an important role in maintaining its heat transfer efficiency over time.

Note that some HTFs freeze at 10–12°C and may need to be heated prior to charging to the system.

It should also be noted that many of the available HTFs are not simple materials but a blend of several similar compounds. Thus, the physical properties may not follow traditional correlations e.g. Thermalane (saturated synthetic paraffin based) vapour pressure is an extremely poor fit to the Antoine equation and is much better represented by the equation:

$$Pv = Ae^{BT}$$

Where A, B are constants, Pv is the vapour pressure and T is temperature. Similarly for this material, the basic Arrhenius equation gives a very poor fit to the measured data and a modified equation is needed to provide sufficient accuracy.

Thus, when choosing a heat transfer fluid use the physical properties data provided by the manufacturer or supplier rather than estimate using typical methodology.

It should also be noted that many HTFs have relatively high coefficients of thermal expansion and adequate allowance must be made for this at the design stage when sizing head tanks or overflow and venting systems.

HTFs are non-corrosive and any corrosion problems within the system are usually caused by contaminants such as cleaning fluids left in the system at start-up or else leakage of process fluid into the system.

## OPERATIONAL PROBLEMS

Many operating problems with HTF systems arise as a direct result of poor system design causing degradation of the HTF. In particular, overheating of the fluid can cause rapid degradation. When a heat transfer fluid degrades, it forms a combination of "lights" and "heavies". The lights are short chain molecules formed by thermal cracking and may also include hydrogen gas. These have the effect of reducing the flashpoint of the HTF as well as being boiled off from the liquid as a flammable vapour.

Heavies are long chain molecules, caused by the linking of thermally cracked long chains and these become thick tarry material which increases the viscosity of the HFT. As the viscosity increases, heat transfer becomes less efficient causing further overheating of the HTF and hence more rapid degradation. The tarry materials tend to stick to the sides of heat transfer surfaces and eventually to carbonise into a a thick black coating which offers significant resistance to heat transfer. Eventually, the tarry coating will harden into a solid coating which will result in poor heat transfer rates with the possible result of high film temperatures and accelerated oil degradation.

Oil degradation is one of the main causes of safety issues on all HTF systems as it causes the following problems:

Reduction in heat transfer caused by coke deposition on furnace tubes and consequent overheating of furnace tubes.

Generation of flammable vapour from system vents with potential for external fire caused by ignition of the vented vapour.

Damage to pumps caused by solids getting in to seals and bearings.

Clogging of filters etc. reducing flow and impairing heat transfer efficiency.

## FLUID DEGRADATION

When heat transfer fluids degrade, they form a mixture of high-boiling polymeric materials and volatile low-boiling compounds. The high-boilers dissolve in the liquid and increase the viscosity thereby reducing heat transfer efficiency. In general, it is recommended that the fluid should be replaced if the proportion of high-boilers exceeds 10% w/w. It should be noted that the presence of high boilers has an autocatalytic effect on degradation i.e. the more high boilers, the faster the fluid degrades. Excessive degradation also occurs when the fluid is contaminated with oxygen and thus air must be excluded from the system. Other contaminants such as cleaning fluids left in the system, or contamination by process fluids may also have a significant effect on HTF degradation.

Low-boiling compounds are problematic because they can lead to vapour locking if the system is not properly vented. In addition, if they accumulate in the HTF, they can significantly reduce the flash point and autoignition temperature of the HTF. Typical degradation reactions are, for example:

$$2C_{12}H_{10} \rightarrow C_{18}H_{14} + C_6H_6 \quad (1)$$

This reaction yields a high-boiler and a low-boiler. At higher temperatures the following reaction may also occur:

$$C_{12}H_{10}O \rightarrow 12C + H_2O + 4H_2 \quad (2)$$

Giving high carbon deposition and extremely flammable hydrogen gas. Note that reaction [2] only occurs at very high temperatures, typically more than 600°C. These are only example reactions and there are many other potential reactions which may occur in the degradation process.

It is essential that the system is cleaned out and all traces of the old fluid are removed from the system prior to recharging with fresh fluid. Failure to do so will result in premature degradation of the new fluid.

