HOT OIL SYSTEMS

Expansion and Drain Structure

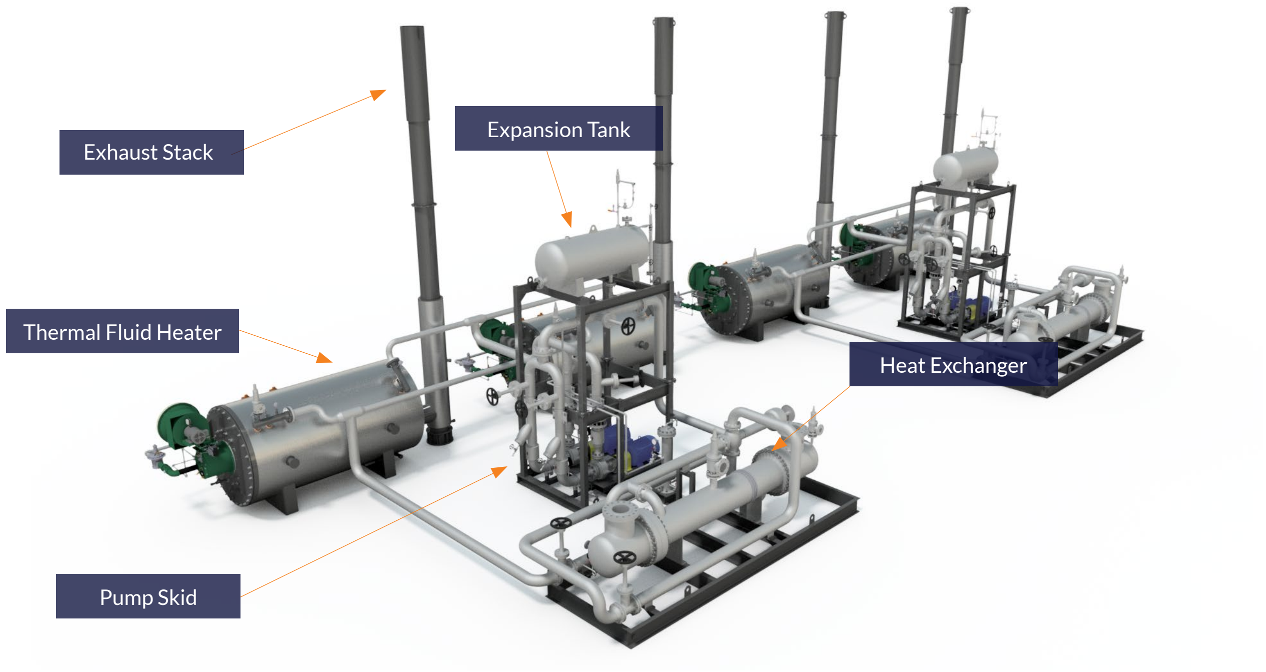
SIGMA THERMAL INC.

INDUSTRIAL PROCESS HEATING SYSTEMS,
AUTOMATION, SERVICES AND PARTS

EXPANSION AND DRAINING OF THERMAL OIL, CRUCIAL FOR SUCCESSFUL INSTALLATION

The provisions made for thermal expansion and draining of thermal oil is a key factor to consider for the successful installation of a thermal oil heating system. Important system design principles like this are commonly overlooked and the focus is placed on specific components like pumps, valves, or the heater itself. Because most thermal oil heating systems are closed loop systems, and because thermal oil expands with increasing temperature, accommodations must be made for that expansion.

It is also inevitable that some part of the system will require service in the future, at that point in time the system will need to be partially or fully drained depending on the nature of the service required. A little thought and preplanning can make draining the system relatively easy, potentially saving precious time and money during planned or unplanned shutdowns.



System Components

There are a variety of ways to design expansion and drain systems, and all have their advantages and disadvantages. Despite the difference, most designs incorporate standard parts and related theories. The most common components and concepts used in both expansion and drain system designs are defined for clarity.

Expansion Tank - Vessel designed to contain thermal expansion within a closed loop thermal fluid system.

Drain Tank - Vessel designed to contain all or part of a thermal fluid system's volume.

Containment Area - An area designated as a safe zone for vents or overflow discharge from pressure safety valves and/or vents and drains of a thermal fluid system.

Inert Gas Blanket - A system that applies inert gas pressure (typically nitrogen at the expansion tank) to prevent oxidation of thermal oil, and/or to create system pressure to overcome height restrictions for an expansion tank.

Thermal Buffer - A vessel that cools thermal oil before it enters an atmospheric expansion tank to help minimize oxidation of the oil.

