



# Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.7.1.5

## ORGANIC & SYNTHETIC HEAT TRANSFER FLUIDS AND EQUIPMENT

### INTRODUCTION

Heat transfer is an important part of many industrial processes. Heat transfer systems provide a medium to distribute thermal energy to various operations which require heat to complete or start a process. Synthetic & Organic fluids (typically called hot oil systems) are often used to transfer heat at temperatures between -70°F (-57°C) and 750°F (400°C). Water or steam has been a traditional low cost method of heat transfer, however, organic & synthetic heat transfer fluids are required for occupancies utilizing high operating temperatures or strict control of process temperatures. Typical occupancies utilizing this medium include the chemical & petro-chemical industries, the wood products industry such as plywood, melamine & fiberboard manufacturing, textile industry, calenders on paper machines, laundries, plastics industry and even food preparation occupancies.

Organic fluid systems and steam/water systems are physically similar and have many of the same hazards, however, organic/synthetic heat transfer fluid hazards pose significantly higher hazard exposures than steam systems. Organic fluids present a severe fire hazard if they release from the closed system they circulate within. The flammability, high temperatures and high pressures can result in a significant risk for explosion or fire condition. Consequently:

- Larger leaks may vaporize and ignite, or they may produce a serious pool fire. Synthetic fluids operating above their flash point (autoignition temperature) may burn immediately when exposed to air or come in contact with a hot surface. Depending on the size of the system this could result in a significant flammable liquid pool fire condition. This fire condition is extremely challenging.
- Small leaks may soak insulation or accumulate on building members, floors or equipment. This creates dangerous continuity of combustibles.
- Piping & associated equipment (pumps etc) can be present throughout a plant which can expose other plant important operations.
- These systems are often large and contain significant quantities of organic or synthetic product and are under high flow rates.
- Fluid leakage on hot surfaces may degrade exothermically over time and produce compounds that autoignite at normal system temperatures.
- Fluid leakage inside a vaporizer or fired heater is an uncontrolled fuel source. Shutting down and securing a leaking unit may be difficult and dangerous.

Organic & Synthetic fluid systems present additional challenges:

- Systems are very difficult to seal. A water tight system may still leak organic fluid. The physical and solvent properties of organic fluids allow the fluids to penetrate ordinary valve and pump packing and bleed through porous materials including some cast irons.
- Organic fluids are not as chemically stable as water or steam and are not compatible with as many other materials. Organic fluids will deteriorate if they overheat, contact air or become contaminated. The fluids may also react with materials in process. However, organic fluids may be used for heat transfer applications in which steam or water would react violently with materials in process.
- Organic fluids can gradually break down under normal system operating conditions. Degradation products can clog boiler tubes, heat exchangers and other system components. If undetected, this can lead, not only to system underperformance, but also to tube/ equipment ruptures and severe loss of containment incidents.
- Some organic fluids at normal ambient temperatures are too viscous to pump. Other fluids may solidify. Therefore, detailed startup procedures are needed to ensure fluid is flowing in all parts of the system before the system is placed in service. Also, piping containing stagnant fluid may require heat tracing and insulation. Examples include piping connections to expansion tanks, instruments or relief devices.
- Water in organic fluid systems may produce severe overpressure. For example, if condensed water accumulates in vessels during shutdown, system operation may transport the water to a hot area. Boiling water may produce a pressure high enough to rupture the system.
- Organic fluid systems tend to be less flexible than steam/water systems. Components in an organic fluid system strongly affect each other. For example, changing the system loading may change the peak temperature or alter the heat flux distribution in the vaporizer or heater.

This section provides loss prevention guidelines for organic fluid systems and their major components. The focus is on heating systems using organic & synthetic fluids in liquid or vapor form. Systems using fluids having a flash point less than 140°F (60°C) require additional precautions. This section does not apply to such systems or to refrigeration systems.

## POSITION

### Hazard Analysis

Perform a formal process hazard analysis on all heat transfer systems and applications when designing the systems and before making any subsequent modifications. Consider the possible consequences of product and heat transfer fluid cross-contamination. Unintended reactions or rapid thermal expansion may require special relief systems.

### Design and Installation

Minimize the area served by organic fluids. Do not use organic fluids for a service such as comfort heating that does not require high temperatures. Whenever possible, serve such loads with a central heat exchanger and a secondary steam, hot water, glycol or brine system.

Select all system components, including heat exchangers, piping, insulation, pumps, valves, gaskets, seals, relief devices and instrumentation for compatibility with the heat transfer medium and the intended system temperature and pressure. Use extreme caution when using any component not specifically designed for the specific organic fluid used.

Design systems and components to accommodate all expected temperature extremes. Thermal growth in organic fluid systems requires careful study, because organic fluid systems often experience larger temperature variations than similar steam/water systems.

Refer to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) or the local (national) equivalent to design and construct equipment within the scope of the code; refer to ASME B31.1 and B31.3 or the local (national) equivalent as applicable for piping.

