HEAT TRANSFER BY ORGANIC AND SYNTHETIC FLUIDS

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1.0 SCOPE

This loss prevention data sheet provides recommendations for the siting, design, operation, maintenance, inspection, and fire protection of circulating heat transfer systems using flammable heat transfer media.

1.1 Changes

January 2009. Minor editorial change was made in Table 2.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Sprinkler protection alone cannot ensure that a fire involving a heat transfer fluid (HTF) release will not cause roof collapse. It is critical that the prevention items, and other means of minimizing the incident in all of the recommendation sections below, also be applied.

2.2 Construction and Location

2.2.1 Where an HTF having a flash point below 425°F (218°C) is heated to or above its atmospheric boiling point, locate the vaporizer or heater and the user facility outdoors or in a room of damage-limiting construction as described in Data Sheet 1-44, *Damage-Limiting Construction*. Design damage-limiting construction in accordance with Data Sheet 1-44 using Table 4 to determine the vent area and reduced pressure (Pr).

2.2.2 Locate HTF heaters or vaporizers, especially those creating a room explosion hazard (see 2.2.1 above), in a detached building. Ensure construction and space separation of the detached building is in accordance with Data Sheet 7-32, *Flammable Liquid Operations*.

If attached to the main production building, locate the heater room at an outside wall and ensure it is cut off from adjacent production areas with a minimum 1-hour rated fire wall. Where the heat transfer system is operated under a pressure greater than approximately 15 psig (1 barg), ensure the cutoff walls have some impact resistance to prevent being breached in the event of a system component failure. Types of construction materials, in order of preference, are: reinforced concrete; reinforced and fully grouted concrete block; unreinforced concrete block; metal lath and plaster; metal sheathed gypsum board.

Ordinary gypsum board walls would provide virtually no impact resistance. Where metal-sheathed gypsum board is to be provided, ¼ in. (6.4 mm) thick steel plate is best, but 18 gauge sheet metal will also provide some resistance to projectiles.

2.2.3 Ensure HTF user rooms (i.e., rooms containing equipment that use the heat provided by the heat transfer system) are cut off from other important facilities by construction of at least 1-hour fire resistance. Where such isolation is not practical due to operational considerations, then provide draft curtains (see Data Sheet 1-10, *Interaction of Sprinklers, Smoke and Heat Vents, and Draft Curtains*) combined with floor slope, curbs and/or dikes to limit both floor spills and area of sprinkler operation.

2.2.4 Provide curbs or dikes, coupled with sloped floors leading to a properly designed drainage system, to prevent a potential HTF spill from flowing into adjacent production areas, storage areas, or to floors below. Ensure pumps and any other equipment prone to leakage is surrounded by curbing. Refer to Data Sheet 7-83, *Drainage Systems for Flammable Liquids,* for additional guidance regarding the design and installation of drainage and curbing.

2.2.5 For new installations, ensure control rooms, control equipment, wiring, and switchgear are separated from the heater or vaporizer pump and piping as much as practical. For new installations with more than one heater or vaporizer, ensure adjacent units are separated by a 1-hour (minimum) fire wall.

2.3 Protection

2.3.1 Building Fire Protection

2.3.1.1 Provide automatic sprinkler protection throughout all building areas subject to a heat transfer fluid spill fire. This includes the vaporizer or heater room, user room(s), and areas containing heat transfer fluid piping. (See exceptions in 2.3.1.3.)

Install sprinklers on a spacing suitable for extra-hazard occupancies (i.e., maximum 100 ft^2 [9.3 m^2] per head; see Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers* , for additional installation criteria), and hydraulically design them as indicated in Table 1. In areas that may be exposed to an HTF spill fire, ensure sprinkler protection is provided under any obstruction to water distribution that exceeds 3 ft (0.9 m) in width or diameter and 10 ft^2 (0.9 m^2) in area (e.g., under large pieces of equipment).

An automatically actuated deluge sprinkler system is an acceptable alternative to an automatic sprinkler system. Where a deluge system is used, ensure nozzle spacing does not exceed 100 ft^2 (9.3 m^2). Ensure detector spacing is as specified in Data Sheet 2-0.

2.3.1.2 Where the heat transfer system user or heating equipment is located within a multi-level processing structure with open or incompletely sealed floors, provide fire protection as detailed in Data Sheet 7-14, *Fire and Explosion Protection for Flammable Liquid, Flammable Gas, & Liquefied Flammable Gas Processing Equipment & Supporting Structures*. This applies to buildings with grated floors, or solid floors with numerous penetrations to the level below, or where heat transfer fluid piping, pumping equipment, heating or user equipment are on elevated grated mezzanines (i.e., where a three-dimensional fire is a possibility).

2.3.1.3 Automatic sprinkler protection may be omitted in building areas that contain no combustibles other than the heat transfer fluid in the pipeline, if:

a) the piping is all welded, with no flanged joints;

b) there are no valves, pumps, or other accessories that are known to be potential leakage points; and

c) the piping system consists solely of ferrous piping installed as recommended, including either automatic or manual remote shutoff.

2.3.2 Heat Transfer Fluid Heater or Vaporizer

2.3.2.1 Where the HTF heater or vaporizer provides a major source of process heat for production, protect the interior of the firebox and portions of the heat exchanger subject to an internal HTF spray or spill fire (depending on configuration) with an automatically actuated fixed inerting system.

Table 1[1,2]. Sprinkler Protection for Indoor Heat Transfer Equipment

Room Explosion Hazard	*Type of Sprinkler System*	*Sprinkler Temp Rating °F (°C)*	*Density gpm ft^2 (mm/min)*	*Area of Demand ft^2 (m^2)*	*Hose Stream Demand gpm (lpm)*	*Duration (min)*
No	Wet	High 286 (141)	0.25 (10)	3000 (278.7)	500 (1900)	60
No	Wet	Ord. 160 (71.1)	0.25 (10)	4000 (371.6)	500 (1900)	60
No	Dry	High 286 (141)	0.25 (10)	5000 (464.5)	500 (1900)	60
No	Dry	Ord. 160 (71.1)	0.25 (10)	6000 (557.4)	500 (1900)	60
Yes[3]	Wet	High 286 (141)	0.25 (10)	6000 (557.4)	1000 (3800)	120
Yes[3]	Wet	Ord. 160 (71.1)	0.25 (10)	8000 (743.2)	1000 (3800)	120

Notes:
[1]To determine the demand area for intermediate temperature (212°F, 100°C) sprinklers, interpolate halfway between high temperature and ordinary temperature sprinkler demand areas.
[2]See *Water Demand Modifications to Densities and Areas*, in Data Sheet 3-26 for further guidance where significant positive or negative considerations exist.
[3]See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for protection of sprinkler systems against explosions.

Use an inert gas, such as carbon dioxide or nitrogen. Steam is acceptable only when there is an independent, reliable source of it. For carbon dioxide or nitrogen inerting systems, refer to Data Sheets 4-0, *Special*

Protection Systems, 4-11N, *Carbon Dioxide Extinguishing Systems (NFPA)*, and 7-59, *Inerting and Purging of Tanks, Process Vessels, and Equipment*, for additional design criteria. See also NFPA 12, *Carbon Dioxide Extinguishing Systems*, for further information.

For steam inerting systems, provide steam at a rate of 4 to 8 lb/min per 100 ft^3 (0.64 to 1.3 kg/min/m^3) of enclosure volume (The enclosure is defined as the entire volume being protected. This would normally include the entire interior volume of the heater or vaporizer, but would not normally include the exhaust stack.). The lower figure can be used for relatively tight enclosures if steam is introduced at or below the level of a possible fire. Use the higher figure if there is unavoidable leakage of up to one air change per minute, or if steam is introduced above the level of the fire. Adequate steam condensate trapping must be provided for steam inerting systems.

The inerting concentration needs to be maintained until hot surface parts, especially refractory, cool below the ignition temperature of the HTF.

Extended-discharge systems are preferred over one-shot discharge systems due to the increased reliability and added cooling capability.

2.3.2.2 Ensure the fixed inerting system is automatically actuated by detection of any *two* of the following conditions. Provide an alarm when any one of these conditions is detected.

a) High values from a differential flow detector comparing HTF flowing into and out of the heater. On very large units (i.e., where heat exchange tubes or coils have a diameter of 4 in. 100 mm or more) with multiple tubes or coils, provide a differential flow detector for each tube or coil.

b) Low HTF level in the expansion tank. (Note: This function can be used only if the expansion tank level is not automatically corrected with a pumped re-supply of HTF from the storage tank.)

c) High values from flue gas combustibles analyzer

d) Increase in opacity of smoke exiting the heater or vaporizer

e) High flue gas temperature

f) Increase in carbon monoxide in flue gas

g) Decrease in oxygen in flue gas

The inerting system should also be provided with a remotely located manual actuator.

