TECHNICAL INFORMATION BOOKLET

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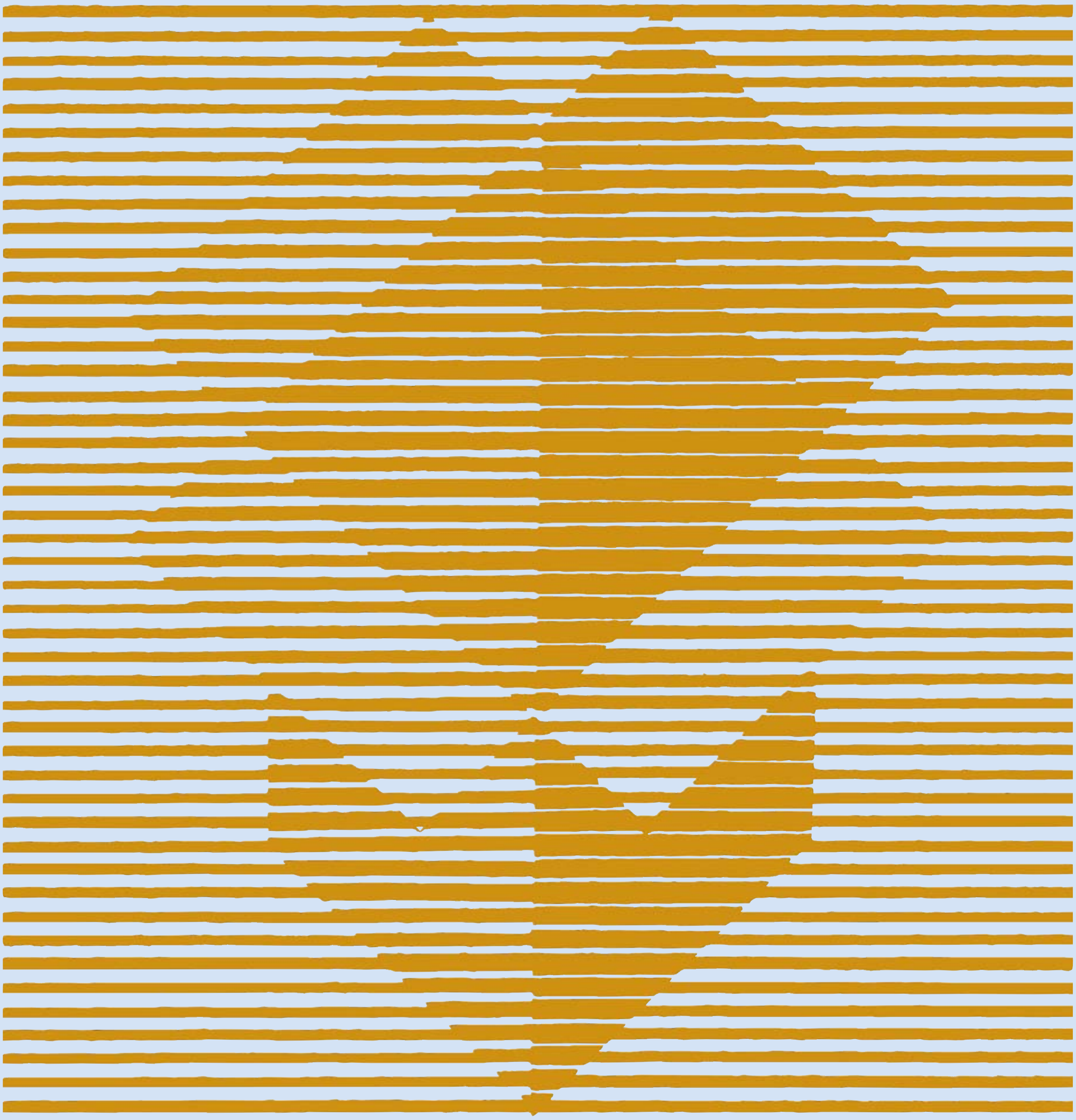
FCBM 40:07

Guidelines for Designing Heat Transfer System using Heat Transfer Fluids



FEDERATION OF CORRUGATED BOX MANUFACTURERS OF INDIA

FOREWORD

Application of heat is an important process in the manufacture of corrugated boxes.