It is also possible to extend the life of the fluid by continuous flash distillation of a small side stream but this is not generally justified unless the system is operating at high temperatures and the degradation rate is otherwise unacceptable.

## FURNACE TUBE FAILURES

The failure of furnace tubes can result in a large fire and major damage. Tube failures can occur for a variety of reasons. The two main ones are:

Flame impingement onto tubes. The direct impingement of a flame on a tube can cause localised overheating and erosion of the external tube metal. Secondly, the resultant hot spot causes localised overheating of the metal resulting in rapid degradation of the HTF. As secondary effect of this degradation is that carbonised deposits can form on the inside of the tube further reducing the heat transfer in the affected area reducing heat transfer efficiency and increasing the overheating problem. Eventually, the tube can burn through.

Overheating of tubes. If the thermal flux is too high, the HTF may degrade causing carbon build-up on the inside of the tube. As above, this reduces heat transfer and causes overheating of the tube wall. Eventually, failure can result. Overheating of tubes can result from insufficient flow of HTF through the tubes.

The flame pattern produced by the burner is important in order to prevent impingement of the flame on the burner tubes. Regular monitoring of the flame pattern should be carried out and operators should be trained to understand the effects of incorrect flame shape.

It is important to understand that there is a very narrow operating range between efficient operation and the point at which degradation of the oil and decrease of tube wall life commence. This can be as little as 20–30°C difference.

## SYSTEM DESIGN

A number of typical HTF systems are shown in Figures 1 and 3 below.

### VAPOUR PHASE SYSTEMS

Vapour phase systems have the following advantages:

Heat transfer at constant temperature
Temperature is controlled by pressure
High heat transfer rate
Lower HTF inventory
Small condensate piping
Smaller heat exchangers
Gravity flow is possible

### LIQUID SYSTEMS

Liquid phase systems have the following advantages:

Wide operating temperature range
Fast temperature response
Lower heat losses than vapour
Lower operating pressure
Easy removal of light ends
Lower thermal degradation rates than vapour systems generally
Smaller piping overall than vapour systems

### FURNACE & TUBES

Furnace tube designs are complex and depend on the configuration of the particular furnace in use. The majority of tubes are single pass designs i.e. one continuous tube. There are, however, designs which utilise two or more tubes. Where this is the case, it is critical that the flow through each of the tubes is balanced up correctly. If flows are not balanced, then there is the likelihood that uneven heat transfer will occur with potential for overheating of some tubes. Provision should be made for monitoring and balancing up of the flows through the tubes.

Heat transfer to the tubes should preferably take place by convection from the flue gas and not by direct radiant heat transfer. Radiant heat transfer can cause very high film temperatures and thus premature degradation of the HTF. Under no circumstances must the burner flame be in direct contact with the tube(s) as this will result not only in high degradation rates but also in rapid erosion of the exterior of the tube and ultimately tube failure.

### HARTFORD LOOP

Vapour systems operating with gravity return should have a Hartford Loop installed (see Figure 1 below). The Hartford Loop is designed to prevent the pressure within the boiler from pushing liquid back up the line and thus starving the boiler (causing overheating of the tube). The design of the loop is such that it also prevents the boiler draining back in the event of a leak on the liquid return line.

The Hartford Loop should be installed as close to the boiler as possible and the distance between the vertical part of the riser and the loop should be as short as possible as this will minimise hammer between the vapour and the cold return.

The loop should be placed such that it is above the level of the tube heated area and slightly below the normal liquid level. This will give the optimum safety performance.

### PUMPS & PUMP SEALS

Pumps are a critical component of any HTF system. The pumps have to cope with a wide range of temperatures