Do not use gray cast iron parts. They may be porous to organic fluid. Unless specifically allowed by the fluid manufacturer, do not use copper or any alloy containing copper. Select gauges and other instruments carefully to avoid using units containing brass or bronze sensing elements. Do not use austenitic stainless steels if chlorides could be in the organic fluid or in the process being served. Some organic fluids may react with other metals, including aluminum. Consult the fluid manufacturer for guidance.

Use welded construction whenever possible. Small diameter pipe or tubing should be bent when possible to minimize connections. If threaded or flanged connections are unavoidable, use 300 lb (21 bar) class steel fittings and schedule 80 pipe. Cut all threads cleanly, using a gauge to ensure proper fit. Ground-joint unions, if used, should be 600 lb (41 bar) class steel.

Select materials and fabrication techniques that ensure suitable fracture toughness when designing systems that may operate below -20°F (-30°C). See the ASME Boiler and Pressure Vessel Code, Section VIII, or the local (national) equivalent for more information.

Avoid flexible connections when possible by using expansion loops and by carefully planning thermal expansion and other movement of components. When flexible connections are unavoidable, use telescoping connections or metallic-armored hose.

Align and support supply piping so it drains back to the vaporizer, or heater. Slope condensed fluid or return piping so it drains back to the heater or vaporizer, or to a condensed fluid tank. Provide valve drains at low points from which fluid cannot gravity drain to the vaporizer, heater or condensed fluid tank. Pipe all valve drains to a safe point, preferably a dump tank.

Select automatic valves carefully. Where necessary, use models with heat-radiating fins or other accessories to protect the valve operating mechanism and packing from excess heat. Automatic control valves are very unlikely to seat tightly against organic fluids; therefore, if positive shutoff is needed, use an additional block valve.

Mount valves with their stems positioned horizontally whenever possible to prevent packing leakage from soaking insulation. Code and manufacturer's specifications may require upright mounting for safety and relief valves, and some special purpose valves. Use drip pans, metal lagging or other devices with these valves to keep leakage out of insulation.

Provide an adequate number of representative sample collection points in the system.

Use nonabsorbent insulation, such as closed-cell, cellular glass or reflective aluminum foil. Aluminum or stainless steel lagging may help, but only if the seams are carefully designed and oriented to prevent fluid from entering the insulation.

Provide heat tracing and insulation as needed to prevent fluid from freezing in relief valve, vent, expansion tank, gauge and instrument lines, and other piping containing low or intermittent flow.

Provide a storage tank large enough to contain all the heat transfer fluid at its operating temperature. The tank should be designed to receive a dump of system fluid while the system operates in case the system leaks seriously or ruptures, or a fire starts. Keep combustible materials and construction away from the tank at all times. Prevent condensed water from accumulating in a tank for a heating system by maintaining the tank above 212°F (100°C) or by using other means. Use a float or an inert gas purge to exclude air. Vent the tank to a safe location.

Clean all piping and vessels before assembling them. The wetting and solvent properties of organic fluids will remove mill scale and other materials which may later clog the system. A temporary strainer may be installed at the pump suction to remove debris during initial system operation.

Use gases to test systems for leakage. A system may pass a hydrostatic test but still leak when in service. A pneumatic pressure-drop test may be used to detect leakage in a new system. Further testing, using a noncombustible but detectable gas, such as helium, may be needed to locate leaks. A photo-ionization detector may be used to locate small organic fluid leaks in an operating system. New or repaired systems may need a hydrostatic or pneumatic pressure test in addition to any leak tests.

Pumps can be a source of leakage and can result in a situation of high pressure atomization of a flammable liquid if a small leak occurs. Use pumps without seals (canned rotor or magnetically coupled) if possible. Otherwise, use pumps with a double seal. Ensure a reliable source of clean cooling water for pumps with water cooled seals or packing, and provide an interlock to prevent the pumps from operating without cooling water. Examine the packing design carefully. Ensure the arrangement will prevent cooling water from leaking into the organic fluid system.

Solid fuel-fired systems require a backup pump powered by a source other than the normal facility power. Use a diesel engine, a dc motor with batteries, or an ac motor with a dedicated engine generator.

## Operation

Establish operating limits for temperature, pressure, liquid level, flow rates, and chemical composition for the heat transfer system and the process it serves. Design instrumentation, control equipment and operating procedures to ensure that the system and process remain safe.

- Provide detailed written procedures for all normal and emergency operations. Supplement the written procedures with formal operator training programs for initial qualification and periodic refresher training. Pay special attention to startup and warm-up when fluids used may solidify or significantly thicken at ambient temperatures. Warm-up rate should not exceed 100°F/h (56°C/h). Heat input limiting interlocks are suggested.
- Some organic fluid systems heat temporarily connected vessels. Examples include heating coils installed in barges and railcars. The coils heat materials such as wax, asphalt or sodium so that they can be pumped. Such applications require strict procedures to keep the system free of contamination. Previous barge or railcar users could contaminate the coils with incompatible fluids. Coils in barges and railcars can contain water from the action of weather or other exposure to water or humidity. Use dedicated barges or railcars if possible. Seal the coils when the coils are not in service. Blow inert gas through coils that are not kept full of fluid, and flush them with fluid before connecting them to the heating system.