Heat is required to be applied for formation of flutes in single faces and for gelatinization of adhesive in double beaker.

This booklet provides guidelines for installation of thermal oil heat transfer systems.

This booklet is the latest addition to the Standards and Technical Information Booklets being brought out by the R & D Committee of FCBM.

I do hope the readers will find it a very useful reference book.

Shri Ram Kumar Sunkara and his team deserve congratulations on their continuing work in the field of R & D.

Kirit B. Doshi

President
Federation of Corrugated Box
Manufacturers of India

Guidelines for Designing
Heat Transfer System using Heat Transfer Fluids

Introduction

In the manufacturing process of corrugated boxes, heat is applied for formation of flute, and for gelatinization of starch adhesive. The heating systems used in single facers and double backer are either steam system or liquid phase thermal heat transfer fluid system. Both types of systems have their advantages and disadvantages.

This technical information booklet is aimed to provide guidelines for installation of thermal oil heat transfer system.

Therminol heat transfer fluids cost less to install, operate and maintain. Low pressure thermal liquid systems utilizing Therminol fluids can significantly reduce capital costs. The savings in eliminating installation of larger diameter vapor piping, special vent piping, flash drums, pressure control devices and boiler feedwater treatment equipment can amount to 25%-50% of the system cost.

A second source of savings is in operation: thermal liquid systems require less maintenance, eliminate heat lost through draining of steam condensate in supply lines, and do not usually require licensed operating personnel when operated in a manner consistent with the recommendations in this guide (however, check local codes).

Therminol fluids have minimal potential for corrosion and fouling.

Heat transfer fluid systems using liquid phase Therminol heat transfer fluids offer the designer and the operator the following advantages:

- Simple to design
- Energy efficient
- Easy to operate
- Eliminates multiple ignition sources
- Low maintenance cost
- Flexible operation (heats and cools)
- Minimal capital cost

Process Design Factors

Every thermal fluid system is different. Operating temperatures, flow rates, process equipment, system components, and a host of other design details vary from system to system. But one thing remains constant: properly designed and operated heat transfer fluid systems are exceptionally reliable and economical.

The basic engineering checkpoints of designing a system are five-fold:

1. The heater:

To control heat transfer rate to ensure consistent energy supply with minimal fluid degradation.

2. The pumps and piping:

To provide adequate system circulation, maintain the heat flux at user stations and to ensure proper handling of the fluid.

3. The expansion tank:

To provide for fluid expansion, venting and positive pump suction head. A properly designed expansion tank reduces difficulties in start-up and contributes to trouble-free system operation.

4. The process/safety controls:

To ensure safe operation and effective use of the heating/cooling system.

5. The materials and construction:

To ensure compatibility, and proper layout and design. With sufficient heater capacity, good control of flow at user stations and compatible materials, a well-designed system can give reliable, efficient and precise delivery of heat. Proper selection of fluid and a clean, moisture-free system allow minimum maintenance and trouble free operation.

Mechanical Design Factors

1. The Heaters

The heater, is a critical component in designing a heat transfer system with Therminol. With the proper balance of heating capacity, temperatures and fluid velocity, the service life of the heat transfer fluid is increased to the maximum.

Two basic fired heater designs for Therminol heat transfer fluids are available:

- The liquid tube, and
- The fire tube types.

In liquid tube heaters, Therminol is pumped through the tubes as it is heated. The fire is outside the tubes.

In fire tube heaters, Therminol flows through the heater “shell” around the outside of the fire tubes.

Liquid tube heaters are preferred at all temperatures.

At temperatures below 260°C, fire tube heaters with a special baffle design to eliminate hot spots can be used.

2. Pumps

Pumps must have sufficient capacity and pressure head to circulate the fluid at the rate required by the particular installation. For large flow rates, the pump should generally be of the centrifugal type. Pumps conforming to ANSI B73.1 or to API Standard 610, for high-temperature service, will usually be suitable. Fluid-cooled bearings and seals are recommended to extend pump service life.

For most systems, cast steel pumps are preferred. Pump manufacturers usually specify that above 230°C a cooled, jacketed stuffing box or a cooled mechanical seal should be used. Mechanical seals are widely used. Secondary sealing with vent and drain glands is recommended to collect fluid leakage and to provide space for inerting the outside of the seal. This secondary sealing provides additional safety in the case of sudden seal failure.

