THERMINOL®
from Eastman

Vapor phase systems design guide

A design, operating, and maintenance guide for heat transfer systems using Therminol VP-1, Therminol VP-3, or Therminol LT

Contents

Physical and chemical characteristics

Eastman Therminol® vapor phase heat transfer fluids are specifically designed to meet the demanding requirements of vapor phase systems. They combine exceptional heat stability and low viscosity for efficient, dependable, uniform performance.

Three distinctly different Therminol vapor phase heat transfer fluids allow users to select the one that best matches their needs.

Therminol VP-1 is a eutectic mixture of diphenyl oxide and biphenyl. It is usable as a liquid or as a boiling-condensing heat transfer medium up to 400°C (750°F). It is miscible and interchangeable (for top-up or design purposes) with other similarly constituted diphenyl oxide/biphenyl fluids. Therminol VP-1 delivers the highest thermal stability available in any synthetic organic fluid.

Therminol VP-3 is a proprietary vapor phase fluid. Thermal stability testing in a laboratory suggests a maximum continuous operating temperature of 330°C (625°F) in the liquid or vapor phase. With a normal boiling point of 243°C (469°F), it permits vapor phase heat transfer at lower temperatures than diphenyl oxide/biphenyl fluids. A freeze point of 2.4°C (36°F) makes Therminol VP-3 easy to handle and may eliminate the need for costly heat tracing in moderate climates. Therminol VP-3 has a mild odor and contains virtually no biphenyl.

Therminol LT delivers the uncommon combination of exceptionally wide operating range and good thermal stability. Therminol LT remains liquid down to –75°C (–103°F) and may be used as a liquid or as a boiling-condensing heat transfer medium up to 315°C (600°F). The normal boiling point of 181°C (358°F) is the lowest of the Therminol vapor phase heat transfer fluids.

Users should consult the Safety Data Sheets (SDS) for toxicity and handling information. They may be obtained from an Eastman representative or by visiting our website at www.Therminol.com.

Fluid parameters which influence design

Physical characteristics of the heat transfer fluid should be considered in the general arrangement of any heat transfer system in which it is to be used.

All Therminol vapor phase heat transfer fluids have low viscosity between their melting points and the temperatures at which they vaporize. In geographic areas where the system may be exposed to temperatures below the melting point, heat tracing should be considered for all piping that may contain the fluid in its liquid state.

Therminol heat transfer fluids are exceptionally heat stable. However, care must be taken to avoid overheating which could lead to deposition of solids on the heating surfaces of the vaporizer. Circulation rates in the heater should be selected to limit skin temperatures below recommended maximum values, with due consideration to the cost of replacing damaged fluid and the cost of maintaining an adequate heat flux. This is normally accomplished by the vaporizer or heater manufacturer in the course of recommending a particular unit and its operating parameters.

Under normal operating conditions, a vapor phase fluid will accumulate low-boiling contaminants such as air, water, and degradation products. These noncondensables must be vented from the system to avoid aberrations in temperature control. Each user or group of users, if arranged in a series that operates after the same control valve, should have at least one vapor accumulator installed for detecting and venting noncondensables. This is especially true if close temperature control is needed.

The physical and thermodynamic properties of Therminol heat transfer fluids can be found in their respective product bulletins.

Typical vapor phase systems

The following diagrams illustrate the arrangement principles for vapor systems operating on Therminol heat transfer fluids. The text and illustrations explain the overall system characteristics required by the nature of the heat transfer medium in its liquid and vaporized states.

Primary systems

The least complex and most easily operated system is shown in Figure 1.

The user can be process equipment (jacketed or coil-heated vessels, ovens, etc.), reboilers transferring heat to secondary systems, or a combination of these.

This simple primary system operates with a gravity return of condensate. In such an arrangement, the dimension of H_1 must provide a hydrostatic pressure somewhat greater than the total system pressure drop to allow for a gravity return of the condensate.

