What do these items have in common?
Overview of Thermal Fluid Heaters

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Purpose

- Compared to Power Boilers and Heating Boilers, there are a limited number of installations of thermal fluid heaters.
- Minimal guidance is available on these heaters and systems.
- Jurisdictions vary in how these heaters and systems are regulated.
Overview

- Description of a thermal fluid system
- Comparison of thermal fluid to steam
- Critical system components
- System and safety considerations
- Installation
- Codes and Standards
What is a thermal fluid system?

• Thermal fluid (also known as hot oil) systems may be liquid or vapor.
  ▫ Vapor phase systems may either incorporate a heater in which vaporization of the fluid takes place within the vessel, or a flooded heater where the fluid is vaporized externally through a flash drum.
    • Vapor systems with condensing vapor provide a uniform heat source than liquid phase systems.
  ▫ A liquid phase thermal fluid system uses a flooded pressure vessel (heater) in which the heat transfer media (fluid) is heated but no vaporization takes place within the vessel.
    • Closed loop systems which may be open or closed to the atmosphere
    • Similar in concept to hot water boiler systems
Vapor Phase System
Typical Hot Oil Heat Transfer System
Designed to Operate at Atmospheric Pressure
Design Features

- Heaters are commonly direct-fired by combustion of a fuel, or electric resistance elements can be used.
- Heater design may be similar to a fire-tube boiler, electric resistance heated boiler, or a water tube boiler.
- Heaters may operate at temperatures up to 750°F depending on the process requirements and fluid selection.
- Large heaters may be field erected; however, heaters less than 30,000,000 BTU/hr are similar to packaged boilers utilized in a variety of process applications and may be found in typical “boiler room” installations.
Thermal Fluid Heaters
Why use thermal fluid instead of steam?

- No corrosion or freezing concerns
- Simple circuit; no blow downs, steam traps, or condensate return systems
- Minimal maintenance
  - No hand-hole gasket replacement
  - No re-tubing
- No water treatment requirements
- High operating temperatures obtained with minimal system pressures (system pressure drop only).
- If a process requires heating and cooling, it may be done with a single fluid.
Steam Pressure Comparison
Steam vs. Thermal Fluid

![Graph showing pressure vs. temperature for saturated steam and thermal fluid.](image)
Hot oil can be utilized with the following types of equipment:

- Steam / Hot Water Generators
- Storage Tanks
Hot oil can be utilized with the following types of equipment:

- Baths / Kettles
- Rolls
- Reactors
Hot oil can be utilized with the following types of equipment:
Applications using thermal fluid heaters
System Components

A typical thermal fluid system is comprised of four main components:

- Thermal fluid heater
- Thermal fluid circulating pump
- Expansion tank
- User
System and Safety Considerations

- Thermal fluid selection
- Pump and proof of flow
- Fluid excess temperature protection
- Stack excess temperature limit
- Expansion tank design and fluid level
Thermal Fluid Selection

- Any fluid specifically designed for heat transfer use may be considered.
  - Lubricating or hydraulic oils are not acceptable.
  - Fluids must have physical property data at elevated temperatures.

- Factors to consider include:
  - **Maximum recommended bulk temperature**
    - System operation should never exceed the maximum bulk temperature of the fluid.
  - **Minimum operating temperature.**
    - Is cooling required?
  - **Minimum start-up temperature.**
    - Outdoor or indoor application.
Thermal Fluid Selection

- Vapor pressure/boiling point
  - Special construction requirements if the operating temperature exceeds the boiling point.

- Some common thermal fluids include:
  - Dow
  - Monsanto
  - Paratherm
  - Petro Canada
  - Dowtherm A, G, RP
  - Therminol 55, 59, 66
  - NF, HE
  - Calfo AF, Purity FG
Thermal Fluid Maintenance

- Fluids should be tested annually.
- Lubricating oil tests that include dissolved metals are not adequate.
- Do not top off with different thermal fluid chemistry.
  - Mineral oil/petroleum vs. synthetic/aromatic.
- Track heater inlet and outlet temperatures and pressures.
- Always record the date and the amount of fluid addition.
- Changing the type of fluid used in a system may require a change in the system components (pump, expansion tank etc.).
  - Chemical cleaners may also be required.
Thermal Fluid Pump

- Must be designed for use with thermal fluids at temperature
  - Standard hot water and boiler feed pumps are not appropriate.
- Pumps may be air cooled, water cooled, canned or mag drive designs.
- The pumps are sized to overcome the pressure drop in the system and must be sized based on the specific gravity of the fluid at operating temperature.
Proof of Fluid Flow

• Proof of fluid flow is critical for vessel longevity and system integrity.

• Means should be provided to prove minimum fluid flow through the heater at all operating conditions to ensure proper velocities and film temperatures.

• A low flow condition can cause overheating, degradation of the fluid, or heater coil/tube failure.

• Proof of flow is typically interlocked into the combustion circuitry

• Means to prove flow may include vortex shedding meters, flow switches, pressure switches, an orifice or a differential pressure switch.
Fluid Excess Temperature Protection

• This limit prevents the fluid temperature from exceeding the maximum allowable temperature of the specific fluid. It should be set no higher than the maximum bulk temperature of the fluid.
• The temperature sensing device should be compatible with the fluid and the system operating temperature and pressure and located at the heater outlet.
• It is generally interlocked into the combustion safety circuitry and often incorporates a manual reset functionality.
Stack Excess Temperature Limit

• Many installations include a high stack temperature switch interlock.
• In the event of a high stack temperature this device shuts off the burner and circulating pump.
• The manufacturer of the heater determines the acceptable stack temperature for the heater.
• A high stack temperature indicates improper combustion (or soot build up) or a failed coil.
• Manual reset is recommended.
• The stack limit may be part of an inert gas smothering system.
Expansion Tank Design

- Fluid selection, system volume and operating temperature will impact expansion tank size.
- Depending on the fluid selection and operating parameters, systems may be open or closed to the atmosphere.
- Closed systems may be pressurized with an inert gas blanket.
- An ASME tank may be required.
When should a pressurized expansion tank be used?

