Insight: Heat Transfer Fluids in Renewable Energy

Recognizing the Risk

Two risks associated with Heat Transfer Fluids (HTFs) are freezing and fire which could lead to a vapor cloud explosion.

Heat Transfer Fluids (HTFs) are organic liquid compounds that are used specifically for heat transfer applications. They can be sourced from materials derived directly from crude oil or manufactured synthetically. The use of HTFs in renewable energy systems can present unique hazards. These fluids are often used in Concentrated Solar Power (CSP) facilities. In the CSP application, the HTF is circulated in a pipe set at the focal point of the mirrors. The HTF is heated up to approximately 750°F (400°C) then either heat exchanged with steam to drive a turbine or alternatively used to heat up molten salt used as a longer-term heat storage medium to extend generation past daylight hours.

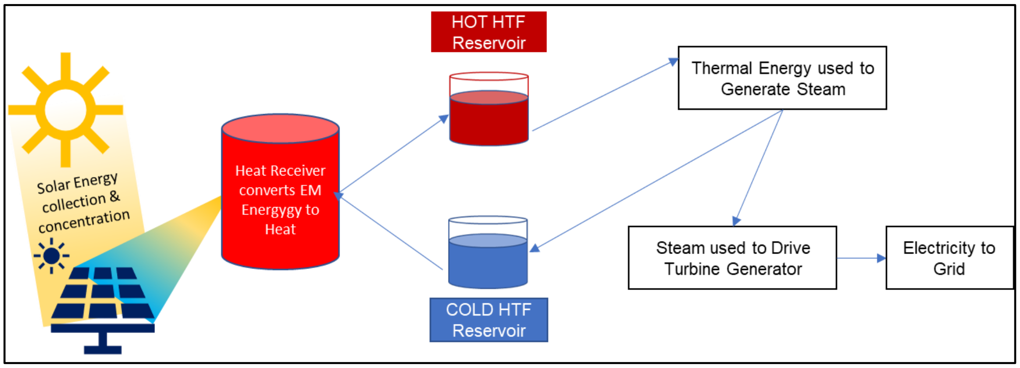
HTFs work well in these applications because it is a stable material, have low viscosity, and have a very low vapor pressure at elevated temperatures. This makes it ideal for these applications, being easy to pump and circulate through the large network of heat exchangers typically found on these types of plants. Although they are generally well suited to the applications, one potential hazard is that they normally have quite high freezing points typically well above water. Therefore, the fluid must be constantly circulated and kept above its freezing point. In certain locations, this might need to be above the ambient temperature.

HTF products are typically Class II or Class III combustible liquids per the National Fire Protection Association (NFPA) 30 Flammable and Combustible Liquids Code[1]. Properties do vary somewhat between the many different types available. Specific properties will be detailed in the supplier's “Material Safety Data Sheets” (MSDS) or Safety Data Sheets (SDS). HTF fluids can pose significant fire hazards including the formation of a vapor cloud explosion.

A Typical HTF System

A typical HTF system will include heat collection equipment, pumping, ullage, anti-freezing, nitrogen cylinders, expansion tanks and heat transfer equipment.

Heat collection equipment – For solar applications this includes a field of parabolic, mirror-surfaced heat collectors, while in other applications such as geothermal, it will be a series of heat exchangers in contact with the heat source material. The equipment will experience a wide range of temperatures that could reach up to 750°F (400°C). Consequently, the equipment experiences considerable expansion and contraction. As most systems comprise multiple connection points there are many opportunities for leaks to develop.



Pumping system – a pumping system is provided to move the HTF liquid throughout the system. Operating pressures will vary but most operate under a reasonable level of pressure. System operating pressures of up to 435 psi (30 bar) are not uncommon. Isolation valves, pump seals and connections are therefore natural points for leaks to occur. Pump alignment should be checked while cold and again after the system reaches operating temperature. Pump design should be in accordance with American Petroleum Institute (API) 610 Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries and API 682 Shaft Sealing Systems for Centrifugal and Rotary Pumps.

Ullage system – A waste removal system is required for purging oxidation and cracking products that accumulate in the HTF over time. If not kept clean, contaminants have the potential to create deposits within the pipework of the system and will also lower the HTF flash point. A typical purging system is designed to extract 1-2% of the total oil flow volume. The purge stream is subjected to a low-pressure environment (generally below 4 bar), where the lower boiling point contaminants flash off and are separated out from the bulk of the higher boiling point HTF. The cleaned HTF stream is then returned back into the main system.

Anti-freezing system – Since some HTFs may freeze at ambient conditions, it is normally necessary to provide systems to prevent this from occurring. Fired heaters are commonly used for this purpose, using either natural gas or liquid fuels (in more remote areas). As well as being able to protect against freezing the system will also serve as a warm-up system or can be used on occasions to provide additional heat when the main energy source proves insufficient. Burner protection for this equipment will be required as per NFPA 87[2] Recommended Practice for Fluid Heaters. In addition to fired heating support systems, much of the HTF piping will be insulated and heat traced to prevent the oil solidifying in-situ.