With direct-fired or electrically heated vaporizers, a Hartford loop should be installed in the condensate return line, as shown in Figure 1, whenever the condensate is returned to a point in the vaporizer below the lowest safe liquid level. This prevents unexpected siphoning of the liquid medium. In an electrically heated unit, if there is no liquid in contact with heating element surfaces, overheating will occur and the heat transfer medium will be decomposed rapidly. This could also cause structural damage to the heater and greatly increase the risk of fire.

A more complex system is shown in Figure 2. This arrangement includes several users operating at various temperatures. The control valves regulate pressure, which in turn controls the user temperature. If gravity is used for condensate return, the slope must create hydrostatic pressure greater than the pressure drop across the combined control valve and the user with the highest pressure drop. In practical terms, such a system is often difficult to design because of space limitations. More commonly, a pumped return of the condensate is employed.

There are two basic ways to handle a pumped return system. The first is used when the temperature limits at the user stations must be precisely controlled, as is common with many kinds of process vessels. The arrangement shown in Figure 3 exemplifies this type of system.

Here, the dimension H_3 must provide a hydrostatic pressure greater than or equal to the maximum pressure difference between the user stations. An alternative would be to provide individual pumps to handle each condensate return.

Where the temperature control for the users may not be as critical (e.g., in users such as reboilers where it is acceptable to flood with condensate), the arrangement shown in Figure 4 could be followed. Here the distance H_3 must simply provide hydrostatic pressure greater than or equal to zero.

