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Hazard Recognition

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My Steam Trap Is Good — Why Doesn't It Work?

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Even a relatively new steam trap in seemingly good condition can fail if it is applied incorrectly. Here's how to recognize and avoid situations that can lead to a failure.

Steam is the most efficient and cost-effective means to provide massive amounts of heat to a production process. The reliability of a steam system can be greatly enhanced by focusing on the ability of the steam trap population to successfully drain condensate from the system. Draining condensate as it forms is a key factor in achieving the highest levels of performance.

Condensate drains from the steam system at condensate discharge locations (CDLs). A CDL is an assemblage of piping and valves, with the critical component being a steam trap. Any condensate that is not removed can collect in the steam distribution system and be propelled downstream by steam that can travel at speeds of more than 100 mph. Such high-velocity condensate produces erosion and system hammer, which in turn can cause catastrophic safety or equipment reliability events — or, at the very least, leaks from flanges, piping, and valves.

Unfortunately, many sites do not perform an annual steam trap survey. A basic steam trap survey provides an assessment of each trap's condition, labeling it either *good* or *failed.* A more in-depth analysis identifies failed traps as either *cold failures* or *hot failures*. A system with a cold failure is not adequately draining condensate because the trap is blocked or operating at an unusually low internal temperature, or the trap itself is hot but the equipment being drained is cold. A hot failure refers to steam leaking while the condensate is being discharged. For safe and reliable operation, each site should establish a minimum threshold number of CDLs in good condition.

Condition failures can be caused by a trap malfunctioning due to damage, debris, or wear, or by the incorrect application or installation of a trap. It can be particularly frustrating to maintenance or operations personnel who replace a failed trap only to have the new trap fail in the same way as the trap it replaced. This raises the question: "Why doesn't my good steam trap work?"

There can be several reasons why a new, correctly manufactured steam trap might not be functioning properly, most of which are due to misapplication. This article explores some of these reasons and explains how to recognize potential problems, and provides guidance on avoiding such problems.

Cold Failures

Cold failures should be considered the highest priority. A cold trap does not adequately drain condensate from the system. This has the potential to cause the most disastrous results *(1).* Possible causes for cold failures of good steam traps include:

- negative pressure differential
- undersizing
- modulating into a stall condition
- steam locking due to lift or to distance
- group trapping
- double trapping
- pressure blockage
- incorrect low temperature setpoint
- high backpressure
- backwards installation
- debris or deposits
- inability to discharge air
- isolation or valving-out.

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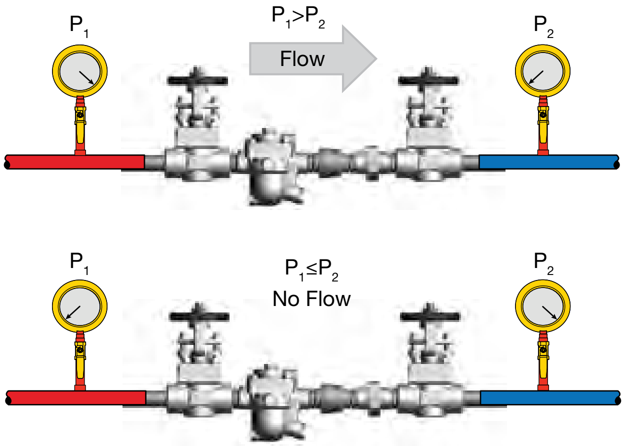
Negative pressure differential, undersizing, and modulating into a stall condition

A steam trap will discharge condensate if there is a positive pressure differential, but will not discharge condensate if the pressure differential across it is zero or negative (Figure 1). An undersized trap will not allow sufficient condensate flow to maintain proper drainage. These basic principles are easy to understand.

Drainage becomes more complicated, however, when steam equipment or tracing operates under modulating control. For instance, a modulating control valve may operate with a steam supply pressure of 150 psig and the equipment may have a 30-psig backpressure, but the valve's delivery pressure modulates to achieve equilibrium between the supply heat and the heat demand. When pressure differential varies, because of either modulating control or undue influence of backpressure, the system may encounter a *stall* condition (Figure 2). This may occur, for example, in thermally stratified heat exchange equipment. Equipment in a stall that experiences rapid valve modulation can also suffer from hammer due to the multiple effects of thermal and hydraulic shock (Figure 3).

A related effect occurs when the modulating valve reduces the supply pressure while maintaining a positive pressure differential across the trap. The pressure differential may decrease to the point where the trap's capacity is no longer sufficient to meet the adjusted demand. Such modulation (*i.e.,* a positive but smaller differential) is analogous to an undersized trap at static pressure conditions. Whenever traps are to be installed on equipment with inlet modulating control valves or regulators, it is advisable to analyze the steam chest pressure profile for the full range of process or heating demand.