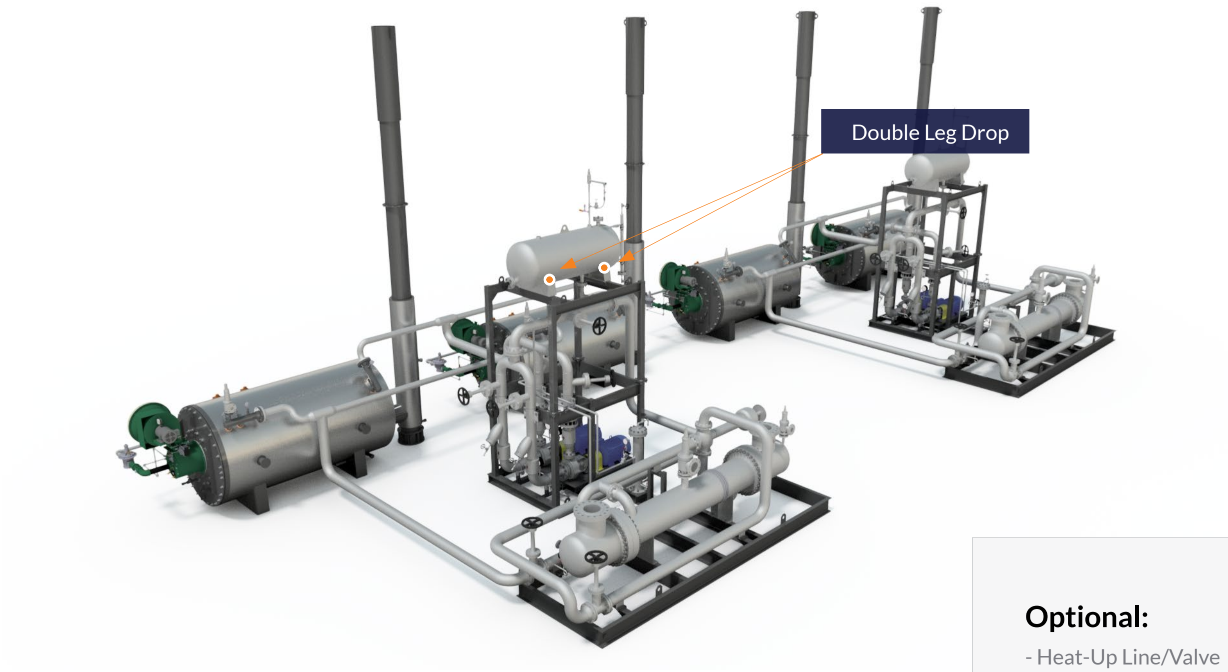
System Components (cont.)

Heat-Up Line/Valve – The line connected to the expansion tank, from a low-pressure part of the system, to create flow through the expansion vessel when the heat-up valve is open to assist in deaeration, during thermal oil cookout.

Double Leg Drop - A piping structure, consisting of a block and bypass valve, that forces a high-volume flow rate through the expansion tank, to aid in deaeration during thermal oil cookout.

Deaerator – A vessel created to continually assist in the degassing of a thermal fluid system.

Cold Seal Tank - Vessel constructed to create a cold fluid seal between ambient air and any hot fluid that may be present in the expansion tank, helping to minimize oxidation of the thermal oil.



Optional:

- Heat-Up Line/Valve
- Deaerator
- Cold Seal Tank

Design Principles

Let us take a closer look at the design principles for some of the system components and analyze how they are employed during commissioning and the everyday operation of a thermal oil system.

Calculating expansion volume →
What tank size do I choose? →
Tank Height →
Degassing the System →
Preventing Fluid Degradation →

Expansion Volume

As the fluid within a closed looped system is heated during liquid phase, it will expand. Your system must be designed to accommodate the liquid expansion to avoid the overflow of hot oil into the operating facility or overpressure of your system devices and associated equipment damage.

First, let us look at how to calculate the amount a fluid will expand from its cold fill volume to its max operating level. Since the fluid volume is changing but the fluid mass is not, this is a simple conservation of mass equation.

Use Therminol 55 in this example, while filling at 60°F

$$\rho_{cold} := 54.6 \frac{lb.}{ft^3}$$

Density of Therminol 55 @ 60°F

Assume total system volume (all of the users, piping, cold fill level in the expansion tank, etc.):

$$V_{cold} := 1000 gal = 133.681 ft^3$$

Total system volume at initial fill (cold)

$$\rho_{hot} := 42.6 \frac{lb.}{ft^3}$$

Density of Therminol 55 @ 550°F

$$m = V_{cold} \cdot \rho_{cold} = V_{hot} \cdot \rho_{hot}$$

$$V_{hot} := V_{cold} \frac{Cold}{hot} = 1281.7\ gal$$

mass is conserved. Therefore, solve for the expanded volume:

The difference in volume is the amount of fluid expansion that we must accommodate:

$$V_{exp} := V_{hot} - V_{cold} = 281.69\ gal$$

What tank size do I choose?