Figure 1. Vaporizer with Hartford loop

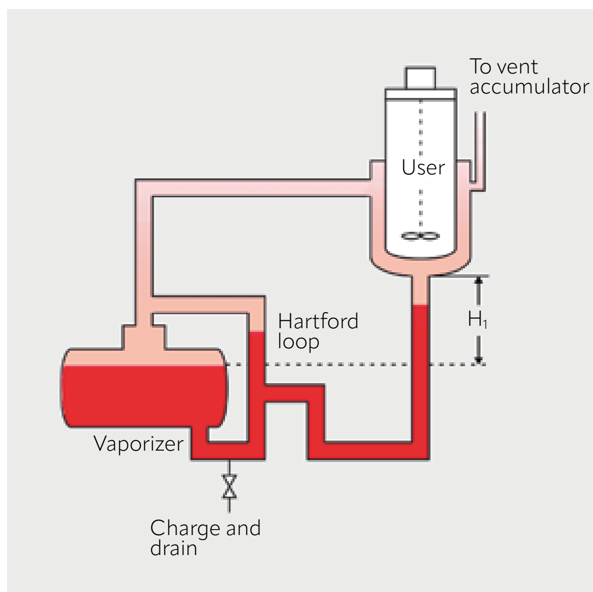


Figure 2. Primary system with gravity return

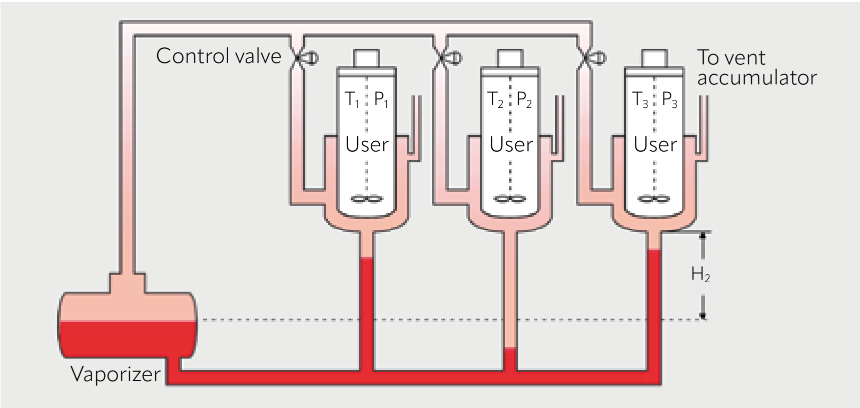


Figure 3. Primary system with pumped return

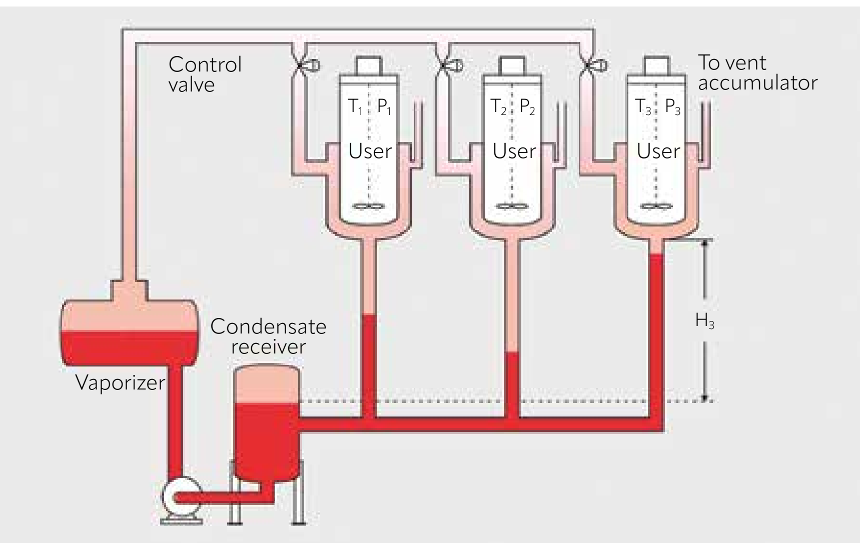


Figure 4. Primary system with pumped return

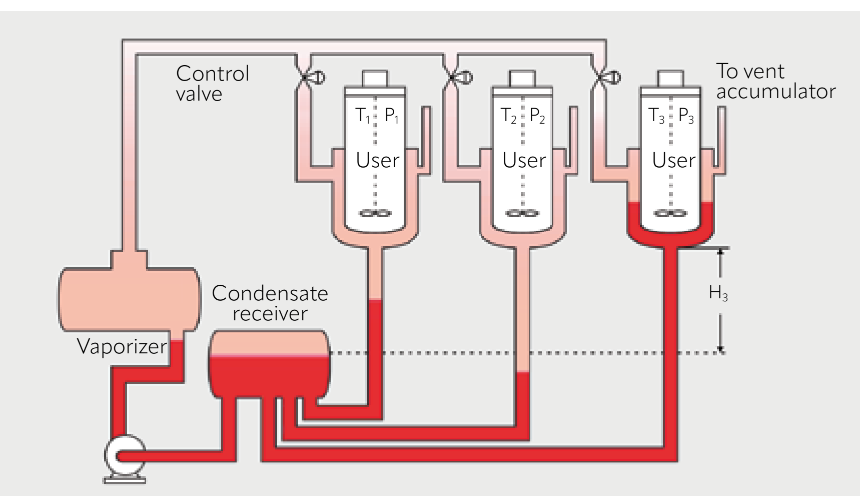
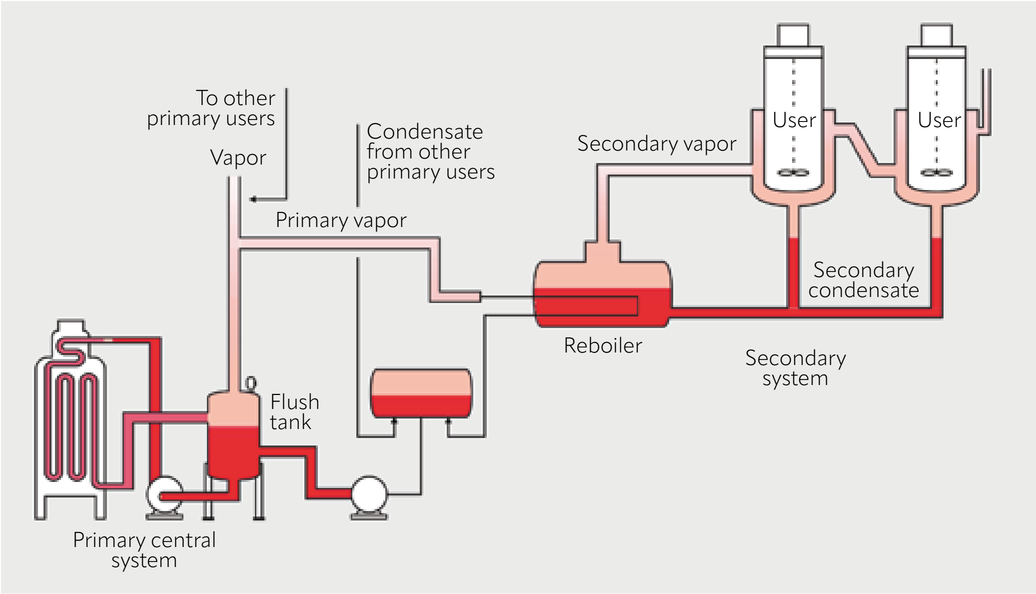


