HEAT TRANSFER FLUID SYSTEMS

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1.0 SCOPE

This data sheet provides loss prevention guidance for heat transfer fluid (HTF) systems using a fluid medium that is considered an ignitable liquid or flammable vapor (thermal oil or hot oil). Often, HTF systems use organic and synthetic-based fluids to support production equipment or recover thermal energy by heating and/or cooling. The fluids are in closed systems, often operating above their flash points in a liquid phase, with some systems operating well above their normal boiling point (NBP) in vapor phase.

If an occupancy-specific data sheet offers **fire protection** guidance for HTF equipment areas that differs from this data sheet (7-99), apply the guidance in the occupancy-specific data sheet. Apply the guidance in this data sheet (7-99) to the remaining HTF equipment areas. Several occupancy-specific data sheets exist for production systems and equipment (e.g., heat consumers):

- Data Sheet 6-9, *Ovens and Dryers*
- Data Sheet 7-4, *Paper Machines and Pulp Dryers*
- Data Sheet 7-10, *Wood Processing and Woodworking Facilities*
- Data Sheet 7-20, *Oil Cookers*
- Data Sheet 7-36, Pharmaceutical Operations

This data sheet does not apply to heat transfer systems using the following solutions:

- For alkali salt solution, refer to Data Sheet 7-85, *Combustible and Reactive Metals*.
- For glycol solutions, refer to Data Sheet 7-32, *Ignitable Liquid Operations, for fire and explosion protection guidance*.

1.1 Application

The fire and explosion hazard loss prevention concepts in this data sheet are based on Data Sheet 7-32, *Ignitable Liquid Operations*. In order to focus on unique HTF system hazards and exposures, Data Sheet 7-32 references were incorporated in this data sheet when guidance remains unchanged.

The fire, explosion, and boiler & machinery guidance offered in this data sheet is geared towards larger or more complex HTF systems that may consist of multiple primary loop(s) and/or secondary loops, or single loop systems containing a large fluid volume. Since a direct relationship exists between the volume of fluid released and the resulting fire severity, these larger, more complex systems often warrant more robust ignitable liquid safeguards.

1.2 Hazard

Similar to other ignitable liquid hazards, ceiling sprinklers alone will not extinguish pool, spray, or three-dimensional spill fires involving ignitable liquids unless the quantity of fluid released is limited. A direct relationship exists between the volume of ignitable liquid or fluid released and the resulting fire severity (i.e., intensity and/or duration). Additional ignitable liquid safeguards, beyond ceiling sprinklers, are often required to limit the initial pressurized fluid release duration; manage the released fluid to prevent fire spread and thermal damage; and minimize the potential for secondary fluid or other ignitable liquid release points as well as a long gravity release following depressurization. If a major fluid release occurs and/or the fluid fire spreads to adjacent combustibles, the fire scenario may escalate to an uncontrolled fire significantly increasing property damage and recovery duration. A major fluid release is relative to the protection afforded along with the exposure posed to the surrounding occupancy.

1.3 Changes

October 2026. Interim revision. Guidance for damage limiting construction (DLC) was aligned with Data Sheet 7-32, *Ignitable Liquid Operations.*

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2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 General

2.1.1.1 Use FM Approved equipment, materials, and services whenever applicable. Select and install FM Approved products and services in accordance with their *Approval Guide* or Roof*Nav* listing. For available products and services that are FM Approved, refer to the *Approval Guide* and Roof*Nav*, online resources of FM Approvals.

2.1.2 Fluid Evaluation

2.1.2.1 When feasible, use either a (heat transfer) fluid that does not have a flash point and a fire point (i.e., nonignitable liquid), or an FM Approved industrial fluid. When a nonignitable liquid or FM Approved fluid is used, provide fire protection based on the surrounding occupancy.

2.1.2.2 Evaluate and provide room explosion protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

2.1.3 System Evaluation

2.1.3.1 If a fluid release can not be depressurized or isolated in response to a fluid fire emergency and conditions in A and B below are not present, provide fire and explosion protection in accordance with Data Sheet 7-14, *Fire Protection at Chemical Plants*. Alternatively, if the fluid release can not be depressurized or isolated in response to a fluid fire emergency and conditions A and B are present, provide fire protection for HTF equipment areas per sections 2.2 through 2.6 of this data sheet.

A. The total fluid volume within the HTF system is 660 gal (2,500 L) or less.

B. Continued fluid circulation is required as part of the heater shutdown sequence to prevent tube coking (e.g., in bulk, solid-fired heaters). Though circulation is not immediately stopped, the shutdown sequence should include reduced fluid circulation followed by depressurization of the fluid circuit once internal temperatures permit.

Occasionally interruption of fluid circulation can pose a greater hazard than a sustained pressurized fluid release and fire. For example an HTF system supplying cooling for a chemical reaction where discontinuing HTF cooling for the reactor may result in a pressure vessel rupture.

2.1.3.2 Apply the fire protection guidance in this data sheet to HTF equipment areas. In general, the fire protection guidance contained within this data sheet is intended for HTF equipment areas subject to a major fluid release with ″major″ relative to the protection afforded along with the exposure posed to the surrounding occupancy.

If the fluid release is inherently small given the total fluid volume in the system, the fluid fire hazard may be managed by less robust fire protection than that offered in section 2.1.3.2.1 (very small system) and 2.1.3.2.2 (small system), provided the following exposures are not present.

A. Critical production or support (HTF) equipment exposed within the fire area is susceptible to damage by direct flame impingement resulting in a lengthy production outage without an equipment contingency plan.

B. The surrounding occupancy is highly susceptible to smoke and water damage. Examples of such occupancies may include pharmaceutical production, electronics manufacturing, or food & beverage processing.

C. The HTF fire exposes adjacent combustibles capable of escalating the fluid fire to uncontrolled fire. Examples of such combustibles include rack storage or combustible building construction (e.g., wood roof, Class 2 insulated steel deck roof, or non-approved fiber-reinforced panels).

A small fluid fire in the wrong areas can have a significant impact on property and production. When a fluid release from a smaller system results in a increased exposure, more robust ignitable liquid protection, closer to that offered in sections 2.2 through 2.6, may be needed to better manage the fluid fire risk.

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2.1.3.2.1 In the absence of the exposures listed in 2.1.3.2, apply the following fire protection guidance for HTF systems containing a total fluid volume less than 70 gal (265 L).

A. Provide spill containment around primary loop equipment (e.g., heater as well as expansion tank and circulation pumps). When feasible, provide spill containment at the use point as well (i.e., when not presenting a trip hazard).

B. Provide automatic sprinkler protection per the surrounding occupancy, but not less than HC-2 per Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*.

C. Provide a fire detection interlock within the HTF equipment area(s) to automatically shutdown the heater and de-energize the circulation pump. Additionally, upon interlock initiation, have an alarm surface at a constantly attended location.

D. Test the fire detection interlock at least annually. A functional test of the interlock is preferred, but simulated or loop testing is acceptable.

2.1.3.2.2 In the absence of the exposures listed in 2.1.3.2, apply the following fire protection guidance for HTF systems containing a total fluid volume between 70 gal (265 L) and up to 660 gal (2,500 L).

A. Locate the primary loop equipment within a cutoff room constructed in accordance with Data Sheet 7-32 (e.g., heater as well as expansion tank and circulation pumps).

B. Provide spill containment around the primary loop equipment (e.g., heater as well as expansion tank and circulation pumps). When feasible, provide spill containment at the use point as well (e.g., when not posing a trip hazard).

C. Provide automatic sprinkler protection over HTF equipment areas in accordance with HC-3 in Data Sheet 3-26.

D. Provide a single quick-response, ordinary temperature rated K5.6 (80) or larger sprinkler within 2 ft (0.6 m) above the fluid circulation pump.

E. Provide thermal protection for any steel columns supporting the building or equipment within the fire area in accordance with Data Sheet 7-32.

F. Provide interlocks to automatically respond to HTF system upset conditions listed in Table 1. Additionally upon interlock initiation, have an alarm surface at a constantly attended location.

Table 1. Interlock Conditions for Small Systems

Mishap	*Upset Condition (Interlock)*	*Measurement Location (Applicability)*
Fluid Release and Internal Heater Fire	High Flue Gas Exhaust Temperature[1] (Tube Leak)	Flue Gas Path (Fluid-Tube)
Heater Dry Fire	Low Pressure or Flow[2]	Outlet (Fluid-Tube)
	Low Level	Heating Chamber (Fluid-Shell)
Heater Overheating	High Temperature or Pressure[3]	Outlet
Heater Fuel Explosion	Refer to the appropriate fuel-fired equipment Data Sheet.	
Pump Cavitation	Low Level	Expansion Tank (Elevated)
Fluid Release (From System)	Low Level	Expansion Tank
Fluid Release and Fire in HTF Equipment Area	Fire Detection[4]	HTF Equipment Area

Note 1. Set the high flue gas exhaust temperature (stack excess temperature limit) interlock at a temperature close as possible to the operating limit for the heater system but at most 100°F (56°C) above. Establish the flue gas temperature operating limit based on heater OEM and/or fluid supplier guidelines.
Note 2. Set the low pressure or flow interlock based on the minimum flow needed to achieve sufficient turbulent flow and/or adequate cooling of heat transfer surfaces (tube walls).
Note 3. Set the high temperature or pressure interlock based on the operating limits established by the heater OEM (maximum operating temperature) and/or fluid supplier (maximum bulk and/or film temperature).
Note 4. Fire detection options may include spot or linear heat, radiant-sensing, or video-smoke/flame sensing. Another option is to utilize a fire protection system actuation alarm such as a sprinkler waterflow alarm.

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G. Initiate the appropriate corrective actions listed below automatically upon reaching an interlock condition in Table 1. The intent is for the interlock to drive the equipment and/or system to a safe state automatically. The appropriate interlock corrective actions and defined safe state depend on the production equipment supported, HTF system, and anticipated fluid release and fire scenarios. At a minimum perform the following within small systems.

1. Shutdown heat input to the heater (e.g., isolate burners and de-energize electrical heating elements).
2. Deenergize fluid circulation pumps, if provided.
3. Isolate fluid hold-up available for a gravity release through a system low-point (e.g., close safety shutoff valves as shown in Figures 1 and 2).

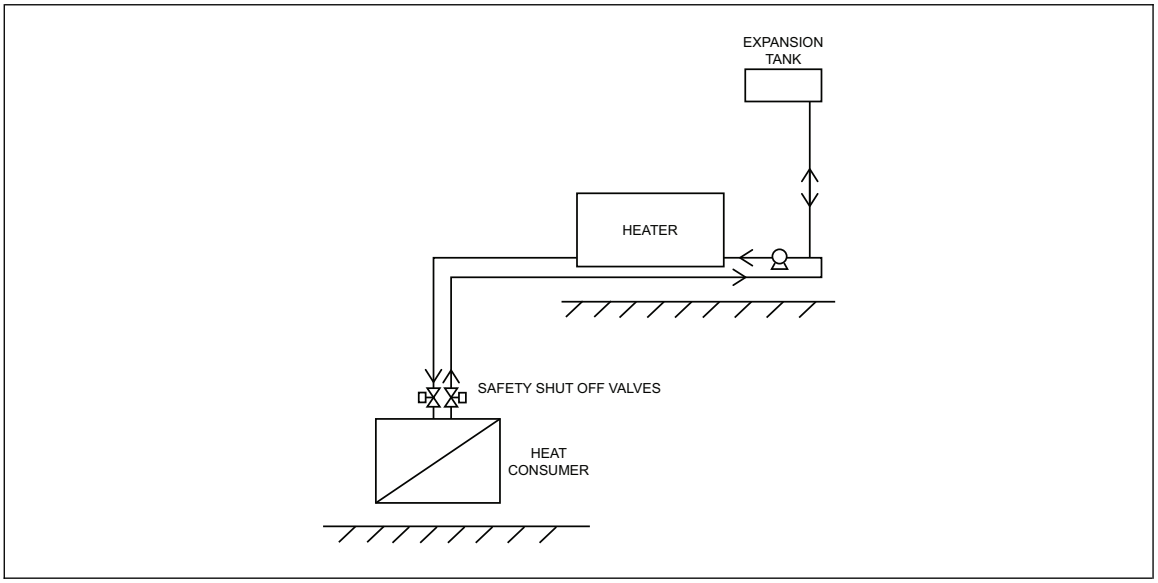


Fig. 1. Example of heat consumer isolation from an elevated HTF supply

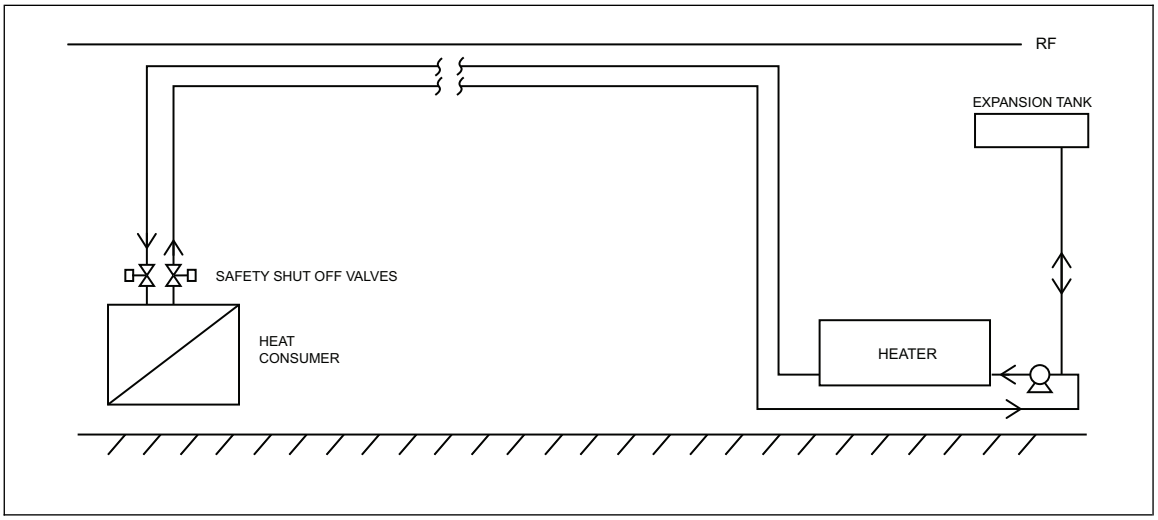


Fig. 2. Example of heat consumer isolation from elevated transfer piping

H. Provide a means to manually initiate the appropriate interlocked actions listed in Section 2.1.3.2.G using an emergency stop button in at least one remote location that will remain accessible under anticipated fire conditions.