2.3.2.3 If an HTF fire occurs in the combustion chamber of a heater or vaporizer, ensure the following actions are taken:

a) Shut off the fuel supply.

b) Stop combustion air fans and shut any combustion air inlet dampers.

Outlet dampers should preferably remain open to prevent overpressure of the firebox due to the inert-gas smothering system discharge as well as to help purge any combustible vapors. However, isolation dampers may be provided on flue gas ducts where it is determined that lack of these would possibly prevent adequate inert gas concentrations from being achieved and held, such as with systems that only provide a one-shot inert gas discharge, as opposed to extended discharge systems.

Ensure dampers fail-safe in the desired position since power may be lost or shut off in the event of a fire.

c) Open steam or inert-gas smothering systems or use portable extinguishers at openings to the fire box.

d) With a heater or vaporizer provided with a fixed inert-gas smothering system, do not drain the HTF until after the fire is extinguished. HTF pumps may also be kept running to continue fluid circulation through the unit, if desired.

e) On units that are not provided with an inert-gas smothering system, drain the heat transfer fluid within the heater or vaporizer as soon as possible and as quickly as possible, regardless of residual heat damage considerations. This is justified by the overriding consideration that the flow of leaking HTF must be stopped to extinguish the fire. Rapid draining is best accomplished by isolating the unit from the remainder of the system with valves and then draining only the liquid in the heater or vaporizer itself back to the storage tank. Use oversized emergency drain piping to help provide short drain times. If a storage tank is not available, drain to a safe location. Where damage to empty tubes from hot refractory heat holdup is a concern, air dampers may be re-opened and fans re-started after the fire is out.

Exceptions:

i) Where the HTF is at a temperature above its atmospheric boiling point, ensure the heater or vaporizer is subjected to a rapid drain only if an emergency cooler is provided that can cool the HTF to below its atmospheric boiling point prior to discharge into the storage tank(s). Otherwise, ensure the HTF is drained slowly, and only in cases of extreme emergency.

ii) Where the leakage rate is visually verified to be small enough to allow the combustion of HTF immediately after issuance from the leaking tube(s), without a constant size or growing pool of HTF at the bottom of the firebox chamber, then manual fire extinguishment may be attempted without draining the HTF from the tubes. Perform a manually controlled heat transfer system shutdown. Shut off fuel to the heater or vaporizer. Ensure the tubes are depressurized (e.g., throttled back on valves upstream of the heater or vaporizer) while continuing minimal circulation to prevent fouling. If the fire cannot be extinguished after this has been done, then drain the tubes.

iii) Drainage is not possible with certain tube configurations, such as horizontally oriented helical coils or vertical pendent tubes, due to the lack of a single low point.

f) Where an inert gas extinguishing system is provided and is automatically actuated, then ensure steps a. to c. above are all automatic. Step d. may be manually initiated. Where the inert gas extinguishing system is manually actuated due to the lack of appropriate instrumentation as enumerated in 2.3.2.2, then steps a. through d. may all be manually initiated. If the inert gas extinguishing system is ever converted to automatic actuation, then convertall of steps a. through c. to automatic at that time as well.

g) Where a fixed inert gas extinguishing system is not provided, but heat transfer system instrumentation is already present that can detect at least two of the conditions enumerated in 2.5.2.2 (i.e., conditions indicative of a firebox fire), ensure steps a. and b.) above are automatic upon detection of any two of these conditions. Where appropriate system instrumentation is not present, steps a. and b. above may be manually initiated.

2.3.2.4 Perform a full discharge test after installation of an inert gas extinguishing system. Where possible, do this during normal operation of the heat transfer system to ensure all extinguishing system components and process interlocks will operate and that inert gas design concentrations are being achieved and maintained. Ensured the unit is not being used for production purposes during the test.

Note: Where an inert gas discharge nozzle is unusually close to a hot component inside the protected volume, there may be a possibility of thermal shock damage to that component. In such a case, discharge the system running, but cold.

Verify isolation dampers that are intended to actuate in the event of a fire to help maintain inert gas concentrations on a regular basis to ensure they are operational. Ensure a minimum yearly test frequency.

2.3.3 Outdoor Equipment

2.3.3.1 Protect outdoor equipment in accordance with Data Sheet 7-14 where the holdup within one piece of equipment is greater than 500 gal (1890 l) or the HTF flow rate through the equipment exceeds 50 gpm (190 lpm).

For outdoor equipment handling quantities or flow rates less than these, localized protection may be acceptable (e.g., hose streams or monitor nozzles where personnel for firefighting is limited).

2.3.3.2 On large, outdoor vertical vaporizers or heaters where a long sustained spray fire on release of hot vaporized heat transfer fluid is possible, fireproofing of exposed steel supporting members is advisable, in addition to water spray protection as recommended in 2.3.3.1.

In cases where there is a severe three-dimensional fire hazard (e.g., large, multi-level support structures), ensure main structural steel and equipment supports (loadbearing members) are fireproofed with a material having at least a 2-hour fire resistance rating, weathering resistance, corrosion resistance as needed, and the capability to withstand direct application of large fire hose streams.

2.3.3.3 Provide outdoor heaters or vaporizers with the following minimum space separation:

a) 75 ft (23 m) away from important buildings, or 25 ft (7.6 m) if the total system HTF capacity does not exceed 1500 gal (5.7 m^3). Where this space separation cannot be provided, ensure the exposed wall(s) has a minimum 1-hour fire resistance.

b) 100 ft (30 m) away from outdoor flammable liquid or gas processing equipment. The space separation may be less than this if either the process area or the HTF heater or vaporizer is protected by an automatically actuated deluge sprinkler system. Where the loss expectancy does not justify the cost of deluge sprinkler protection, and space separation is less than 100 ft (30 m), then provide manual protection (e.g., hydrants, monitor nozzles). Regardless of the protection provided, do not locate the HTF heater or vaporizer in any area requiring hazardous location electrical equipment as defined by the *National Electrical Code* Article 500 (or national/international equivalent). See Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations* and NFPA 497A to determine the extent of the hazardous (classified) area.

c) 75 ft (22.9 m) away from important outdoor processing equipment that does not handle any flammable liquids or gases, or 25 ft (7.6 m) away if the total heat transfer system fluid capacity does not exceed 1500 gal (5.7 m^3). Where this separation cannot be provided, ensure manual protection (e.g., hydrants, monitors) is provided to prevent heat damage to the exposed equipment.

2.3.3.4 If outdoor piping has potential leakage points (e.g., valves, flanged joints, fittings, pumps, etc.) and a leak and subsequent fire could cause significant damage to buildings or important structures, provide suitable fire protection.

2.3.4 Manual Extinguishing Equipment

2.3.4.1 Locate portable fire extinguishers should be located throughout all areas containing HTF equipment or piping at easily accessible locations. A 20-30 pound (9-14 kg) dry chemical type is preferable. Portable or fixed foam or aqueous film forming foam (AFFF) extinguishing equipment is an acceptable alternative. Provide personnel with training for fighting small fires.

2.3.4.2 Provide small hoses to reach all areas of possible heat transfer fluid spill and any combustible storage. Provide water fog nozzles on hoses intended for fighting HTF spill fires.

2.4 Equipment and Processes

2.4.1 Overall Design Considerations

2.4.1.1 Accomplish temperature regulation of the user equipment by regulating the flow of HTF to the user and modulating the energy input, while maintaining a constant (optimum) flow velocity through the heater or vaporizer. This can be accomplished by using a three-way valve and a bypass line, as shown in Figure 1. In systems with a primary loop and multiple secondary loops, secondary loops will have individual regulating valves and/or pumps to control the flow within that loop, with one bypass line used to keep the flow through the heater or vaporizer constant. Provide a check valve in the return line, downstream from the heat consumer but upstream of where the secondary loop reconnects to the primary loop or bypass line.

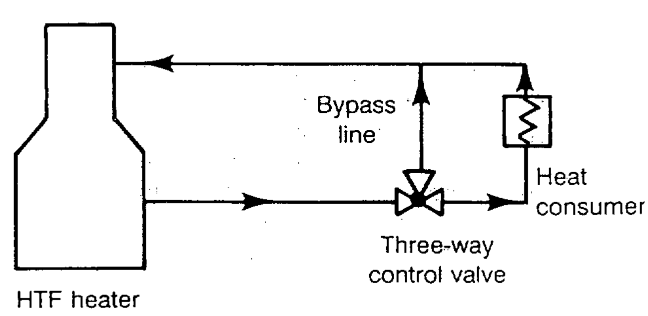

Fig. 1. Flow control by three-way control valve and bypass

2.4.1.2 Ensure the flow velocity through the heat exchange tubes in the heater is sufficient to result in fully turbulent flow in the tubes. Heat transfer calculations should be provided by the system installer to ensure the HTF manufacturer's maximum recommended film temperature will not be exceeded during any foreseeable operating conditions.