Figure 5. Primary/secondary system



Primary/secondary systems

Figure 5 outlines typical components of a primary/secondary system, indicating the reboiler, flash tank, primary and secondary vapor lines, and a combined condensate return system. The condensate return arrangement of Figure 4 is commonly used in the primary loop.

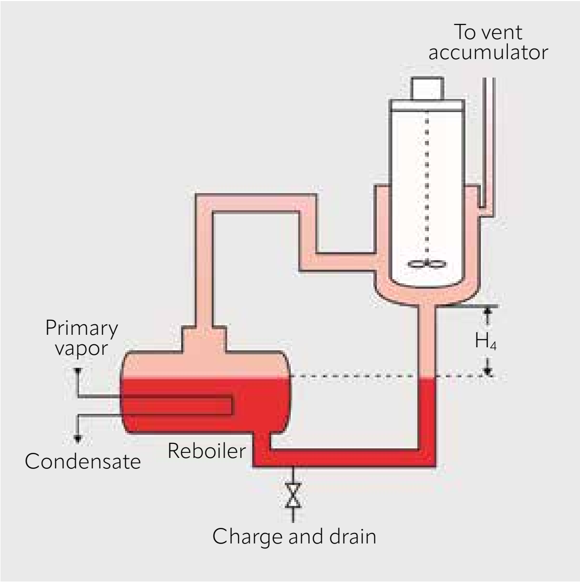
In the secondary system, heating vapor is generated in a reboiler and then transferred to one or more users. The user stations may be processing equipment, jacketed piping, etc. One section of a secondary system might appear as in Figure 6. A gravity return to the reboiler, as shown in this diagram, is common in such secondary loops.

Secondary system with reboiler

As before, the dimension H_4 must provide a hydrostatic pressure greater than or equal to the pressure drop across the total secondary system.

Multiple users can be grouped in a secondary system if their operating temperature is the same. Users in a single secondary system should be stopped and started at the same time. It is not possible to start a cold user in a multiple-user system without drastically affecting the temperature of an operating user.

Figure 6. Secondary system with reboiler



Integral systems

For many plant layouts, an integral system (as many as needed) might be the simplest or most practical arrangement. An integral system, as illustrated in Figure 7, combines the vaporizer and the user in a single piece of equipment.

Electrical vaporizing elements make such systems practical for a variety of chemical and synthetic fiber processing operations.

Auxiliary systems

Charge system

A charge system can be common to several vaporizers and/or reboiler loops. Its function is threefold: to provide a way to introduce the initial charge of Therminol heat transfer fluid, to top up heating loops in operation, and to allow for external storage capacity for fresh fluid.

To avoid upsets, the fluid generally should be introduced into the operating loops at a temperature which is near the operating temperature. This can be done by charging from another system's pumped hot condensate stream or by providing an independent charge system which maintains an adequate amount of liquid at an elevated temperature.

Drain system

For maintenance, it may be necessary from time to time to evacuate the charge from a heating loop. A standby vessel should be provided to receive the charge. One way to remove the fluid is by pressure draining with inert gas.

Vacuum system

The vacuum system serves a number of purposes: to evacuate the heating loop prior to start-up, to collect noncondensables during operation, to empty individual user stations for maintenance, and to take off any excess fluid from a heating loop that is overcharged. All the connections necessary for these functions should be designed and installed between the heating loops and the vacuum header. The header itself connects with the vacuum pump and a condenser that collects fluid and discharges it by gravity into a collection tank, as shown in Figure 8.