Now that we know how much the fluid will expand, we must select the right expansion tank size to accommodate the expansion. Generally, you will need some excess volume (commonly 20-25%) to account for the possibility of calculation errors (impossible!) or in case the system has temperature excursions above your anticipated operating temperature. Keep in mind that having some volume of vapor space (vapor disengagement area) at the top of the tank is crucial for deaeration and/or vapor removal during startup or when new fluid is added.

In addition, all systems should include a level switch to maintain a minimum liquid level in the expansion tank. Such factors will reduce the available volume in the tank, and therefore must be accounted for in the final tank size selection.

For instance, in the previous example (calculating fluid expansion), let’s presume that the next standard tank size is 400 gallons, and the minimum fill in the tank (to satisfy the level switch) is 35 gallons (typically specified by the manufacturer).

$$V_{spare} := 400gal - 281.69gal - 35gal = 83.31gal$$

As a percentage, this leaves you with about 21% volume remaining in the tank.

Tank Height

Now that we have sized our tank, we must think about where we want to place it. There are several factors that govern the location of the expansion tank. These factors are important and should be thoroughly discussed when laying out the system. Generally, many of these factors are installation specific (e.g. location of available safe containment, maintenance access). Safety of operators and plant personnel must also be well thought out, as expansion tanks are occasionally full of hot thermal oil that is both a burn and fire hazard

The ideal height for the expansion tank is above the highest liquid level in the system. This can be system piping, the heater, or sometimes the thermal fluid space within a user (e.g. heat exchanger, calendar roll, or press platen). The bottom of the tank should be several feet above the highest point (5 ft. is a good rule of thumb). This provides several benefits:

- Creates static head above the pump inlet to prevent pump cavitation
- Aids in degassing of the system
- Your neighbors will be impressed

What happens if the tank cannot be placed at the highest point? Don't abandon all hope. While not ideal, there are ways to accommodate this.

Option 1

Use an inert gas blanket system (usually nitrogen)

Option 2

Use a bladder style expansion tank (only possible on lower temperature systems)

Option 3

Seal the tank with nitrogen in the vapor space

1 With option 1, either plant nitrogen (if available) or bottled nitrogen are used to fill the vapor space in the expansion tank to a relatively low pressure (5-10 psig is typical).

This will vary depending on the net positive suction head (NSPH) requirements of the pump, and the vapor pressure of the fluid. The amount of nitrogen used will depend on how often the system temperature is cycled. Remember, the change in temperature will change the system volume. If the system is cooled, the fluid will contract and the liquid level in the expansion tank will drop. This change in level (and thus volume) must be made up by adding more nitrogen. Conversely, if the system is heated, the liquid level will rise and push some of the nitrogen out.

2 The rubber bladder, option 2, separates the liquid in the tank from the vapor space.

The vapor space is then charged with air to some pressure. As the system expands, the air in the vapor space increases in pressure. As the system cools, the pressure in the vapor space will fall (but never below the original charge pressure). Also, as previously mentioned, bladder tanks are typically made from some type of rubber compound and can only be used at lower temperatures. They are commonly found in water-glycol systems, but can also be used in thermal oil systems, provided the bladder materials are compatible with the oil and the operating temperature.

3 Option 3 is similar to option 2, but with no barrier between fluid and vapor space.

To keep the fluid from oxidizing, an inert gas must be used. Careful consideration must be used if either option 2 or 3 is chosen such that the rise in liquid level does not increase the pressure in the tank above its design rating. A pressure safety valve is critical to protect the tank if it is not open to atmosphere.

Degassing the System

Each thermal fluid system, when initially filled, will contain several undesirable constituents. As the system is operated over time, or when maintenance is performed, new fluid can be added that can create conditions similar to the initial fill. If not removed, these gasses can create flow stability problems and pump cavitation that will prevent the system from operating reliably. The most common constituents are:

1. Air
2. Water
3. Low molecular weight components of the thermal fluid (also known as low-boilers)

These constituents must be removed for trouble-free system operation. The ease with which these gasses can be removed is heavily dependent on the system piping design and expansion tank elevation. Generally speaking, piping should be designed to minimize local high points and the expansion tank should be above the highest point of the system. Piping should also be designed to include high point vent valves. If the tank is the highest point, then removing these troublesome elements from the system can be relatively easy through the disengagement space in the expansion tank. Otherwise, high point vent valves must be used and the system vented (burped) intermittently until vapor is no longer present.

Depending on the piping design and expansion tank elevation, there are a few methodologies that can be used to effectively get the vapor to the highest point.