On pumps with a stuffing box, at least five rings of packing should be provided, i.e., laminar graphite rings. When a new system is first put into operation, a slight leakage may be noticed at the pump packing. The pump gland should not be tightened, however, until the system has heated to near the temperature of operation.

Regardless of the type of pump selected, the flow rate should be checked regularly against the pump’s performance when new. To prevent alignment problems and seal leakage, it is important to avoid pipe support stresses on the body of the pump. Each pump should be fitted with a control device to switch off the heat source in case of pump failure.

If expansion loops are used in the pump suction piping, they should be installed horizontally.

3. Filters

Before starting up a new system, install a wire mesh strainer in the pump section. These strainer baskets may be removed after debris removal from start-up is completed.

Piping systems should be designed with provisions for the installation of a side-stream filter. Filters that have generally been employed for these applications are glass fiber string-wound cartridges or cleanable sintered metal filters in the 1-30 micron range. Clean fluids prolong the life of system components, i.e., pump shaft seals and valve stems. Filtration also reduces fouling and plugging.

4. Materials of construction (Excluding heaters coils)

The majority of metals and alloys normally encountered in high-temperature heating systems can be used with Therminol heat transfer fluids. Materials of construction are generally selected on the basis of their suitability for operation throughout the system’s temperature range. Mild steel is widely used, but it must be qualified for low-temperature use (brittle/ductile transition temperature).

While Therminol heat transfer fluids are compatible with aluminum, bronze and brass alloys, etc., the use of these metals should be kept to a minimum because of their loss of mechanical strength at higher temperatures. Due to their temperature limitations, non-metallics (plastics and elastomers) are not recommended for materials of construction in heat transfer systems.

5. The expansion tank and venting arrangement

Usually, the expansion tank is installed at the highest point in the system and is connected to the suction side of the pumps. It should serve as the main venting point of the system, as well as provide for system fluid expansion, which can be 25% or more depending on fluid choice and on the operating temperature range. All vent lines should be routed to a safe location.

The double drop leg expansion tank provides greater flexibility of operation than a single leg tank. From a single leg expansion tank, venting of non-condensibles (water, etc.) is often difficult in heating systems as is purging of air/water on start-up. A double leg expansion tank provides uninterrupted flow on start-up and significantly improves the venting capability of the system.

Experience indicates that systems with expansion tanks open to the atmosphere have fluid contamination problems related to oxidation and excessive moisture. Therefore, open expansion tanks should not be employed in systems using Therminol heat transfer fluids.

An effective way of minimizing fluid oxidation is to blanket the system with an inert gas (e.g., nitrogen) as shown in Figure A. If this is not practical, air contact can be minimized by a cold seal trap arrangement as shown in Figure B.

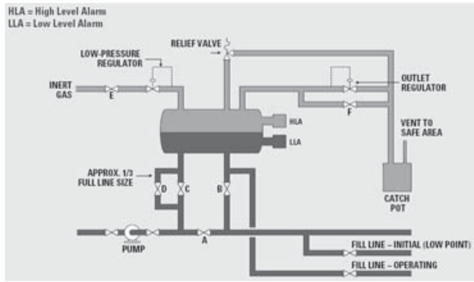


Figure A: Suggested Inert gas arrangement for expansion tank

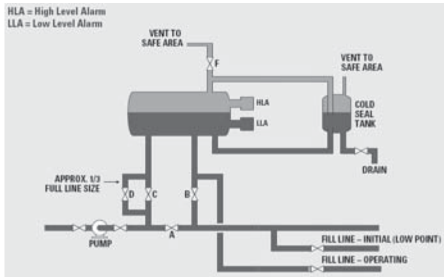


Figure B: Suggested Cold seal trap arrangement for expansion tank

The expansion tank should be sized so that it is one-fourth full when the system is at ambient temperature and three-fourths full when the system is at operating temperature. It should be fitted with a high-pressure sight glass at the full range and with a minimum level switch to shut off the heater and the pump in the event of accidental fluid loss.

As is good design practice with all large components in a heat transfer system, the expansion tank should be fitted with a pressure relief device, such as a relief valve, rupture disk or vent traps. These can relieve excessive pressures to prevent damage or rupture of the expansion tank. These devices should be sized to vent the expansion tank vapor space in anticipation of the most severe venting condition. Industrial standards for relief devices and sizing are covered in API Standards 520-527.

