Heat Transfer

Prevent Fires in Thermal Fluid

Follow these design and operating guidelines for a safe heat-transfer-fluid system.

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Thermal fluids have proven exceptionally safe during many years of operation in a wide range of industries. However, there is no way to completely prevent fires in these systems because the major components required — fuel, air and an ignition source — are always present by design.

The potential for a serious fire caused by the thermal fluid system can be minimized by observing sound design and operating procedures. This article provides such guidance. It explains flash and fire points, autoignition temperature and boiling range, outlines the types of fires that typically occur, and discusses how the potential for fires in the thermal fluid system can be minimized.

Data for gauging fluid safety

lash point is the most commonly requested piece of information when prospective users are screening fluids for an application. In many cases, the system operating temperature is well above the flash point, which prompts concern about the potential for fires. Understanding this property (and others) is important to making cost-effective decisions.

The flash point of a fluid is the temperature at which sufficient vapor is generated to “flash” when exposed to a source of ignition. In the Cleveland Open Cup (COC) test method, ASTM D92, an open cup is partially filled with a sample of fluid and then heated at a fixed rate. The vapor is ignited by a small flame that is continuously passed back and forth just above the surface of the fluid. An alternative is the Penske Marten Closed Cup (PMCC) test method, ASTM D93. In this method, the container is totally closed except for a small opening where the flame is exposed to the vapor. Results of this method are usually 8 to 10°F lower than the COC method, because the closed cup concentrates the vapor.

Fire point is the temperature at which a fluid generates sufficient vapor to support continued combustion. It is typically 40–100°F higher than the flash point. To determine fire point, most often the COC method is used.

While these tests do provide an indication of the ease at which various fluids will ignite, the data need to be viewed in the context of an actual thermal-fluid system. To achieve ignition, the fluid must at least reach its flash point, with a source of ignition close enough to the surface to ensure an ignitable concentration of vapor. In actual operation, leaking fluid will cool quickly below the flash point when exposed to air. Any vapors that are produced while the fluid is still hot will typically turn into smoke if the area has adequate ventilation. This smoke is most noticeable around small volume leaks known as “weepers.”

The most important use of flash and fire points is that they indicate the fluid’s volatility or ability to generate vapor under a given set of conditions. If a significant leak occurs, for example, a fluid with a lower flash point will generate more vapor, which in turn creates more of a potential for fire.

Autoignition temperature (AIT) is another test that is sometimes used when screening fluids for fire potential. AIT is the temperature at which a fluid will ignite without any external source of ignition.

For many years, the most commonly reported method was ASTM D-2155, which was superceded several years ago by ASTM E659-78. This procedure involves injecting a sample of the fluid into a test beaker filled with hot air. The temperature of the air at which the fluid ignites is the AIT. There has been some controversy over whether the test is applicable in assessing risk in thermal fluid systems, since it requires that the air be heated and not the fluid. Because most thermal fluids have an AIT of 675°F or higher, the only real-life situation that compares to this test is when fluid leaks into an existing fire.

Boiling range can also be used to evaluate the fire potential of thermal fluids. Several years ago, Factory Mutual Insurance investigated a number of incidents where thermal fluid leaks produced a mist that either exploded or caught fire in an enclosed area *(1)*. As a result of this study, they proposed that no thermal fluid be operated at a temperature above its atmospheric boiling point. This restriction mostly affected synthetic fluids that have relatively low boiling points. Interestingly, there were no reported incidents of mist explosions for fluids with a flash point of 425°F or above.

In summary, while these tests provide data that can be useful in understanding the potential for fires, they should not be used as the only selection criteria.

Types of thermal-fluid system fires

There have been relatively few fires that have originated in thermal fluid systems. Those that have occurred can be loosely categorized as follows:

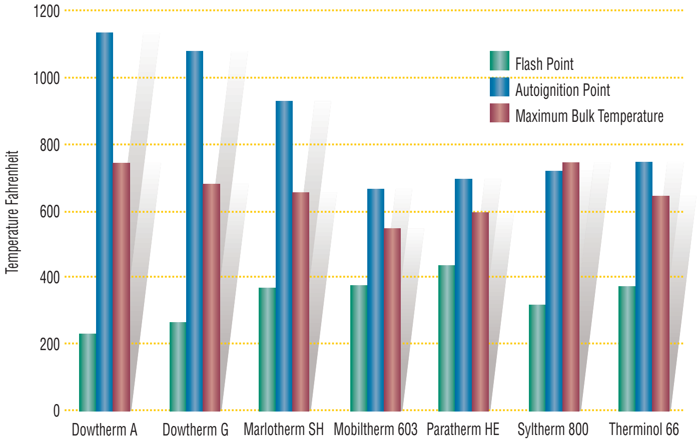
- *Major leaks.* These typically involve the mechanical failure of a non-pipe component, such as an expansion joint, flexible hose or rotary union, that allows a significant quantity of fluid to leak onto an ignition source. The source of ignition is usually close to the leak, since thermal fluid systems operate at an insufficient line pressure to spray the fluid any distance. Sources of ignition have included rotary joints that were red hot due to bearing failure, pump seals

Systems

that were seizing, sparks created by rotating shafts, and an open motor several floors below the leak.