The vacuum header should be sloped toward the condenser so that any liquid that collects at low points will drain off. If there is a long upward run in the vacuum header in which liquid can collect, it will reduce or eliminate the effective vacuum.

Figure 7. Integral system

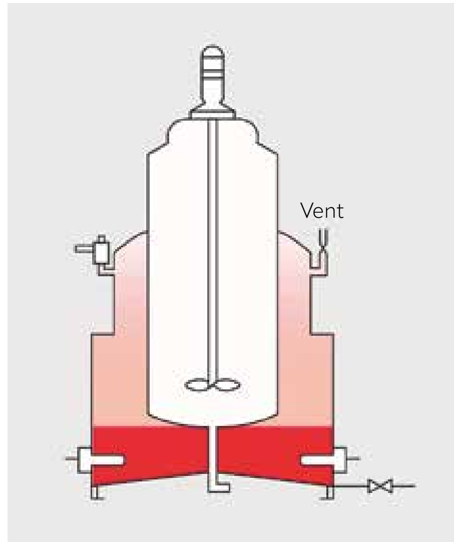
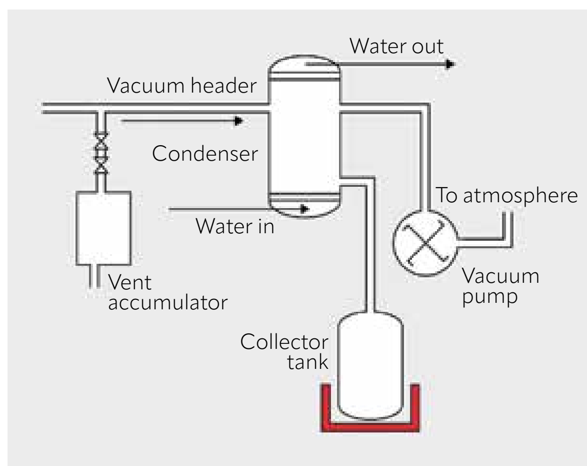


Figure 8. Typical vacuum system



Relief system

It is imperative that vapor phase heating systems be properly safeguarded with pressure relief devices. This is because of their high operating temperature, pressurized operations, and potential for overheating. Relief ports can constitute danger points if they do not discharge away from areas where people could be exposed to contact.

All possible heat sources must be recognized and evaluated to properly select the locations for relief valves. Three sources must be prominently considered: the source of heat for vaporizer, reboiler, or fluid heating; user stations where exothermic reactions may attain temperatures higher than the heating vapor; and accidental fire.

In general, all sections of the system that are subject to heat exposure and can be isolated should be relieved separately. Obviously, the fewer valves in a system, the fewer locations that require a relief device. Isolating valves for a user station should be provided only if the entire heating loop serving it cannot be drained for maintenance.

Heat tracing system

Since Therminol® VP-1 heat transfer fluid solidifies at 12°C (54°F) and Therminol VP-3 solidifies at 2.4°C (36°F), precautions must be taken to ensure lines do not freeze, particularly in outdoor installations. Heat tracing must be installed wherever lines run a danger of cooling below a fluid's melt point. All pipelines and equipment which may contain stagnant liquid should be traced, including all charge and drain lines, all vacuum lines, and any pumped liquid streams. Vapor lines, vent lines, and free-draining condensate lines generally need not be traced.

Therminol vapor phase heat transfer fluids are normally hotter than the tracing line. If steam is used, the possibility exists that water condensed in a tracing line could become overheated and rupture the tracing. To avoid this, the tracing should be open to the condensate header, steam header, or atmosphere at all times.