6. Pipe work

The piping layout for systems utilizing Therminol heat transfer fluids should be sized to provide the normal required flow rate at an economical pressure drop. Because the system will undergo temperature changes, adequate flexibility to relieve thermal expansion and contraction stresses is essential. The tendency to leak through joints and fittings is characteristic of Therminol fluids unless these fittings are very tight. Control of piping leaks is especially important since fluid-soaked insulation poses a more serious hazard than the leaking fluid itself. The best way to prevent piping leakage is to weld all connections. Use of threaded fittings is strongly discouraged due to their tendency to leak.

Pipe-Flanged Installations

ASTM A-106 Grade B schedule 40 seamless carbon steel pipe up through $1^1/_2$" diameter.
ASTM A-53 Grade B schedule 40 seamless carbon steel pipe for 2" and greater diameter.

Materials and methods should minimize weld spatter and slag. Pipe should be free of mill scale, welding flux, quench oils and lacquers before assembling.

Flanges/Fittings

ASTM A-181 1/16" raised face 300 lb rating up to 4" pipe diameter; 150 lb rating greater than 4" pipe diameter.

Flange Gaskets

Recommended flange gasketing for high-temperature heat transfer fluid systems is the spiral-wound type conforming to ASTM B16.20. Standard materials for spiral-wound flange gaskets are Type 304 stainless steel and flexible graphite filler. For leak-free performance of spiral-wound gaskets, the following points are important: use of raised-face flanges (125 RMS finish) and alloy steel bolting with copper- or nickel-based thread lubricants, uniform compression of the gasket during bolt pull-up, and flange faces clear of imperfections and parallel.

Bolts

ASTM A-193 Grade B7.

Nuts

ASTM A-194 Grade 2H.

Pipe-Threaded Installations

ASTM A-106 Grade B schedule 80 carbon steel pipe up to 1" diameter.

ASTM A-106 Grade B schedule 40 carbon steel pipe from 1" to 2" diameter.

ASTM A-53 Grade B schedule 40 carbon steel pipe greater than 2" diameter.

Use high temperature thread sealant for all connections. Back welding all connections is suggested.

7. Packing

Various types of high-temperature packing have been used to seal valve stems and pump shafts in high temperature Therminol fluid service. Excellent service life has been achieved through the use of graphite-based packing (as long as said packing contains no soluble organic binders). Generally, a minimum of five rings of packing is specified on valve stems to assure a reasonable seal. Mechanical seals or ring-shaped flexible graphite packing gives the best service for pumps.

8. Insulation

Normal high-temperature insulation, such as calcium silicate, mineral wool and cellular glass, can be used in Therminol fluid service. However, fluid-saturated insulation is a potential fire hazard at the temperatures often encountered while operating a heat transfer fluid system. Heat transfer fluids can exhibit a slow oxidation reaction with air in the presence of porous insulating materials. This phenomenon can be minimized through the use of cellular glass insulation which resists saturation by the heat transfer fluid due to its closed cell nature.

The following additional suggestions may help minimize the fire hazard potential in insulation systems:

- Install and maintain a leak-free piping system.
- Reduce the number of flanges and other mechanical joints in initial system design.
- Use suggested piping specifications.
- If a leak develops, remove the insulation, and contain and control the fluid until the leak can be repaired.
- On vertical runs of pipe where occasional leaks can develop at flanges, install protective tight-fitting caps to divert any fluid leakage outside the insulation.
- Install valve stems horizontally or in a downward position so that any stem leakage does not enter the insulation.
- Always consult your insulation supplier and insurance company for additional suggestions on reducing fire hazards in insulation.

9. Valves

Cast or forged steel valves with 13-chrome trim are satisfactory for systems utilizing Therminol fluids. Globe valves with an outside screw (as a protection against high temperatures) should be used throughout the system when tight sealing of Therminol fluids is desired. Gate valves are acceptable for Therminol fluid service; however, they should not be relied upon to provide reliable positive shut-off. The use of metal bellows valve stem seals should minimize leakage.