- *Insulation fires.* The most common type of fire, these are similar to the “oily rags” scenario in that a fire starts without any apparent cause. These fires occur when fluid leaks from a valve stem, flange or crack into “open” types of insulation materials, such as glass fiber, calcium silicate or mineral wool. The open structure allows the fluid to migrate away from the source of the leak and disperse within the insulation. Spontaneous ignition of the trapped fluid can occur due to a sudden increase in available oxygen if the insulation cladding is removed or punctured. An abrupt change in operating temperature has also caused spontaneous ignition. Ref. 2 discusses fires in thermal-fluid system insulation further.
- *Loss of flow.* This type of fire occurs when a series of equipment failures interrupts the flow of thermal fluid to the heater. The first failure is due to the loss of a pump motor, coupling failure, a system pressure-control valve that sticks closed or a full-flow filter that has “blinded.” The second failure is a high-temperature cut-off that fails to shut down the heater due to fouling, burnout or poor location. As the heater continues to fire, the temperature of the now stagnant fluid increases rapidly above the boiling point and the autoignition temperature. When a crack develops in the heater coil or the piping connected to the heater, superheated fluid is discharged into the hot atmosphere, where it spontaneously ignites. If the piping remains intact, the vaporized fluid either discharges through the relief valve into the catch tank or pushes fluid up into the expansion tank, which then discharges into the catch tank. Violent discharges have caused fires when volatile material in the tank is vaporized by the hot thermal fluid and then ignited by the heater.
- *Cracked heater tubes.* Serious fires inside heaters due to cracked heater tubes are relatively rare. Cracks can form due to excessive thermal cycling or near hot spots that develop due to internal fouling. The leaking fluid will burn off immediately while the heater is operating. When the system is not operating, fluid continues to leak into the combustion chamber due to head pressure from the expansion tank and overhead piping. In the most serious case, the fluid formed a large pool inside the heater during a prolonged shutdown. During start-up, the entire pool ignited and destroyed the heater.

Plants can minimize the risk of fires caused by thermal fluid systems in several ways, as discussed in the remainder of the article.



Properties of Common Heat Transfer Fluids

Mechanical design and installation

If the heater is located in a building, provisions should be made for adequate ventilation to prevent any possible buildup of vapors. Other fired equipment such as steam boilers should be located in another area. Hydraulic systems that have the potential for spraying fluid across extended distances should be located well away from the heater.

A dike encompassing the heater and pumps should be considered to contain any leaks. While flange leaks are usually more of a nuisance than a hazard, they create a housekeeping problem and result in smoke in the area. This type of leak can be minimized by specifying 300-lb flanges (For pipes 3” diameter and less,) and using gaskets made of graphite or an appropriate fiber-reinforced Teflon.

Isolation and bleed valves should be installed in the piping to each heat user so that maintenance can be performed without draining the whole system. Globe, ball or plug valves with appropriate stem packing are recommended for thermal-fluid service. Wherever possible, install valves with stems sideways so that any leaks run down the stem and away from the piping.

> Expansion joints should always be located so that they expand axially and not sideways.

If cold startups are planned, a bypass valve should be installed at the heater to avoid overheating the fluid. To prevent excessive thermal cycling of the heater tube bundle, oversized heaters should be de-rated by installing a smaller burner or increasing the turndown ratio.

Another area of concern is the catch drum that collects material discharged from the relief valves and overflow from the expansion tank. Catch drums can contain water that has been boiled out of the system and the more volatile components of the thermal fluid that accumulate in the expansion tank. Catch drums should be drained periodically, because either of these types of materials can create a vapor cloud if hot fluid is discharged into it. Catch drums should be located inside a fireproof enclosure away from the exit door of the heater room.

Expansion tank

Expansion tanks provide room for the fluid as it expands during heat up. The tank should also maintain a positive head pressure on the pump suction. Because the tank is usually located above the system, it can provide a continuous source of fuel to a fire if a leak develops. A

properly sized expansion tank will minimize the amount of fuel available for any fires.