I. Design and install system piping using materials and joints in accordance with ASME B31.3 or local equivalent.

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J. Install flexible hoses and expansion joints within the HTF system designed in accordance with Data Sheet 7-32.

K. Use nonabsorbent, noncombustible insulation (e.g., cellular glass).

L. Route discharge from pressure relief devices such as safety valves or safety relief valves to a safe location such as a properly arranged catch tank.

M. Implement an emergency response plan (ERP) for the prompt and effective reaction to a HTF fire or explosion in accordance with Data Sheet 10-1, *Pre-Incident Planning and Emergency Response* and the following.

1. Develop the plan addressing the fluid release and fire scenarios for HTF equipment areas as well as other combustibles that may become involved.
2. Specify response actions and assign those responsibilities to personnel. Example actions include the following.
   a. Applicable actions listed in sections G.
   b. Confirm any fire or system interlocks respond as intended, and if any interlocks failed to do so or are not present, manually initiate the respective response.
   c. Confirm fire protection system operation, and if the system failed to do so automatically, manually actuate the system.
   d. Isolate any fuel supplies to the fire area.

N. Test the fire detection interlock at least annually. A functional test of the interlock is preferred, but simulated or loop testing is acceptable.

O. Test fire detection devices and/or systems used to initiate a fire detection interlock in accordance with Data Sheet 5-48, *Automatic Fire Detection*.

P. Test all other system interlocks at least annually via a functional or simulated test.

Q. Design, install, and maintain fuel-fired heaters in accordance with the relevant FM Data Sheet.

R. Sample and test heat transfer fluid per OEM guidelines but at least annually. Retain records details on fluid sampling procedure, test results, and fluid treatment activities (e.g., fluid filtration or regeneration).

2.2 Location and Construction

2.2.1 Isolate indoor and outdoor HTF equipment areas from other areas of the facility in accordance with Data Sheet 7-32. Locations 1 and 2 are recommended for primary loop equipment given their frequency and severity of fires and explosions (e.g., heaters as well as any expansion tanks and primary circulation pumps).

2.2.2 Do not locate fuel fired equipment such as a heater within areas electrically hazardous/classified.

2.2.3 Construct detached buildings and cutoff rooms containing HTF equipment in accordance with Data Sheet 7-32.

2.2.3.1 When a fuel-fired heater is located in a cutoff room, construct interior walls using reinforced masonry, concrete, or other wall system affording some resistance to room overpressure and projectile penetration. Ordinary gypsum board walls provide virtually no impact resistance.

2.2.4 Protect steel columns where a fluid/liquid pool fire will affect all four sides of the column in accordance with Data Sheet 7-32. Columns may be supporting the building, process structure, and/or elevated process equipment.

2.2.5 For outdoor heaters with a heating capacity greater than 20 MM BTU/HR (5.9 MW), provide thermal protection for steel columns supporting the heater in accordance with Data Sheet 7-14. Extend protection at least 3 ft. above the pad.

2.2.6 Provide ignitable liquid spill containment and emergency drainage for indoor and outdoor HTF equipment areas in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*. Additionally, refer to section 2.4.3 for containment and drainage guidance around expansion tanks.

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2.3 Protection

2.3.1 Sprinkler Protection

2.3.1.1 Provide non-storage automatic sprinkler protection over indoor and outdoor HTF equipment areas designed and installed in accordance with Data Sheet 7-32. Select the appropriate sprinkler protection scheme for the given system and fluid application (i.e., hazards present, fluid flash point, presence of drainage, and protection goal).

2.3.2 Heater Internal Protection

2.3.2.1 Provide fire protection within heaters when either of the following situations is present: (1) the heater is bulk, solid-fuel fired; or (2) a heater equipment contingency plan involving a workaround with rental heater(s) is not feasible to support production until the subject heater is repaired or replaced.

2.3.2.2 Install a fine water spray system actuated automatically when two heater upset conditions that indicate a tube leak such as high flue gas exhaust temperature, abnormal emissions, and high differential fluid flow (in-out). Use of voting logic is tolerable as is up to a 10-minute delay for operators to respond and possibly resolve the upset condition(s) prior to actuation. Voting logic may be two of three duplicate sensors monitoring for a given condition or two of three conditions. Determine sensor trip settings based on input from the heater OEM. Upon protection actuation, initiate the appropriate HTF system actions discussed in section 2.4.1 (e.g., shutdown the heater).

2.3.2.3 Provide a means of manually actuating the fire protection system from the HTF system control panel and at least one remote location that will be readily accessible under anticipated fire conditions. Refer to section 2.5 for guidance on human element programs involved with manual emergency response and emergency operating procedures.

2.3.2.4 Design and install the automatic fine water spray system in accordance with Data Sheet 4-1N, *Fixed Water Spray System for Fire Protection*, relevant equipment listings in the FM *Approval Guide* and the following recommendations.

A. Install fine water spray coverage within the following portions of the heater: bulk, solid-fuel combustion chamber; volumes containing fluid-tubing (i.e., heat exchanger); internal locations where released fluid may pool or collect; and downstream flue gas ductwork or emissions equipment where fluid vapor may condense or need cooling during the fire. Typically, the protected volume includes the combustion chamber, convective passes, and flue exhaust ductwork up to the exhaust stack.

B. Position and orient nozzles in a manner that limits the potential of a water spray stream from impinging upon or dripping onto hot internal surfaces such as refractory or tubing.

C. Design the fine water spray system to discharge until the fluid circulation is shutdown, internal surfaces have sufficiently cooled to prevent reignition of unburnt fluid, and any remaining bulk, solid-fuel is consumed or wetted.

D. Perform acceptance testing of the protection system in accordance with Data Sheet 4-0, *Special Protection Systems*.

E. At a minimum, design the fine water-spray system to deliver at least 4 to 8 lb/min (0.64 to 1.3 kg/min/m^3) for every 100 ft^3 (2.8 m^3) of protected volume, which corresponds to a volumetric flow rate of 0.5 to 1.0 gpm (1.9 to 3.8 L/min) per 100 ft^3 (2.8 m^3).

2.3.3 Manual Protection

2.3.3.1 Provide manual fire protection systems and equipment (firefighting) based on established first responder pre-incident plans and emergency response plans. Consider the following manual firefighting systems and equipment.

A. Hoses to attack a fluid fire in HTF equipment areas from at least 2 opposing directions. Of particular importance is outdoor equipment not protected by automatic fire protection systems.

B. Firefighting foam to attack a fluid fire in HTF equipment areas.

C. Enable access to heater volumes containing fluid or where released fluid may collect.

D. Provide foam fire extinguishers for incipient fires.

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2.4 Equipment and Process

2.4.1 Interlocks and Permissives

Tables 2 and 3 contain upset or emergency conditions for which automatic corrective action is needed to drive the system and/or equipment to a safe state to protect production equipment and HTF equipment areas. The interlock setpoints may vary depending on application and OEM guidance, as will the appropriate system response and definition of safe state. Refer to section 2.4.1.4 for a list of corrective actions to be considered.

2.4.1.1 Provide interlocks to automatically respond to the primary loop upset conditions listed in Table 2. Additionally, upon interlock activation, have an alarm surface at a constantly attended location.

Table 2. Interlock Conditions for Primary Loops (Large System)

Mishap	*Upset Condition (Interlock)*	*Measurement Location (Applicability)*
Fluid Release and Internal Heater Fire	High Flue Gas Exhaust Temperature[1] (Tube Leak)	Flue Gas Path (Fluid Tube)
HeaterDry Fire	Low Pressure or Flow[2]	Outlet (Fluid-Tube)
	Low Level	Heating Chamber (Fluid-Shell)
Heater Overheating	High Temperature or Pressure[3]	Outlet
HeaterFuel Explosion	Refer to the appropriate fuel-fired equipment Data Sheet.	
Pump Cavitation	Low Pressure (Inert Gas)	Expansion tank head space
	Low Level	Expansion Tank (Elevated)
System Fluid Release	Low Level	Expansion Tank
Fluid Overflow From Expansion Tank	High Level or High Temperature	Expansion Tank
Fluid Release and Fire in HTF Equipment Area	Fire Detection[4]	HTF Equipment Area

Note 1. Set the high flue gas exhaust temperature (a.k.a., Stack Excess Temperature Limit) interlock at a temperature close as possible to the operating limit for the heater system but at most 100°F (56°C) above. Establish the flue gas temperature operating limit based on heater OEM and/or fluid supplier guidelines.
Note 2. Set the low pressure or flow interlock based on the minimum flow needed to achieve sufficient turbulent flow and/or adequate cooling of heat transfer surfaces (tube walls).
Note 3. Set the high temperature or pressure interlock based on the operating limits established by the heater OEM (maximum operating temperature) and/or fluid supplier (maximum bulk and/or film temperature).
Note 4. Fire detection options may include spot or linear heat, radiant-sensing, or video-smoke/flame sensing. Another option is to utilize a fire protection system actuation alarm such as a sprinkler waterflow alarm.

2.4.1.2 Provide interlocks to automatically respond to the secondary loop and/or heat consumer upset conditions listed in Table 3. Additionally, upon interlock initiation, have an alarm surface at a constantly attended location.

Table 3. Interlock Conditions for Secondary Loop and Heat-Consumer (Large System)

Mishap	*Upset Condition (Interlock)*	*Measurement Location*
Fluid Release and Internal Fire (Tube Leak)	High Enclosure/Exhaust Temperature[1]	Heat Consumer Enclosure
Fluid Release and Fire in HTF Equipment Area	Fire Detection[2]	HTF Equipment Area

Note 1. Trip when enclosure temperature reaches approximately 50-100°F (28-56°C) above the maximum operating temperature.
Note 2. Fire detection options may include spot or linear heat, optical, and thermal imaging. Another option is to utilize a fire protection system actuation alarm such as a sprinkler waterflow alarm. Refer to Data Sheet 7-98 for fire detector design and installation guidance.

2.4.1.3 For the interlocks listed in Table 2 and 3, provide an alarm at an intermediate threshold between normal operating condition and interlock setpoint to afford operators the opportunity to intervene prior to reaching the upset condition. An intermediate alarm is not feasible for fire detection.

2.4.1.4 Initiate the appropriate corrective actions listed below automatically upon reaching an interlock condition listed in Tables 2 and 3. The intent is for the interlock to drive the equipment and/or system to a

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safe state automatically. The appropriate corrective actions and defined safe state depend on a number of factors including production equipment supported, HTF system complexity, and anticipated fluid release and fire scenarios.

A. Shutdown the heater (e.g., isolate burners, de-energize electrical heating elements, or divert hot waste streams).

B. Depressurize (e.g., by de-energizing circulation pumps) and/or isolate HTF equipment and piping in the anticipated fire area. Additionally, if adjacent HTF equipment areas may be exposed to the fire, take action to depressurize and/or isolate those equipment areas as well. When depressurizing and/or isolating, incorporate the following into the ignitable liquid protection scheme when appropriate.

1. For isolation, use either safety shutoff valves or fail-safe 3-way valves.
2. After depressurizing, ensure the HTF equipment area is not subject to a long, gravity-driven fluid release from a release point low in the system. If such a gravity release is possible, isolate the supply, return, or other piping connecting the HTF equipment area to the large fluid hold-up. For example, Figure 3 offers one method for isolating an expansion tank from the pumps using a safety shutoff valve in the riser pipe.
3. During a heater tube leak (i.e., internal fluid fire), if the primary loop fluid circulation continues to prevent to heater tube coking damage (e.g., bulk, solid-fuel fired heater), decrease fluid flow to the minimum required until internal heater temperatures cool allow circulation shutdown. In this instance, design the ignitable liquid protection scheme within the primary loop equipment room to control the sustained pressurized fluid release until the circulation pumps can be depressurized and/or large fluid hold-ups isolated.

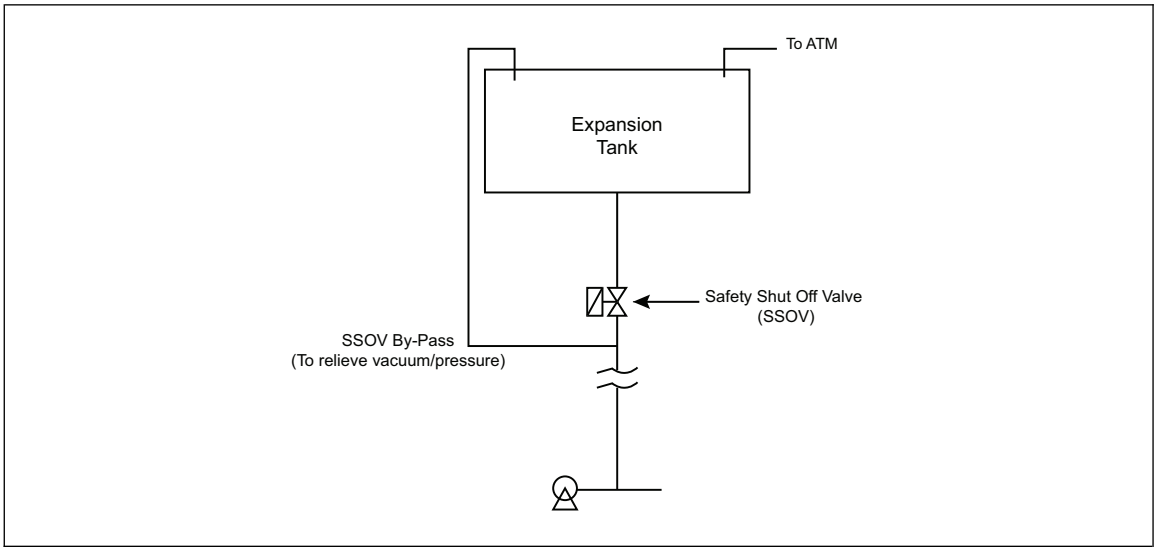


Fig. 3. Example of expansion tank isolation with by-pass

C. Shutdown other fluid transfer pumps including automatic or manual expansion tank refill pumps, and/or fluid condensate return pumps.