10. Controls

Controls for heating systems using Therminol heat transfer fluids should be installed both on the heater itself and on the energy-using units. Install heater controls to regulate the firing mechanism in direct proportion to the required output. These controls should increase or decrease the heat input to maintain Therminol fluid at the operating temperature required by the energy demand. Small units may be operated satisfactorily by relatively simple “on-off” or “high-low” controllers. However, units of all sizes will operate more uniformly if equipped with modulating temperature controls.

Install user controls to regulate the flow of the heat transfer fluid in proportion to the energy consumption of the equipment. In a multiple-user system, separate controls should be installed on each consuming unit to assure the proper energy delivery.

11. Safety controls

In addition to activating controls, the system also must be fitted with the proper safety devices to meet local code requirements. Knowledgeable equipment manufacturers should be able to provide guidance on proper safety controls. Safety controls should include, but not be limited to:

1. **High-temperature cut-off at the heater outlet:**
   To shut off the burner in the event of an excessive temperature rise.
2. **Heater low-flow cut-off:**
   To shut down the burner should flow rate drop below design rates or should a loss of flow occur due to pump malfunction or failure. Regular automatic ignition controls and flame-failure controls should be included on all burners. In wide-ranging firing, an over-fire draft control will save heat losses.
3. **Expansion tank low-level shut-down:**
   To shut off the heater and the pump(s) in the event of accidental fluid loss.
4. **Expansion tank high-level alarm:**
   To alert plant operations of system leakage into the fluid.
5. **Safety relief valves:**
   All safety relief devices in thermal liquid heat transfer systems should discharge at a point remote from possible ignition sources and away from areas where danger to personnel exists. Pressure relief devices should be placed on the heater outlet, on the expansion tank, and (where appropriate) on system users.
6. **Other safety controls:**
   Electric power failure and instrument air failure safety controls also are desirable. In general, a policy of “fail-safe” instrumentation and control in the designing is essential, using quality indicating and recording gauges, with accurate-reading scales calibrated for the specific limits of operation.

Typical Thermal Fluid Heat System

Systems utilizing Therminol heat transfer fluids are characterized by their extreme flexibility. A single heater can serve multiple “users” operating at the same or different temperature levels. The systems can be designed to deliver and to remove heat.

The three system diagrams next illustrate a few of the many arrangements of heat users that can be operated with Therminol fluids.

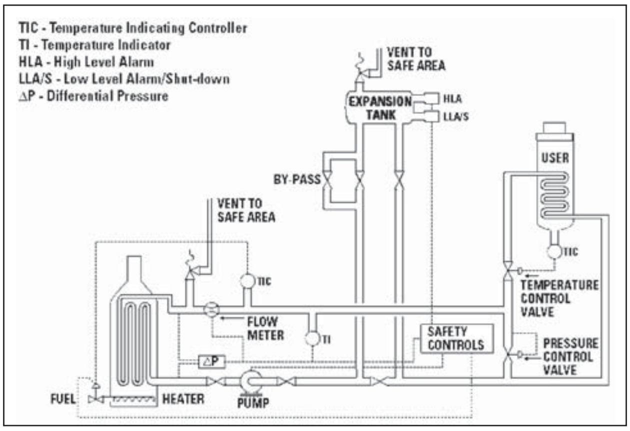
System 1 is the basic system configuration with a single user operating at heater outlet temperature. The temperature control valve regulates flow of the hot Therminol to meet the user’s temperature requirements. The pressure control valve assures that a minimum flow will be maintained through the heater at all times. This system has maximum temperature flexibility. Note also the heater and the pump safety controls and their connection to the heater flow, the heater outlet temperature and the expansion tank low-liquid level sensors.

System 2: This is the same system as Number 1 except several heat users are connected to the heater, all operating at the same temperature. To control temperature, each user has a modulating control valve. A single minimum flow by-pass valve is used at the end of the piping loop.