Nitrogen system – Nitrogen is used to provide an inert atmosphere over the HTF in waste disposal, expansion and overflow tanks. An Inert atmosphere helps to prevent oxygen entering the system thereby protecting the oil from harmful oxidation reactions. Nitrogen is typically provided for this purpose via a bank of high pressure cylinders.

Expansion tanks – expansion is required to absorb the differences in volume when the fluid is heated. It is positioned at the higher point of the system and will typically be associated with the pump systems and over flow tank. Expansion tank vents will require monitoring.

Heat transfer equipment – This is the hot HTF heat exchanger or steam boiler where the heat in the HTF is transferred to another medium, either directly to produce steam for driving a steam turbine generator, or to molten salt where the energy is stored for later use.

Risk Exposures

AIG has experienced multiple claims where fires have been caused by hot HTF leaking out and finding an ignition source. HTFs operate at high temperatures and pressure. Should a leak occur, it is likely to take the form of a vaporizing spray. In these circumstances, the HTF is likely to be above its flash point and can be easily ignited should an ignition source be nearby (e.g. a hot surface). In some cases it may be possible for the vaporized oil to explode should sufficient vapor buildup before finding an ignition source. HTFs have a high energy density and once ignited they burn with great intensity. Firefighting operations can be challenging and extinguishment may only be possible if the source of the leak is eliminated (or the HTF is totally consumed by the fire). Hot oil may also ignite nearby vegetation allowing it to spread further, perhaps even sparking a wildfire under the right conditions (i.e. significant amount of dry vegetation cover close by plant).

Two recent losses on concentrated solar plants have identified another failure mode not previously anticipated. This involves facilities using molten salt for heat storage. In both these cases, HTF leaked into the molten salt at the heat exchanger and mixed with air that had accumulated within the circulating inventory. Eventually, the contaminants (HTF + air) reached the right level to form an explosive mixture, ignited within the pipework, and caused significant damage. Air accumulations within the HTF resulted from a failure to maintain the nitrogen blanket on the expansion tank and/or improper venting.

Controlling the Hazards

HTFs should be handled, used, and maintained in accordance with NFPA and API codes and standards. A list of the appropriate standards is provided below. The following comments highlight some of the more important considerations.

Design

A complete risk assessment must be completed for the specific HTF being used. The systems must be designed to meet the guidance in NFPA 30 and NFPA 850[3]. These standards will provide guidance regarding specific risk mitigation measures. These may include the installation of explosion-proof components in proximity to fluid handling systems, operational and fluid alarms, and automated isolation requirements. Specific pump and piping systems designs may require double seals on pumps, fire suppression systems, and explosion detection and monitoring.

Fluid Quality

Fluid quality must be maintained at all times. The HTF manufacturer will provide guidance for testing frequency and HTF minimum quality standards. Testing should be done in accordance with manufacturers' guidelines. More regular testing is recommended for new installations. Sampling systems should be such that the sample is collected at an acceptable temperature of less than 195°F (90°C) i.e. cooling systems provided where necessary. As a minimum, tests should include:

- Acid Number: indicates oxidation level of the HTF, predicts onset of fouling and sludge problems
- Viscosity – if too high it will lead to inefficient heat transfer
- Distillation Range - indicates whether HTF composition has changed due to overheating.

Operational Inspections / Housekeeping

Regular inspection of the HTF system is required on each operating shift:

- ✓ Look for any leaks or signs that HTF is leaking into the insulation. Particular attention should be paid to bellows or other points of expansion. Leaks should be reported immediately and cleaned up by properly trained individuals. No threaded fittings should be used on the pipework. New pipe sections, fittings, valves, or instruments should not be insulated until the plant reaches full operation and is found to be leak-tight.

- ✓ Monitor for internal leaks within the heat exchanger system by checking expansion tank vents and the properties of the other heated medium (e.g. molten salt or water). If molten salt is used then it must have a high-point vent and nitrogen blanket to prevent the accumulation of explosive mixtures. If an HTF leak is detected or suspected in a heat exchanger, then the system must be immediately (but safely) shut down to repair the leak. Operating the plant with known leaks, even if considered small is inadvisable.

Monitor the Operating Area for Explosive Conditions

- ✓ Observe the system for unusual sounds or odors that might indicate contamination of the HTF or heated medium.

- ✓ Maintain system temperatures in accordance with design criteria. Generally, the expansion tank fluid should be maintained around 176°F (80°C). Also, the circulating fluid must be kept well above the HTF freeze point.

References & Resources

[1]NFPA 30, Flammable and Combustible Liquids Code

[2]NFPA 87, Standard for Fluid Heaters

[3]NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection

API 610, Centrifugal Pump for Petroleum, Petrochemical, and Natural Gas Industries

API 682, Shaft Sealing Systems for Centrifugal and Rotary Pumps

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*While NFPA documents are the global standard used by AIG, international equivalents may be acceptable.

For more information, contact your local AIG Risk Engineer.