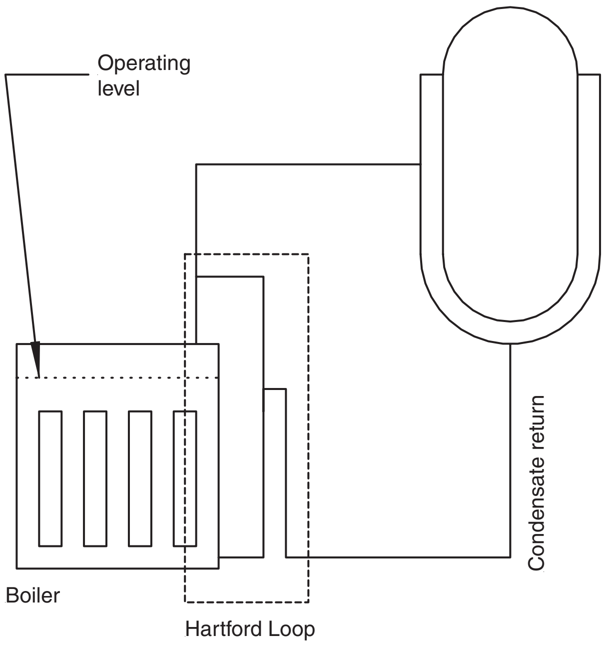


**Figure 1.** Simplified vapour system showing Hartford Loop (dotted)

and flow rates and remain reliable and leak tight. Since environmental legislation has tightened up, it has become unacceptable to allow significant leakage of virtually all HTFs. In the past, single mechanical seals were often used however these often leaked and were responsible for both environmental emissions and in several cases, significant fires. Single mechanical seals do not offer sufficient protection against leakage and can fail with a spray of liquid from the pump. This may be acceptable depending on the location, however, in the majority of cases, the use of a single mechanical seal may not be acceptable.

If a higher reliability is needed then a double mechanical seal should be installed. The space between the seals (interspace) should be purged to maximise reliability. As HTF systems are a high temperature environment then seal cooling may also be required which can be achieved by circulating the seal liquid through a cooler. This offers a higher level of reliability than a single mechanical seal.

Canned or glandless pumps have been used on HTF applications however, whilst these offer theoretically better containment and reliability, experience has shown that this is not always the case and the additional cost of these units is usually not justified when compared to conventional centrifugal units with mechanical seals. In particular, canned pumps can suffer from the high operating temperature which can cause overheating of the unit. Premature can failure has also been experienced in some cases caused by scoring due to particulates. Canned pumps are also intolerant of dry running for any period of time. It should be noted that although heat transfer fluid is often known as "hot oil", most of these fluids have limited lubrication properties.

Pumps are also vulnerable to thermal stresses from the expansion and contraction of pipework. Pipework must be designed to minimise the stresses on the pumps throughout the foreseeable cycle of operating conditions also allowing for time when the system is shut down and cold where temperatures may fall below freezing.

## NATURAL CONVECTION LIQUID SYSTEMS

It should be noted that natural convection systems can be used for HTFs but these tend to be limited to low heat transfer rates because of the flow limitations. The main advantage of a natural convection system is that no pumps are required and thus there is less risk of leakage from the system.

In order for a natural convection system to function effectively, the height between the furnace and the process vessel must be maximised and the pipework distance minimised. The pipe diameter must also be as large as possible to maximise the flow. These requirements means that it is often difficult to use natural convection systems effectively.

Pumped systems offer higher heat transfer coefficients and greater flexibility and therefore are the best choice for the vast majority of users. Convection systems are rarely used nowadays.

## PIPEWORK

Pipework systems should be constructed from carbon steel schedule 40 pipework at 40 mm and above sizes and schedule 80 below this in order to ensure suitable mechanical strength. Spiral wound type gaskets are preferred as these have better failure characteristics than fibre types. Flanges should generally be to ANSI 300lb standard as these offer better sealing properties at high temperature than ANSI 150. The thinner ANSI 150 flanges are prone to distortion due to thermal stresses on the system.

Care must be taken to ensure that pipework is designed to allow for thermal expansion stresses and in particular where it connects to fixed items such as vessels and pumps. The design of pipe supports is important to allow for the expansion across the full range of expected temperatures.

Note that if the HTF is viscous at normal ambient temperatures then heat tracing will be needed in order to maintain the pumpability of the liquid or to prevent freezing. The best method of heat tracing is usually by low-pressure steam. Note that tracing may also need to be applied to vent and relief lines.