## Liquid Systems

Any liquid system requires an expansion or surge tank. The expansion tank is the most important element in allowing expansion without damaging the system and in turn maintaining normal design operating pressures. Therefore, size the expansion tank to be at least 25% full when the system is at ambient temperature and at most 75% full when the system is at operating temperature. When adding equipment to the system, consider how the added fluid volume will affect the expansion tank capacity. Provide each expansion tank with a high-pressure armored type gauge glass with gaskets that are compatible with the fluid. Install the glass with isolation valves, but do not use steam-type fittings with ball check valves. Use heating and insulation if necessary to prevent fluid from freezing in the gauge glass or connecting piping.

If the system temperature is less than the flash point of the liquid, the tank may be vented to atmosphere, however, air should be excluded. A float or an inert gas purge is most often used.

For a system operating at a higher temperature, maintain the expansion tank pressure at least 15 psi – 25 psi (1 bar – 1.7 bar) above the vapor pressure of the fluid at the hottest part of the system. An inert gas head on the expansion tank may be used. If the pressure head is lost, vapor may form in the heater or at a point of high fluid velocity and force fluid into the expansion tank. Therefore, the expansion tank(s) in a system operating at higher temperatures should be large enough to hold the entire system contents. Furthermore, an interlock should shut down the system if the head pressure is lost or low level of liquid occurs. This interlock is primarily provided to keep the system from dry firing.

Throttle fluid flow in a liquid system cautiously to ensure the fluid flow through the heater is sufficient. If necessary, use three-way valves to bypass heat load devices instead of attempting to restrict flow through the load devices.

## Vapor Systems

Most organic heat transfer fluid vapors are much heavier than air or steam. Therefore, air and moisture entering the system during shutdown will readily separate from the fluid vapor and might air bind high points in the system. Condensed moisture can generate steam which can vapor lock or overpressurize the system. If enough moisture is present, the system may be ruptured. Provide equipment and procedures to remove air and moisture from the system during startup and as needed during operation.

Design systems with vent valves at the high points of piping and all vessels. Select component elevations to avoid local high points that cannot be vented. Systems may also be evacuated before startup if needed.

Provide piping to conduct vented fluids to a safe location. Preferably, vents should be piped to a blowdown or dump tank via a water or air-cooled condenser. The condenser should be operated at a temperature that will condense the heat transfer fluid vapor but not the entrained steam.

When organic fluid vapor heats a rotating vessel (roll), some method of venting the roll is needed. Typically, the fluid vapor enters the roll through a rotary joint. An internal siphon tube collects condensed fluid and conducts it back out of the roll through the rotary joint. Air has to be removed, or it will tend to collect at the top and back of the roll. Uneven heating of the roll will result. To vent the air, rotary joints are available that allow the siphon tube to rotate 180° to the top of the roll during warm-up of the roll. Vacuum purging and liquid flooding may also be used to vent rolls.

## Using Organic Fluids In Existing Steam Systems

Existing steam systems may be retrofitted with organic fluids to obtain higher system temperatures at lower operating pressures. When using organic fluids in equipment designed for steam, consider the following:

- The physical and chemical environment for all system materials will change. Thermal movement will more highly stress piping and vessels operating at higher temperatures. Therefore, piping and vessels may need to be redesigned to allow for more expansion and contraction. Higher system flows may also be needed because of the lower fluid heat capacity.
- Seals, gaskets, packings and coatings may be attacked physically by the higher temperatures or chemically by the fluid.
- When using organic fluids in rolls designed for steam heating, consider how the fluids and their operating temperatures might affect the bearings.
- A vessel designed only for pressure stresses may rupture. For example, a jacketed vessel, particularly one with staybolts, must be designed to withstand stresses from extreme temperature differentials. When hot fluid begins to flow in the jacket, the jacket wall temperature will quickly rise to the fluid temperature, but the temperature of the vessel wall may rise very slowly.
- Steam systems contain residues such as scale. Organic fluids are likely to remove these residues. System cleaning and an online strainer may be needed to prevent clogging.

## Vaporizers and Heaters

Provide combustion controls and safeguards in accordance with PRC.4.0.1.

Strictly adhere to the manufacturer's specifications when operating any organic fluid vaporizer or heater. Maintain the ASME Code-required margin between safe operating pressure and design pressure. Do not exceed the maximum heat flux in any part of the unit, because heat transfer fluids will withstand only a limited heat flux. If the maximum heat flux is exceeded, heat will rapidly degrade and carbonize the fluid, causing tube failure.