A widely used rule of thumb is to multiply the expansion volume of the fluid by 2.25 to obtain the total expansion-tank volume. For example, if a system circulates 1,000 gal of fluid with a thermal expansion of 0.05 gal/gal of fluid per 100°F temperature rise and operates at 470°F, the increase in volume will be (1,000 gal) X (0.05 gal/gal/100°F) X (470 – 70°F), or 200 gal. Using the 2.25 rule, the proper size of the expansion tank for this system would be 450 gal.

Some facilities have installed an automatic shut-off valve on the line connecting the expansion tank to the system that is activated by the building fire-detection system.

> Another concern with expansion tanks is that they can contribute to fluid oxidation.

Oxidation occurs if the tank is vented to atmosphere and the tempeature of the fluid remains above 140°F during normal operation. The reaction of the hot fluid and air forms byproducts that coat surfaces and reduce heat transfer. In the heater, these deposits create the hot spots that can ultimately cause cracks. Oxidation can be prevented by keeping the expansion tank below 140°F and/or oxygen free.

Flowrate

Fired heaters transfer heat to the thermal fluid in two ways — by radiant and convection heat transfer. The convection section is the portion of the piping that is in contact with the high-temperature combustion gases. The radiant section is the portion of the piping that directly faces the flame.

Because a disproportionate amount of heat is transferred in the radiant section, the tube surface temperature can routinely reach 700°F, which can cause thermal cracking of the fluid. Thermal cracking causes the fluid molecules to break apart, resulting in smaller, more-volatile components ("low boilers") and also forming solid carbon. The increase in concentration of low boilers decreases the fluid density, which in turn reduces the heat delivered by each gallon of fluid.

Users compensate for this loss of heat by increasing the heater outlet temperature, thereby increasing the rate of fluid degradation. The accumulation of low boilers will also decrease the fluid's flash point, which can increase the potential problems due to leaks.

To prevent excessive cracking, the fluid flowrate must be maintained under all operating conditions. It is critical that pumps are sized to provide the required flowrate under all process conditions. Systems with multiple users should incorporate a pressure control valve connecting the fluid feed and return headers. Any filters should be installed either parallel to the process or on a side-stream loop aroundthe pump.

Insulation

As noted previously, insulation fires almost exclusively occur when fluid leaks into open type materials, that allow the fluid to migrate away from the source of the leak. Closed-cell materials (such as Foamglas) contain the fluid near the leak, reducing the fire potential of the fluid. It should be installed on valves, filters or anything that has a potential for leaks. While open insulation does present more of a potential for fires, it is cheaper than closed materials.

Open insulation can be installed on long piping runs where the possibility of leakage is extremely remote. Closed-cell material should be extended 18 in. on either side of the potential leak point and weep holes should be drilled in the bottom to drain any leaked fluid.

Do not use plastic ties to attach weather shields or insulation — they can melt during a fire and allow burning insulation to fall off the pipe. Flanges should not be insulated — install drip caps if necessary for personnel protection. Do not insulate pump seal and shaft areas.

Low-flow indicators

Low-flow shutdown should be included in the burner safety interlock. Flow detectors that are immersed in the fluid are not recommended, since they can fail in the wrong position. Pressure sensors have proven to be the most reliable in long-term service. To provide effective indication of a no-flow situation, pressure sensors should be installed across a fixed restriction or as high and low pump-discharge-pressure detectors.

Operating procedures

Excessive thermal cracking can also occur during heater startup and shutdown. Cold fluid (below 100°F) has a high viscosity, which not only makes it difficult to pump but also reduces its ability to transfer heat. During startup, the burner should not be operated at a high firing rate until the fluid temperature has reached 150°F.

To properly shut a heater down, the fluid should continue to circulate until the temperature is below 250°F. This will ensure that the residual heat from the heater refractory has been removed.

Literature Cited

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BIO

Jim Oetinger, Paratherm Corporation's Sales Director, has over 20 years experience in the chemical and plastics industry. He has been involved with a wide range of products and processes including pigments, refrigerants, consumer plastic recycling, polymer compounding, process instrumentation and spray dried polymers as well as having extensive experience in sales and marketing of thermal fluids. Jim has authored articles on system troubleshooting and fire prevention for Process Heating, Chemical Engineering Progress and Die Cast Management magazines among others. A member of the Delaware Valley Chapter of the American Institute of Chemical Engineers, he holds a Chemical Engineering degree from Clarkson University and a Masters of Management degree from Northwestern University. Jim and his family reside in suburban Philadelphia PA.