## INSTRUMENTATION

As a minimum the following instrumentation is recommended for fired heaters:

High/low fuel feed pressure to burner
Flame failure (2 independent devices, self checking)
Pressure alarm (high) on HTF inlet
Flow alarm (low) on HTF inlet
Flue gas temperature (high)
High HTF temperature (outlet)
Low HTF level

Two flame failure devices should be installed because if the flame does fail then there is the potential for an explosion within the furnace caused by late ignition. The devices should be of the self-checking type in order to prevent potential fail-to-danger scenarios and should also register different wavelengths in order to prevent common mode failure.

High pressure on the HTF inlet to the furnace will indicate a partial blockage in the furnace coil which could foreseeable cause high film temperature and consequent accelerated degradation of the HTF. It can also result in vapour locking and overpressure of the system due to boiling in the heating coil.

Low pressure at the HTF inlet would indicate a partial blockage of the line upstream and/or a failure of the circulation pumps. The blockage may be due to particulate matter blocking the pump filters. Again, the risk is that there will be high temperatures in the furnace coil.

High flue gas temperature may be indicative of several problems including a pinhole in the heating coil with combustion of the leaking HTF, low heat transfer to the heating fluid or a problem with the burner management system. Note that an oxygen analyser may also be fitted to the flue gas as this will indicate the combustion efficiency (this will probably be installed as part of the burner management system).

High temperature on the HTF outlet will indicate overheating of the HTF and high film temperatures within the furnace tubes which will cause rapid degradation of the HTF. It should be noted that there is often a tendency for operators to ramp up the fluid temperature to speed up the heating process. This should not be done as it will result in excessive HTF film temperatures.

A low HTF level warning (alarm and trip) will prevent damage to the system due to loss of HTF e.g. from a leak. The alarm should be placed in the header tank and the settings must take account of the thermal expansion of the fluid at the operating temperature. Note also that the potential density change of the HTF must be taken into account if a float type sensor is used. Ideally, if low level is detected, the fuel supply to the burner should be tripped out.

HTF STORAGE

It is often useful to have an empty tank which is sized for the total capacity of the HTF system in order to provide an emergency dump facility. This tank can be used if there is a serious problem with the system to prevent a total loss of the HTF. The hold tank may be fitted with a cooling coil to cool the fluid down and prevent vaporisation and also a heating coil to ensure that it is kept at a temperature to allow pumping.

COLD SEAL/HEADER TANK

For liquid systems not operating under pressure, a cold seal tank is required in order to minimise losses from the system and also to compensate for any changes in level e.g. due to thermal expansion. The design of the cold seal is very important to the overall system because it performs several functions:

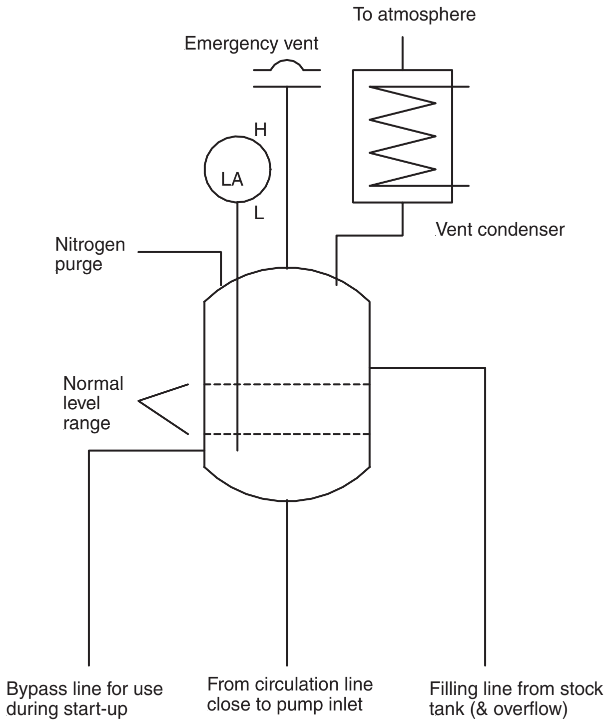


**Figure 2.** Cold seal/header tank

Allows removal/venting of water at start-up
Minimises losses of HTF from system due to vaporisation
Provides nitrogen blanket to eliminate oxygen
Provides make-up capacity for minor losses & leaks

EMERGENCY DUMP TANK

An emergency dump tank may be provided so that in the event of a serious problem, the whole system inventory can be dumped to a safe place rapidly to minimise the hazard. The dump tank must be designed to cope with the thermal stress of the hot liquid being fed into it. A cooling coil may also be incorporated in order to reduced the temperature of the dumped fluid and prevent vaporisation.