**TABLE 1**  
**Suggested Maximum Average Heat Flux For Organic Fluid Heaters**

Operating Temperature °F	Fired Units Btu/h/ft <sup>2</sup>	Electrically Heated Units* W/in. <sup>2</sup>
Below 550	5000	16
550 to 599	4000	12
600 to 649	3500	10
Above 650	3000	8

SI Units: °C = °(F-32) × 0.555; kW/m<sup>2</sup> = 0.00316 × Btu/h/ft<sup>2</sup>; kW/m<sup>2</sup> = 0.645 × W/in.<sup>2</sup>

\* The maximum heat fluxes for electrically heated units are higher than those for fired units, because electric heating elements provide more uniform heating than is usually possible in a fired unit.

**TABLE 2**  
**Suggested Maximum Setting For High Temperature And Pressure Cutouts\***

Vaporizer Or Heater And Fluid Type	Maximum Temperature** °F	Maximum Pressure psi
All heaters, orthodichlorobenzene fluids	500	72
Diphenyl-diphenyloxide eutectic fluids:		
Fire tube heaters	650	58
Natural circulation water tube heaters	700	105
Forced circulation water tube heaters	750	160

SI Units: °C = °(F-32) × 0.555; Bar = psi × 0.069

\* Values listed are for guidance only. Consult the vaporizer and fluid manufacturers for additional information.

\*\* Temperatures listed are for vaporizing units. For liquid vaporizers and heaters, use one-half the difference between the normal operating temperature and the boiling point of the fluid.

Table 1 suggests heat flux limits for heaters and vaporizers using diphenyl-diphenyloxide eutectic fluids. Some vaporizer or heater designs, particularly those with forced circulation, may use higher average heat fluxes. Other designs may require lower average heat fluxes. Average heat flux is the heat input divided by the heating surface. Heat input is the maximum burner capacity. If the burner capacity is not available, use 75% of the maximum fuel flow rate multiplied by the heating value of the fuel. Consult the vaporizer and fluid manufacturers for additional information.

Provide each organic fluid vaporizer or heater with:

- A recording-type burner or heat input controller. Use a pressure controller for vapor systems or a temperature controller for liquid systems.
- Independent high pressure and high temperature cutouts. Locate the high temperature cutout as close to the vaporizer or heater outlet as possible. Table 2 provides suggested maximum settings for the high temperature and pressure cutouts.
- A stack temperature monitor. Arrange the device to alarm at 50°F (28°C) above the normal stack temperature, and shut the unit down at 100°F (56°C) above the normal stack temperature.
- A low fluid level cutout. Vaporizers should have a second independent low fluid level cutout that does not automatically reset when the fluid level is restored. Select and position float-actuated devices carefully. Floats that perform properly at low fluid temperatures may sink at higher temperatures when the fluid density decreases.
- Where large volume systems are in place consider the use of a new technology called dynamic leak detection may be appropriate. This detection is placed on the expansion tank and utilizes a single level indicating device that gives a variable output according to the level in the tank. Typically this would be a pressure transducer connected to the bottom of the expansion tank. This provides a variable signal to the process control system depending on the volume elevation in the expansion tank. This can result in the detection of even small leaks prior to a low level detection alarm point.

Provide a flow switch for each vaporizer or heater that has pumped circulation. Arrange the switch to shut the burner down when fluid flow is insufficient. Units with multiple flow paths may need more than one flow switch to prevent partial blockage of one path from upsetting the flow balance. Although a circulation pump motor interlock is recommended, it is not a satisfactory substitute for a flow switch.

Provide a high fluid level alarm for vaporizers and all liquid systems that do not have an expansion tank large enough to hold the entire contents of the system.

Use a Hartford Loop to connect vaporizers with gravity fluid returns. A Hartford Loop connects the vaporizer outlet to the vaporizer return. If the return line is connected to the loop at an elevation above the lowest allowable vaporizer level, then a leaking return line cannot gravity-drain the vaporizer to an unsafe fluid level.

Organic fluid service is a severe environment for safety and relief valves. The fluids are difficult to seal, and the extreme service temperatures may affect the materials used in valve construction. The relatively low pressures involved allow very little spring pressure to properly reseat the valves if they lift. Organic fluid relief devices should comply with the applicable rules in the ASME Code, Section 1, Part PVG. Relief valves for liquid systems should be sized to relieve at a rate equivalent to at least 150% of the burner capacity. The following recommendations apply to safety and relief valves in organic fluid service:

- Use only safety valves, relief valves and other overpressure protective devices designed for organic fluid service at the extremes of system temperature that may be encountered. Such safety and relief valves have special alloy springs, closed bonnets and no test lever.
- Bench test safety and relief valves in organic fluid service annually. If using the system fluid for in-place testing, install dual valves on a Y-base with a three-way valve. This arrangement also allows safety or relief valves to be removed for bench testing or repair while the system is in service. The three-way valve must not have an intermediate (closed) position.
- Keep a spare on the premises for every safety or relief valve in the system. Spares are needed, because typically, valves which lift must be removed and serviced before they can be made leak tight. Valves removed from service for routine testing or repair should be promptly dismantled and repaired as necessary. They should then be tested for setting and leak tightness, sealed, and reinstalled or properly stored.