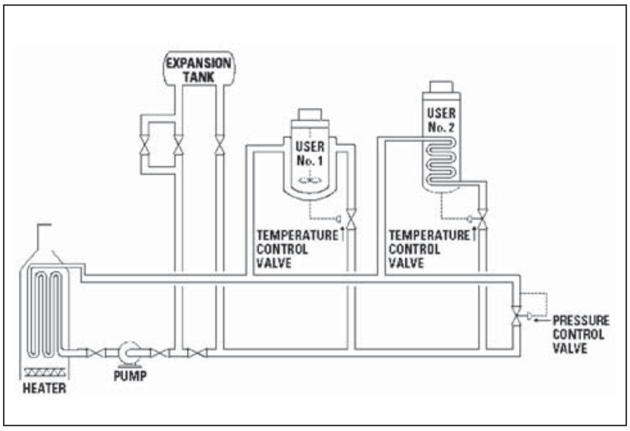
Note: Refer to System 1 diagram for placement of safety controls and fluid relief devices.

Sysatem3: With this arrangement, several heat-users at different temperatures may be operated at one time. Each temperature zone has its own recirculating pump located at the user inlet with the temperature control valve located downstream of the user. A by-pass from the zone pump inlet is connected to the user outlet. When the temperature control valve us opened, fresh high temperature Therminol heat transfer fluid is admitted to the zone where it is mixed and recirculated. This blending of hot and cold Therminol fluids gives precise temperature control at some temperature below heater outlet temperature.

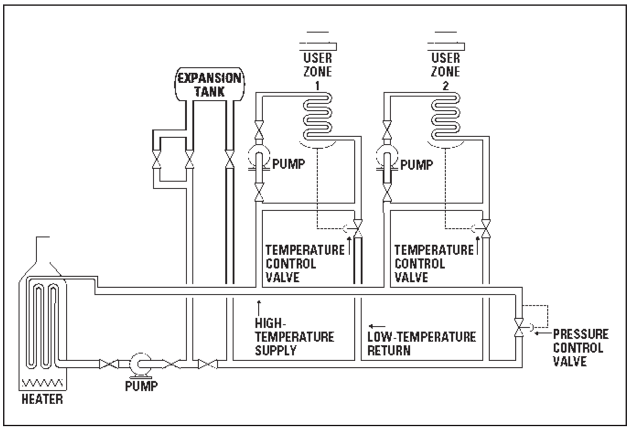
Note: Refer to System 1 diagram for placement of safety controls and fluid relief devices.



System 1



System 2



System 3

Preventing Fires in Thermal Oil Heat-Transfer Systems

As the thermal fluid heating systems include fuel, air and an ignition source, the risk of fire always is present. However, plants can minimize the risk of fire by strictly observing proper installation, maintenance and operating procedures.

Fire safety in thermal fluid systems depends on three measurements:

- Flash point,
- Fire point, and
- Auto-ignition temperature

Flash Point

The flash point of a fluid is the temperature at which sufficient vapor is generated for the fluid to flash when exposed to an ignition source.

Two common methods of determining a flash point are:

- The Cleveland Open Cup (COC) test method, which complies with American Society for Testing and Materials (ASTM) D92, uses an open cup partially filled with a fluid sample.
- The Pensky-Martens Closed Cup (PMCC) method, which complies with ASTM D93, uses a container that is closed except for a small opening through which the fluid's vapor is exposed to a flame.

Fire Point

The fire point is the point at which a fluid generates sufficient vapor to support continued combustion. The fire point typically is 40° F to 100° F hotter than the flash point. The Cleveland Open Cup (COC) test method is used most frequently to find the fire point.

Auto-ignition Temperature

The temperature at which a fluid will ignite without any external source of ignition is the auto-ignition temperature (AIT).

The current ASTM E659-78 standard superseded the popular ASTM D-2155 standard several years ago. ASTM E659-78 calls for an injection of sample fluid into a test beaker filled with hot air. The temperature of the air at which the fluid sample ignites is the AIT.

Relatively few fires have originated in thermal fluid systems. Most of those that do occur are:

- Insulation fires,
- Or are caused by loss of flow,
- Cracked heater tubes or leakage

Insulation

Insulation fires occur when heat-transfer fluid leakage from valves, gaskets, welds or instrument ports infiltrates porous insulation such as calcium silicate or fiberglass wool. The porous installation's open structure allows the heat transfer fluid to "wick" away from the leak and spread throughout the insulation. Spontaneous ignition might result upon the fluid's sudden exposure to air if, for example, the protective covering is punctured.