D. Drain the subject loop to a catch tank or other safe location to limit the fluid hold-up available for a gravity release.

E. For fuel-fired heaters, arrange combustion air fans and dampers to take the appropriate actions to an internal fluid fire. The appropriate response may depend on the type of fuel, the quantity of fluid expected to be released prior to detection, and the presence of internal fire protection. Include the original equipment manufacturer for guidance on actions to be taken. Two common responses are:

1. Manage the released fluid vapor in a fuel-rich atmosphere - Shutdown fan(s) and close combustion air damper(s) to reduce fire intensity, but allow hot, unburnt fluid to vaporize and slowly cool below the auto-ignition temperature and condense dropping below the lower flammable limit.

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2. Allow the released fluid to burn-off - Reduce but maintain fan(s) operating and/or combustion air damper(s) open to allow airflow through the heater to burn the hot fluid.

F. In a bulk, solid-fuel fired heater with grate conveyor, speed up the conveyor to remove unburnt fuel.

2.4.1.5 Provide a means to manually initiate the appropriate interlocked actions from section 2.4.1.4 within the control room or at the control panel, and at least one remote location that will remain accessible under anticipated fire conditions. For larger, more complex HTF system with multiple loops, a central control room and a separate remote station for each loop may be warranted. For a smaller HTF system dedicated to a single heat consumer, the local control panel and a remote station in the egress path may be sufficient.

2.4.1.6 Install fail-safe final control elements such as valves or dampers. A fail-safe condition depends on the application. For example, fail-safe condition for a valve may be closed or open.

2.4.1.7 When a fusible-link actuated firesafe shutoff valve is used, locate the fusible link within the anticipated fire area. If the shutoff valve is not designed to withstand exposure to a fluid fire, locate the valve outside the anticipated fire area and provide additional fusible links over the anticipated fire area with a cable attached to the valve actuator arranged to close the valve upon loss of cable tension.

2.4.1.8 When a remotely actuated firesafe shutoff valve is used, locate the valve outside the HTF fire area. If locating the valve within the HTF fire area is unavoidable, use a FM Approved firesafe shutoff valve along with FM Approved firesafe valve actuator. If a FM Approved firesafe valve actuator is not available, select an actuator with sufficient torque to operate a firesafe shutoff valve which can require greater torque than general-use shutoff valves.

2.4.1.9 Install manually operated isolation valves based on emergency response plans and fire service pre-planning to isolate and/or drain portions of the system during a fire emergency. Install valves in locations that will remain accessible under anticipated fire conditions.

2.4.1.10 When isolating fluid within equipment or piping, install the following when appropriate: a vacuum breaker if trapped hot fluid may be allowed to cool pulling vacuum or a vacuum may form while draining; or a safety/relief valve if trapped fluid may continue to be heated by an exposure fire or hot equipment increasing pressure. Refer to section 2.4.2 for guidance on relieving system design.

2.4.1.11 When an emergency drain system is installed, consider the following:

A. Install drains at system low points. Place emphasis on draining portions of the system containing large fluid hold-ups and especially when those large fluid volumes are located in proximity to common release points (e.g., heater, flexible connections, rotary joints, and pumps).

B. Install double-block vent valves (with position indication) atop the system to facilitate rapid draining.

C. If systems are operating above the normal boiling point of the fluid and portions of the system will be drained to atmospheric tanks, provide a dump cooler to lower the fluid temperature below the boiling point prior to discharging into the atmospheric tank. Dump coolers may operate as air-cooled (blast cooler) or water-cooled (circulated water or water evaporation). Design the dump cooler to maximize availability and reliability.

D. Size the catch tank receiving the drained fluid to hold the largest portion of the system likely to be drained at operating temperature plus 10%.

2.4.1.12 Provide the following heater start-up permissives and interlock trips, when appropriate.

A. Minimum fluid pressure or flow through a fluid-tube heater (i.e., not applicable for a system operating using thermosiphon).

B. Minimum fluid level in a well-type electric heater.

C. Minimum fluid level in the expansion tank.

2.4.1.13 Design the fuel supplies including isolation valving and burner management systems in accordance with Data Sheets: 6-4, *Oil and Gas Fired Single-Burner Boilers*; 6-5, *Oil or Gas Fired Multiple Burner Boilers*; 6-2, *Pulverized Coal-Fired Boilers*; 6-13, *Waste Fuel-Fired Boilers*; and 6-7, *Fluidized Bed Combustors and Boilers*.

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2.4.2 Heater

2.4.2.1 Design, construct, and install a heater in accordance with *ASME Boiler and Pressure Vessel Code*, or equivalent local jurisdictional requirements.

2.4.2.2 Design and install pressure relief in accordance with *ASME Boiler and Pressure Vessel Code*, Data Sheet 12-43, *Pressure Relief Devices*, and local jurisdictional requirements. Consider the following design and installation aspects in the pressure relief design.

A. Design relief piping to prevent clogging during and following valve operation. Provide insulation and heat tracing as required to prevent frozen fluid from plugging relief piping.

B. Design relief piping to discharge into a catch tank arranged in accordance with section 2.4.5.

C. Design discharge piping to prevent water from entering and accumulating within the relief piping and/or any interconnected catch tanks. Several solutions to prevent water ingress include ″U″ bends on outside discharge points, and/or drip legs with normally closed valves to facilitate draining water. An example of pressure relief discharge piping arrangement is shown in Figure 4.

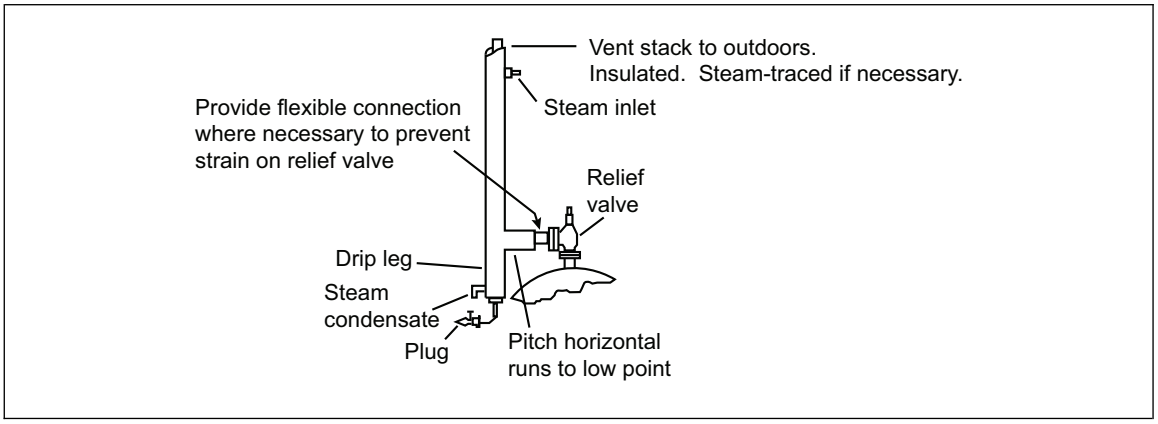


Fig. 4. Example of pressure relief device discharge piping

2.4.2.3 For vaporizers, provide a Hartford Loop when both of the following conditions exist: fluid condensate is gravity returned to the vaporizer; and the fluid inlet is located below the lowest safe liquid level for the vaporizer.

2.4.2.4 When the heater is interconnected to upstream and downstream equipment, consider the following safeguards when applicable. Examples of such installations include the following.

- Physically separate the bulk, solid-fuel combustion chamber from a downstream fluid heat exchanger.
- Use a fluid heat exchanger to capture waste heat.
- Have the heater exhaust/flue gas fed to downstream production equipment.

A. Provide a by-pass duct and dampers to divert incoming hot gas flow from the heater during a tube leak emergency.

B. Provide a by-pass duct and dampers to divert outgoing heater flue gas from downstream equipment during a tube leak emergency.

C. Treat a fluid heat exchanger in a waste stream as a heater, and provide ignitable liquid protection per this data sheet.

2.4.3 Expansion Tank

2.4.3.1 Provide spill containment and/or emergency drainage around expansion tanks in accordance with Data Sheet 7-32. Design containment and drainage to hold the contents of the tank. As an alternative to containment and/or drainage, provide all of the following.

A. Design and install expansion tanks as follows:

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1. If the expansion tank operates at atmospheric pressure, construct expansion tanks to a maximum allowable working pressure of at least 30 psi (2 bar) and designed in accordance with ASME or equivalent local jurisdictional requirements.

2. If the expansion tank operates above atmospheric pressure, design, construct, and install the expansion tank in accordance with *ASME Boiler and Pressure Vessel Code*, or equivalent local jurisdictional requirements.

B. Provide an expansion tank overflow drain or vent to a safe location. Do not install isolation valves on the drain or vent lines.

C. Provide an expansion tank emergency drain routed to a safe location with a remote-actuated drain valve and drain valve controls are located in an area expected to remain accessible under anticipated fire conditions.

2.4.3.2 Install an indirect fluid level gauge in place of a sight glass. When unavoidable, use a FM Approved sight glass installed per the FM Approval listing.

2.4.4 Circulation Pump

2.4.4.1 Install a seal-less type circulation pump meeting API 685, *Sealless Centrifugal Pumps for Petroleum, Petrochemical, and Gas Industry Process Service* when available (electro-magnetically coupled or canned motor pumps). Alternatively, install pumps with mechanical seals meeting API 682, *Pumps – Shaft Sealing Systems for Centrifugal and Rotary Pumps*, or equivalent local standard.

2.4.4.2 When mechanical seals are used, provided spray shields around pump shaft seals.

2.4.4.3 Provide a back-up circulation pumping not subject to a common failure as other circulation pumps when fluid circulation through the heater or system cannot be immediately shutdown due to the damage or risk posed. Examples include a bulk, solid-fuel fired heater where heat cannot be removed promptly or a system providing temperature control for a chemical reactor subject to thermal runaway upon loss of temperature control. Back-up pumping options may include but are not limited to the following:

- Back-up pump(s) powered by a different motive driver such as a diesel engine or DC power with uninterruptable power supply.
- Electric back-up pumps powered by an onsite emergency generator with separate electrical.

2.4.5 Dump or Catch Tank

2.4.5.1 Locate dump or catch tanks outside HTF equipment areas, preferably in a dedicated cutoff room or outside under a canopy.

2.4.5.2 Vent dump or catch tanks to a safe location such as outdoors. Aspect to consider when defining a safe location include: free of combustibles; separated from critical production, support, or utility equipment; and adequate ignitable liquid protection.

2.4.5.3 Prevent water from accumulating in the catch tank. Options include maintaining the tank warm or providing a liquid level alarm that sounds at a constantly attended location.

2.4.6 Piping, Joints, and General Equipment

2.4.6.1 Select fluid-containing materials based on equipment OEM and fluid OEM guidance. Avoid the use of copper, aluminum, and associated alloys for fluid-containing components given their lower melting points and incompatibility with many fluids under typical operating conditions.

2.4.6.2 Arrange, design, and install HTF system piping per Data Sheet 7-32. This includes pipe routing, materials, and jointing.

2.4.6.3 Provide clearance around hot HTF system piping as follows when that piping penetrates through or runs in proximity to combustible construction.

A. For insulated piping with surface temperatures less than 200°F(93°C), provide a minimum of 1 in. (25 mm).

B. For insulated piping with surface temperatures of 200°F (93°C) or greater, provide sufficient clearance to maintain adjacent combustible surfaces below 160°F (71°C).

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C. For uninsulated piping, provide a minimum of 18 in. (450 mm).

2.4.6.4 Install spray shields around flange joints and rotary joints capable of withstanding and redirecting fluid spray to a safe location. Install spray shields in a manner that permits joint inspection for leakage, which may include a small drain hole at a low point.

2.4.6.5 Install flexible connections (e.g., hoses and expansion joints) within the HTF piping system in accordance with Data Sheet 7-32.

2.4.6.6 Provide protection against freeze (crystallization) when fluid within HTF equipment and piping may drop near or below the pour point upon loss of circulation or heating for any extended period of time. Of particular concern is outdoor HTF equipment in colder climates. Protection measures may include additional insulation, heat tracing, a back-up circulation pump driven by an alternate means, a back-up heater utilizing an alternate power source, or the ability to drain the exposed fluid circuits to a storage tank.

2.4.7 Insulation

2.4.7.1 Use nonabsorbent, noncombustible insulation (e.g., cellular glass).

2.4.7.2 Provide removable insulation around equipment and/or piping to allow for periodic leak checks of common leak points such as pump, flange joint, and valve stem.

2.4.8 Valves

2.4.8.1 Position valves with stems oriented in the horizontal position to allow stem seal leaks to drip away from pipe and insulation.

2.4.8.2 Install valves with double seals to minimize valve stem leakage.

2.4.8.3 Do not use isolation valves for instrumentation that can trap fluid such as ball valves or plug valves, as these valves can trap cold fluid, which upon being exposed to system operating temperatures, can expand and/or vaporizing causing the valve to rupture.