Combination rupture disk and safety or relief valve overpressure protection may be provided as authorized by the ASME Code. Design such protection to prevent rupture disk fragments from entering the valve and jamming it. Also, provide a gauge to monitor the pressure in the space between the rupture disk and the valve.

Set all relief devices substantially above the normal operating pressure. The ASME Code, Section 1, Part PVG, requires at least a 40 psi (2.8 bar) differential for vaporizers. The high differential minimizes the probability of a valve operating while the system is in service.

Pipe the relief device discharge to a blowdown tank, dump tank or equivalent containment system. Containment is needed because of fluid combustibility, cost and environmental effects. Drainage is also a consideration and would be ideal to draw the hazard away from the process.

Install discharge piping and its supports to prevent putting mechanical stress on the relief device. An expansion joint may be needed to allow the piping to thermally expand when the relief device operates. Use piping at least as large as the discharge connection. Slope the piping to drain the fluid to prevent the fluid from collecting in low points and solidifying. Use heat tracing and insulation as needed to prevent fluid from freezing inside the relief devices and their inlet and discharge lines.

Use only high-pressure armored type gauge glasses with gaskets that are compatible with the fluid. Install the glasses with isolation valves, but do not use steam-type fittings with ball check valves. Provide heating and insulation if necessary to prevent the fluid from solidifying in the gauge glass or connecting piping.

## Inspection and Maintenance

It is generally agreed that frequent observation of heater tube conditions during operations is essential. In order to accomplish this task all heaters should be equipped with an adequate number of inspection ports. Visually inspecting tubes over the entire length is highly ideal to detect pinhole leaks and hot spots. This method detects leaks much faster than a low level indication which usually means a significant amount of product has already leaked out. Therefore, visually inspect the entire system for leaks at least once a shift. Control any spills immediately; repair leaks promptly. Immediately strip and replace any fluid-soaked insulation.

Monitor vaporizer and heater tube temperatures periodically while the system is operating. Thermocouples can be used to monitor key points or inaccessible areas; infrared instruments can be used to scan all visible areas. Abnormal temperatures or changes in the temperature distribution might indicate coke deposits have built up on internal surfaces.

Visually inspect the firebox each shift the unit is in service and immediately after each fuel shutoff. While the unit is firing, look for flame impingement, damaged refractory, distorted or discolored tubes or fluid leakage. After fuel shutoff, look for glowing tubes or fluid leakage. Discolored or glowing tubes might be fouled or plugged.

Check the burner fuel firing rate, the stack temperature and the system fluid inventory daily. A high firing rate may signal the need for a burner adjustment to avoid overheating. Low firing rate, high stack temperature or loss of system fluid may indicate leakage. Leakage must be found and corrected immediately. When a leak inside a vaporizer or heater becomes too large, shutting the unit down becomes extremely dangerous.

Other symptoms possibly indicating leakage include:

- Low expansion tank level.
- High flue gas combustibles.
- Increased flue gas opacity or smoke.
- Increased flue gas carbon monoxide content.
- Decreased flue gas oxygen content.

At least twice a year, remove a sample of the heat transfer fluid for laboratory analysis. Sample the fluid more often if contamination or deterioration is detected or if the manufacturer recommends more frequent sampling. At least quarterly, sample and analyze the fluid in systems used for operations such as unloading barges and railcars. In general, samples must be cooled below 100°F (38°C) before they are transferred to the shipping container. This prevents low-boiling contaminants from escaping. When checking vapor systems, take the sample from the lower part of the vaporizer. When checking liquid systems, take the sample from the main circulating line. Consult the fluid manufacturer for suggested sampling techniques and equipment.

Inspect and maintain heat transfer surfaces and equipment to ensure they operate efficiently and safely. Unless otherwise required by the jurisdiction or experience, internally inspect vaporizers and heaters at least annually and all other vessels at least every five years. To remove all traces of fluid, steam clean vaporizers or other vessels that persons will enter to inspect. Persons entering vessels which have not been steam cleaned will need breathing apparatus and protective clothing to protect against organic vapors and mists.

Fire prevention measures are also required when systems are opened for any reason. Strictly control smoking, sparking tools and hot work. If an organic fluid system component requires welding, purge the system with steam until all traces of organic fluid are removed. For piping systems, this may require 6 to 8 hours. As an additional precaution, maintain an inert gas purge during welding.

Have an authorized inspector examine vaporizers, heaters and vessels. Look for coke deposits, bulging, distortion, refractory problems and signs of flame impingement or local overheating. Select a sample of tubes in watertube units, and inspect their entire lengths for coke buildup. Select some tubes in areas of low flow, usually at the ends, and some in areas of highest heat, usually adjacent to



the burner(s). Use a borescope if possible or else a flexible probe or tube brush. Units with coke deposits require cleaning, usually by high pressure steam or hot water and/or strong chemicals. A specialist should be consulted.