Option 1

A double leg drop or heat-up line piping arrangement connecting to the expansion tank

Option 2

Deaerator

1 **A double leg drop arrangement allows all or a portion of the fluid to flow through the tank during commissioning.**

A heat-up line piping arrangement achieves the same purpose, but with smaller piping and by using pressure differential across different parts of the system to drive flow through the expansion tank. By forcing circulation through the expansion tank while the fluid is being circulated, the vapor in the system can disengage from the liquid level in the tank and it can be vented from the top of the tank. This can be done with the system open to atmosphere or using an inert gas blanket with settings that allow it to 'sweep' the vapor from the expansion tank through continuous purge.

2 **A deaerator performs a similar function as the double leg drop arrangement, but is a part of the system return piping and is used continuously rather than exclusively during commissioning.**

While deaerators are effective for continuous deaeration, it is worth noting that they are not always as effective as forcing large volumes of flow through an elevated expansion tank, and don't necessarily negate the need for a double leg drop or heat-up line piping structure. Simple centrifugal deaerators are very common, but there are many different types that can be used effectively. Regardless of the vessel design, the basic premise is to allow a way for the vapor and liquid to disengage and rise up to the expansion tank instead of disengaging within the expansion tank. The vapor should flow up and out of the system and the liquid flow down and back to the suction side of the pump.

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Preventing Fluid Degradation

If properly designed and maintained, thermal fluid systems are easy to operate and the life of the fluid within the system can be sustained for a long time. If the fluid should degrade, it will diminish the performance of your system. There are a couple of reasons why fluid degradation could occur:

1. **Oxidation** – thermal fluids when exposed to oxygen, especially at elevated temperatures will oxidize and break down into lower molecular weight components. They can also form acidic byproducts that can damage system components.
2. **Contamination** – the most common contaminant is water, but can also be a leak on the process side of the system (a heat exchanger tube, reactor jacket, etc.).
3. **Thermal Degradation** – Thermal Degradation typically occurs when the fluid molecules receive more thermal energy than they can absorb and carry away at a particular time. The excess energy causes molecules to break down, or crack.

Preventing oxidation is simple in concept; either remove the heat or remove the oxygen at the interface point in the expansion tank. Removing the oxygen is typically done with an inert gas blanket as mentioned above. If you don't have the ability to inert the expansion tank and it is directly open to atmosphere, removing the heat is the only solution.

As a rule, the expansion tank and the piping leading to the tank should not be insulated. This allows any hot fluid that expands into the tank to cool before it hits the vapor disengagement space at the top of the tank. Most often, expansion piping alone does not allow enough surface area to cool the expanding fluid before it gets to the tank. In those cases, the use of a thermal buffer allows the fluid to cool by creating more surface area and residence time than the expansion piping alone.

Preventing contamination can be tricky, as it is not always a dramatic event that is noticeable. Impurities often creep into a system over time, and won't necessarily create an increase in system volume or an obvious change in performance. Since there are many potential sources of contamination and because it can be hard to detect with observation alone, the best defense is to have the fluid tested at least yearly. Most fluid manufacturers offer this service at no charge, and based on the results, they can usually pinpoint the root cause of the contamination.

To prevent thermal degradation, vent the lower boiling point hydrocarbons based on vendor's oil analysis results, adopt best practices for start-up and shut-down, continuously filter the oil with glass media filters down to at least 10 µm and monitor the system's heat flux.

Drain Tank Sizing

Inevitably, at some point in the life of any thermal fluid system, the system will need to be drained to perform maintenance or to perform a repair. There is also a benefit to routing things like PSV discharge and emergency drain lines to a location where the thermal oil is safely contained. Routing these devices to small drums or inadequate containment vessels (e.g. plastic totes – yes someone did that) may not be sufficient. Many smaller systems do not have a dedicated drain tank, and this can be a problem in case an emergency repair is needed or safety relief event is triggered. It is highly recommended to have the drain tank sized for the entire system volume (e.g. smaller systems upward to 10,000 gallons) or adopt a design that segments the system in such a way that sections can be isolated and drained independently. This is common with larger systems. Normally you want a 20-25% buffer with the drain tank size, and depending on your insurance carrier the drain tank will typically be placed away from any building or main process areas.

It is also noteworthy that relatively low-cost reversible fill & drain pumps are available, and they will make filling and draining of your system considerably easier. When designing the system piping, be sure to pay special attention to creating low point drains and connecting that piping back to a central drain tank. A small amount of investment in a drain tank, fill & drain pump, and well-planned drain piping can save hours or even days during commissioning and maintenance activities.

About Us

Sigma Thermal designs, engineers, supplies, and services process heating systems for industry. Our products include thermal oil and thermal fluid heating systems, indirect process bath heaters, electric process heaters, biomass fired energy systems, direct fired process heaters, system automation, parts, retrofits/upgrades, and support services. Our staff of dedicated and experienced engineers can help to provide solutions specific to your project needs. Whether you need a standard package heater, a highly engineered process heating system, or just a tune up on your current system, our engineers and technicians have the knowledge and experience to make your project a success.

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