Don't blow your money on a steam trap

Steam and condensate leaks cost buildings and industrial plants millions of dollars in lost energy while increasing emissions from boilers due to increased operation, creating potential safety hazards, and lowering the reliability of operations. This article will review the many factors that impact the reliability, performance, longevity, and maintenance requirements for condensate return piping systems.

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Figure 1, above: Float and thermostatic (F&T) steam traps at a steam-to-hot-water heat exchanger are shown. All graphics courtesy: Ring & DuChateau

According to the U.S. Dept. of Energy (DOE), approximately 20% of steam leaving a boiler plant could be lost due to leaking steam traps in steam systems without a preventative maintenance program. This represents a considerable amount of wasted dollars in energy production. A relatively simple maintenance program can help reduce losses by approximately half, while more sophisticated programs can virtually eliminate steam trap losses for improved building performance and reliability.

Unfortunately, loss of steam through a steam trap is virtually invisible as steam is lost into the condensate system—unless a program is in place to quickly and accurately identify these leaks. This bypassed steam provides no useful heating value to the system and effectively reduces the overall capacity of the system or requires additional capacity to make up for the system losses to meet the demand of the building.

This article will provide a holistic approach to steam and condensate systems by discussing the various types of steam traps, recommended locations for them, basic trap sizing, general steam and condensate design guidelines, and the various methods for testing steam traps to reduce wasted energy and dollars.

Purpose of steam traps

Steam is unique compared to hydronic systems in that the latent heat of steam contains the bulk of the energy and holds more energy per pound than water. As steam releases its latent energy, it converts back to water, typically called condensate, which must be separated and removed from the system immediately to prevent damage or reduced efficiency in the steam or condensate system. After condensing the steam, the best method to improve steam system efficiency is to return the maximum quantity of condensate to the boiler plant for reuse in the production of steam.

Steam traps are automatic valves that remove air, condensate, and noncondensable gases from steam piping or steam utilization equipment while preventing steam loss. The ability to separate these constituents from steam allows the steam system to reach the operating temperature quickly, and provides a safe and efficient system. Excess water in steam lines and poor condensate management can cause water hammer, which results from water being picked up by high-velocity steam and creates dangerous conditions that can damage piping and equipment. Air limits piping systems' ability to carry their full capacity of steam and acts as an insulating agent within heat transfer devices. Noncondensable gases such as oxygen and carbon dioxide produce carbonic acid, scale, and corrosion, creating conditions that promote leaks within the distribution system.

Learning objectives

- **Understand the variety of steam trap options and when to use each one.**
- **Learn to estimate the amounts of energy and money wasted from a blown steam trap.**
- **Understand how to pipe steam and condensate systems for safety and reliability.**

Types of steam traps

There are a variety of steam traps on the market today for heating and process systems, and no single type of trap is appropriate for all applications. Steam trap selection varies based on system pressures and temperatures, capacity, trap function, piping orientation, and cost. As steam pressures, temperatures, and flow rates constantly vary, selection of the appropriate steam trap becomes more complicated. This is why there are multiple options for traps. Steam traps are classified based on the physical process that allows them to open and close; they generally fall into one of the categories described below, while some traps may utilize a combination of two categories.

Mechanical: Mechanical steam traps, also known as density steam traps, operate by using a float within the trap that will rise or fall based on the density of the fluid in the trap. The floating device is connected by mechanical linkage to a discharge valve that opens or closes based on the fluid level in the trap. For example, when condensate fills the trap, the denser fluid rests on the bottom of the trap and steam rises to the top. As the trap fills with condensate, the float will rise, actuate the valve, and discharge the condensate. The trap will then fill with less dense steam, which causes the float to fall and the valve to close for another cycle.

Application	F&T	Inverted bucket	Thermostatic	Thermodynamic
Drip trap steam mains				
up to 30 psig	1	2		
30 to 250 psig		1		1
HVAC equipment				
Heat exchangers	1	2		
Heating coils	1	2	2	
Humidifiers	1	2	2	
Radiators	1	2	1	
Unit heaters	1	2		
Process equipment				
Autoclaves	1		2	
Sterilizers	1		2	

Notes:
1 - First choice
2 - Second choice
Blank - Not recommended

Table 1: This table lists the recommended steam traps to use based on application of the trap in the system.