2.4.1.3 Provide an emergency drain line at the system low point(s), piped to one or more vented storage tanks, or to a safe area capable of accommodating the total fluid contents of the system or that part that can be isolated. Drainage may be by gravity flow or by pumps as long as power to the pumps is ensured in the event of an emergency. The same drain lines may be used for both routine and emergency drainage. Arrange the tank(s) as indicated in 2.4.1.8.

2.4.1.4 Do not pumpHTF throughout a facility to provide building heat via local heat exchangers. When HTF is used for building heat, provide a central heat exchanger to generate hot water, hot glycol, or steam, which can then be piped throughout the facility.

2.4.1.5 Provide control equipment to permit operation of key equipment and valving from both the control room and from close to the location of the equipment.

2.4.1.6 In designing and building a heat transfer system, consult the manufacturer of the HTF for advice on the choice of gasketing material (for joints) and packing material (for valves and pumps) that will provide the best leak-free service for their fluid at the intended operating temperatures and pressures, and considering the operating environment, both internal and external. (See also general recommendations in Section 2.4.2 below.)

2.4.1.7 Locate piping and equipment containing HTF so they will not be exposed to temperatures below the pour point of the fluid. (See Table 2 in Appendix D for pour points of various fluids.) Provide a combination of insulation and electric or steam heat tracing on critical system piping and equipment where it is impractical to reliably guarantee that temperatures will not go below the pour point for any extended period of time (e.g., outdoor equipment where the ambient temperature occasionally reaches values below the pour point; equipment indoors in unheated buildings where the only source of heat is the heat transfer system itself and outdoor temperatures regularly or seasonally reach values below the pour point).

Refer to Data Sheet 9-18/17-18, *Prevention of Freeze-Ups*, for additional recommendations to prevent freeze damage and for information on heat tracing systems.

Freeze protection may be omitted for system segments that may be drained to the storage tank(s) through valved system low points.

2.4.1.8 Where possible, locate the storage tank(s) below the lowest system drain opening to permit gravity flow when emptying. Due to the fact that the fluid does not circulate through the storage tank, make provisions for freeze protection where necessary. Provide adequate breather vents based on the maximum emptying or filling rates.

2.4.1.9 Do not convert steam boilers to HTF operation except under the guidance of the equipment manufacturer.

2.4.2 System Components—General

2.4.2.1 Ensure heaters or vaporizers with an operating pressure exceeding 15 psig (1.03 barg) conform to the requirements of the *ASME Boiler and Pressure Vessel Code*, or national/international equivalent.

Note: This recommendation may also apply to heat exchangers that heat the HTF in a secondary circulating system using hot HTF from a primary circulating system.

2.4.2.2 Do not use copper or copper alloys in heat transfer systems with a hydrocarbon fluid unless air (oxygen) is excluded from contact with the fluid by hermetic sealing and/or an inert gas blanket. Do not use aluminum equipment in systems using chlorinated heat transfer fluid.

2.4.2.3 To help prevent a spray release leading to a spray fire or mist explosion, provide shielding around seals, flanges, valve packings, and any other potential leakage points. Where potential leakage points are insulated, provide a metal covering over the insulation. Where shielding or metal insulation covering is provided, ensure there is a small drain hole at the low point of the cover to allow prompt detection of a leak. Ensure the metal shield is solidly fastened so it is not blown off by a strong spray.

2.4.2.4 Do not use mixtures of HTFs in a system, unless such mixtures are in accordance with recommendations of the manufacturer of the fluids and heat transfer equipment.

2.4.2.5 Prior to changing an existing system from one heat transfer fluid type to another, ensure a full engineering review is done to determine that all aspects of the system are appropriate for the new fluid (e.g., system materials, flow rates, temperatures, pressures, vented vs. closed/inerted system, etc.).

2.4.2.6 Avoid gauge glasses if possible. Where used, ensure gauge glasses are of a high pressure rated type consisting of a steel body with a special tempered glass window secured between bolted flanges.

2.4.2.7 Do not use trycocks for checking liquid levels in vaporizers. It would be undesirable to release the substance in the vaporizer room.

2.4.2.8 Provide FM Approved combustion safeguards and fuel safety shutoff valves on gas and oil burners. (See Data Sheet 6-4/12-69, *Oil- and Gas-Fired Single-Burner Boilers*, Data Sheet 6-5/12-70, *Oil- or Gas-Fired Multiple Burner Boilers*, and Data Sheet 6-10, *Process Furnaces*, as applicable.) Consult Data Sheet 6-2/12-63, *Pulverized Coal-Fired Boilers*, Data Sheet 6-13/12-13, *Waste Fuel-Fired Boilers*, or Data Sheet 6-7/12-7, *Fluidized Bed Combustors and Boilers*, as applicable, for recommendations where the heat transfer fluid is heated by burning solid or waste fuels.

2.4.2.9 If stack gas from the HTF heater or vaporizer is recovered to provide auxiliary base load heat for other equipment (e.g., rotary dryers), provide suitable dampers, isolation gates, burner control logic, etc., to ensure that all equipment is properly purged and will operate in a safe manner. Ensure the control logic is able to anticipate all possible operating modes of the individual pieces of equipment, whether operating singly or together, to ensure safe startup and shutdown under normal or upset conditions.

2.4.2.10 Tightly seal ny openings in pipes or equipment, such as manholes, instrument ports, inspection ports, etc., to ensure they will not allow HTF leakage in the event of a system upset.

2.4.3 Tanks

2.4.3.1 If located indoors and above ground, ensure the expansion tank and storage tank are located within diked areas capable of containing the total volume of the tanks. Where storage tanks are located below grade in a pit, ensure the pit is capable of containing the total volume of the tank.

The following can provide acceptable alternatives to secondary containment where a full capacity dike is economically impractical or physically difficult:

a) If the tanks are located in dedicated rooms cut off from manufacturing or storage areas, ensure curbs at the door(s) are sufficiently high to contain the total spill volume of the tank within the room.

b) Provide minimum 4 in. (100 mm) high curbing around the tank, with adequate drainage provided within the curbed area capable of draining away fire protection water (sprinkler flow plus hose stream flow) discharged in the event of a fire. See Data Sheet 7-83 for required drainage capacity and other drainage system installation details.

c) Where an expansion tank includes an internal overflow line that is piped to a low-level storage tank, secondary containment is not required as long as the overflow line is unvalved, or has shutoff valves that are locked in the fully open position. Ensure there are no other openings or weak fittings on the expansion tank that could allow fluid escape into the immediate environment in the event of overflow line blockage. However, where the expansion tank is located directly above high-value or critical process equipment, at least provide a drained drip pan below the tank to catch and remove to a safe location any minor (i.e., non-catastrophic) leakage that might occur.

d) An emergency drain is provided on the expansion tank as detailed in 2.4.3.2.

2.4.3.2 Where the expansion tank is located above floor level and has a capacity of over 250 gal (1000 l), provide it with a low-point drain line that can allow it to be drained to the low-lying drain tank (storage tank). Ensure the drain line valve is remotely operable from a safe place. Provide a low-point drain for expansion tanks with a capacity of less than 250 gal (1000 l).

2.4.3.3 For systems that approach or exceed the atmospheric boiling point of the HTF, provide the expansion tank with an inert gas (e.g., nitrogen) blanket under a positive pressure of at least 15–25 psi (1–1.7 bar) above the fluid's vapor pressure. Provide an interlock that will shut down the fuel source to the heater or vaporizer if the inert gas pressure falls below the minimum required. Always provide a pressure relief device in conjunction with inert gas pressurization. Refer to Section 2.4.9, as well as to Data Sheet 12-43, *Pressure Relief Devices*, for additional guidance on pressure relief devices.

2.4.3.4 If an HTF expansion tank is provided with a breather vent, ensure the discharge outlet from this vent terminates at a safe location so if burning vapor or liquid is discharged it will not expose buildings, equipment, combustibles, or personnel.

2.4.3.5 Ensure any above-ground HTF storage tanks (indoors or outdoors) are constructed, located, and arranged as detailed in Data Sheet 7-88, *Storage Tanks for Flammable and Combustible Liquids*.