A typical liquid system is shown in Figure 3.

## START-UP & SHUT-DOWN

As with all continuous systems, start-up and shut-down are the times when serious problems can occur. This is especially true when the system has been drained for maintenance and either the original HTF recharged or else new fluid added.

Water is soluble to a small degree in most heat transfer fluids but is relatively highly soluble in some blends. All HTF, when new, contains some water, although this should typically be in the order of 20 ppm or less, it is not uncommon for drums that have been stored for a period to have

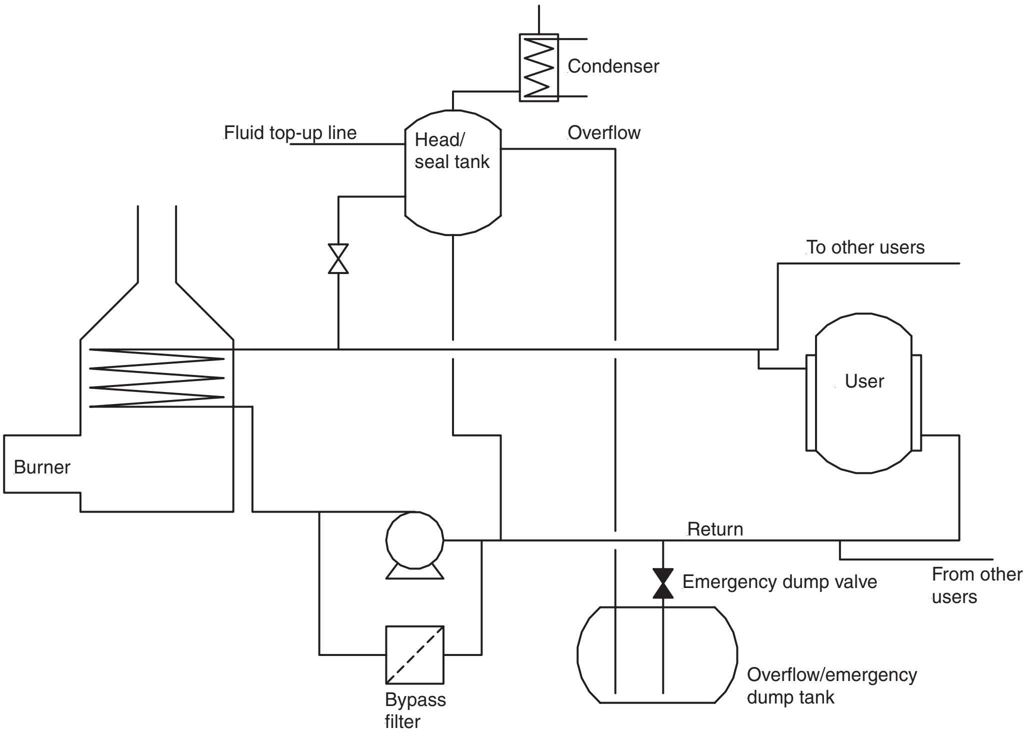


**Figure 3.** Typical liquid system

considerably more than this concentration. Drums should not be stored outside since water will inevitably get into the drum and be charged to the system. Experience has shown that some drums of recycled material have actually had free water in them after rain ingress.

Since the system will be operating above the boiling point of water it is essential that this water is removed from the system safely. The system must be warmed up slowly from cold. This should be done with the heating on low rate and under no-load conditions. As the liquid temperature in the system approaches 100°C the water will start to boil off. This results in a characteristic crackling sound known as the "chip pan" effect as water droplets boil off. It is essential that the water is allowed to boil off slowly since the steam generated can cause the header tank and other components to overpressure if heated too quickly.

The system should be designed such that the HTF can be circulated through the header tank so that the water being vaporised can be vented safely. This bypass circulation line can be shut off after all water has been removed from the system. If large amounts of water are present at start-up then this can cause problems with vapour locking and over-pressurisation of the system if the vents are unable to cope with the required vapour venting rate. If pumps vapour lock then overheating of the furnace coil can occur within a very short space of time.