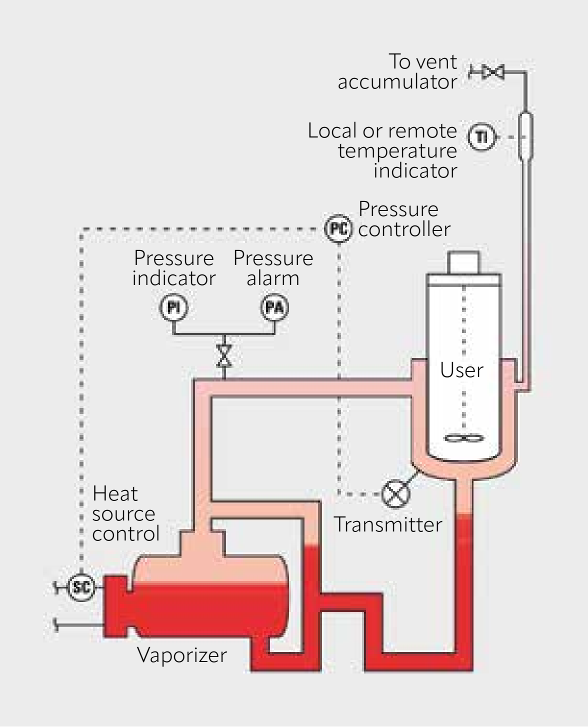
Instrumentation of vapor phase systems

There are many ways to instrument a vapor phase heating system, and they will vary depending on the complexity of the system and the degree of control deemed necessary. Process heat control at user stations can be monitored by temperature, pressure, or various combinations of these measurements.

Pressure control

The suggested instrumentation for a basic system is illustrated in Figure 9. Pressure control is recommended because it results in a safer and more stable system. If the system is controlled by temperature alone, the presence of noncondensables in the system may result in an overpressure condition when the heat source controller attempts to add enough heat to bring the noncondensables up to temperature. If temperature control is needed, the temperature controller can be used to choose the set point for the pressure controller and the pressure set point can thus be limited to a safe operating range.

Figure 9. Suggested instrumentation



Vent accumulator temperature indicators

Concentrated noncondensables are at a lower temperature despite being at the same pressure as vaporized Therminol heat transfer fluid. Consequently, their presence in vent accumulators can be detected by temperature indicators. Remote indicators allow an operator to monitor a system in which there are many vent accumulators without having to visit each one.

Pressure indicators and alarms

A local indicator of system pressure is necessary for start-up and shutdown, and it should be located near the vaporizer. This should register vacuum as well as positive pressure.

High- and low-pressure alarms should be installed in each heating loop to warn of system malfunction. The high-pressure alarm is of particular importance because it will ensure attention to pending overpressure in the system.

Level indicators and alarms

Vaporizers, condensate collectors, and liquid preheaters should be fitted with level indicators. Vaporizers especially should have level indicators to charge them and maintain the proper liquid level in the heating space. Particularly with electrically heated vaporizers, there is always danger of overheating if an adequate liquid level is not maintained in contact with the heating elements. Low-level alarms, as well as low-level power cutoffs, are essential on the vaporizer.

Fire safety considerations

Leaks from pipes, valves, or joints that saturate insulation are potentially hazardous because of the wicking effect and large surface exposure. Under such conditions along with high temperatures, many organic liquids can spontaneously ignite. Leaks should be promptly repaired and the contaminated insulation replaced.

Leaks from a direct-fired vaporizer into the fire chamber normally result in burning of the vapor, which should be avoided.

When vapor leaks from a pressurized system to the atmosphere, it is condensed by the relatively cold air which it contacts. This causes formation of a fog of tiny liquid droplets. Fogs of combustible liquids of sufficiently high concentration in air will burn if ignited. The fogs are flammable even though the overall temperature of the fog-air mixture may be below the flash point of the liquid and the vapor saturation concentration is below the flammable level.

The combustion of a fog-air mixture can result in an explosion, much like the combustion of a flammable vapor-air mixture. Such a fog-air mixture, however, does not normally ignite spontaneously. An ignition source is necessary, together with a sufficient concentration of the combustible fog.

Good safety practice in design, maintenance, and operation can circumvent the potential dangers associated with pressurized organic vapor systems. In addition, further safeguards can be provided through the installation of special safety systems. The use of protective devices may be required to minimize fire risk, and users of Therminol fluids should check with their safety and risk management experts for specific instructions.

For further information on such safety devices for vapor phase systems, refer to the engineering study on this topic, available in reprint from the American Institute of Chemical Engineers[1,2] (CEP Technical Manual, Volume 10, "Loss Prevention").