2.4.4 Piping

2.4.4.1 Ensure piping is securely supported and protected against mechanical injury. Provide adequate clearance between HTF piping and wood or other combustible construction materials, as follows: insulated piping with surface temperature below 200°F (93°C): 1 in. (2.5 cm) minimum; uninsulated pipe: 18 in. (0.45 m) minimum.

For insulated pipe whose surface temperature exceeds 200°F (93°C), provide suitable clearance to keep the surface temperature of nearby combustible construction materials below 160°F (71°C). Keep piping well away from any combustible storage.

2.4.4.2 In and around process equipment where combustible materials will unavoidably settle on HTF piping or heated surfaces, provide sufficient insulation on the piping or equipment to prevent ignition of the deposited material. Where hot surfaces must be kept uninsulated due to process considerations, remove any combustible accumulations on a daily to weekly frequency, depending upon the rate of accumulation.

2.4.4.3 Minimize overhead routing of HTF piping. Run piping underground, outside, or in floor trenches where possible.

2.4.4.4 Welded pipe connections are preferred throughout an HTF piping system. Use of mechanical joints should be limited to pump, valve, and equipment connections if possible. For systems operating above 15 psig (1.03 barg), ensure pipe materials and types are in accordance with ANSI/ASME B31.1, *Power Piping*, or ANSI/ASME B31.3, *Chemical Plant and Petroleum Refinery Piping*, (or national/international equivalent) as applicable. For systems operating at or below 15 psig (1.03 barg), refer to Data Sheet 7-32 for recommendations regarding acceptable pipe materials and types. The ANSI/ASME standards can also be used as a guide. For systems operating at any pressure, do not use copper or cast iron piping.

2.4.4.5 Incorporate a Hartford loop into the condensate line of vapor-phase heating equipment having a gravity return whenever the condensate is returned to a point in the vaporizer below the lowest safe liquid level.

2.4.4.6 Where HTF system piping is connected to heated rolls with rotary joints, use flexible connections (e.g., flexible metal hose) at the joint so it is free to follow any movement of the roll.

2.4.4.7 Design piping from safety valves to the point of safe discharge to withstand the anticipated backpressure and mechanical stresses. Weld all joints. Ensure changes in direction of the discharge line are adequately braced to resist anticipated thrust loads caused by fluid flow.

2.4.4.8 Do not use threaded pipe fittings used with HTF temperature above 350°F (177°C), or at temperatures above 220°F (104°C) where the pressure exceeds 100 psig (6.9 barg). (Note: Flanged joints are the preferred mechanical connection at all temperatures.)

2.4.5 Valves

2.4.5.1 Install valves with stems in the horizontal position so any leaking fluid will drip away from the insulation.

2.4.5.2 Use double-seal valves in order to minimize leakage.

2.4.6 Joints

2.4.6.1 Weld all joints to minimize the potential for leakage.

Where flanged fittings are used, use the following gasket materials, which have been shown to provide acceptable reliability:

a) spiral-wound stainless steel flexible graphite-filled

b) spiral-wound steel and asbestos*

c) iron-clad asbestos*

d) nickel-clad asbestos*

* Use substitute materials in the U.S.A.

2.4.7 Pumps

2.4.7.1 Use sealless pumps of cast steel construction to minimize leakage.

2.4.8 Insulation

2.4.8.1 Ensure the insulation used to cover HTF piping and equipment is nonabsorbent.

Any type of insulation may be used where the pipe is all welded (i.e., without flanged fittings) and where there are no other sites prone to leakage, such as valves or pumps. Commonly used insulating materials are grouped as follows:

NONABSORBENT	ABSORBENT
closed cell cellular glass (foamed glass)	calcium silicate
reflective aluminum foil or sheets	85% magnesia
	glass fiber batts
	ceramic wool
	mineral wool
	asbestos fibers, silicate bonded

2.4.8.2 Apply insulation to system piping and equipment only after a leakage or pressure test of the plant has been conducted. Allow a full heating cycle before applying insulation.

2.4.8.3 In existing installations where equipment and piping is covered with open cell (HTF absorbing) insulation, remove the insulation from system components that are prone to leakage and cover only with a spray shield. Where insulation must be provided, the components may be re-covered with nonabsorbing insulation. Alternatively, cover the existing open cell insulation with hydraulic-setting oil-resistant cement in areas of potential leaks.

2.4.9 Pressure Relief Devices

2.4.9.1 Provide pressure relief devices on the heat transfer system as required by Data Sheet 12-43, and as required by the ASME Boiler and Pressure Vessel Code (or national/international equivalent).

2.4.9.2 Pipe all pressure relief device outlets that do not discharge back into the closed system (i.e., into the atmospheric storage tank) to a safe outdoor location or to a blowdown tank or equivalent system, so that burning vapor or liquid will not expose building, equipment, combustibles, or personnel. Where an atmospheric discharge line is to be used, choose the siting of the discharge point bearing in mind the following considerations:

a) If allowed to land on a roof, hot discharged HTF, in either the liquid form or as a condensed vapor, can damage a building roof covering by both thermal and chemical action.

b) Combustible roofing materials not covered by either gravel or stone ballast may catch fire.

c) HTF that enters a roof drain system may create a contamination problem.

Additional recommendations pertaining to blowdown tanks can be found in Data Sheet 7-49/12-65, *Emergency Venting of Vessels*.

2.4.9.3 Ensure vent piping downstream of a pressure relief device has been sized taking into account the possibility of two-phase flow, where that possibility exists.

2.4.9.4 Do not allow liquid to accumulate in the vent line. This can be prevented by providing a drip leg and drain plug at the bottom of the vent line (Fig. 2). Ensure horizontal piping in the vent line is sloped so there are no spots where liquid can accumulate.

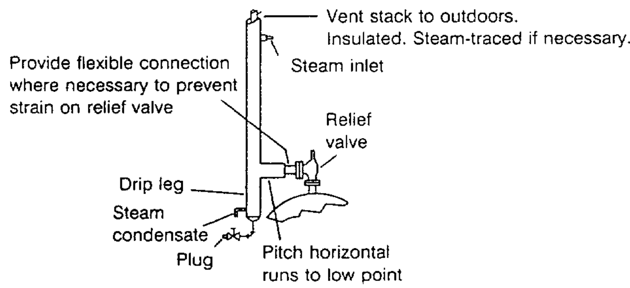

Fig. 2. Typical vent line details

2.4.9.5 Ensure outdoor discharge piping from pressure relief devices for media having high pour point temperatures is heated by steam tracing or other means, so that during cold weather, leakage or emergency discharge of such media will not solidify and obstruct piping.

2.4.9.6 Ensure outdoor vent pipe outlets are either hooded or terminated in a U-bend to keep out rain.

2.4.9.7 Ensure discharge piping is supported and arranged according to the recommendations of pressure relief device manufacturers to avoid strain on the valve, which could cause leakage.

2.4.9.8 Where allowed by codes, a non-fragmenting rupture disk may be installed upstream of the safety relief valve. Where this is done, provide a pressure gauge, bleed line, or vent between the rupture disk and the safety valve, to test the rupture disk for leakage. Refer to Data Sheet 12-43 for additional guidance.

2.4.9.9 Ensure afety relief valves have tapered or streamlined inlets and externally guided disks to avoid sticking of valves, which might result from carbon formation on internal guides.

2.4.9.10 Ensure safety relief valves have enclosed springs to prevent vapor from escaping around the valve spindle. Use special steels to withstand the high temperatures. Cap adjustment screws to avoid tampering with the setting of the valves. Ensure all safety relief valves comply with applicable pressure vessel codes.

2.4.10 System Interlocks

2.4.10.1 Provide measuring instrumentation and interlocks to sound an alarm and automatically shut down the fuel source to the HTF heater or vaporizer when any of the following conditions is detected:

a) Low HTF flow through the heat exchange tubes of the heater, measured at the discharge (i.e., when flow velocity is below that required for turbulent flow)

b) High HTF temperature or pressure at the heater or vaporizer outlet (Note: Ensure the high temperature interlock is set at or below the HTF manufacturer's maximum recommended bulk fluid temperature. See values in Table 2 in Appendix D.)

c) Low pressure at the heater or vaporizer outlet or elsewhere in the system (Note: This interlock may require a by-pass to allow for conditions at startup.)

d) High heat exchanger tube temperature or high film temperature, as measured by thermocouples at the surface of the tubes (optional) (Note: Ensure the set point is at or below the HTF manufacturer's maximum recommended film temperature. See values in Table 2.)

e) Low fluid level in expansion tank

f) Low vaporizer liquid level

g) High temperature of liquid entering the heater or vaporizer (optional if b. is provided)

h) Sprinkler system flow in any area containing HTF equipment or piping

i) High temperature at bridge wall (optional) (See 2.4.10.8 below.)

j) High value from a differential flow meter measuring HTF heater or vaporizer inlet and outlet flows. (optional)

Note: Provide an alarm set point at levels below or above the auto shutoff levels to monitor the above-mentioned variables and provide an opportunity for operators to correct the problem before conditions reach an unsafe level.