2.5 Operation and Maintenance

2.5.1 Operation

2.5.1.1 Implement an emergency response plan (ERP) for the prompt and effective reaction to a HTF fire or explosion in accordance with Data Sheet 10-1, *Pre-Incident Planning and Emergency Response*, and include the following within the plan.

A. Address the fluid release and fire scenarios in HTF equipment areas as well as other combustibles that may become involved.

B. Specify response actions and assign those responsibilities to personnel. Example actions include the following.

1. Applicable actions listed in sections 2.4.1.4.
2. Confirm any fire or system interlocks respond as intended, and if any interlocks failed to do so or are not present, manually initiate the respective response.
3. Confirm fire protection system actuation, and if the system failed to do so automatically, manually actuate the system.
4. Isolate any fuel supplies to the fire area.

2.5.1.2 Provide initial and periodic refresher training for the emergency response team on the ERP for prompt and effective reaction an emergency.

2.5.1.3 Perform pre-incident planning with the fire service on fluid fire and explosion scenarios in accordance with Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*.

2.5.1.4 Perform exercise drills on HTF system fire and explosion response procedures including emergency operating procedures (EOP) and emergency response plan (ERP). When possible, involve the fire service.

2.5.1.5 Implement an emergency response plan (ERP) for the prompt and effective reaction to fluid freeze (crystallization) in accordance with Data Sheet 10-1, *Pre-Incident Planning and Emergency Response*

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Planning. Of particular concern is outdoor HTF equipment in colder climates. Actions may include starting a back-up circulation pump or back-up heater utilizing an alternate power source, or draining the exposed fluid circuits to a storage tank.

2.5.1.6 Establish standard operating procedures (SOP) for the HTF system and heat consumers covering the following.

A. Establish applicable control limits and operating limits. Key parameters may include: fluid bulk temperature; fluid film temperature; pressure; fluid levels; and fluid flow rates; heater fuel-firing rate; burner fuel pressure; maximum power input for electric heating elements; and fluid properties and condition. Base safe operating limits on the OEM and fluid supplier guidelines.

B. Start-up from cold and start-up from warm.

C. Placing the system in hot stand-by and conducting a full-system shutdown.

D. Fluid charging and conditioning per fluid supplier for guidelines.

E. After a heater trip, determine the trip device (interlock), and investigate the cause prior to a restart attempt.

2.5.1.7 Establish emergency operating procedures (EOP) for responding to abnormal operating conditions and emergencies. Consult with OEM on recommended practices. Authorization by local management allowing operators to initiate an emergency response which may involve shutting down the HTF system and interrupting production. At a minimum, cover the following potential emergency conditions when applicable.

A. Suspect, verify, and respond to a tube leak in a heater.

B. Suspect, verify, and respond to a fluid release into the HTF equipment area. Applicable actions are discussed in section 2.4.1.4.

C. Loss of or reduction in fluid flow through the heater.

D. Abnormal fluid level or temperature changes in the expansion tank.

E. Loss of power or other condition requiring shutdown of bulk, solid-fuel fired heater. Address the following considerations when applicable.

1. Isolate fuel feed, and increase the travel speed of remaining fuel to remove from the combustion zone.
2. Isolate or significantly reduce primary air (e.g., under grate air).
3. Maintain or maximize secondary air (e.g., overfire air).
4. Use of an emergency fluid cooler.
5. Conditions allowing reduced fluid circulation and eventually shutting down fluid circulation.

2.5.1.8 Provide initial and periodic refresher training for operators covering SOPs, EOPs, and ERPs in accordance with Data Sheet 10-8, *Operators*.

2.5.1.9 Implement a jumper/force permit program to manage by-passing control and/or safety system components during operation or maintenance outages. Avoid by-passing safety systems during operation. Refer to Data Sheet 7-45, *Safety Controls, Alarms*, and Interlocks for program guidance.

2.5.1.10 Maintain a HTF system log documenting abnormal conditions such as exceeding operational limits or interlock trips. When appropriate, determine and document the respective root-causes and corrective actions.

2.5.1.11 Implement a hot work permit program to manage grinding, cutting, welding and similar hot work operations on HTF equipment and piping, or in HTF equipment areas in accordance with Data Sheet 10-3, *Hot Work Management*.

A. Prohibit the use of hot work (e.g., open flame) to thaw frozen fluid within equipment and piping, or equipment areas. Consider methods with cooler working temperatures or mechanical alternatives to remove frozen fluid such as using building heat, steam heating, or temporarily installed electrical heat tracing to thaw frozen fluid.

B. Inspect the hot work area prior to the start of work for frozen fluid deposits and oil-soaked insulation (additional required precaution).

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C. When performing work on/in equipment, ensure fluid has been removed and equipment and piping purged. Employ lock-out/tag-out and line-breaking procedures.

2.5.1.12 Implement a lock-out/tag-out program to prevent a fluid release and provide safe conditions in preparation for HTF system inspections, repairs, or alterations.

2.5.1.13 When system complexity warrants, implement a line-breaking procedures to prevent a fluid release during HTF system inspections, repairs, or alterations. Line-breaking procedures are intended to complement the lock-out/tag-out program and ensure the subject loop is properly isolated from any remaining active portions of the HTF system and/or drained, which may include walking the subject piping/line between isolation points.

2.5.1.14 Implement a management of change (MOC) program to oversee physical, operating, and/or procedural changes to the HTF system, or heat consumer impacting the HTF system, in accordance with Data Sheet 7-43, *Process Safety.* Key changes may include the following:

- Switching fluid
- Converting a steam boiler to a fluid heater
- Expanding the operational limits or system/equipment capacity (e.g., temperature, pressure, firing rate)
- Switching fired fuels (e.g., bulk solid, suspended solid, gas, or liquid)
- Upgrading soot blower systems
- Upgrading control systems
- Adding a heater or heat consumer

2.5.1.15 Implement an incident investigation program to determine root cause and other factors associated with near misses, fluid releases, fires, explosions, and equipment/mechanical integrity breakdowns. Document the data gathered, findings, and corrective actions.

2.5.2 Maintenance

2.5.2.1 Manage and maintain all hardware and software components in the HTF system control and safety systems in accordance with Data Sheet 7-45, *Safety Controls, Alarms, and Interlocks (SCAI)*, except test fire detection interlocks as follows. Test any burner management system interlocks and permissives in accordance with the appropriate data sheet.

2.5.2.1.1 Test all fire detection interlocks as follows.

A. Perform a functional test of the interlock at commissioning.

B. Perform a functional test of the interlock impacted by changes as determined through the management of change program. Of concern are field devices, and controls equipment and logic.

C. Perform simulated testing at least annually with the HTF system online, in standby, or shutdown (i.e., loop testing).

2.5.2.1.2 Develop a procedure for fire detection interlock testing to verify operability, connectivity, and appropriate settings of the hardware and software involved. Include the following aspects in the test procedure.

A. List the HTF equipment involved in interlock testing such as field sensing devices (e.g., instrumentation), operator interfaces (e.g., manual push buttons), controller and logic loops, field control devices (e.g., valves and power disconnect switches).

B. Develop a checklist for documenting interlock testing. At a minimum record: individuals performing the test; date; interlock tested; field devices and equipment involved; type of test; results (e.g., pre-trip conditions, trip point, post-trip conditions, and time required); and as found and as left conditions.

C. Conduct functional testing with equipment in a safe operating state (e.g., heater low fire condition).

D. Initiate a functional test using a single field device, while verifying all other field sensing device and operator interfaces separately via loop testing.

2.5.2.1.3 Test fire detectors and detection systems associated with the fire detection interlock in accordance with Data Sheet 5-48, *Automatic Fire Detection*.

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2.5.2.2 Sample and test the heat transfer fluid per fluid OEM guidelines but at least annually. Retain records detailing fluid sampling procedures, test results, and fluid treatment activities (e.g., fluid filtration or regeneration).

2.5.2.3 Perform a walkthrough of the HTF system preferably every shift, but at least daily looking for abnormal operating conditions. Of particular importance are the heater, circulation pump, expansion tank, catch tank, rotary joints, flexible hoses, expansion joints, and pressure relief devices and associated piping.

2.5.2.4 Implement an asset integrity program for a heater in accordance with Data Sheet 9-0, *Asset Integrity* and the following.

2.5.2.4.1 Perform external and internal visual examinations of the heater per the asset integrity program and local jurisdictional requirements, but at a minimum annually. For fluid-tube heaters, inspect and test the following portions of the heater.

A. Furnace and Convective Pass (Fire-Side)

1. Visually inspect tubes for indications of overheating or burner-flame impingement, cracking, erosion, or other damage.
2. If soot blowers are present, check soot blower alignment and operation. Visually inspect soot blower paths for scouring/erosion.
3. If soot blowers are present, perform nondestructive examination (NDE) on tubes to verify adequate tube thickness for continued service.
4. Visually inspect refractory for damage.

B. Tubing (Fluid-Side)

1. Visually inspect tube internals when overheating and/or coking or fouling is suspected (e.g., inspect bulged tubes with a borescope). If coking is discovered, refer to the OEM and fluid manufacturer for guidance on addressing the condition which may include flushing and cleaning the tubes and system piping, and/or fluid regeneration.

2.5.2.5 Inspect and test safety valves, relief valves, and safety relief valves in accordance with Data Sheets 7-49, *Emergency Venting of Vessels* and 12-43, *Pressure Relief Devices* along with local jurisdictional requirements.

2.5.2.6 Exercise HTF system remotely operated and manual isolation valves their full-travel at least annually.

2.5.2.7 Perform vibration monitoring on fluid circulation pumps. Start with daily testing to establish a baseline then adjust monitoring frequency based on trended results but conducting surveys at least on a quarterly basis.

2.5.2.8 Perform inspection, testing, and maintenance for flexible connections and rotary joints per OEM guidelines.

2.5.2.9 Implement an asset integrity program for fluid-process/water heat exchangers in accordance with Data Sheet 9-0, *Asset Integrity*.

2.5.2.10 Perform HTF system equipment and piping repairs in accordance with the *ASME Boiler and Pressure Vessel Code* or local jurisdictional requirements, and OEM guidelines.

2.5.2.11 Following HTF system commissioning, alterations, or repairs, perform a pressure part integrity test (i.e., hydrostatic test) in accordance with the requirements of ANSI/ASME B31.1, *Power Piping* or B31.3, *Process Piping*, or local jurisdictional requirements. If water is used, ensure all water has been removed prior to charging the system with fluid and a boil-out is conducted per fluid supplier guidelines.

2.5.2.12 Apply insulation to HTF equipment and piping only after a leakage or pressure test has been conducted and a full heating cycle.

2.6 Contingency Planning

2.6.1 When an HTF equipment breakdown results in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

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2.6.1.1 Develop an equipment contingency plan for fluid tube heaters. A common breakdown scenario associated with a fluid tube heater is a sustained tube leak emergency that causes thermal damage within a large portion of the heater of origin requiring lengthy recovery time for significant coil or tube bundle repair or replacement. When evaluating equipment contingency plan options involving a rental or multiple rental heaters, the plan should address siting options for the rental heater(s); the need for or already installed piping and utility connections; in a vapor-phase systems, condensate gravity flows; and/or freeze/crystallization protection in colder climates. Additionally, emissions controls and permitting for these temporary installations should be addressed as overlooking these can lead to lengthy delays in some regions.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Supplemental Information

3.1.1 Overview of HTF Systems

Most often, HTF systems provide heat to a heat consumer that may be part of production equipment or in a process. Figures 5, 6, and 7 are simplified diagrams of several HTF systems. HTF heaters are available in an array of sizes and types. Figures 8, 9, and 10 are examples of common heater types.