Unless otherwise indicated, inspect all controls and safety devices daily; test them weekly and recalibrate them annually.

### **Fire Protection**

Maintenance and housekeeping are the most important parts of fire protection for a properly designed and operated organic fluid system. Continuously look for leaks and repair them promptly. Maintaining the combustible fluid within the piping is the best prevention of the need for fire protection on the exterior. Do not tolerate combustible materials near the system.

Large organic fluid systems can release large amounts of hot combustible liquids if they fail which are in many cases heated above their flash points. Where the system holdup is excessive, provide automatic or remote-operated zone valves to isolate portions of the system in case of system rupture or a fire exposing the system. Depending on the size of the system segregation using valve and check valve arrangements should be installed based on volume leakage potential. Furthermore, the most critical design feature is to ensure emergency venting goes to atmosphere. Failure to properly design a safe location discharge could result in the release of hot oil into a plant interior.

The following recommendations supplement the AXA XL Risk Consulting fire protection recommendations that apply to occupancies containing heat transfer systems:

- Detachment from critical portions of a property is the most important feature when considering placement of these systems. If possible locate vaporizers or heaters so they do not expose other parts of the facility or adjoining property values. If the climate permits, locate units outside and provide suitable enclosures for controls and other delicate equipment. Locate indoor units in a separate building, or in a room cut off from the rest of the facility with walls fire-rated for at least 2 hrs.
- Regardless of the location, the system tank, pump(s) and controls should be cut off from the vaporizer or heater.
- Spacing between storage tanks and surrounding structures or rights-of-way should be in accordance with PRC.2.5.2.
- Fire proof exposed structural steel, including vaporizer or heater support legs, in accordance with PRC.2.5.1. This is typically a minimum two hour rated application using any of the methods of fire proofing with a UL Listing or FM approval.
- Slope the areas under equipment and use dikes and controlled drainage to divert leakage and runoff to a safe location. Drainage to a waste treatment facility would be the ideal protection measure, however, at a minimum a dike at the thermal heater or boiler to contain fluid to this area is critical.

Provide full automatic sprinkler protection, with particular attention to the following areas:

- Burner fronts
- Relief device discharge points
- Control rooms
- Furnace openings
- Heat transfer fluid vessels and piping
- Operating areas
- Pumps (directional spray heads is the ideal installation)

Provide deluge or water spray protection for systems containing more than 500 gal (1890 L) of fluid or operating above the fluid autoignition temperature. Design deluge protection in accordance with NFPA 13 and PRC.12.1.1.0 . Design water spray protection in accordance with NFPA 15 and PRC.12.2.1.2.

Supplement automatic fire protection water supplies with additional capacity for hose streams. Provide 500 gpm (1890 L/min) for single vaporizers and 1000 gpm (3780 L/min) for multiple vaporizers. Consideration should be given to large volume systems to have supplemental foam protection as a manual application.

Provide two 150 lb (68.1 kg) Class B dry chemical extinguishers within 50 ft (15.25 m), for systems containing more than 500 gal (1890 L) of fluid or operating above the fluid autoignition temperature. See NFPA 10 for more information.

Fire protection for heat transfer fluid leaks inside a heater or vaporizer firebox depends upon the fuel type and the firebox design. The following factors limit the need for fixed protection inside the unit:

- Source of heat that can be readily shut off, such as most gaseous or liquid fuels or electricity.
- Limited use of heat-retaining materials, such as refractories, in construction.
- Design which will contain leaked fluid and resulting fire inside the unit.

Liquid or gaseous fuel fired firetube units may require no additional protection. Liquid or gaseous fuel fired watertube units may require a smothering system, depending upon the heat capacity of the furnace refractory. Solid fuel-fired units must have a firebox smothering system. Engineer firebox smothering systems specifically for each unit. The following considerations apply:

- The system must be able to suppress combustion in the firebox long enough to cool all internal parts, including residual solid fuel, below the autoignition temperature of the heat transfer fluid. To cool down the system at a reasonable rate, the airflow must usually be continued simultaneously with the smothering system operation. Cool down for solid fuel-fired systems will probably exceed four hours.
- If possible, continue heat transfer fluid flow during the cool down period unless:
  - The leak is so large that a pool fire hazard develops, or,
  - Continued temperature rise indicates the smothering system cannot control the fire.
- Steam smothering systems must have a reliable source of steam capable of providing 15 psi (1 bar) at the discharge nozzle(s) at a rate of 8 lb/min/100 ft<sup>3</sup> (10.27 kg/min/100 L) of furnace volume during the cool down period. Place the injection nozzle(s) low in the firebox. Systems should be manually actuated from local and remote locations. The following formula relates the parameters involved in steam flow through the nozzle(s):

$$W = 0.7 AP$$

Where:

W = steam flow rate, lb/min (kg/min)

A= discharge nozzle opening area, in.<sup>2</sup> (cm<sup>2</sup>)

P = outlet steam pressure, psi (bar)