2.4.10.2 Interlock the heat transfer system to stop the circulation of fluid throughout the system and to isolate major piping segments in the event of a fire. To accomplish this, provide the following, arranged to actuate either in the event of sprinkler system operation or abnormally low pressure in the heat transfer system, or upon operation of a heat detection system using FM Approved (see Appendix A for definition) detectors installed according to the limitations indicated in the *Approval Guide*, a publication of FM Approvals.

a) Provide safety shutoff valves or 3-way divert valves of fail-safe design to isolate all secondary circulating loops from the primary loop running into and out of the vaporizer or heater. A positive displacement pump arranged to stop operating is an adequate substitute for a safety shutoff valve located in the same place.

b) In primary or secondary loops that have sizeable HTF hold-ups (greater than approximately 500 gal 2000 l), provide additional safety shutoff valves along the length of piping within the loop to minimize the volume of a potential release. The following are some factors to consider in deciding the need for and location of additional safety shutoff valves:

i) Attempt to prevent released HTF from flowing at or near equipment that is particularly valuable, has long repair/replace times (e.g., foreign and/or very specialized), or is a production bottleneck.

ii) Attempt to prevent any significant gravity flow from occurring, such as at low points of loops that have much piping or equipment at higher levels.

c) If safe to do so, arrange all system pumps to stop.

d) Exceptions/modifications to a–c. The refractory inside some heaters or vaporizers can retain enough heat to cause HTF breakdown and tube fouling if fluid circulation through the unit is stopped, even with the fuel supply shut off. Where this is the case, or with solid waste-fuel fired units, the HTF may continue to be pumped until the heater or vaporizers is deemed to have cooled sufficiently under any of the following conditions:

i) If the fire is within the heater or vaporizer and a fixed inert gas extinguishing system is provided, then circulation may be continued, through the entire system if desired.

ii) If the leak or fire is somewhere other than within the heater or vaporizer room, the HTF flow can be diverted from the secondary equipment loops and most of the primary loop to an emergency cooling loop connected local to the heater. All piping through which the HTF is flowing during the diversion to the emergency cooling loop should be located in an area(s) not involved in the fire. The acceptability of this arrangement is based on the provision of zoned automatic sprinkler system flow detection and zoned low pressure interlock switches to ensure the HTF fire or leak is not in the heater/vaporizer room or other areas where the emergency cooling loop piping is located.

iii) If the leak or fire can be pinpointed to a specific secondary loop, and a fire involving the one leaking loop or system cannot involve other secondary HTF loops or another primary loop due to space separation or physical barriers, then flow may be continued through the primary loop and other secondary loops if needed. Safety shutoff valves should be provided as explained in 2.4.10.2a and 2.4.10.2b above to isolate the loop involved in the leak or fire. Acceptable means of pinpointing the leak or fire to a specific secondary loop include zoned sprinkler system flow detection, differential flow detectors located on secondary equipment loops, or zoned low pressure interlock switches.

2.4.10.3 Where safety shutoff valves or other valves are provided to isolate a length of piping or a piece of equipment, provide either an automatically opening drain line or a pressure relief device for the trapped volume if there is the potential for fire exposure or other condition leading to overpressurization. A pressure relief device may, in some cases, be required by applicable jurisdictional codes.

2.4.10.4 Provide a well-marked remote emergency shutoff switch capable of safely shutting down the entire heat transfer system. Locate it either in a constantly attended control room or at a location that would be accessible in the event of an HTF leak and/or fire.

2.4.10.5 Where leakage from a secondary HTF loop can result in a fire with a particularly high loss expectancy, such as at critical and/or very high value production equipment, provide differential flow detection for any such loops (i.e., measure and compare flow to and from the loop), interlocked to shut the safety shutoff valves that isolate that loop. Ensure the flow differential set point is as low as possible (a function of the sensitivity of the flow measuring devices) so isolation of small leaks will occur without inadvertent shutdown due to instrument sensitivity.

Additionally, acoustic leak detection can be provided. Arrange acoustic leak detection to only provide an alarm, with the operator responding by shutting the safety shutoff valves that isolate that loop. Acoustic leak detection will detect smaller leaks than can be detected by differential flow monitoring.

2.4.10.6 Ensure safety shutoff valves used to isolate portions of the HTF piping system are of the pneumatic type, or other type that can be arranged for fail-safe operation. Where pneumatic type valves are provided, provide a fusible plug on the pressure line used to operate the valve so it will automatically close in the event of a nearby fire exposure. Plastic air lines may also be used to accomplish the same effect.

2.4.10.7 If there are any flammable gas lines running in or through rooms (areas) containing parts of the HTF system, such as to feed gas-fired HTF heaters, provide an emergency shutoff valve on the gas line, located such that it would be readily accessible in the event of a fire inside the building. Train employees or the Emergency Response Team in the location and operation of the shutoff valve.

2.4.10.8 To prevent overheating of tubes due to faulty firing or heating operation, or due to an internal HTF leakage fire, provide a thermocouple located at the bridge wall (transition from radiant section to convection section of firebox) interlocked to shut off the fuel supply when the recorded temperature exceeds the normal maximum temperature by approximately 100°F (56°C).

2.4.10.9 Where the level in the expansion tank is prevented from going below a pre-set level by an automatically actuated low-level supply pump fed from the storage tank, provide an interlock to shut down the supply pump when a high level indicator is actuated, regardless of whether the pump is in automatic or manual mode.

2.4.11 Solid Waste-Fuel Fired Equipment

2.4.11.1 Provide redundant HTF circulating pumps for heaters or vaporizers fueled by solid waste fuels not burned in suspension. Ensure the redundant pumps are powered using an independent power supply or an independent drive, such as a diesel engine. Where an independent second power supply is not available, provide a diesel-driven emergency generator for backup power, or a dc motor drive with batteries. This is needed because the heat source cannot be quickly stopped with this type of burning, and the heat that continues to be produced after the stop of fuel feed must continue to be removed to prevent thermal damage to firebox internal parts and HTF heater or vaporizer heat exchange tubes.

Where it is desired to maintain HTF circulation during an HTF leak/fire inside the firebox, provide an automatically actuated fixed inert gas extinguishing system. Where it is desired to maintain circulation during an HTF leak or fire other than within the heater or vaporizer room, provide one of the leak isolation and by-pass arrangements (ii or iii of Section 2.4.10.2d).

Review operating procedures to ensure the inventory of solids burning on the grate is minimized, and that the fuel particle size is as small as practicable.

2.4.11.2 If HTF circulation is lost or significantly reduced in a waste-fuel fired heater or vaporizer that uses grate burning (i.e., pile burning, semi-pile burning, semi-suspension burning), do the following:

a) Stop the feed of fuel material.

b) Stop or minimize the supply of undergrate air (air that percolates up through the bottom of the grate) in accordance with manufacturer’s recommendations.

c) Maintain or maximize the overfire air (air introduced above the grate).

2.4.11.3 Where the HTF is heated in a packaged heat exchanger physically separated from the combustion chamber (i.e., hot exhaust from the burner is ducted to an independent heat exchanger), make provisions for the exhaust gases to automatically bypass the HTF heat exchanger in the event that any of the conditions a through g of Recommendation 2.4.10.1 are detected.

2.4.11.4 Provide appropriate hardware and set automated control logic and/or manual operating procedures prevent the accumulation of explosive concentrations of combustible gases in the combustion chamber, exhaust ducting, or any stack gas utilization equipment, following a shutdown with unburned fuel in the combustion chamber.

2.4.11.5 Provide additional safeguards that are not directly linked to the heat transfer system per Data Sheet 6-13/12-13, *Waste Fuel-Fired Boilers*.

2.4.12 Indirectly Heated Secondary HTF Piping Systems

2.4.12.1 Where a secondary circulating heat transfer system is provided that is heated, via a heat exchanger, by a primary heat transfer system, apply all recommendations in this data sheet to the secondary system as well, except for those that pertain directly to the fuel fired heater or vaporizer itself. (In other words, Sections 2.2.2, 2.4.2.8, 2.4.10.2d, 2.4.10.8, 2.3.2, 2.5.3, 2.6.3, and 2.4.11 are not applicable to the secondary system.)

