Insight: Heat Transfer Fluids (HTF's) in Renewable Energy

Use of HTF's in Renewable Energy Systems Can Present Unique Hazards!

Recognizing the Risk

Heat Transfer Fluids (HTF's) 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. These fluids are often used in the 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 day light hours.

HTF works well in these applications because it is a stable material, has low viscosity, and has 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, so 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 as by the National Fire Protection Agency (NFPA) 30 Flammable and Combustible Liquids Code. Properties do vary somewhat between the many different types available. Specific properties will be detailed in the suppliers "Material Safety Data Sheets" (MSDS) or Safety Data Sheets (SDS). HTF fluids will pose significant fire hazards and may have the potential to form vapor clouds.

A Typical HTF System will include

Heat Collection equipment – For solar applications this would be 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 a 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 typically 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 HTF's 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 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 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. HTF's operate at high temperature and pressure. Should a leak occur a then 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 be easily ignited should an ignition source be nearby (note that this could be a very hot surface). In some cases it may be possible for the vaporized oil to explode should sufficient vapor build-up before finding an ignition source. HTF's have a high energy density and once ignited they will burn with great intensity. Firefighting operations are therefore likely to prove challenging and extinguishment may only possible if the source of the leak eliminated (or HTF 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 then mixed with air that had accumulated within the circulating inventory. Eventually the contaminants (HTF + air) reached the right level to form an explosive mixture and subsequently ignited within the pipework causing significant damage. Air accumulations within the HTF resulted from a failure to maintain the nitrogen blanket on the expansion tank and/or improper venting.

Recommendations

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

The systems must be designed to meet the guidance in NFPA 30, and NFPA 850 Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations chapters 11. A complete risk assessment must be completed for the specific HTF being used. These standards will provide guidance regarding specific risk mitigation measures. These may include 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 and 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 at in accordance with manufacturers guidelines. More regular testing is recommended for new installations or when HTF first added to system. Sampling systems should be such that the sample is collected at an acceptable temperature less than 195°F. (90oC.) 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, and should include:

Look for any leaks or signs that HTF is leaking in to 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 instrument should not be insulated until they plant reaches full operation and 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 high point vent and nitrogen blanket to prevent accumulation of explosive mixtures. If a 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.

Resources / Standards

The references are:

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

NFPA 30, Flammable and Combustible Liquids Code

NFPA 87, Recommended Practice for Fluid Heaters

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

API 682, Shaft Sealing Systems for Centrifugal and Rotary Pumps

NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations Chapter 11 and 12

For more information, contact your local AIG Property Risk Control Representative.