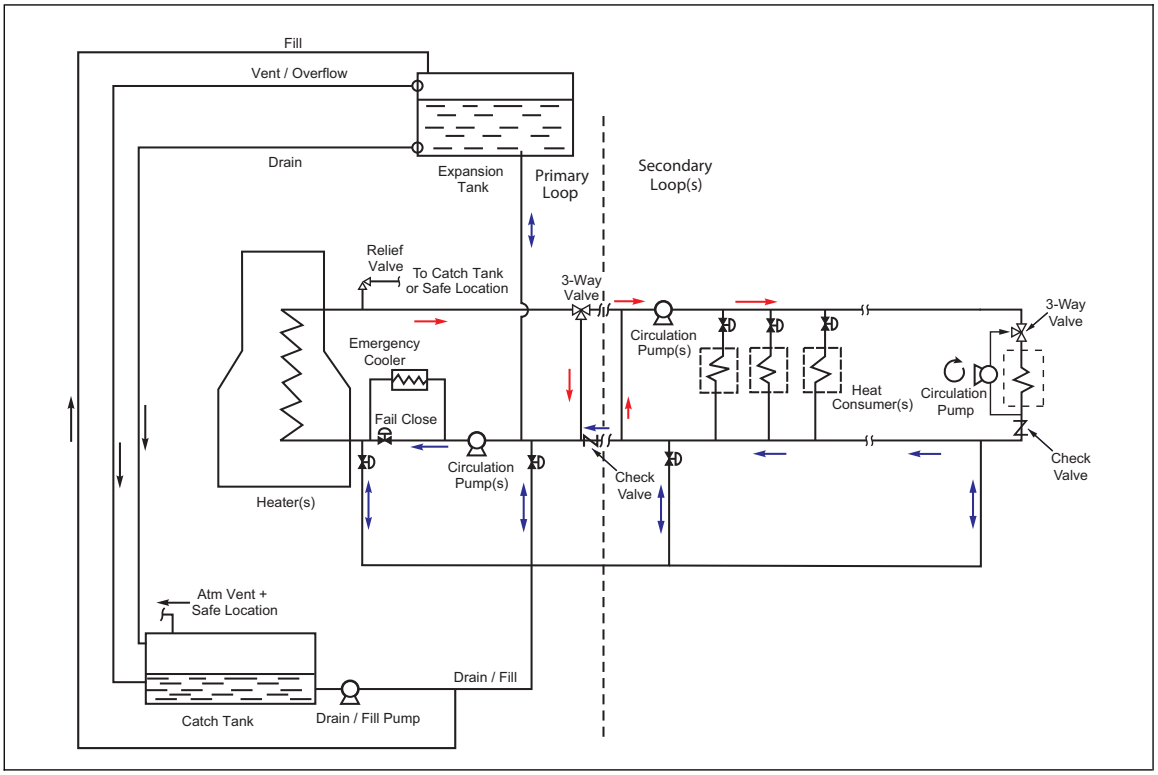


Fig. 5. Example of a liquid-phase HTF system

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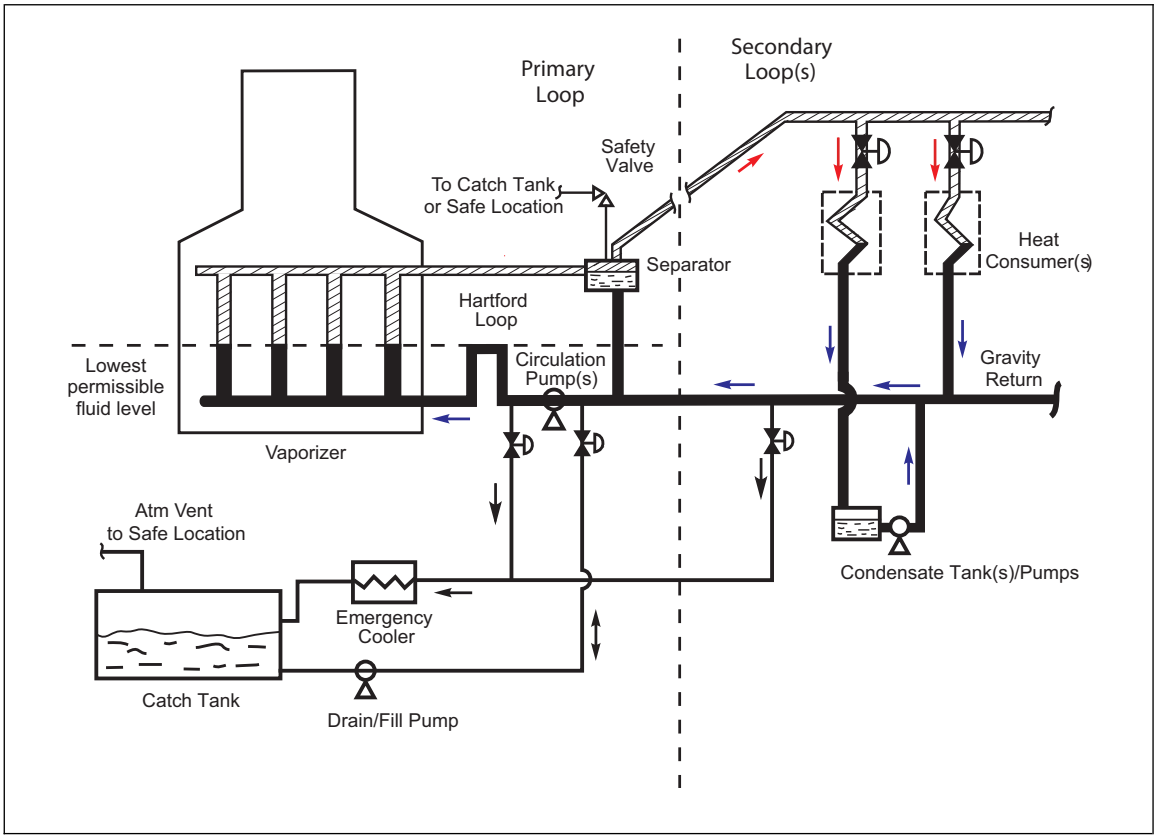


Fig. 6. Example of a vapor-phase HTF system

3.1.2 Fire Hazards

3.1.2.1 Fluid Fires Within HTF Equipment Areas and Production Equipment

Liquid-phase HTF systems operate circulating hot ignitable liquid at high flow rates making a fluid release a high risk of producing a large, quick spreading fire. Further with hot equipment surfaces and fluid releases often having a mist or spray component, make ignition of the released fluid more likely. A fluid release may pose a pool or three-dimensional spill fire hazard. Loss history indicates that in general most fluid releases result in a pool or three-dimensional spill fire compared to spray fire. However, spray fires have occurred in particular at pumps or rotary joints, while spill fires are also possible in open process structures or from mezzanines.

The intensity and duration of the pool fire is largely influenced by the quantity of fluid released, which is a function of release rate and duration. Heat transfer systems circulate fluid at relatively large flow rates compared to other ignitable liquid systems such as hydraulic systems, thus detecting and isolating a release is a critical fire protection feature for HTF systems. A larger fluid release often results in a sustained, intense fire requiring situationally appropriate combinations of fire-resistant construction, cutoff rooms, and spill containment and/or emergency drainage to control the fire and limit damage. When a smaller release occurs, less robust fire protection features may sufficiently control the lower intensity, shorter duration fire and limit damage.

Loss history has shown that prompt isolation of a fluid release has been particularly beneficial in secondary loop equipment areas. When prompt detection and isolation are accomplished, other fire protection features for these equipment rooms/areas have a lower impact thus become less critical. Conversely, primary loop equipment areas contain a number of potential releases points, which may be difficult to impossible to isolate, resulting in larger pressurized and gravity fluid releases. For this reason, isolation of fluid releases in primary loop equipment areas often needs to be accompanied by a combination of other fire protection features for fire control and to limit damage (e.g., cutoff room, or containment and drainage).

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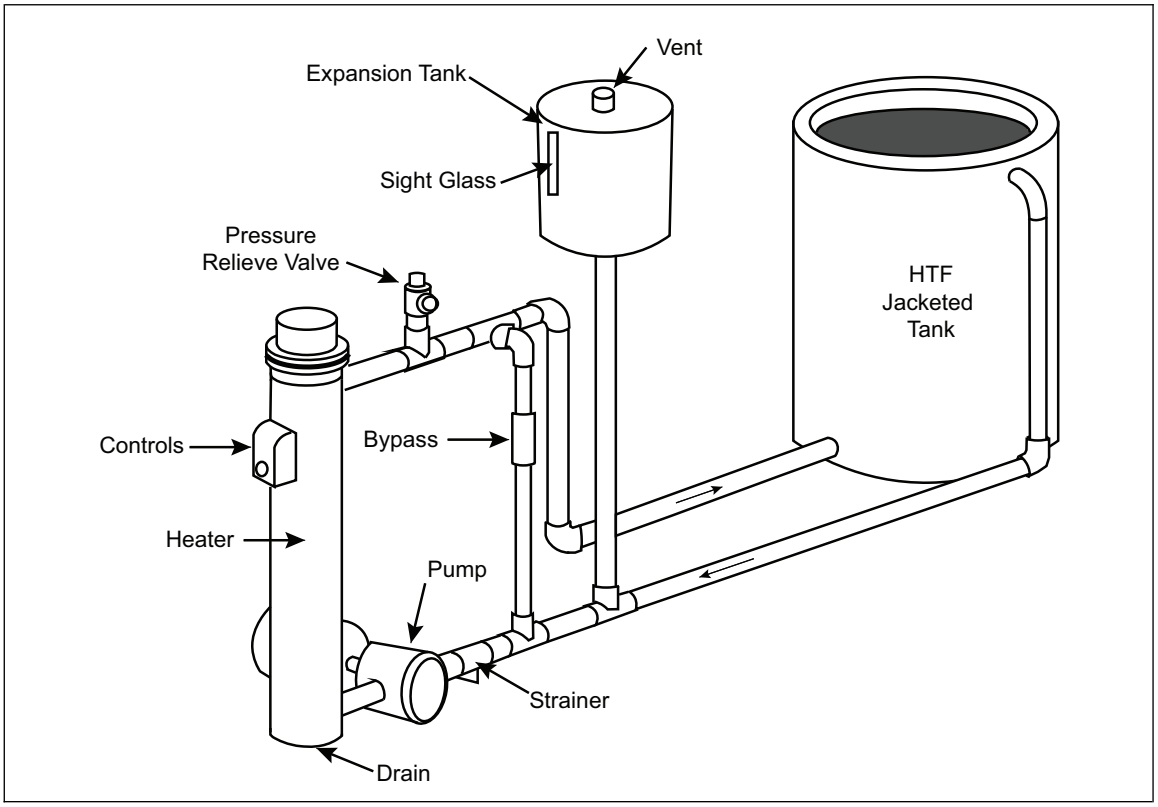


Fig. 7. Example of a simple HTF system dedicated to production equipment

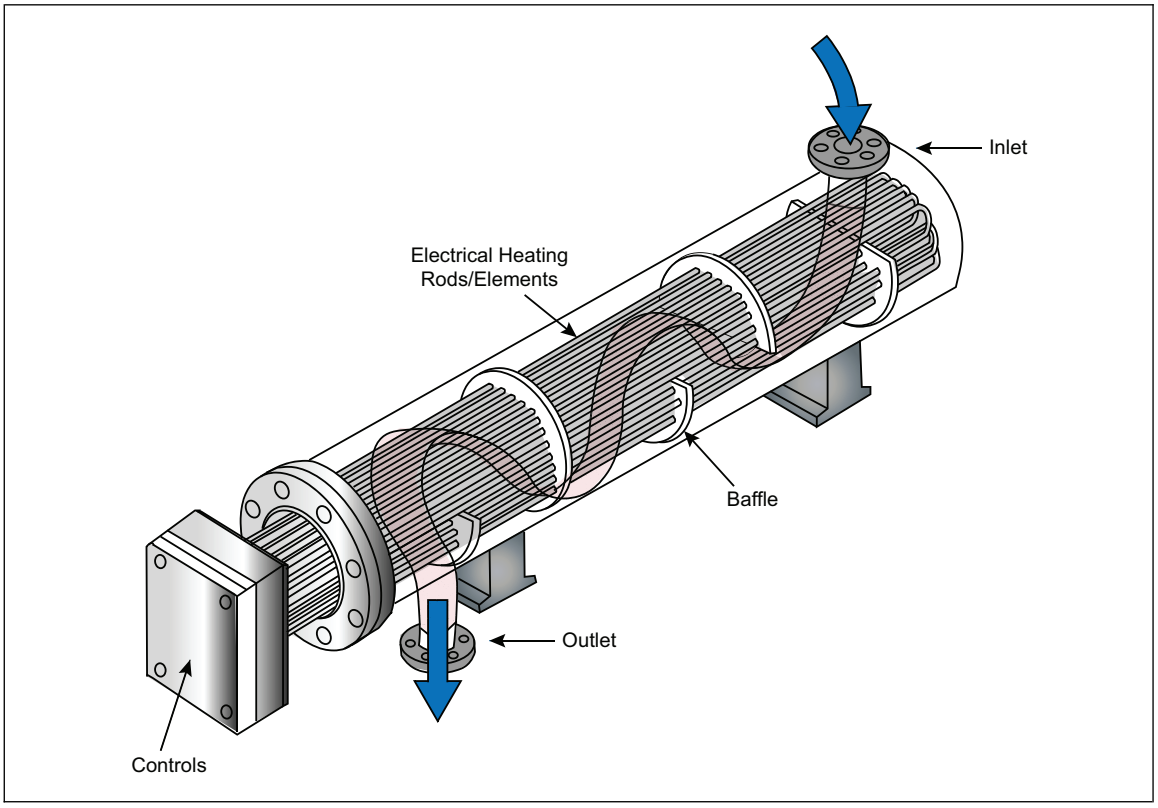


Fig. 8. Example electric tubular-type heater

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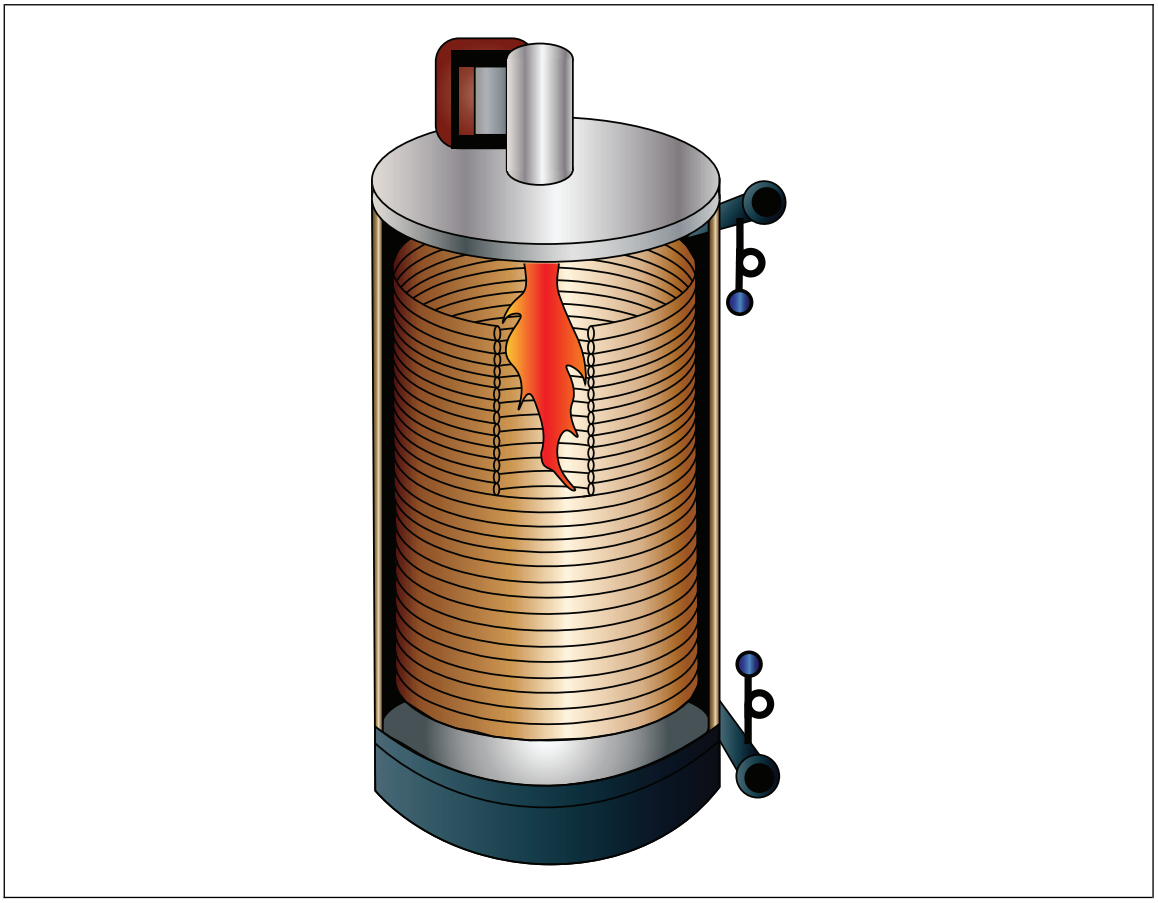