The recommendations for high temperature alarms and interlocks (Sections 2.4.10.1b, 2.4.10.1d, 2.4.10.1g) need only be applied to the secondary system if the primary system temperature can or does exceed the maximum recommended film temperature of the HTF used in the secondary system, or where unusually high temperatures of the HTF in the secondary system can lead to potentially hazardous conditions. To achieve the needed cessation of heat input to the secondary system, the primary system HTF flow through the heat exchanger must be stopped.

Recommendations in Sections 2.4.1.1 and 2.4.1.2 for temperature regulation and flow velocity need only be applied if the primary system temperature can or does exceed the maximum recommended film temperature of the HTF used in the secondary system.

2.5 Operation and Maintenance

2.5.1 System Commissioning/Routine Startup

2.5.1.1 Purge all piping, equipment, and reservoirs with an inert gas prior to charging the system with heat transfer fluid. Using inert gas that is heated can help vaporize more of the water trapped within the system, making for a more thorough job. Alternative procedures specified by the system supplier/designer may also be accepted if the same objectives are achieved.

2.5.1.2 Fill the system with heat transfer fluid slowly and from the bottom to avoid entrainment of air. In most cases the system circulating pump(s) will have too high a flow capacity and a small positive displacement pump must be used. Allow the heat transfer fluid to sit and warm up to at least room temperature before charging into a system. This will allow air bubbles, which may have been entrained in the viscous fluid during shipping, to rise out of the fluid. Alternative filling procedures specified by the system supplier/designer may also be accepted if the same objectives are achieved.

2.5.1.3 To ensure that the system will be leak-free when filled and pressurized with hot heat transfer fluid, conduct special leakage testing in addition to a hydrostatic test. Obtain details of leakage testing procedures from the manufacturer of the heat transfer fluid. (Note: A pipeline may pass a hydrostatic test and yet have leaks when the heat transfer fluid is used.)

2.5.1.4 Always bring the system to operating temperature slowly to avoid unusual stresses in the equipment and to prevent rapid vaporization of any trapped water that could lead to system overflow. Switch on the full heat output of the burners only after fully turbulent flow has been established within the heater or vaporizer tubes.

2.5.1.5 Perform hydrostatic testing of newly installed piping in accordance with the requirements of ANSI/ASME B31.1 or B31.3 codes or local jurisdictional requirements.

2.5.2 Normal Operation

2.5.2.1 Ensure the system is operated within the temperature and pressure limits specified by the supplier or manufacturer of the heat transfer fluid and by the manufacturer of the equipment. If operation above design (nameplate) conditions is desired, contact the equipment manufacturer so maximum safe operating conditions may be established, and so revised calculations verifying the new service conditions are made available and accepted by the authority having jurisdiction. Never compromise the safety factors and design contingencies. Also consult the HTF manufacturer so an alternative fluid can be selected if the new process conditions exceed the existing fluid's limitations.

2.5.2.2 Ensure system vaporizers and heaters are under automatic control and regulated by a temperature or pressure element in the outlet.

2.5.2.3 If it is suspected that the material being heated is infiltrating into the HTF loop, shut down the system and find the internal leakage point as soon as possible.

2.5.3 Routine System Verifications

2.5.3.1 Make a visual examination at least once daily of the inside of the heater or vaporizer combustion chamber using available observations ports to check for any HTF leaks (which would be burning) and to verify there is no damaged refractory. Check the appearance of the flame in a fired vaporizer or heater to ensure that it appears normal and is not impinging directly on any heat transfer surfaces, particularly after any change in load. Check tube surfaces as much as possible for evidence of overheating. Unusually colored tubes may indicate coking or plugging. Infrared scanners may also be used for a more precise examination.

2.5.3.2 After each fuel shutoff, check the inside of the combustion chamber for glowing tubes due to fouling and plugging, burning HTF from a leak, and fuel leaking past the safety shutoff valve(s).

2.5.3.3 If it can be done in a relatively simple manner, check the rate at which fuel flows to the heater or vaporizer daily to ensure the nameplate rating is not exceeded. If a more complex and time-consuming procedure is required, check the fuel flow rate when routine verifications of the combustion safety controls are made.

2.5.4 Heat Transfer Fluid Degradation And Monitoring

2.5.4.1 Test samples of the heat transfer fluid for impurities and/or degradation at least yearly. Consult the HTF manufacturer to help determine where in the system to take samples. The samples should ordinarily be sent to the supplier, although facilities with laboratories can make their own tests. Make a full internal inspection if tests of the heat transfer fluid indicate a significant level of impurities or thermal degradation.

2.5.5 Maintenance

2.5.5.1 Ensure any and all system leaks are corrected promptly, regardless of how small they may be. Make corrections of a permanent nature, such as repacking valve stems, replacing leaky gaskets, etc., as applicable. Ensure any fluid spilled from a leak or from safety valve operation is cleaned up immediately if it is or can come into contact with a hot or warm surface. Clean up other spills at the first available opportunity.

Ensure any pipe or equipment insulation that is discovered to be oil-soaked is promptly removed and replaced with clean, oil-free insulation, and the cause of the leak is corrected.

2.5.5.2 Ensure systems are shut down and allowed to cool before being opened to the atmosphere. Where freezing of cooled HTF is a concern, drain piping and/or equipment.

2.5.5.3 Use a permit system to control cutting and welding. Drain and clean (or inert) equipment or piping that is to be worked on. Blank off any pipes left disconnected during the work.

2.5.5.4 Ensure any openings in pipes or equipment, such as manholes, instrument ports, inspection ports, etc., are on the same inspection and maintenance schedule as all system flanges, equipment, seals, and other known potential leak points.

2.5.5.5 Disconnect safety valves at least once yearly, and inspect, repair or replace as necessary. Test them at the same time to be sure they open below the design pressure of the equipment. Refer to Data Sheet 7-49/12-65, *Emergency Venting of Vessels*, and Data Sheet 12-43, *Pressure Relief Devices*, for additional maintenance recommendations and details of acceptable test procedures. (Note: Safety valve inspection and testing is a requirement of the National Board Inspection Code, which has been adopted by all Canadian and most United States jurisdictions.)

2.5.5.6 Use extreme care when cleaning the outside of the tubes within the heater or vaporizer, to prevent doing any damage that could eventually result in tube leakage or rupture.

2.5.6 Annual Inspection and Testing

2.5.6.1 Make a regular inspection of the HTF heater or vaporizer as required by local jurisdictional requirements for boilers and pressure vessels.

As a minimum, perform the following regardless of jurisdictional requirements. Make an annual inspection of the fire side surfaces with the heater or vaporizer idle. It may not be possible to make an inspection of the internal surfaces. However, if a system is to be emptied, notify the regular boiler inspection agency so an inspection can be made.

In the event that any bulges or other indications of overheating are found during the inspection of the fire side surfaces, drain the heater or vaporizer and make an internal inspection to determine the cause of overheating and the condition of the heat transfer fluid. If an external inspection reveals carbon deposits, formed from flame impingement or faulty operation, or metal oxides and ‘‘fish scales’’ indicating high metal temperatures, then ensure cleaning is done following the equipment manufacturer’s recommended procedures.

Where construction permits, perform annual ultrasonic examination or eddy current testing to assess tube wall conditions for continued service.

2.5.6.2 Set up a periodic inspection schedule to verify the accuracy of system pressure gauges, perform needed calibration, and closely examine gauge glasses and other fittings for signs of leakage. Calibrate gauges at least yearly.

2.5.6.3 Ensure control devices and safety interlocks are inspected, calibrated, and tested (when practicable) at least yearly to ascertain they are in proper operating condition.

2.5.6.4 Conduct an annual leakage test by pressurizing the entire heat transfer system to 1½ times the working pressure, or to the maximum pump pressure, whichever is greater, but not exceeding the set pressure of the safety or safety relief valve having the lowest setting. HTF must be at ambient temperature if it is to be used as the medium for this test.

2.6 Training

2.6.1 Provide all operators involved with heat transfer systems with formal training detailing the proper operation of the heat transfer system along with emergency procedures to be taken in the event of all conceivable process control upsets and emergency conditions. Ensure operators are aware of hazards relating to heat transfer system misoperation and leakage. Ensure training should includes recognition of upset conditions that could lead to dangerous situations. Give refresher training to all operators at least annually.

2.6.2 Make complete operating manuals available where system operators are stationed, detailing normal and emergency procedures. Ensure emergency procedures include scenarios such as system leak or fire. Also ensure an emergency procedure is available for an orderly shutdown in the event that a small HTF leak is detected within the heater or vaporizer firebox.