- Dry chemical systems may be effective alone or as a knockdown agent accompanied by steam or CO<sub>2</sub> smothering. If using dry chemical systems alone, make sure the connected and reserve chemical inventory is sufficient to suppress combustion during the cool down period. If using a dry chemical system with a smothering agent, provide one connected unit and at least one reserve unit. Design the systems in accordance with NFPA 17 and PRC.13.1.1.1.
- CO<sub>2</sub> systems may be effective, however, design them to provide an initial and continuous discharge of agent. Design the initial discharge to quickly knock down a fire and the continuous discharge to last long enough to suppress the fire during cool down. Design systems in accordance with and NFPA 12 and PRC.13.3.1.
- Bypass precipitators, or otherwise protect them.
- Submit plans to the XL Risk Consulting Plan Review Office before installing any firebox fire protection system. Include the following information:
  - A one-line or schematic drawing of the heat transfer system, showing all vaporizers or heaters, steam generators, valves, piping, vessels and connected loads.

- A one-line or schematic drawing of the proposed protection system and a verbal description of its operation.
- Prints or drawings of each solid fuel-fired vaporizer or heater, showing the size and firebox construction and the proposed system for introducing the smothering medium or agent.
- Calculations demonstrating that the source can supply and the piping system can transport the required smothering medium or agent volume and flow rate to the firebox for the required time period.
- A description or copy of the procedure to be followed in case organic fluid leaks inside the vaporizer.

NFPA 664 contains additional fire protection information for organic fluid systems in woodworking facilities.

## DISCUSSION

Heat transfer systems conduct heat between primary or waste heat sources and processes or cooling systems. The fluids used in heat transfer systems include:

- Steam, water, refrigerants and other gases.
- Mineral oils and other organic fluids.
- Molten metals and salts.

Steam, water, refrigerants and other gases may have other excellent properties, but they have steeply-rising pressure-temperature curves. If temperatures much higher than 300°F (149°C) are required, the equipment wall thickness needed to contain the corresponding pressure unacceptably reduces efficiency and increases cost.

Molten metals and salts are used in specialized applications, but these fluids have various properties that challenge widespread use. None of the metals or salts except mercury are liquid at normal ambient temperatures. This complicates startup and shutdown. The metals as a group are also highly toxic. Many of the fluids are hazardous and corrosive.

Therefore, organic fluid systems are becoming more popular for heating processes that once would have used steam. These materials require much less system pressure for a required process temperature. Table 3 illustrates the advantage for two Dow Chemical Company patented organic fluid products.

**TABLE 3**  
**Comparison Of Heat Transfer Fluid Saturation Temperature**

Required Process Temperature °F	Minimum Saturated Steam System Pressure psi	Minimum Dowtherm A* System Pressure psi	Minimum Dowtherm G** System Pressure psi
300	67	0.64	0.33
500	700	15.7	8.2
700	3100	106.0	58.0

SI Units: °C = °(F-32) × 0.555; Bar = psi × 0.069

\* Liquid or vapor phase

\*\* Liquid phase

Specially refined mineral oils are occasionally used to transfer heat, but these oils are less stable and more combustible than desired. A variety of “made to order” organic fluids have been developed; a eutectic mixture of diphenyl and diphenyloxide is one of the most common. This mixture is sold under trade names such as Dowtherm A (Dow Chemical Co.) and Therminol VP-1 (Monsanto Chemical Co.). Many other organic fluids are available. The proper fluid selection can accommodate service temperatures from above 750°F (400°C) to below -70°F (-57°C). Organic fluid systems are most

commonly used to aid in the manufacture of drugs, plastics, synthetic fibers, resins and other chemicals; plywood, particle board and other pressed forest products; roofing materials and other asphalt products; and corrugated board and turpentine.

Organic fluids have other advantages. They do not expand when they solidify. As inconvenient as an unplanned system cool down may be, fluid solidification will not rupture components. Organic fluids are not corrosive to most materials. However, organic fluids are difficult to contain. They must be carefully matched to the application: a relatively minor change in process conditions may require a different fluid, and changing fluids may require changes in piping sizes, flow rates and other system parameters. Some fluids are poor lubricants. The fact that organic fluids burn is most significant for loss prevention. The most common heat transfer fluids are Class III B combustible liquids.

Most organic fluid heat transfer systems operate in the liquid phase. These systems look very much like hot water heating systems but operate at much higher temperatures. The major system components are:

- The heater to transfer heat of combustion or process waste heat to the heat transfer fluid.
- Pumps, valves and piping to circulate the fluid.
- An expansion tank, located above the system, to maintain a low pressure head on the system.
- Process heat exchanger(s), such as jackets, coils or heater plates, to transfer heat to the product.

Organic fluid vapor systems are similar to steam systems. Like steam systems, they may have a single vapor supply/condensed fluid return line or separate lines. Gravity or a pump may return condensed fluid to the vaporizer.