[1] *G. C. Vincent and W. B. Howard, Hydrocarbon Mist Explosions, Part I—Prevention by Explosion Suppression.*
[2] *G. C. Vincent and R. C. Nelson, W. B. Howard and W. W. Russell, Hydrocarbon Mist Explosions, Part II—Prevention by Water Fog.*

Vapor system start-up

There are several ways to start vapor phase heating systems, but they generally contain these basic steps:

1. Open the vacuum system connection to the vapor system and wait until a steady-state vacuum is reached.
2. Close all valves to isolate the vapor system from the vacuum system.
3. Wait approximately 15 minutes and note any significant increase in pressure in the system. (This step is necessary to ensure that the system is fully closed.)
4. Introduce the proper Therminol vapor phase heat transfer fluid to the vaporizer (or reboiler) and gradually heat to operating temperature. Periodically open the vacuum connections on the vent accumulators to evacuate the noncondensables. Continue venting until the temperature indicators show that hot vapor has reached the vent accumulators.

System shutdown, vacuum draining

When the system is to be drained to a vacuum vessel, the shutdown procedure is to:

1. Cut off the heat source from the system.
2. Open the drain line to the vacuum vessel. (The liquid in the system will continue to flash into the drain until the vapor pressure of the liquid reaches the vacuum being pulled.)
3. When the liquid level stops dropping, introduce nitrogen to break the vacuum. The remaining liquid will drain relatively quickly.

System shutdown, pressure draining

For draining into a pressure vessel, the procedure is only slightly different:

1. Make sure the available nitrogen pressure is less than the relief pressure of the vapor system.
2. Cut off the heat source.
3. Introduce nitrogen to the system.
4. Open the drain line to the pressure vessel.
5. Close the drain line after the system is drained.
6. Open all high-point vacuum connections to purge and help cool the system.

Converting to a vapor phase heat transfer fluid of different chemical composition

Converting a heat transfer system to a vapor phase fluid of different chemical composition requires careful evaluation of system design issues. Users should consult a qualified engineer before changing fluids. The following list of considerations should be reviewed on every fluid change. Depending on the specific system, there may be additional considerations to those listed here.

1. **Eliminating traces of previous fluid**—A precisely known boiling point is required for most vapor phase heat transfer systems. When converting from a fluid of one chemical composition to another, care should be taken to thoroughly remove all of the previous heat transfer fluid, since mixing vapor phase heat transfer fluids with different boiling points will result in a boiling point that differs from either of the fluids. Multiple flushes with the new heat transfer fluid may be required to remove the previous fluid. After transition, users are encouraged to submit a sample of the operating fluid to Eastman to confirm that previous fluid residues have been eliminated.
2. **Film temperature limits**—The vaporizer should be evaluated to assess whether the film temperatures are within the limits recommended for the new heat transfer fluid.
3. **Instrumentation**—Recalibration of level and flow measuring instruments throughout the heat transfer fluid system will likely be required.
4. **Overpressure-relief system design**—In the event of an upset, proper operation of the overpressure-relief system may be vital to prevent equipment damage and serious safety consequences. Any change in system configuration, including a change in working fluid, should include an evaluation of the relief system design by a qualified engineer.
5. **Fluid-handling systems**—Pumps and piping systems, especially condensate return systems, should be evaluated for impacts caused by changes in operating conditions or fluid properties.
6. **Heat tracing**—Some vapor phase heat transfer fluids are subject to freezing at temperatures as high as 12°C (54°F). Users should evaluate the need for heat tracing of their heat transfer fluid system.
7. **Material compatibility**—Elastomers, polymers, and gaskets should be evaluated for compatibility with the new heat transfer fluid.
8. **Electrical classification**—Flash points vary among the vapor phase heat transfer fluids. Users should evaluate the design of their system with respect to the flash point of the selected heat transfer fluid.
9. **Procedures, training, and communication**—Consideration should be given to procedures, training, or communications that may be necessary for use of a different heat transfer fluid.

Eastman Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other locations, +(1) 423-229-2000

eastman.com/locations