Mechanical traps discharge condensate at the same temperature as steam, which makes them great for areas of high heat transfer at equipment such as heating coils or heat exchangers. Mechanical traps are typically combined with a thermostatic valve to vent air out of the system, resulting in float and thermostatic (F&T) traps or various bucket traps such as the inverted or open bucket trap. Figure 1 shows an example of a F&T trap at a steam-to-hot-water heat exchanger.

Thermostatic: Thermostatic steam traps operate based on the temperature change of the steam and sub-cooled condensate to open or close the discharge valve. Within the steam trap, depending on the style of the trap, either a fluid is evaporated and condensed or two dissimilar metals expand and contract based on whether steam or condensate is located within the trap. Thermostatic traps will not open until condensate within the trap has been cooled below the saturated steam temperature. Because steam will not cool below the saturation temperature, the valve is normally open and closes in the presence of the hot steam or condensate. Examples of thermostatic steam traps include bi-metal and bellows type steam traps.

Thermodynamic: Thermodynamic steam traps operate due to the change in fluid dynamics of flash steam within the trap. As the fluid within the trap changes, static and dynamic pressures change based on velocity to operate the discharge valve. Condensate is a low-velocity fluid causing an increase in static pressure that lifts the valve and allows the condensate to be removed from the trap. Conversely, steam has a much higher velocity and dynamic pressure, so when steam approaches the trap, the decrease in static pressure and increase in velocity creates a pressure drop to close the valve, according to an article in Chemical Processing written by Tracy Q. Snow. The most common type of thermodynamic trap is a disc type where the disc is the only moving part. Thermodynamic traps discharge condensate close to saturated steam temperature and are very compact, simple, and rugged valves, making them ideal for steam main header drip traps.

Table 1 provides the recommended steam trap to use based on the location and function within typical heating and process systems.

Figure 2: A steam drip leg and trap on a main high-pressure steam pipe upstream of a flow meter are shown.

Locations, sizing of steam traps

With an overall understanding of steam traps, it is appropriate to discuss where steam traps are located within a steam distribution system and how trap sizing affects the system. Steam traps in HVAC applications are generally found in two locations: drip traps and at process equipment.

Drip traps are located as part of the main steam distribution piping as the system radiates heat, loses energy, and creates condensate within the piping system. Drip traps consist of a short piece of vertical pipe called a drip leg on the bottom of the steam main with a steam trap. The drip leg must be adequately sized to collect and remove the condensate, with a recommended diameter the same size as the main piping up to 4 in. and half the diameter for piping above 4 in., but never less than 4 in.

The recommended vertical length of the drip leg should be 28 in. to create 1 psi of head pressure on the steam trap according to the ASHRAE Handbook—HVAC Applications. These traps should be located at the end of mains; bottom of risers; ahead of pressure regulating valves, controls valves, and isolation valves; at pipe bends; and near expansion joints to allow the collection of condensate. Straight sections of piping should also receive drip traps at regular intervals depending on the pitch of the piping. Piping that pitches in the direction of flow should receive drip traps every 200 to 300 ft, and piping that pitches opposite the direction of flow should receive drip traps every 150 ft3 according to the ASHRAE Handbook—HVAC Applications. These traps only see a small amount of condensate from heat loss or start-up and are typically low-capacity traps that are not required to bleed air from the system. Figure 2 shows an example of a drip leg and trap.

Steam traps located at the outlet of process equipment serve the same general purpose as drip traps, but the overall intent is to confine the steam within the heat transfer equipment until the steam has released all its latent heat and condenses to condensate. At this point, it is acceptable to return the condensate to the boiler for reuse. These traps require large condensate and air handling ability to maintain efficient heat transfer.

All steam traps should be located below the device they serve to allow condensate to be removed by gravity and not rely on pressure or velocity. There are conditions when lifting condensate is acceptable, but it should be avoided wherever possible to reduce backpressure on the traps. At the bottom of the drip leg, a drain valve should be provided to remove condensate, and isolation valves and unions are recommended at the inlet and outlet of the steam trap to simplify trap removal. At the inlet to the steam trap, a strainer with a blowdown valve will provide the ability to remove any scale, dirt, and debris in the piping system and allow an operator to depressurize the steam trap for maintenance. Downstream of the steam trap, a check valve eliminates the potential for condensate to back up into the steam system. In all cases, the steam trap must be located with maintenance in mind in an accessible location, as an inaccessible steam trap may be forgotten for years.