Fig. 9. Example vertical coil heater

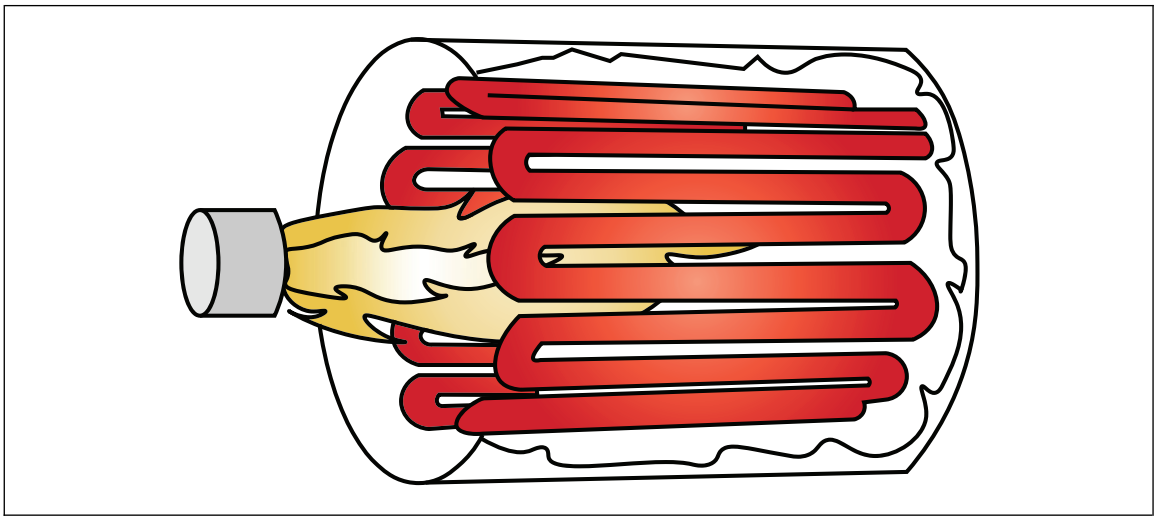


Fig. 10. Example horizontal serpentine tube heater

Fire hazards are inherent to heat transfer fluid systems containing ignitable liquid. The property risk posed by the fluid fire hazards depends on the release scenario, active and passive protection features, and the exposed building, production equipment, and surrounding occupancy. The performance goals of the fire

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protection features presented in this data sheet aim to control the fluid release and fire, prevent uncontrolled fire spread into surrounding areas, minimize thermal damage to production equipment, and limit water and smoke damage within the surrounding occupancy.

While the emphasis should be placed on mitigating the fluid fire exposure, fluid fires can be prevented by implementing human element programs focused on maintaining the fluid within the system. Well-established asset integrity and operator training programs can prevent fluid releases through maintenance and operating within the defined control limits (integrity operating window).

3.1.2.2 Internal Fluid Fires within Heaters (Tube Leaks)

The heater combustion chamber and convective passes are designed to withstand harsh normal operating conditions. The addition of a small quantity of fluid from a pin-hole tube leak is not likely to cause significant damage the heater. However, a sustained tube leak may enlarge the initial release orifice and/or damage adjacent tubes escalating the fluid release scenario and risking significant damage to tubing, casing, structural supports, and interconnected equipment.

Further, a sustained tube leak and fluid release within the heater has the potential of spreading beyond the unit of origin and exposing adjacent combustibles to a fluid pool fire. To mitigate the consequences of these fire hazards emphasis should be placed on reliable, prompt tube leak detection and response before the scenario can escalate.

As a secondary layer of protection against heater tube leaks and the heater damage inflicted by a sustained tube leak, an equipment contingency plan can limit the expected downtime. Investigating the feasibility of attaining and using rental heaters as well as developing a plan to position, connect, and operate temporary rental heaters are key planning steps to avert the potential significant forced downtime while heater repairs or replacement is completed. Where rental heaters are not feasible, internal fire protection should be considered to limit heater damage thus recovery time.

3.1.2.3 Fires Initiated by Fluid-Soaked Insulation

One of most frequent types of fires involves auto-ignition of fluid-soaked insulation. While these incidents are typically small, slow growing, and easily controlled, insulation fires pose an ignition source for large fluid releases. The auto-ignition phenomena is described below.

All organic materials tend to decompose (oxidize) when exposed to oxygen. This oxidation reaction is exothermic but very slow at room temperature. However, the reaction accelerates at elevated temperatures and when surface area increases. When leaking fluid is absorbed by the insulation, conditions are present for rapid oxidation of the fluid given the high operating system temperatures and the high surface area of absorbent insulation. After the exothermic oxidation reaction initiates, it accelerates as it produces heat.

Eventually, the insulation conditions reach the auto-ignition temperature of the fluid; however, the only component missing for a diffusion flame fire is air. When the insulation is removed or falls, or the reaction compromises the exterior surface of the insulation flaming combustion ensues.

The auto-ignition process may take hours to days to weeks to occur depending on the conditions present. To prevent insulation fires, fluid contaminated insulation should be replaced and nonabsorbent (closed cell) insulation should be used. Nonabsorbent insulations is particularly important where piping runs in areas with nearby combustibles or combustible deposits (e.g., woodworking plants) or near common large release points (i.e. pumps, rotary joints, flexible hoses). Examples of nonabsorbent and absorbent insulation are provided in Table 4.

Table 4. Nonabsorbent and Absorbent Insulation Examples

Nonabsorbent Insulation	*Absorbent Insulation*
Cellular glass (foamed glass)	Calcium silicate (85% magnesia with glass fiber)
Reflective aluminum foil	Glass wool
	Ceramic wool
	Mineral wool
	Asbestos fiber (silicate bonded)

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3.1.3 Fluid Crystallization

Fluid does not need to reach the freeze or solidification point to halt circulation through the system. When a liquid reaches the pour point, the liquid flow characteristics degrade significantly making pumping nearly impossible. For a heat transfer fluid, the increased viscosity is often attributed to the formation of crystals, which at first restrict circulation through the HTF system, and if not addressed promptly, is followed by circulation being completely halted. Once fluid flow stops, piping and equipment must be heated or a flow path otherwise cleared requiring days to weeks get hot fluid flowing again depending on accessibility and size of the affected section.

Although many fluids will not actually solidify at low ambient temperatures, the viscosity of these fluids increase to the point where they can no longer be pumped resulting in a system “freeze-up” due to fluid crystallization. The temperature at which excessive viscosity occurs for a given fluid is defined as the pour point. At this temperature a sufficient quantity of solids or crystals form creating a slurry dramatically increasing viscosity.

Fluid crystallization exposure may be attributed to seasonal changes in temperature, or loss of a critical utility service or equipment. An example of potential freeze exposure due to ambient conditions include piping routed outdoors in a colder climate. Critical HTF system equipment typically consists of heaters and circulation pumps to warm and circulate fluid. This equipment can be rendered out-of-service due to a utility outage (e.g., loss of electrical power or natural gas), or an equipment failure.

3.1.4 Equipment Breakdown

HTF systems support production equipment by supplying and/or removing heat. When compared to the closely related steam and water-based systems, the often hydrocarbon-based heat transfer systems are prone surprisingly similar damage mechanisms and failure modes capable of degrading system reliability, availability, and performance. Common undesired outcomes include loss of mechanical integrity, dry-firing, and overpressure, while a more unique outcome for HTF systems is the inability to circulate fluid (crystallization). As with most support systems, interruptions such as these can damage or destroy work-in-process, and shutdown production until HTF equipment repairs or replacement are completed. Fluid degradation, process contamination, fatigue, steam surge, coking, pump failure, and service interruption (e.g., electrical) are just some of the concerns when operating a HTF system. However, all of these concerns can be managed through the proper inspection, testing, and maintenance practices as part of an asset integrity program, operation management, maintaining the integrity operating window, and reliable safety devices. While equipment breakdown alone has caused production downtime, the potential perils that ensue during loss of mechanical integrity events can result in a loss of fluid containment with ensuing fire and/or explosion.

3.1.4.1 Fluid Degradation

Fluid specifications always provide an upper limit of temperatures that the fluid can reliably operate under. Exposure above the specified limits can degrade the fluid into solids that can foul the system, high-boiling viscous fluids that can hinder system operation, and low-boiling components that can be evolved as gas in areas of low system pressure or high fluid velocity, also causing problems such as pump cavitation, evolution of flammable gases in the expansion tank, or frothing of the fluid. The recommended upper limits are specified as the maximum bulk temperature and the maximum film temperature.

3.1.4.2 Excessive Temperature

The maximum film temperature is the temperature which no part of the fluid mass should ever exceed. It is referred to as the maximum film temperature since the film in question is the very thin (i.e., fractions of an inch; 1 mm or less) boundary layer at the surface of the heat transfer tubes where the fluid will reach its highest temperature due to heat transfer gradients.

The maximum bulk fluid temperature is the temperature which the output of the whole heater or the output of any of the heater tubes should not exceed for any significant amount of time.

Degradation of the fluid due to exposure to excessive temperature is undesirable due to the domino effect it causes. If the fluid flowing through the heat exchange tubes inside a heater is exposed to temperatures above its maximum film temperature anywhere in the tubes, then fluid may degrade and deposit on the tube as a viscous (tar-like) mass. This highly viscous coating hinds heat transfer, and as local tube temperatures increase, the viscous coating is turned into a solid deposit by a process called coking. The solid deposit on the tube further hinders heat transfer, and tube skin temperature continues to rise. Furthermore, the system

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responds to reduced heat transfer to the fluid (lower fluid outlet temperatures) by increasing burner heat input to maintain needed bulk fluid temperature. This scenario perpetuates until the metal overheats and weakness eventually resulting in fluid leaks within the heater.

3.1.4.3 Oxidation

Oxidation of the fluid can also lead to deposits on tubes. Although organic fluids oxidize at negligible rates when exposed to air at room temperature, oxidation occurs relatively rapidly at high temperatures. The oxidation products thicken the fluid and eventually form insoluble material that is deposited on tube walls and other surfaces of the system. The insulating effect of the deposits has a domino effect on increasing tube temperature, as discussed above, eventually leading to fluid leaks within the heater.

The points of possible air-fluid contact in a system are typically in the expansion tank and/or storage tank. Piping leading to these tanks is typically long and uninsulated to allow the fluid to cool before being exposed to the air. Where the fluid entering either of these tanks may be hot, then an inert-gas purge is typically provided.

Besides tube fouling, oxidation of the fluid may also cause the fluid to become acidic and therefore corrosive to system components, depending on the specific fluid used. The corrosive nature of the fluid is reported to be even further exacerbated by water in the system. Therefore, fluid contact with air and water should be prevented so as to avoid the slow irreversible system deterioration caused by corrosion. Degradation of the fluid due to high temperatures or foreign contaminants in the system can be detected by performing a chemical and physical analysis of the fluid.

With operation of a heat transfer system within the temperature range specified by the manufacturer, the fluid will normally last for years without any significant change in chemical or physical properties. However, contamination by moisture, air or solids such as rust or weld slag can result in fluid degradation causing equipment overheating, corrosion, and solids accumulation.

In obtaining a sample of HTF for testing, ensure the sample is cooled prior to being depressurized and exposed to air (i.e., prior to be exposed to atmosphere). Otherwise, the low boiling point materials may flash off and be lost from the sample, giving a false laboratory analysis of its composition.

This same phenomenon should be kept in mind if a sample is collected for testing when doing a fire (or other incident) investigation.

3.1.4.3.1 Charging and Conditioning Fluid

Before charging the HTF system with fluid, purging the system suspend and remove trapped water (liquid or vapor) and solid contaminants (dirt, rust, or slag), and remove air (oxygen). Water, oxygen, and solids can accelerate fluid degradation and cause violent system upsets such as pressure surge that can result in equipment damage and fluid release. Below are common practices to consider when charging a system.

A. Verify the discharge piping from the pressure relief piping is free of obstructions.

B. Allow stored fluid to warm-up to room temperature prior to charging the system. This will allow air, which may have been entrained in the viscous fluid during shipping or storage, to separate out of the fluid.

C. Remove other contaminants from equipment, piping, and tanks (e.g., slag, scale, rust, dirt). Use a cleaning or flushing fluid recommended by the fluid supplier.

D. Purge air from equipment, piping, and/or tanks using an inert gas.

E. Charge fluid slowly and from a low point in the system to avoid entraining air in the fluid and allowing air to escape through opened vents.