Also, if pipework has been washed out with water or pickled with acid for corrosion resistance then it is essential that the system is thoroughly drained and dried out prior to recharging with HTF. The system should be designed to ensure that there are sufficient drain points to ensure that all liquid can be drained and that there are no dead legs in the system that may retain water. Note that this may be difficult to achieve with some furnace coil designs.

If maintenance has been carried out then steps should be taken to ensure that the system has been cleansed of all potential contaminants. In particular, weld spatter, pickling acid and water can all cause problems if trapped within the system. Weld spatter and other solid materials can cause rapid wear on pumps as well as internal erosion of pipework.

When the system is re-filled, provision must also be made to bleed all gas out of the system so as to prevent air locks. Suitable small bore bleed valves and lines must be provided at high points in the system. The presence of air locks may result in potential damage to pumps, overheating of the furnace tube etc. Bleeding the system may take some time and the design of lines should be arranged with suitable falls to facilitate the air bleeding process.

## TOPPING UP

In a well designed HTF system, topping up of the HTF should not be needed regularly since the system will be effectively sealed and there will only be minor losses e.g. due to degradation. Periodic topping up can be carried out by pumping fresh fluid into the header tank. This must be done under controlled conditions.

Under no circumstances should cold fluid be injected into a hot part of the system e.g. directly into the pump inlet when the system is at the operating temperature. The thermal shock of the cold fluid can result in severe damage to the system due to thermal shock. The top-up fluid should only be fed into the cold header tank.

## SYSTEM/FLUID CLEANING

The level of system cleaning required depends on the amount of contamination and degradation that has occurred. If only light degradation of the HTF has occurred then it may be sufficient to filter the fluid to remove particulates. This can be done by filtering through a fine filter (100 micron) at the operating temperature until the fluid is clear. The filter media must be able to withstand the normal operating operating temperature and therefore conventional polypropylene media are not suitable. Glass fibre filter media are available and are suitable for the elevated temperatures.

If the level of degradation is higher with some limited fouling of heat transfer surfaces then other cleaning methods may be appropriate. If severe degradation has occurred then the fluid can be fractionally distilled to remove both high and low boilers.

### FILTRATION (NORMAL OPERATION)

Under normal operating conditions, a bypass filter should be installed around the pump(s) in order to provide ongoing filtration of solid particulates. A duplex basket filter with a 100 micron screen can be used for this. This will allow for one basket to remain on line whilst the other is being cleaned. The bypass flow should be less than 10% of the normal operating flow which can be regulated by an orifice plate or similar flow restriction.

A flow indicator or alarm should be installed on the bypass in order to identify if the filter is becoming blocked.

### HTF TESTING

Testing of the HTF should be carried out periodically in order to determine the level of degradation of the fluid. This testing service if usually offered by the manufacturer and should include as a minimum:

*Viscosity* – this will identify if the viscosity of the fluid has changed significantly over time and thus the effect on pumping and heat transfer efficiency

*Total Acid Number* (TAN) – this is a measure of thedegree of oxidation or possible fluid contamination which results in acidic compounds being formed within the system

*Distillation* – This test is a measure of fluid thermal degradation and allows you to estimate if the fluid has undergone severe overheating by assessment of the amount of heavies and lights in the fluid

Additional tests such as:

*Acetone insolubles* – amount of materials insoluble in acetone i.e. solids in the liquid which may clog filters and heat transfer surfaces

*Moisture* – amount of water present – which may point to process leakage into the HTF stream

These tests may also provide useful information on the condition of the fluid. Regular testing will enable a degradation profile to be built up and predict the point at which fluid renewal is necessary.

### SOLVENT FLUSHING

Solvent flushing can be carried out to remove light fouling of heat transfer surfaces and the build-up of tarry materials. The preferred solvent is usually something such as Acetone which has good solvent properties for tarry materials coupled with low toxicity and water solubility. Xylene and similar solvents can be used but are less preferable because of the toxicity. The solvent should be pumped through the system at maximum rate for several hours at ambient temperature before draining. A line filter should be used (100 micron) in order to capture any solid materials. The filter should be checked frequently for blockage and cleaned as necessary. A duplex type basket filter is useful for this duty.