2.6.3 Ensure operator training and the operating manual establishes the relationship between percentage of full firing rate, HTF temperature increase through the heater, and HTF flow rate through the heater, so that when a high HTF exit temperature condition is first detected, it can immediately be verified whether the overtemperature condition is due to HTF leakage within the firebox or a ‘‘normal’’ process upset. Have the operating manual specify a visual verification of the inside of the heater or vaporizer upon receipt of a high temperature alarm (flue gas or HTF exit temperature) or on observation of heavy (dark) smoke exhaust.

2.6.4 Make the Emergency Response Team (ERT) and fire service aware of the location of HTF piping and shutoff valves and proper fire fighting methods. Ensure the ERT is also aware of the freeze-up potential of the HTF.

2.6.5 Use a written permit system to ensure equipment shutdown and lockout during system maintenance and to control ignition sources during repairs to oil piping.

2.6.6 Ensure operating procedures specify shutdown of the heater or vaporizer fuel supply as soon as the HTF temperature anywhere in the system exceeds the fluid manufacturer’s recommended maximum bulk fluid temperature (Table 2). Any actions taken to correct a high temperature condition must be done with the heat source shut completely off.

2.6.7 Establish a written policy to indicate to operators that safety controls and interlocks must not at any time be bypassed, even at the expense of a system shutdown that might curtail production activities.

2.6.8 Do not use direct flame heating to thaw HTF that has frozen (i.e., temperature below the pour point) in system piping or equipment. Use general area heating, steam heating, or temporarily installed heat tracing.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

For the 10-year period from 1981 to 1990, FM Global loss experience shows 54 fire and explosion losses involving organic or synthetic heat transfer fluids. The gross loss amount was US$150,800,000. The average loss amount was US$3 million.

The dollar value distribution can be broken down as follows:

Less than US$100,000: 18 losses
US$100,000 to US$300,000: 15 losses
US$300,000 to US$1,000,000: 9 losses
US$1,000,000 to US$2,500,000: 1 loss
US$2,500,000 to US$5,000,000: 6 losses
more than US$5,000,000: 5 losses (US$10.9 million, US$16.8 million, US$27.2 million, US$31.0 million, US$32.8 million)

As can be seen from the figures above, many incidents do not result in very substantial damage. (30% were below US$100,000) This is probably due to the fact that the systems on the whole are quite well engineered and constructed. However, they are prone to leakage due to the high system temperatures and pressures and due to low fluid surface tension and viscosity. These smaller noncatastrophic leaks do result in fires, but are typically of a relatively low severity in otherwise well-protected facilities.

There are 12 losses in the multi-million dollar range, with 11 of these exceeding US$2.5 million. This reinforces the lesson learned from examining the details of the losses: that when some system component experiences a catastrophic failure, a catastrophic fire or explosion is usually the result. These systems have the potential for great destruction, as they involve the pumping of hot flammable liquids in conjunction with one or more unfavorable factors, such as: HTF virtually always well above the flash point; systems often have large holdups and high flow rates; piping and user equipment are located throughout the plant; and piping and user equipment are adjacent to other important equipment or nearby combustibles.

Because of this inherent high severity potential, these systems need to have all aspects of design, installation, maintenance, and operation adhere to the highest possible standards.

Of the 54 HTF losses recorded, 49 were fires, four were room explosions due to HTF release, and one was a gas explosion involving a fuel-fired HTF heater.

One of the most common leakage and subsequent fire causes that could be easily prevented is the improper siting of a discharge outlet from a system breather vent or safety valve. This is the most likely site of liquid or vapor evolution in the event of a minor or major process upset. Yet, this has been implicated in numerous fires due to discharge directly into facility areas. Any inspection or plan review of a heat transfer system should pay particularly close attention to these easily identifiable potential danger points. (See Recommendations 2.4.3.5 and 2.4.9.2.)

A study was done by one manufacturer of heat transfer fluids that also reveals some interesting facts. Their 3-year study found 23 fires among the users of their fluids alone. This would tend to indicate the frequency of HTF fires is even much higher than the frequency suggested by the FM Global loss data. (This is doubtless due to the fact that FM Global loss data consists only of incidents that are reported and the percentage of incidents reported would be well below 100% due to the effect of deductibles. Furthermore, FM Global loss experience represents only a portion of the total industry loss experience.)

The study also established the cause for 22 out of 23 of these fires. Operation/misoperation of the system was the primary cause for 5 of the fires (23%), system design was the primary cause for 5 of the fires (23%), and system maintenance was the primary cause for 12 of the fires (54%).

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-10, *Interaction of Sprinklers, Smoke and Heat Vents, and Draft Curtains*
Data Sheet 1-44, *Damage-Limiting Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 4-0, *Special Protection Systems*
Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems (NFPA)*
Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*
Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
Data Sheet 6-4, *Oil-and Gas-Fired Single Burner Boilers*
Data Sheet 6-5, *Oil-or Gas-Fired Multiple Burner Boilers*
Data Sheet 6-7, *Fluidized Bed Combustors and Boilers*
Data Sheet 6-10, *Process Furnaces*
Data Sheet 6-13, *Waste Fuel-Fired Boilers*
Data Sheet 7-14, *Fire & Explosion Protection for Flammable Liquid, Flammable Gas & Liquefied Flammable Gas Processing Equipment & Supporting Structures*
Data Sheet 7-32, *Flammable Liquid Operations*
Data Sheet 7-49, *Emergency Venting Of Vessels*
Data Sheet 7-59, *Inerting and Purging of Tanks, Process Vessels and Equipment*
Data Sheet 7-83, *Drainage Systems for Flammable Liquids*
Data Sheet 7-88, *Storage Tanks for Flammable and Combustible Liquids*
Data Sheet 9-18/17-18, *Prevention of Freeze-Ups*
Data Sheet 12-43, *Pressure Relief Devices*

4.2 Others

ANSI/ASME B31.1, *Power Piping*
ANSI/ASME B31.3, *Chemical Plant and Petroleum Refinery Piping*
ASME Boiler and Pressure Vessel Code
NFPA 12, *Carbon Dioxide Extinguishing Systems*
NFPA 497A *Classification of Class I Hazardous (Classified) Locations for Electrical Installations and Chemical Process Areas*
National Electrical Code Article 500

APPENDIX A GLOSSARY OF TERMS

AFFF: aqueous film forming foam.

FM Approved: References to "FM Approved" in this data sheet mean the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, a publication of FM Approvals, for a complete listing of products and services that are FM Approved.

HTF: heat transfer fluid.

APPENDIX B DOCUMENT REVISION HISTORY

January 2009. Minor editorial change was made in Table 2.

January 2006. Minor editorial changes were made for this revision.

May 2003. Minor editorial changes were made for this revision.

September 2001. Recommendation 2.2.1 had additional guidance added on the application of Data Sheet 1-44 for the design of damage-limiting construction.

September 2000. This revision of the document has been reorganized to provide a consistent format.

APPENDIX C NFPA STANDARDS

There are presently no NFPA standards that cover this subject. NFPA 664, *Woodworking*, contains a chapter on HTF systems, that requires only a small fraction of the measures detailed in this data sheet. FM Global has made a public proposal to the NFPA 30 committee (Flammable Liquids Code) to incorporate some material from this data sheet into the 2002 version of NFPA 30.

APPENDIX D TABLE OF HEAT TRANSFER FLUID PROPERTIES

The table of heat transfer fluid properties in the data sheet contains all of the information available to FM Global as of the date of data sheet publication. Users of this data sheet are requested to submit to FM Global any data they might obtain that fills in the information gaps. If possible, include the original reference (MSDS, etc.) when submitting the information.