The most effective precaution against insulation fires is the identification of all potential leak points and the specification of high-temperature closed-cell insulation or no insulation at these points. Closed-cell insulation prevents the fluid from spreading throughout the insulation. If necessary, flanges should be covered only with metal caps with weep holes – users should avoid insulating these areas if possible.

Loss of Flow

Loss of flow occurs when a series of equipment failures interrupts the flow of thermal fluid to the heater. A pump motor loss, a coupling failure, a system pressure control valve failure or a blinded full-flow filter might cause the initial failure.

The second failure then occurs when fouling, burnout or poor location causes the high-temperature cut-off device to miss the sudden temperature increase. As the burner or electrical element continues to put energy into the now stagnant fluid, the temperature increases rapidly beyond the AIT. If a crack develops in the heater coil or the piping connected to the heater, hot fluid is discharged into the hot atmosphere, where the fluid spontaneously ignites.

To avoid incidents resulting from loss of flow, low-flow shutdown should be included in the burner safety interlock. Flow detectors that are immersed in the fluid are not recommended because they might fail in the open position. Pressure sensors have proved to be the most reliable for long-term service. To provide effective indication of a no-flow situation, plants can install pressure sensors across a fixed restriction such as an orifice plate or the heater itself to measure pressure drop, or as high- and low-discharge pump pressure monitors.

Cracked Heater Tubes

Serious fires caused by cracked heater tubes are relatively rare, but can occur. Cracks are formed by excessive thermal cycling or near hot spots that develop from internal fouling or flame impingement. Leaking fluid will burn off immediately while the heater is operating. However, when the system is not in operation, fluid will continue to leak into the combustion chamber as the result of head pressure from the expansion tank and overhead piping. In the most serious cases, fluid forms in a large pool inside the heater during a prolonged shutdown. When the heater is restarted, the entire pool ignites and destroys the heater.

To prevent excessive thermal cycling of the heater tube bundle, oversized heaters should be derated by the manufacturer. Flame impingement will cause severe thermal cracking of the fluid that can be detected by routine fluid analysis. Heat tube fouling often is caused by deposits that result from fluid oxidation. Oxidation occurs if the expansion tank remains hot (more than 140℉) during normal operation and is open to air. The reaction of the hot fluid and air forms tars and sludge that coat surfaces and reduce heat transfer. These deposits could create heater hot spots that ultimately cause cracks. Oxidation, which also is detected by routine fluid analysis, could be prevented by keeping the expansion tank cool (lower than 140℉) and by keeping air out.

To prevent leaks, plants should:

- Allow expansion joints and flexible hoses to move along their axes, never sideways.
- Maintain lubrication systems for rotary unions and supply these systems with the correct lubricating oils.
- Install isolation and bleed valves in the piping for each piece of equipment so maintenance can be performed without draining the whole system.
- Use the appropriate recommended stem packing for globe, ball or plug valves in thermal fluid service.
- Install valves with their stems sideways so any leaks run down the stem and away from the piping.

Proper operation and maintenance of thermal fluid systems also reduce the risk of fire. Maintenance should include daily and weekly inspections for signs of smoke from potential leak points, especially valves, flanges, welds, instrument ports and threaded fittings. By performing timely inspections and understanding the fire risks, plants can increase safety dramatically.

Start-Up and Shutdown Procedures

Regardless of system design, size or heat source there are a few basic procedures that should be followed when starting up or shutting down your heat transfer system. Following these procedures will help maximize your fluids life.

System Start-Up

A fluid at room temperature may have a viscosity as high 100℃st but if the system is outdoors and the ambient temperature is below 32℉ or 0℃ the viscosity could be 1000℃st or higher.

While a fluid with these viscosities is quite easily pumpable it is not yet 'ready' for full heat. Your heater whether small or large is designed to apply heat at a set rate in consideration of the fluids flow or velocity.

When a fluid hasn't achieved the ideal viscosity its flow or velocity will not be of that specified and required by the heat source. Basically the fluid will be too thick to allow for efficient flow.

If a heater is allowed to fully fire during these periods it will most likely overheat and thermally degrade the fluid. Basically the fluid will move too slow past the heater and absorb too much heat.

Therefore when starting up any system it is important to allow for gradual temperature increases until the fluids flow or velocity is with the range required by the boiler.

Generally a 20° to 30° incremental increase in the set-point will allow for steady even heating without the chance of overheating or thermally degrading the fluid.