- The tank is not the highest point in the piping system.
- The tank contents can be at a temperature such that exposure of the fluid to the air would cause degradation of the fluid.
- The fluid is operated above its atmospheric boiling point.
- The fluid manufacturer recommends the use of an inert blanket.
TYPICAL ASME HOT OIL HEAT TRANSFER PRESSURIZED SYSTEM (OVER 15 PSIG)
Expansion Tank – Fluid Level

- A minimum liquid level must be maintained in the expansion tank to prevent pump cavitation.
- A liquid level switch or similar device is typically provided and interlocked with the pump and burner to shut them down in the event of a low fluid level condition.
- The switch should be satisfied before the pump can start.
Installation

• Combustion air and ventilation requirements are similar to those of power or heating boilers and determined by the manufacturer.

• A containment curb or seal welded drip lip on the heater skid should be considered.

• Piping, valves and system components are rated for the temperature and pressure of the system
  ▫ Brass, bronze, aluminum and cast iron components are not recommended.
  ▫ Any sign of leaking piping is a safety concern, as the fluid or its vapors can be hazardous or flammable.
  ▫ Piping should be welded or flanged where possible and pneumatically tested for leaks.
Installation

• Pressure relief devices
  ▫ The pressure relief valves should be a totally enclosed type with no lifting lever.
  ▫ The discharge piping of the pressure relief valve should be connected to a closed vented storage tank.

• Insulation
  ▫ The insulation should be selected for the intended purpose.
  ▫ Where there is a potential for fluid leaks, the insulation should be non-absorbent.
Codes and Standards

• Jurisdictions have varying requirements for thermal fluid systems.
• Until recently, limited guidance has been available.
• What resources are available?
  ▫ National Board Inspection Code
  ▫ ASME Boiler Pressure Vessel Code
  ▫ Controls and Safety Devices for Automatically Fired Boilers
  ▫ National Fire Protection Association, NFPA-87
National Board Inspection Code (NBIC)

- The NBIC Part 2 Inspection provides some information on thermal fluid systems.
- Part 1 of NBIC Installation covers the requirements for power boilers, heating boilers, and pressure vessels.
- There is an open item to provide guidance for the installation of thermal fluid heaters as a new supplement to Part 1.
- Requirements such as clearances, ladders, electrical, ventilation and combustion air are consistent with steam boilers, hot water boilers and other pressure vessels.
- Additional requirements regarding expansion tanks, pumps, piping and controls are included.
ASME Boiler and Pressure Vessel Code

- Some Jurisdictions may require ASME Section I or ASME Section VIII Div. 1 construction.
- The specific requirements outlined in the construction codes must be met.
ASME Section I Requirements

- **Organic Fluid (thermal fluid) Vaporizers**
  - Rules in Part PVG are applicable and are used in conjunction with the general requirements of Part PG.
  - Part PVG addresses the pressure relief valves, gage glasses and drain valves.

- **Liquid phase thermal fluid heaters**
  - Applicable requirements for liquid phase heaters are not clearly identified.
  - There is an open item in progress to define the Section I rules for these heaters.
ASME Section VIII Div. 1 Requirements

- Subject to Paragraph UW-2(d) for pressure vessels subject to direct firing.
  - Category A welds must be in accordance with Type No. (1) of Table UW-12.
  - Welded joints in Category B (for thicknesses exceeding 5/8”) must be Type No. (1) or No. (2) of Table UW-12.
  - Post weld heat treatment may be required depending on the material used and weld size.
  - Stamping of the pressure vessel shall include DF for direct firings and the Manufacturer’s Data Report will indicate the special service requirements.

- Safety relief valves may be based on the flow through the heater, operating temperature, fluid and set pressure.
Controls and Safety Devices for Automatically Fired Boilers (CSD-1)

- CSD-1 applies to Power Boilers and Heating Boilers with inputs less than 12,500,000 BTU/hr. It includes requirements for combustion controls as well as steam and waterside control (including pressure, temperature and water level).

- With the current Standard, questions exist regarding the applicability of CSD-1 to thermal fluid systems.
  - Combustion controls covered in CSD-1 are applicable to thermal fluid heaters.
  - However, Part CW, Steam and Waterside Control, does not cover the requirements for thermal fluid systems.

- A task group was formed in CSD-1 to review and define the specific requirements for thermal fluid systems.
National Fire Protection Association, NFPA-87

- While NFPA 85 (boilers) and NFPA 86 (ovens) provide excellent information regarding combustion controls, neither Standard was directly applicable to thermal fluid heaters.
- Recommended Practice for Fluid Heaters, NFPA 87, was developed.
  - Topics covered include:
    - Location and Construction
    - Heating Systems
    - Commissioning, Operations, Maintenance, Inspection and Testing
    - Heating System Safety Equipment and Application (combustion & temperature control)
    - Chapters specific to thermal fluid heaters (pumps, expansion tanks etc.)
    - Fire Protection
In Summary, Thermal Fluid Systems...

- Obtain high temperatures with low system pressures
- Are commonly used in a variety of applications
- Design/safety considerations include:
  - Fluid, flow and temperature
- Codes and Standards are under development to provide additional guidance