Most organic fluid heaters and vaporizers are gas or oil fired. If a small tube leak develops, the gas or oil can be readily shut off, preventing significant heat from entering the system. Fluid circulation can be stopped and the vaporizer “blocked-in” with minimal risk of further damage to the vaporizer. The organic fluid can be drained to a holding tank to stop fluid from leaking into the furnace. Even if a large leak develops, the only concern is fire igniting the leaking fluid.

Organic fluid vaporizers fired with wood or other solid fuels are inherently more hazardous than those fired with liquid or gaseous fuels. Controlling “unfriendly fire” in a solid-fueled firebox without destroying the vaporizer is difficult. There is no way to rapidly shut off a solid fuel fire. Either the burning fuel must be physically removed and extinguished, or the fire must be suppressed in place. Furthermore, solid fuel-fired vaporizers have large furnaces with massive refractory linings. The refractory will remain above the autoignition temperature of the organic fluid long after the fire is out. Accordingly, if a tube fails, an operator has two choices:

- Cool the vaporizer by continuing to circulate the heat transfer fluid, and attempt to smother the fire or remove it faster than the leak can feed it. Removing or smothering the fire and cooling the furnace lining below the autoignition temperature of the organic fluid will probably take at least four hours.
- Isolate and drain the vaporizer while the fire is still burning. This action will probably destroy the vaporizer. Even if the tubes are not directly destroyed, the resulting overheating will probably “coke up” the heat transfer surfaces beyond the ability of any cleaning technique to correct.

Therefore, effective action to control a fire almost assures loss of the vaporizer; any attempt to save the vaporizer risks losing control of a fire. The loss history is poor. A survey of ten installations operating over a two year period revealed two units sustained serious fires and another leaked but was successfully brought under control.

Fire protection for a solid fuel-fired unit requires suppressing fire in the furnace while allowing air cooling flow for upwards of four hours. Protection methods are still being developed. Here are the latest known protection possibilities:

- **Steam smothering** - This is an option for facilities that have a reliable steam source, such as steam generators heated by the organic fluid. These systems are of limited usefulness, as the steam easily escapes through the chimney stack. As such, continued application over a long time is needed to control a deep seated fire.
- **Dry chemical suppression** - Injecting dry chemical extinguishing agent into the furnace to suppress combustion might work, but the amount of agent needed is staggering. Dry chemical knocks down the fire effectively, but continued application over a long time is needed to control a deep seated fire. In one fire, 1500 lb (681 kg) of agent was not enough. In another, 3000 lb (1362 kg) of agent was on hand and another ton (908 kg) was on standby. This may have been enough; fortunately, the organic fluid leak was very small and no suppression was necessary.
- **CO<sub>2</sub> smothering** - Research suggests that a CO<sub>2</sub> system may be feasible but would require a huge inventory of CO<sub>2</sub>, because CO<sub>2</sub> concentration needs to be maintained during the cool down period.

A full analysis of every location having a solid fuel-fired organic fluid heat transfer system is required. Although particle and chip board manufacture are the only occupancies now known to contain such systems, other occupancies may use them.

Organic fluids deteriorate while in service. If fluids react with other materials or if the fluids overheat, molecular bonds in the fluid can break and different compounds can form. Two types of contaminants normally result: "low boilers" and "high boilers." Stable compounds produced are generally low boilers, whose boiling point is lower than the fluid. Low boilers are not normally a problem, because they are vented off during normal system operations.

Often, however, the molecular fragments recombine, forming large molecules with higher boiling points than the fluid. These high boilers can be troublesome. Soluble high boilers lower a fluid's efficiency by raising its viscosity. Insoluble high boilers will foul the system. Because high boilers usually form in the heater, they will probably remain there and coat the heat transfer surfaces. This coating drives up the tube temperature, which accelerates the deterioration process. High boilers can often be removed from fluids by a reclamation process that involves redistillation.

Three factors affect the deterioration rate. The most significant is temperature. The design limit for a heat transfer fluid is normally just below the temperature at which significant or rapid deterioration occurs. Operating the system close to the limit or overheating the fluid will accelerate deterioration.

The amount of deterioration also affects the deterioration rate. The deterioration process is self-accelerating, because the products of deterioration contribute to further deterioration. At some point, the process "takes off" and quickly produces conditions that will cause the system to fail.

Contaminants contribute to deterioration. Oxygen will help deteriorate any organic fluid; therefore, every effort should be made to keep air out of systems. Materials of construction and materials in process may also directly cause or catalyze deterioration reactions in the fluid.

Regular fluid analysis, if the samples are representative, should reveal normal deterioration. Fluid replacement or reclamation can be scheduled as needed. However, local overheating in the vaporizer or heater, even if the overheating lasts a short time, can start a destructive cycle. A carbonaceous ("coke") deposit may form at the point of the overheating. The deposit insulates the tube, which increases the local temperature and possibly decreases the flow. Decreasing the flow further overheats the tube. Higher heat flux in the unaffected parts of the vaporizer are needed to maintain the total heat flow at the required level. The higher heat flux may result in other local hot spots which can potentially result in a rupture condition.