F. Conduct a boil-out per fluid supplier guidelines to remove the remaining moisture in the fluid or any trapped water from the system. During boil-out, ensure fluid is circulated though all equipment. Consider circulating fluid through the expansion and/or thermal buffer tanks in order to drive off water trapped accumulating at the bottom of the tanks.

G. During boil-out, circulate fluid through fine mechanical filters to remove degraded fluid particulate or other solid contaminants (e.g., rust or welding slag). Preferably, use filter media of 60 mesh (254 micron) or smaller.

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H. Draw a fluid sample from the system and test upon finishing commissioning and prior to placing the system into service. These test results provide a baseline to be used for comparison with all future fluid test results.

Filling a system from the bottom reduces the entrainment of gas bubbles that may cause pump cavitation or fluid degradation. Slow filling pushes air (or inert gas if system has been purged first) out of the system via vents at system high points. All vents, including those on heat consumer equipment, must be open during the filling operation and attended by an operator in order to close them once the gas has been purged and fluid appears. When filling the system, minimize the fluid flow rate to limit turbulence that may lead to gas entrainment in the fluid.

3.1.4.4 Process Fluid Contamination

Heated-fluid to process-fluid heat exchangers can leak contaminating the HTF system resulting in abrupt and dramatic symptoms such as water ingress into a hot system resulting in pressure surge due to the rapidly expanding steam, or long-term issue such as fluid degradation, fluid solidification due to reduced hot fluid flow, or corrosion of fluid-side pressure part surfaces. To address these concerns, heat exchangers should be routinely inspected for leaks, while operators should be trained on detecting and confirming leaks.

3.2 Loss History

3.2.1 FM Loss Data

A review spanning a 40-year period was conducted of losses involving HTF systems. Table 5 gives an overview of the HTF system losses by peril. Amounts are indexed to 2020 values.

Table 5. HTF System Losses by Peril

Peril	*No. of Losses*	*Gross Loss (US$M)*
Fire	103	401.35
Explosion	11	17.59
Pressure Equipment Breakdown	11	79.46
Totals	125	498.40

Within the losses comprising Table 5, several incidents were exacerbated by following or ensuing perils.

- Of the 103 fires, six were followed by fluid vapor explosions within heaters or equipment rooms.
- Of the 11 explosions, eight were followed by fluid and/or fuel gas fires.
- Of the 11 pressure equipment breakdowns, six breakdowns led to a contaminated HTF system or process stream, and within three of those contamination incidents, solidification of the HTF system and/or process ensued, significantly impacting the recovery time.

3.2.2 Illustrative Losses

3.2.2.1 Internal Fluid Fire in a Bulk, Solid-Fuel Fired Heater

An oriented strand board (OSB) used liquid-phased HTF systems to supply heat for the hot press, dryers, and a few other heat consumers. There were two independent HTF systems, each with two pile burning, solid-fuel fired heaters.

Prior to the incident, the subject heater was operating normally apart from a slightly increased firing rate to maintain operating temperatures. The following were the sequence of events reported.

- An operator noticed fluid pooling around an induction (ID) fan. Upon investigation, a tube leak was discovered in the convective section.
- A consultant was called to determine appropriate actions.
- The output fluid temperatures were cooled to 100 C, and the heater inlet and outlet valves were closed (heater isolated). However convective chamber temperatures remained at 300-350 C.

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- The consultant was again called and operators began manually cycling the fine water spray system in the heater at several second intervals (on-off) to cool and extinguish the combustion chamber fuel pile fire. This was unsuccessful. An attempt was made to insert a fire hose through a lower access hatch, but this was unsuccessful.
- A tube leak was discovered in the upper radiant section, and the decision was made to drain the system. Over the next few hours, the HTF system was drained to a storage tank as it was sufficiently cool.
- Other heater hot spots were detected (e.g., cyclone). The fine water spray system continued to be manually cycled on-off.
- An attempt was made to apply a hose stream from a high point within the convective section. Upon opening a soot blower inspection door, a ″blowout″ (puff) occurred thrusting refractory and insulation through the door. Operators evacuated the area.
- The decision was made to let the fluid burn out in the convective section.
- A fluid fire was detected in the primary loop equipment area around the pumps.
- The fire service was notified.
- Personnel fought the fire using fire extinguishers first, but was unsuccessful. Ceiling sprinklers actuated then personnel used foam carts. The fire was quickly knocked down with water and foam.
- The fire service responded 30 minutes later to find the fluid fire the equipment area extinguished. Thermal imaging cameras were used to locate hotspots in the heater and ductwork.
- Water mist continued to be applied.
- All the fires were eventually extinguished about 12 hours after detection and consumed approximately 1,900 gal (7,100 L).

The following damage occurred.

- HTF room walls and roof suffered minor thermal damage (scorched and insulation damaged) and soot.
- The heater convection section suffered severe thermal damage (melting and warping) during the long duration event without fluid flow. The lower two of the three tube bundles were sent back to the OEM for repair/replacement, while the third may have been as well. Repairs were needed to the structural steel, refractory, and insulation/casing.
- The transition duct from convection section to cyclone suffered thermal damage, as was the cyclone, all requiring repairs to steel, refractory, and insulation/casing.
- The fuel and ash handling systems suffered thermal damage requiring temporary repairs.
- The 60,000 gal (230,000 L) of fluid was replaced due to degradation.

Following the fire, all production was interrupted, and after a day, reduced production resumed using one heater (around 50%). After roughly two weeks, the heater flue exhaust was isolated from the downstream dryers and full production resumed.

The critical path in heater repairs was the replacement tube bundles, which was estimated at 3 months. With winter setting in about the scheduled installation time, plans were made to prepare back-up heating systems for miscellaneous operations such as log ponds in order to free-up sufficient HTF heat for strand drying and other production processes.

Most of the control wiring and power cabling around the heater burned or melted. Following the fire, personnel responded to restore control wiring and power cabling damaged by the fluid fire in the equipment area in order to restart the subject HTF system.

4.0 REFERENCES

4.1 FM

Data Sheet 1-44, *Damage-Limiting Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*

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Data Sheet 4-0, *Special Protection Systems*
Data Sheet 4-1N, *Fixed Water Spray System for Fire protection*
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 6-13, *Waste Fuel-Fired Boilers*
Data Sheet 7-14, *Fire Protection for Chemical Plants*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-45, *Safety Controls, Alarms, and Interlocks (SCAI)*
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 Ignitable Liquids*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*
Data Sheet 10-3, *Hot Work Management*
Data Sheet 10-8, *Operators*
Data Sheet 12-43, *Pressure Relief Devices*

4.2 Others

American National Standards Institute (ANSI/ASME). B16.25, *Butt-welding Ends*
American National Standards Institute (ANSI/ASME). B31.1, Power Piping
American National Standards Institute (ANSI/ASME). B31.3, Process Piping
American Society of Mechanical Engineers (ASME). *Boiler and Pressure Vessel Code*
American Petroleum Industry. API 682, *Pumps – Shaft Sealing Systems for Centrifugal and Rotary Pumps*
American Petroleum Industry. API 685, *Sealless Centrifugal Pumps for Petroleum, Petrochemical, and Gas Industry Process Service*

APPENDIX A GLOSSARY OF TERMS

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Heat Transfer Fluid: A liquid or vapor phase solution used in either heating applications to transmit heat from a heat source to a heat consumer, or cooling applications to remove or reclaim heat from hot or exothermic processes.

Heater: Equipment used to input thermal energy to a fluid. The output may be in liquid or vapor phase. A vaporizer is a common term for a heater with vapor phase output.

Heater, Bulk Solid-Fuel Fired: A heaters burning piles of solids that upon call to shutdown, solid fuel burning can not be abruptly stopped. Such heaters can be fired on a variety of fuels from waste fuels to wood or bark to lump coal.

Heat Consumer: Process equipment receiving the heat from the heater. In cooling HTF system applications, heat consumers are generating and transferring heat into the fluid to be removed downstream. Heat consumers may be referred to ask heat users, use points, or users, and may include jacketed chemical reactors or other vessels, hot presses (e.g., plywood or OSB), hot rolls (carpet or paper making), or steam generators.

HTF Equipment Area: Portion of a room, floor, building, or process structure with fluid containing equipment, thus containing a fluid fire or explosion hazard.

Liquid-Phase System: A HTF system where the heat transfer fluid supplied to the heat consumers is a liquid phase (i.e., system operating pressure is greater than the fluid vapor pressure at the given operating temperature).

Loop, Primary: Fluid circulation loop or circuit responsible for heating and supplying fluid or fluid vapor to downstream secondary loop(s) with heat consumer(s). The following equipment may comprise a primary loop:

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heater; expansion tank; primary circulation pumps); and/or catch tank. An HTF system may have multiple primary loops feeding a single header supplying secondary loop(s).

Loop, Secondary: Fluid circulation loop or circuit serving heat consumer(s) or use points, and is supplied by the upstream primary loop. The following equipment may comprise a secondary loop: transfer piping; circulation pumps; heat consumers; and/or vapor condensate return systems. An HTF system may have multiple secondary loops serving individual or groups of heat-consumers.

Pour Point: The temperature at which a fluid becomes semi-solid and loses its flow characteristics. With HTF, crystals form with the fluid increasing the viscosity beyond the point where fluid can circulate through equipment and piping.

Tank, Catch: A tank or vessel vented to atmosphere used to hold fluid ejected from the system through pressure-relieving devices, overflow drains, or atmospheric tank vents. The fluid received from the system may not be re-used. Also referred to as a dump tank.

Tank, Collection: A tank or vessel used to supply or receive fluid from the system. The fluid received from the system is typically re-used. Also referred to as a make-up or hold tank.

Tank, Expansion: A tank or vessel used to allow thermal expansion and contraction of the fluid as temperatures rise and fall from ambient to operating. In liquid phase systems, the tank is also used to provide sufficient suction head to primary loop circulation pumps.

Vapor-Phase System: A HTF system where the heat transfer fluid supplied to the heat consumers is a vapor (i.e., system operating pressure is less than the fluid vapor pressure at the given operating temperature).

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2026. Interim revision. Guidance for damage limiting construction (DLC) was aligned with Data Sheet 7-32, *Ignitable Liquid Operations.*

January 2022. Interim revision. Minor editorial changes were made.

October 2021. This document has been completely revised. Significant changes include the following:

A. Changed the title to "*Heat Transfer Fluid Systems*" (from "*Heat Transfer by Organic and Synthetic Fluids*").

B. Updated guidance on fluid evaluation for fire hazards.

C. Updated guidance on identifying room explosion hazards to align with Data Sheet 7-32, *Ignitable Liquid Operations*.

D. Added new fire protection schemes for HTF systems containing a fluid volume less than or equal to 660 gal (2,500 L).

E. Updated ignitable liquid fire protection for large systems (>660 gal [2,500 L]) to align with Data Sheet 7-32.

F. Revised recommendations on internal fire protection for fluid-tube heaters.

G. Clarified recommendations on interlocks and permissives.

H. Added recommendation on testing interlocks.

I. Deleted the recommendation to limit system hold-up to less than 500 gal (1900 L) by installing additional safety shutoff valves.

J. Expanded guidance on fluid maintenance and HTF equipment asset integrity.

K. Added a recommendation for an equipment contingency plan.

L. Added a recommendation for fuel-fired heater equipment contingency plan.

M. Updated the appendix listing common heat transfer fluid properties.

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October 2020. Interim Revision. Table 2 in Appendix D has been updated based on information supplied by a number of heat transfer fluid manufacturers.

January 2014. Table 2 in Appendix D has been updated based on information supplied by a number of heat transfer fluid manufacturers.

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 PROPERTIES OF COMMON HEAT TRANSFER FLUIDS

Table 6 contains several common heat transfer fluids and the necessary properties required for evaluation per this data sheet. Data contained in this table was obtained from the public domain or via correspondences with fluid producers. This table is only intended for quick reference in the absence of other data sources. Preferably, when evaluating the hazards covered in this data sheet, refer to the official fluid safety data sheets (SDS) or product/technical bulletins for the most accurate and up-to-date descriptions, applications, and/or properties.