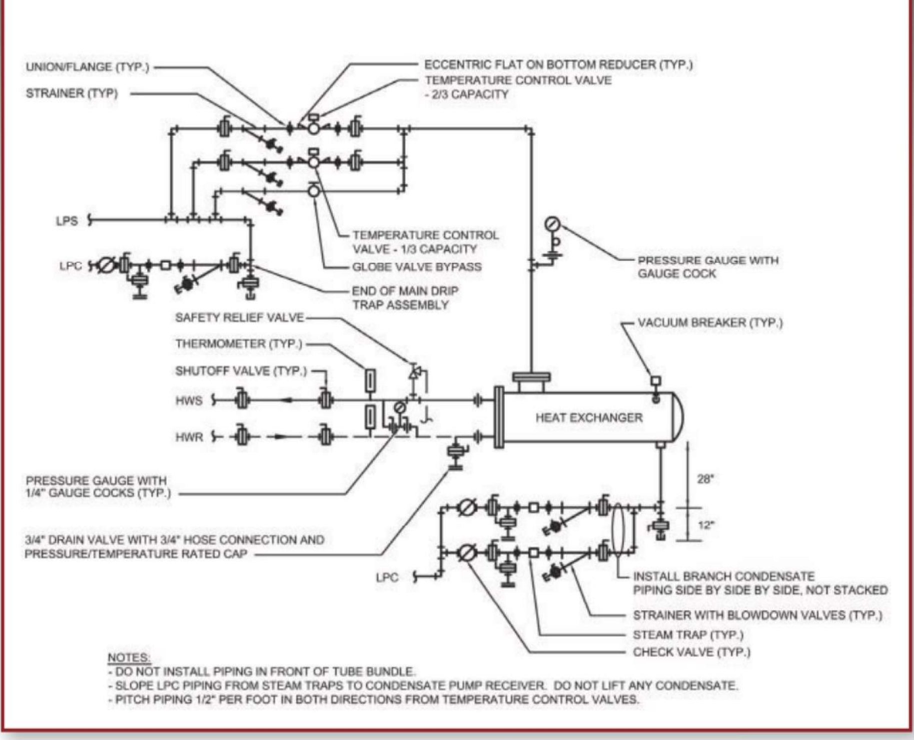

Figure 3: **This schematic shows a steam-to-hot-water heat exchanger with a top takeoff at the main distribution piping and all necessary steam traps and accessories.**

Because proper steam piping design impacts condensate removal, steam takeoff to the process equipment should be a top takeoff to provide the highest quality dry steam in the distribution system, which reduces condensate from the bottom of the distribution main from getting into the equipment. At the takeoff, include a drip leg and trap as described above in addition to the heat transfer equipment steam trap (see Figure 3).

Under- and oversizing steam traps can have adverse effects on the overall system; undersized traps will cause frequent cycling and potentially reduce heat transfer as condensate may back up into the equipment. Oversizing steam traps can be equally as problematic as oversizing traps can cool the condensate prior to discharge. A failed oversized trap has a larger orifice opening that can potentially blow through larger quantities of steam and waste more energy.

Steam traps should generally be sized two to three times the amount of condensate that will be produced under normal operation to account for varying pressures and condensate loads. This will provide additional capacity for cold start-ups when a great deal of condensate is produced and steam pressure is at its lowest value. Since steam pressure is used to move condensate throughout the piping and steam traps, start-ups require high capacity acceptance from the traps, according to the Watson McDaniel product catalog. In any case, the condensate piping to the steam trap should be no smaller than the designed condensate outlet of the process equipment, and the outlet of the steam trap should be the discharge pipe size of the branch piping to the condensate main to maximize gravity flow to the condensate return main piping.

Condensate piping systems design guidelines

Sizing of the condensate return piping system requires careful analysis and depends on system pressure, type of condensate piping system, and slope of the piping. The most common type of condensate piping is a gravity drain, which relies on condensate being drained to a condensate receiver that is vented to the atmosphere. Flow in the condensate piping is two-phase, consisting of flash steam and condensate, and should be sized to keep velocities below 4500 fpm for flash steam and below 7 fps for condensate, according to an article in *Plant Engineering* by Kelly Paffel. Piping should be pitched downward in the direction of the condensate flow at 0.5 in. per 10 ft to ensure adequate condensate removal.

Piping in condensate systems is recommended to be schedule 80 steel piping in most cases, due to heavier wall thicknesses to extend the life of the pipe. Where possible, weld piping connections and avoid threaded connections to limit leak points due to continuous thermal expansion and contraction. Condensate should also be drained into the top of the main condensate header similar to steam takeoffs to prevent hot condensate from mixing with cool condensate, causing flash steam and water hammer, according to the article by Paffel. Figure 4 demonstrates an installation with the appropriate top takeoffs for condensate piping.