After solvent flushing the system must be thoroughly drained and flushed with water to remove any remaining traces of the solvent before recommissioning.

### ACID/CAUSTIC WASHING

Washing can be carried out with weak acid cleaning solution (several proprietary types are available) and will remove many types of scale and carbon build-up. Chloride containing solutions should not be used as the chlorides can cause stress corrosion and cracking of stainless steel components. The acid should be circulated through the system for 8–10 hours at $\sim$80°C at maximum flow rate. Again, a strainer should be fitted to the line and checked frequently for blockage during both acid and caustic washes.

The system should then be washed with 3–5% caustic soda solution containing a strong detergent, again at 80°C as this will remove many of the deposits weakened by the acidic wash and also neutralise any trace of acid. This solution should be circulated for 5–10 hours.

Finally, a water wash should be carried out. At least 3 flushes of water should be used to ensure that all the caustic is removed from the system. Failure to flush the system of cleaning solutions can result in premature degradation of the HTF.

### DRAINING & DRYING

After flushing with water, the system should be completely drained to ensure that the maximum possible water is removed in this way. Once all water has been drained, the system should be dried using a feed of hot dry air. The humidity of the air entering and leaving the system should be checked in order to ascertain when drying is complete. Note that it is important that the air circulates through the whole system and thus it is necessary to take account of all pipework runs and the potential for dead legs.

After drying out with air, the system should be purged with nitrogen to displace the oxygen. This will minimise oxygen contamination and degradation of the HTF.

## HARD DEPOSITS/SEVERE FOULING

If insoluble materials have blocked pipework or furnace tubes are clogged with hard coke then it may be necessary to use mechanical cleaning methods. Typical methods include high pressure water jetting, grit blasting, steam lancing or even mechanical scraping. In some cases it may also be possible use high temperature decoking using a steam/air jet. In any case, mechanical cleaning will require dismantling of sections of the plant.

Note that rodding out of tubes should not be carried out with steel tools as this can cause damage to the pipes, especially furnace tubes and pipe bends. If rodding out is necessary to clear obstructions from blocked pipes then copper or brass tools should be used as these are softer than steel and will minimise the risk of mechanical damage.

## START-UP AFTER CLEANING

This is a key issue as many problems arise directly after system cleaning. Typically, these problems involve either:

Failure to remove water from system
Debris left in pipework
Air locks

The HTF should be circulated through the expansion tank via a small bypass which should be closed once all of the water in the system has been boiled off and the system temperature has been above 110°C for a period of at least an hour. Note that the expansion tank should not be operated at full system temperature and should not be lagged as it acts as a condenser under normal operating conditions.

The pump filter should be checked frequently and cleaned as necessary during the commissioning phase until it is certain that all major debris has been removed from the system.

## LAGGING FIRES

Many fires have been started when HTFs have leaked into lagging. The fluid degrades over a period of time and the autoignition temperature eventually falls to below the system operating temperature causing a fire in the lagging. This is usually preceded by smouldering and smoke generation. Lagging fires are extremely difficult to extinguish since the lagging will inevitably be covered with a waterproof jacket. In this case, the lagging must be physically removed from the pipework in order to extinguish the fire.

Lagging fires are extremely difficult to extinguish and require that the cladding and lagging be removed from the pipe in order to get to the seat of the fire. The lagging used should, if possible, be of a non-absorbent, non-wicking type. Also, where lagging goes over flanges provision should be made that any liquid leaking from the flange will drain out of the lagging and not soak in. Regular visual inspection of flanged joints should be carried out. Insulation must be suitable for the highest expected temperatures under fault conditions.

## CONCLUSIONS

Hot oil heat transfer systems are not simple services but are complex process plants in their own right and should be treated as such. The combination of a hydrocarbon fluid and an ignition source give the potential for serious accidents if the correct design, operation and maintenance procedures are not carried out correctly. The combination of mechanical and thermal stresses on the heat transfer system means that special design considerations are required in particular with regards to system integrity. This paper has summarised the key points of system design, maintenance and operation.

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