To update entries in this table or add other fluids, send proposed changes and supporting information to: DataSheetsFeedback@fmglobal.com

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Table 6. Properties of Common Heat Transfer Fluids[1]

Producer	*Fluid Name*	*Description*	*Max. Operating Temperature*		*Pour Point °F (°C)*	*Atm. Boil-ing Point °F (°C)*	*Flash Point[1] °F (°C)*	*Fire Point °F (°C)*	*Auto-ignit-ion Temp. °F (°C)*
			Bulk °F (°C)	*Film °F (°C)*					
Petro-Canada	Calflo AF	Severely hydrotreated/ hydrocracked base stocks with performance additives	600 (316)	-	-44 (-42)	437 (225)	464 (240)	-	666 (352)
Petro-Canada	Calflo HTF	Severely hydrotreated/ hydrocracked base stocks with performance additives	620 (326)	650 (343)	0 (-18)	448 (231)	473 (245)	608 (320)	666 (352)
Petro-Canada	Calflo LT	Severely hydrotreated/ hydrocracked base stocks/ PAO blend with performance additives	550 (288)	-	-81 (-63)	349 (176)	372 (189)	-	1150 (621)
Petro-Canada	Calflo Synthetic	PAO synthetic base oil with performance additives	-	-	<-60 (<-51)	325 (163)	343 (173)	345 (174)	608 (320)
Dow Chemical Co.	Dowtherm A	Synthetic, biphenyl and diphenyl oxide	750 (400)	800 (425)	53 (12)	495 (257)	236 (113)	245 (118)	1110 (599)
Dow Chemical Co.	Dowtherm G	Synthetic, di- and tri-aryl ethers	675 (360)	-	40 (4)	552 (289)	280 (137)	-	810 (432)
Dow Chemical Co.	Dowtherm HT	Partially hydrogenated terphenyl	25–650 (-3–343)		25 (-4)	650 (343)	342 (172)	375 (191)	662 (350)
Dow Chemical Co.	Dowtherm J	Synthetic - isomers of alkylated aromatic	600 (315)	-	<-100 (<-81)	358 (181)	136 (57)	140 (60)	788 (420)
Dow Chemical Co.	Dowtherm MX	Synthetic - alkylated aromatics	620 (327)	-	-13 (-25)	623 (328)	329 (165)	-	788 (420)
Dow Chemical Co.	Dowtherm Q	Synthetic - diphenylethane and alkylated aromatics	625 (330)	-	-	513 (267)	249 (120)	255 (124)	773 (412)
Dow Chemical Co.	Dowtherm RP	Synthetic, Diaryl alkyl	660 (350)	710 (375)	-	667 (353)	381 (194)	403 (206)	725 (385)
Dow Chemical Co.	Dowtherm T	Synthetic, alkyl benzenes	600 (316)	-	<-40 (<-40)	-	370 (188)	410 (210)	707 (375)
Solvay	Galden HT55	Perfluoropolyether Fluorinated	-	-	<-80 (<-115)	130 (55)	None	None	None
Solvay	Galden HT110	Perfluoropolyether Fluorinated	-	-	-150 (-100)	230 (110)	None	None	None
Solvay	Galden HT135	Perfluoropolyether Fluorinated	-	-	-150 (-100)	280 (135)	None	None	491 (255)
Solvay	Galden HT200	Perfluoropolyether Fluorinated	-	-	-120 (-85)	390 (200)	None	None	482 (250)
Global Heat Transfer	Globaltherm FG	Semi-synthetic/ synthesized hydrocarbon/ white mineral oil/non-fouling/ NSF HT1certified for incidental contact withfood	619 (326)	650 (343)	-21 (-29)	700 (371)	410 (210)	-	662 (350)

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Table 6. Properties of Common Heat Transfer Fluids[1] (continued)

Producer	Fluid Name	Description	Max. Operating Temperature		Pour Point °F (°C)	Atm. Boil-ing Point °F (°C)	Flash Point[1] °F (°C)	Fire Point °F (°C)	Auto-ignit-ion Temp. °F (°C)
			Bulk °F (°C)	Film °F (°C)					
Global Heat Transfer	Globaltherm M	Distillates (petroleum), solvent-refined heavy paraffinic	608 (320)	644 (340)	10 (-12)	689 (365)	410 (210)	-	680 (360)
Global Heat Transfer	Globalthern Omnitech	Phenyl Ether-Biphenyl mixture	752 (400)	797 (425)	52 (11)	495 (257)	236 (113)	-	1150 (621)
Global Heat Transfer	Globaltherm NF	Semi-synthetic/ synthesized hydrogarbon/ white-mineral oil/non-fouling	619 (326)	650 (343)	-21 (-29)	700 (371)	410 (210)	-	662 (350)
Global Heat Transfer	Globaltherm Syntec	Mixture of hydrogenated terphenyls, partially hydrogenated polyphenyls and terphenyls	653 (345)	707 (375)	-19 (-28)	679 (359)	338 (170)	-	705 (374)
Phillips 66	Heat Transfer Oil 22	Severely hydrotreated mineral oil with performance additives	550 (288) [374 (190)][2]	625 (329) [449 (232)][2]	0 (-18)	647 (342)	491 (215)	482 (250)	642 (339)
Phillips 66	Heat Transfer Oil 32	Severely hydrotreated mineral oil with performance additives	550 (288) [374 (190)][2]	625 (329) [449 (232)][2]	-44 (-42)	667 (353)	424 (218)	489 (254)	648 (342)
Phillips 66	Heat Transfer Oil 32/46	Severely hydrotreated mineral oil	374 (190)	449 (232)	5 (-15)	648 (342)	424 (218)	491 (255)	658 (348)
Phillips 66	Heat Transfer Oil 46	Severely hydrotreated mineral oil with performance additives	550 (288) [374 (190)][2]	625 (329) [449 (232)][2]	-38 (-39)	685 (363)	464 (240)	521 (272)	649 (343)
Phillips 66	Heat Transfer Fluid C/S 32, Diamond Class	Severely hydrotreated mineral oil with performance additives	620 (327)	650 (343)	-44 (-42)	640 (338)	439 (226)	-	689 (365)
Phillips 66	Heat Transfer Fluid O/S 32, Diamond Class	Severely hydrotreated mineral oil with performance additives	550 (288)	600 (316)	-44 (-42)	642 (339)	442 (228)	-	685 (363)
Phillips 66	Heat Transfer Fluid O/S 46, Diamond Class	Severely hydrotreated mineral oil with performance additives	550 (288)	600 (316)	-44 (-42)	665 (352)	442 (228)	-	675 (357)
Sunoco Lubricants	HTO 22	Mineral Oil	-	550 (288)	5 (-15)	-	421 (216)	-	-
Sunoco Lubricants	HTO 46	Mineral Oil	-	550 (288)	5 (-15)	-	446 (230)	-	-

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Table 6. Properties of Common Heat Transfer Fluids[1] (continued)

Producer	*Fluid Name*	*Description*	*Max. Operating Temperature*		*Pour Point °F (°C)*	*Atm. Boil-ing Point °F (°C)*	*Flash Point[1] °F (°C)*	*Fire Point °F (°C)*	*Auto-ignit-ion Temp. °F (°C)*
			Bulk °F (°C)	*Film °F (°C)*					
Eastman Chemical Co.	Marlotherm FG	White Mineral Oil	-	-	-	424-1472 (218-800)	338 (170)	-	617-671 (325-355)
Eastman Chemical Co.	Marlotherm LH	Benzyltoluene	625 (330)	715 (380)	-110 (-79)	532 (278)	270 (132)	-	883 (473)
Eastman Chemical Co.	Marlotherm N	Benzene, mono-C10-13- alkyl derivatives, distillation residue	-	-	-76 (-60)	626-752 (330-400)	356 (180)	-	626 (330)
Eastman Chemical Co.	Marlotherm SH	Dibenzyl-toluene	620 (325)	715 (380)	-29 (-34)	738 (392)	426 (219)	-	858 (459)
Eastman Chemical Co.	Marlotherm® XC	Cumene	570 (300)	608 (320)	<-130 (<-90)	306 (152)	102 (38.8)	-	826 (441)
Eastman Chemical Co.	Marlotherm XD	Isododecane	-	-	-	383-428 (195-220)	163 (73)	-	428 (220)
ExxonMobil	Mobiltherm 603	-	550 (285)	-	5 (-15)	-	380 (194)	-	-
ExxonMobil	Mobiltherm 605	-	600 (315)	-	10 (-12)	-	450 (230)	-	-
ExxonMobil	Mobiltherm 610	-	480 (250)[2]	-	21 (-6)	-	180 (250)	-	-
MultiTherm	MultiTherm 503	Paraffinic	500 (260)	550 (288)	<-76 (<-60)	616 (324)	310 (154)	345 (174)	-
MultiTherm	MultiTherm IG-1	White Mineral Oil	550 (288)	600 (316)	0 (-18)	705 (374)	442 (228)	505 (263)	670 (354)
MultiTherm	MultiTherm IG-4	White Mineral Oil	600 (316)	650 (343)	6(-14)	772 (411)	440 (227)	490 (254)	630 (332)
MultiTherm	MultiTherm OG-1	White Mineral Oil	550 (288)	600 (316)	-4 (-20)	704 (373)	455 (235)	520 (271)	675 (357)
Paratherm	Paratherm HR	Synthetic, Alkylated Aromatic	650 (343)	700 (371)	-	638 (337)	>300 (>149)	-	-
Paratherm	Paratherm HT	Synthetic, Partially Hydrogenated Terphenyl	650-675 (343-358)	705 (374)	-	>660 (>349)	>340 (>171)	-	-
Paratherm	Paratherm NF	Hydrotreated Mineral Oil	600-630 (316-332)	650 (343)	-	>700 (371)	>300 (149)	-	649 (343)
Paratherm	Paratherm HE	Hydrotreated Heavy Paraffinic Distillate	590 (310)	650 (343)	-	>700 (>371)	>410 (>210)	-	613 (323)
Castrol	Perfecto HT 21	Mineral Oil	480 (250)	-	-38 (-39)	-	280 (140)	-	590 (310)
Castrol	Perfecto HT 5	-	610 (320)	-	16 (-9)	690 (367)	400 (210)	480 (249)	670 (357)
Caltex (Chevron)	Texatherm 22	Mineral - Paraffinic	570 (300)	590 (310)	-71 (-57)	600 (316)	390 (198)	-	660 (349)
Caltex (Chevron)	Texatherm 46	Mineral - Paraffinic	550 (288)	600 (316)	5 (-15)	630 (330)	470 (246)	-	680 (360)
Solutia (Eastman Chemical Co.)	Therminol 55	Alkyl (C14-30) benzene derivs.	570 (300)	635 (335)	<-65 (<-54)	664 (351)	379 (193)	-	691 (366)

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Table 6. Properties of Common Heat Transfer Fluids[1] (continued)

Producer	Fluid Name	Description	Max. Operating Temperature		Pour Point °F (°C)	Atm. Boil-ing Point °F (°C)	Flash Point[1] °F (°C)	Fire Point °F (°C)	Auto-ignit-ion Temp. °F (°C)
			Bulk °F (°C)	Film °F (°C)					
Solutia (Eastman Chemical Co.)	Therminol 59	Alkyl substituted aromatic	600 (315)	650 (345)	-90(-68)	553 (289)	295 (146)	-	702 (372)
Solutia (Eastman Chemical Co.)	Therminol 66	Modified polyhenyls	650 (343)		705 (375)-25(-32)	678 (359)	363 (184)	-	705 (374)
Solutia (Eastman Chemical Co.)	Therminol 68	Synthnetic, Aromatics mixture	680 (360)	735 (390)	27 (-33)	586 (308)	311 (155)	-	752 (400)
Solutia (Eastman Chemical Co.)	Therminol 72	Synthnetic, Aromatics mixture	715 (380)	750 (400)	0 (-18)	520 (271)	270 (132)	-	1117 (603)
Solutia (Eastman Chemical Co.)	Therminol 75	Terphenyl/ quaterphenyl	725 (385)	770 (410)	~165 (~75)	649 (343)	365 (185)	-	1052 (567)
Solutia (Eastman Chemical Co.)	Therminol ADX-10	Alkyl (C10-13) benzene	480 (250)	535 (280)	-112 (-80)	559 (293)	277 (136)	-	621 (327)
Solutia (Eastman Chemical Co.)	Therminol D-12	Synthetic hydrocarbon	450 (230)	475 (245)	<-137 (<-94)	378 (192)	144 (62)	-	531 (277)
Solutia (Eastman Chemical Co.)	Therminol LT	Alkyl substituted aromatic	600 (315)	650 (345)	-103 (-75)	358 (181)	136 (58)	-	774 (412)
Solutia (Eastman Chemical Co.)	Therminol SP	Alkyl (C14-30) benzene derivs.	570 (300)	635 (335)	<-65 (<-54)	664 (351)	379 (193)	-	691 (366)
Solutia (Eastman Chemical Co.)	Therminol XP	White mineral oil	600 (315)	625 (330)	-20 (-29)	676 (358)	390 (199)	-	655 (346)
Solutia (Eastman Chemical Co.)	Therminol® VLT	m-Cyclohexane and trimethylpentane mixture	350 (175)	410 (210)	<-211 (<-135)	211 (99)	19 (-7)	-	507 (264)
Solutia (Eastman Chemical Co.)	Therminol VP-1	Biphenyl/ Diphenyloxide	750 (400)	800 (430)	54 (12)	495 (257)	255 (124)	-	1114 (601)
Solutia (Eastman Chemical Co.)	Therminol VP-3	Phenylcyclohexane / bicyclohexyl	625 (330)	675 (360)	36(2)	469 (243)	219 (104)	-	680 (360)
Dow Chemical Co.	Syltherm 800	Silicone	750 (400)	-	-	-	320 (160)	380 (193)	725 (385)
Dow Chemical Co.	Syltherm HF	Silicone polymer	500 (260)	-	-	-	145 (63)	-	671 (355)
Dow Chemical Co.	Syltherm XLT	Silicone polymer	500 (260)	-	<-150 (<-100)	108 (42)	116 (47)	-	662 (350)
Dow Chemical Co.	UCON HTF 500	Polyalkylene Glycol	500 (260)	>550 (288)	-54 (-48)	-	424 (218)	-	752 (400)
Radco Industries	Xceltherm 315	Synthetic	550 (290)	600 (315)	5 (-15)	-	338 (170)	425 (218)	779 (415)
Radco Industries	Xceltherm 600	Mineral oil	600 (316)	650 (343)	-20 (-29)	-	380 (193)	421 (216)	725 (385)

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Table 6. Properties of Common Heat Transfer Fluids[1] (continued)

Producer	*Fluid Name*	*Description*	*Max. Operating Temperature*		*Pour Point °F (°C)*	*Atm. Boil-ing Point °F (°C)*	*Flash Point[1] °F (°C)*	*Fire Point °F (°C)*	*Auto-ignit-ion Temp. °F (°C)*
			Bulk °F (°C)	*Film °F (°C)*					
Radco Industries	Xceltherm MK1	Synthetic, Diphenyl Oxide and Biphenyl	750 (400)	800 (427)	-	495 (257)	230 (124)	260 (127)	660 (349)
Radco Industries	Xceltherm SST	Synthetic	700 (370)	750 (399)	-	-	345 (174)	374 (190)	630 (330)
Radco Industries	Xceltherm SX800	Synthetic, dimethyl polysiloxane	750 (400)	800 (427)	-94 (-70)	-	324 (162)	380 (193)	950 (510)

Note 1. Closed cup flash point.
Note 2. Open system application.

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