Table 2. Properties of Heat Transfer Fluids (HTFs)

Fluid	*Composition*	*Maximum Temperature or Temperature Range °F (°C)*		*Autoignition Temp. (AIT) °F (°C)*	*Pour Point (Crystal Point) °F (°C)*	*Boiling Point °F (°C)*	*Flash Point °F (°C)*	*Fire Point °F (°C)*
		Bulk	*Film*					
Bayer "Diphyl"	Same as Dowtherm A			1139 (615)		495 (257)	239 (115)	
Caloria HT 43	Solvent dewaxed hvy. paraffinic distillate, petroleum	600 (316)	680 (360)	670 (354)	20 (–6)	560 (293)	390 (199)	430 (221)
Chevron Heat Transfer Oil 1	Mineral type	550 (290)	600 (315)		5 (–15)		455 (235)	470 (243)
Chevron Heat Transfer Oil 20	Mineral type	600 (315)	700 (371)		5 (–15)		390 (199)	444 (229)
Chevron Heat Transfer Oil HT	Mineral type	600 (315)	650 (343)		16 (–9)		470 (243)	520 (271)
Dow Corning 200	Silicone oil						275[a] (135)	
Dowtherm A	Eutectic mixture of diphenyl and diphenyl oxide	60–750[b] (15–399) 495–750[c] (257–399)	800 (427)	1139 (615)	53 (12)	494.8 (257)	235 (113)	245 (118)
Dowtherm G	Di- and tri-aryl ethers	20–700 (–7–371)	750 (399)	1083 (584)	–40[d] (–40)	575 (302)	266 (130)	275 (135)
Dowtherm HT	Partially hydrogenated terphenyl	25–650 (–3–343)		662 (350)	25[d] (–4)	650 (343)	342 (172)	375 (191)
Dowtherm J	Alkylated aromatic	–100–600[b] (–73–315) 358–600[c] (181–315)		788 (420)	–100[d] (–73)	358 (181)	136 (58)	140 (60)
Dowtherm LF	Aromatic blend	–40–650 (–40–343)	675 (357)	880 (471)	–40[d] (–40)		248 (120)	259 (126)
Dowtherm Q	Mixture of diphenylethane & alkylated aromatics	–30–625 (–34–329)	675 (357)	773 (412)	–30[d] (–34)		249 (121)	255 (124)
Essotherm N69						707 (375)	470 (234)	
Marlotherm L	Mixture of isomeric benzyltoluenes	662 (350)	698 (320)		–94 (–70)	536 (280)	248 (120)	
Marlotherm S	Mixture of isomeric dibenzyltoluenes	662 (350)	698 (370)	>932 (500)	–31 (–35)	734 (390)	374 (190)	

Fluid	*Composition*	*Maximum Temperature or Temperature Range °F (°C)*		*Autoignition Temp. (AIT) °F (°C)*	*Pour Point (Crystal Point) °F (°C)*	*Boiling Point °F (°C)*	*Flash Point °F (°C)*	*Fire Point °F (°C)*
		Bulk	*Film*					
Mobiltherm 600		10–600 (–12–316)			5 (–15)	735 (391)	350 (177)	
Mobiltherm 603	Refined mineral oil	25–550 (–7–288)	625 (329)	670 (354)	20 (–7)	680[e] (360)	380 (193)	
Mobiltherm 605		25–600 (–7–316)			5 (–15)	750 (399)	400 (204)	
Mobiltherm Light		–15–400 (–26–204)			–20 (–29)	485[f] (252)	240 (116)	
Monsanto MCS2424	Synthetic aromatic	0–750[b] (–18–399)	805 (429)	1085 (585)	0 (–18)	520 (271)	270 (132)	290 (143)
Multitherm 503	Polyalphaplefin (Synthetic hydrocarbon)	500 (260)		613 (324)	–75 (–60)	625 (329)	320 (160)	345 (174)
Multitherm IG-2	Single-cut paraffinic oil	600 (316)	650 (343)	700 (371)	0 (–18)	658 (348)	440 (227)	500 (260)
Multitherm PG-1[g]	White mineral oil. USP/NF[h]	600 (316)	640 (338)	690 (366)	–40 (–40)	600 (316)	340 (171)	385 (196)
Para-Cymene		600 (316)		817 (436)	–100 (–73)		117 (47)	152 (67)
Paratherm F.P.						600 (316)	340 (171)	
Paratherm HE	Solvent refined single cut paraffinic oil	600 (316)	650 (343)	700 (371)	0[i] (–18)	658 (348)	440 (227)	500 (260)
Paratherm NF	NF/USD Grade White Mineral Oil[h]	150–600 (66–316)	640 (338)	690 (366)	–45 (–43)	620[j] (327)	345 (174)	385 (196)
Petro-Canada Calflo	Paraffinic oil					671[k] (355)	439 (226)	
Sunoco 21[l]				600 (315)			455 (235)	
Syltherm 800	Modified dimethylsiloxane polymer	–40–750 (–40–399)	800 (427)	725 (385)	–76[m] (–60)		125[n] (52)	380 (193)
Syltherm XLT		500 (260)	550 (288)	662 (350)	–135 (–93)		130 (54)	
Syntrel 350		600 (316)	700 (371)	770 (410)	–29 (–34)		381 (194)	403 (206)
Texatherm 46		600 (316)	640 (338)		5 (–15)		430 (221)	
Thermia B						572 (300)	379 (193)	
Thermia C(33)		500 (260)		625[o] (329)	10 (–12)	680[p] (360)	455 (235)	490[o] (254)
Therminol 55	Synthetic hydrocarbon mixture	–15–550 (–26–288)	605 (318)	675 (357)	–40 (–40)	635[f] (335)	350 (177)	410 (210)
Therminol 59	Alkyl substituted aromatic	600 (316)	650 (343)	770 (410)	–90 (–68)	590[d] (310)	302 (150)	335 (168)
Therminol 60	Polyaromatic compounds	–60–620 (–51–327)	655 (346)	835 (446)	–90 (–68)	550[d] (288)	275 (135)	320 (160)
Therminol 66	Modified polyphenyl	20–650 (–7–343)	705 (374)	705 (374)	–15 (–26)	643[f] (339)	350 (177)	380 (193)

Fluid	*Composition*	*Maximum Temperature or Temperature Range °F (°C)*		*Autoignition Temp. (AIT) °F (°C)*	*Pour Point (Crystal Point) °F (°C)*	*Boiling Point °F (°C)*	*Flash Point °F (°C)*	*Fire Point °F (°C)*
		Bulk	*Film*					
Therminol VP-1	73.5 diphenyl oxide 26.5 biphenyl	495–750[c] (257–399) 54–750[b] (12–389)	800 (427)	1150 (621)	54 (12)	495 (257)	255 (124)	260 (127)
Therminol 44	Modified ester-based fluid	–60–400 (–51–204)	475 (246)	705 (374)	–80 (–62)	638[f] (337)	405 (207)	438 (226)
Therminol 75	Polyphenyl	160–750 (71–399)	805 (429)	1000 (538)	158 (70)	492[f] (256)	390 (199)	440 (227)
Therminol XP	White mineral oil, USP/NF[h]			615 (324)	–7[q] (–19)	630[f] (332)	360 (182)	385 (196)
UCON HTF-500	Polyalkylene glycol	500 (260)	>550 (288)	750 (399)	–65 (–54)	513[r] (267)	540 coc (282) 471 Pensk-Mart (244)	600 (316)

Note: [a]From FM Global loss data base
[b]Liquid-phase systems
[c]Vapor phase systems
[d]This fluid will tend to supercool or form crystals but not freeze solid
[e]From FM Global loss data base
[f]Reported as 10% boiling range by mfgr. (i.e., 10% distilled)
[g]Reported by manufacturer to be "non-Fouling"
[h]USP = United States Pharmacoepia/NF = National Formulary; indicators of purity
[i]Available with -35°F (–37°C) pour point.
[j]10% fraction, ASTM D-1160
[k]Boiling point found to have decreased to 523°F (273°C) when a sample of aged (used) fluid was tested (From FM Global loss data base).
[l]From FM Global loss data base
[m]Thermal tracing of N_2 and vapor-carrying lines and valves to and from the expansion tank is required because one compound of the vapor will crystallize at 142°F (61°C) and cause plugging
[n]Although the flash point of virgin fluid is 350°F (177°C), operation at or above the equilibrium vapor pressure will cause a build up of low molecular weight materials which eventually reach a constant concentration, giving a closed cup flash point of approximately 125°F (52°C)
[o]From FM Global loss data base
[p]From FM Global loss data base
[q]Reported by manufacturer as "low temp pumpability"
[r]Decomposition temperature

APPENDIX E BIBLIOGRAPHY

Dow Chemical Co. *Engineering Manual for DOWTHERM Heat Transfer Fluids.* Form No. 176-1334-591 AMA, 1991.

Dow Chemical Co. *Health, Environmental, and Safety Considerations in High Temperature Heat Transfer Fluid Systems.* Form No. 176-1336-87, 1987.

Green, R. L., and A. H. Larsen, et. al. "Get Fluent About Heat Transfer Fluids." *Chemical Engineering* Vol. 96, No. 2 (February 1989).

Green, R. L. and D. E. Dressel. *Heat Transfer Fluid Fires and Their Prevention in Vapor Thermal Liquid Systems*. Paper No. 9d, presented at the 1989 Spring National Meeting of the American Institute of Chemical Engineers.

Mobil Oil Company. *Heating with Mobiltherm Heat-Transfer Oils*. Mobil Technical Bulletin.

Paratherm Corp. *Fire Prevention in Thermal Oil Heat Transfer Systems*. Paratherm Technical Data publication, Rev. 500.

Wagner, Walter. *Heat Transfer Practice with Organic Media*. 2nd ed. New York: Begell House, 1997.