System Shutdown

When shutting your system down a few basic steps will help ensure that no damage from over heating is inflicted on your thermal fluid.

During the course of normal operation your heat source whether a small or a large boiler will be cycling either on and off or from a low fire to a high fire in order to maintain your set temperature. As well within a short period of time the heater piping or vessel will become nearly as hot as the heat source itself. It is also important to remember that your heater is actually hotter than your output temperature.

The actual temperature at the impingement point of the heater in most cases will even be higher than that of the recommended maximum fluid temperature for your fluid.

If a system is shutdown abruptly without allowing the heat source and adjacent areas to cool when the fluid ceases to flow it will become trapped and subsequently 'burn' or thermally degrade Therefore when shutting down any system it is important to simply allow the fluid to cool below 250℉ (121℃) before shutting down the pump.

The use of a heat exchanger or leaving your heater blower running will help expedite cooling the fluid temperature to under 250℉ (121℃).

Glossary of Terms

- **Anti-Oxidant:** An additive to retard oxidation.
- **ASTM:** American Society for Testing and Materials
- **Autoignition:** Minimum temperature which a substance must be heated without application of flame or spark to cause substance to ignite.
- **Catalyst:** A material which promotes some chemical action without itself entering into the reaction.
- **Cavitation:** In a heat transfer system, failure of the material to flow to the suction of the system pump for any reason.
- **Centipoise and Centistoke:** A centipoise is 1/100th of the unit of absolute viscosity (the poise), e.g., the viscosity of water at 20oC is approximately one centipoise. The centipoise is derived from one kinematic unit of viscosity (the centistoke), by multiplying the latter by the density of the liquid, i.e., 1 centipoise = 1 centistoke x the density of the liquid.
- **Corrosion Inhibitor:** An additive used to retard the corrosion process.
- **Deposits:** Oil-insoluble materials that result from oxidation of the oil and contamination from external sources and settle out in system components as sludge and varnish.
- **Fire Point:** The temperature at which the fluid will sustain a fire if ignited by an outside ignition source. It is quite common for heat transfer systems to be operated at temperatures above the fire point of the fluid as ignition sources should always be far removed from any heat transfer system.
- **Flash Point:** The temperature at which the vapors produced from a fluid will ignite (flash off) with the presence of an ignition source (the fluid will not burn at this point). The flash point is important from the viewpoint of safety; however it is quite common for heat transfer systems to be operated at temperatures above the flash point of the fluid.
- **Hydrocarbons:** Compounds containing only carbon and hydrogen. Petroleum fluids consist chiefly of hydrocarbons.
- **Inhibitor:** A substance that slows or prevents chemical reactions, such as oxidation or corrosion.
- **Oxidation:** The process of combining with oxygen. All petroleum products are subject to oxidation to some degree. The reaction increases with rise in temperature. Oxidation produces oil-insoluble oxidized materials, which result in viscosity increase and deposits.
- **Oxidative Degradation:** Oxidative degradation is the reaction of oxygen (in air) with the fluid by a free radical mechanism to form larger molecules which end up as polymers or solids. These thicken the fluid and increase its viscosity. A more viscous fluid will be more difficult to pump, have poorer heat transfer characteristics as well as an increased chance of coke formation. Oxidation is also accompanied by an increase in the acidity (TAN) of the fluid.
- **Oxidation Inhibitor:** A chemical additive that minimizes the formation of harmful acids and varnish forming compounds that form when a fluid is subjected to air at elevated temperatures.
- **Oxidation Stability:** The resistance of lubricants to chemically react with oxygen. The absorption and reaction of oxygen may lead to deterioration of lubricants.
- **Pour Point:** The lowest temperature at which a liquid will pour under specified conditions.
- **TAN:** Acids are formed when a fluid comes in contact with oxygen, TAN levels are a means to show the extent of which a fluid has been oxidized.

  New fluids typically have a TAN less than 0.05, most fluids should be changed at and have a condemning limit of a TAN of 1.0.
- **Thermal Degradation:** Thermal degradation or thermal cracking is the breaking of carbon – carbon bonds in the fluid molecules by heat to form smaller fragments which are free radicals.
- **Viscosity:** A measure of a fluids resistance to flow. A higher viscosity is essentially a thicker fluid.

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