Piping design should be in accordance with ASME B31, which covers the standards for pressure piping (see the article on page 28 for more on ASME B31). ASME B31.1 includes the design, fabrication, erection, testing, and inspection of high-pressure power piping for systems exceeding 15 psig. Steam systems are considered high-pressure above 15 psig and low-pressure below 15 psig. Although building services can use high-pressure steam piping, the most common locations for ASME B31.1 are within industrial plants or central/district steam heating plants. ASME B31.9 covers similar piping requirements typical of low-pressure steam systems for building services for those systems not directly covered by ASME B31.1. In any case, steam traps and systems must be rated for the temperature and pressures of the system.

Testing steam traps

Unfortunately, in many buildings and campuses, steam trap maintenance is typically ignored unless a larger problem occurs at the boiler plant or distribution system. As steam leaks through steam traps, the steam is condensed by conductive losses in the piping system as it returns to the condensate receiver or is vented out the receiver and lost, many times without detection. A typical steam trap maintenance program should include at least yearly testing of all steam traps to find leaking traps and replace failed traps. This test-and-replace strategy is subject to two main costs by the owner: testing and steam loss.

Figure 4: Multiple branch condensate piping discharges into a main condensate pipe with top discharges.

The most difficult item in a steam system survey is to determine if steam traps are operating correctly or are faulty and wasting energy. Many times, steam system surveys are not implemented due to the cost or staffing required, but the energy savings observed as a result of a properly implemented program will typically pay back the cost to implement the program in less than one year. If a yearly investigation of all the traps can't be completed, the focus should be the larger traps that can waste significantly more energy than smaller traps.

For example, based on the size of the steam trap and orifice size, one can estimate the amount of live steam lost through the trap. The worst-case scenario would assume the entire orifice is open, but typically condensate simultaneously flows through the trap so approximately $^{1}/_{3}$ to $^{1}/_{2}$ of the orifice will contain lost steam, according to the DOE.

Test methods to determine steam trap operation can be segmented into four categories: visual, ultrasonic, temperature, and conductivity.

Visual: Visual testing involves a test valve arrangement or inline sight glass to visually determine if the steam trap is malfunctioning. Inline sight glasses should generally be avoided due to reliability issues. Testing valves provide a visual observation of the fluid downstream of the steam trap by allowing a momentary discharge of the downstream fluid. Visual indication requires that the personnel observing the visual cues be knowledgeable enough to determine the condition of the steam trap as blow-through steam and flash steam can both escape the test connection with only one indicating a failure. Flash steam is created when condensate flashes to vapor upon expansion to atmospheric pressure and is typically a billowing plume, compared to live steam which is a sharper, higher velocity plume that may not be immediately visible as it exits the test valve, according to the DOE.

Ultrasonic: Ultrasonic measuring allows the operator to listen to sonic and supersonic sounds as the steam and condensate flow through the trap. Devices on the market today are able to compare the sound of a known condition to the tested trap to accurately determine if the trap is functional or blowing steam.

Temperature: Temperature testing of steam traps can help identify issues, but must use the pressure/temperature relationship to accurately assess the condition. The most common method of temperature measurement involves infrared testing to determine the surface temperature of an object at the inlet and outlet of the steam trap. The inlet condition should correspond to saturated steam pressure, and the outlet temperature should correspond to condensate pressures. However, care must be taken with the temperature method since saturated steam and condensate can coexist at the same temperature. This method can still be used to provide a general assessment of the trap condition.

Conductivity: A fourth method of testing relies on the use of fluid conductivity to indicate if the steam trap is operating properly. Testing is conducted with a sensor located either inside of the steam trap or in a sensing port upstream of the trap to detect the physical state of the fluid. Under typical conditions, the probe would be immersed in condensate, but if the steam trap has failed, condensate would not be present and the probe would be sensing the conductivity of the steam. To get the most accurate diagnosis, maintenance personnel should integrate conductivity readings with temperature.

Many factors influence the success of a steam and condensate system. Good system design coupled with the understanding of a correctly sized steam trap for the duty is a critical first step. Ultimately, steam traps require a maintenance program to determine if they are working to their full potential. Failed steam traps can have a spiraling cost impact above and beyond wasted steam, including increased feedwater costs, additional chemical treatment and make-up water, and higher blowdown requirements.

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