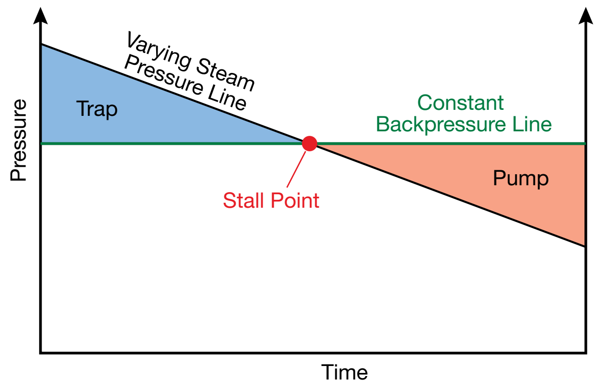


▲ **Figure 1.** The pressure differential across a steam trap must be positive ($P_1 > P_2$) in order for flow to occur (top). If there is no pressure differential or a negative differential ($P_1 \leq P_2$), the trap cannot discharge condensate (bottom).

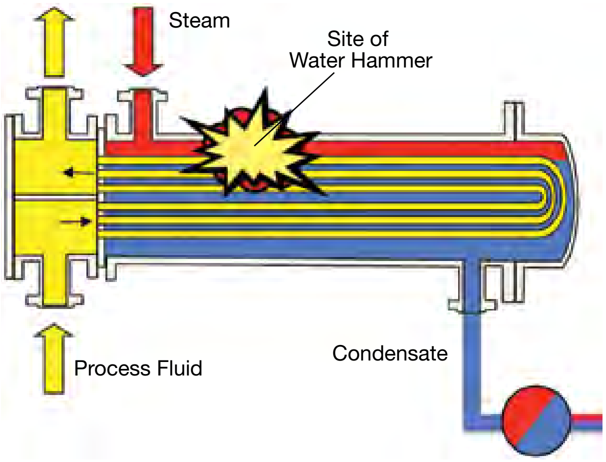
Steam locking

The essential function of a steam trap is to automatically open to discharge condensate and shut off to prevent steam loss. Steam locking occurs when steam collects in the line between the condensing source and the trap, filling the trap and preventing it from opening. Steam locking can occur if there is a vertical rise in the piping or if the trap is located a long distance from the condensate source.

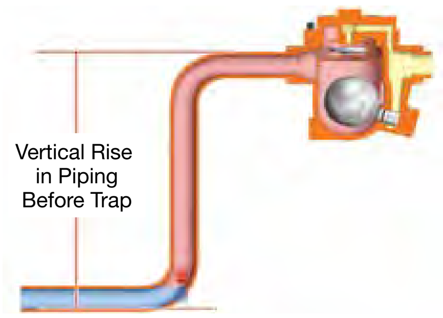
Steam locking due to lift. Figure 4a depicts a steam trap with a vertical lift from the condensing source into the trap. After condensate is initially discharged through the trap, the vertical riser pipe and trap immediately fill with steam, causing the trap to close. Condensate can continue to form in the equipment, but it cannot displace the steam in the trap body, so the trap remains closed. In essence, the trap is steam-locked shut and the equipment becomes cold or thermally stratified, even though the trap itself may be hot to the touch. It is the heat exchange system that is cold due to a steam lock.



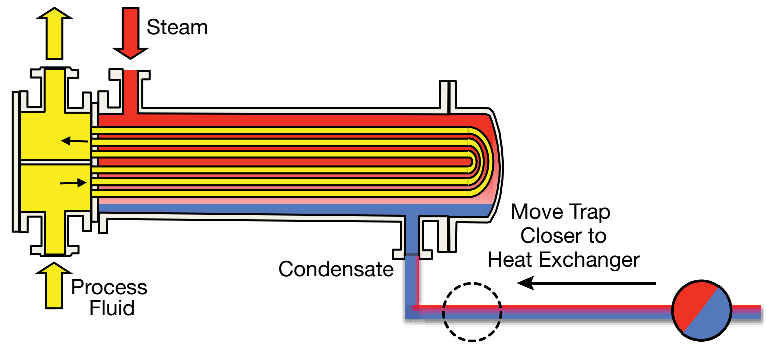
▲ **Figure 2.** Heat exchange equipment may have modulating steam control that adjusts the supply heat to the heat demand. If the equilibrium point is less than or equal to the backpressure, a stall occurs and condensate does not flow.



▲ **Figure 3.** Stall conditions are a common cause of water hammer and damage in heat exchangers.



▲ **Figure 4a.** Some applications may require a vertical rise into the trap. If it is not designed properly, severe steam locking and subcooled temperatures can occur.



▲ **Figure 4b.** Locating a trap a long horizontal distance from the condensing source can allow steam to flow across the top of the condensate, leading to severe steam locking.

Steam locking due to lift can occur with any riser pipe into the trap, particularly when the riser is made of large-bore piping. The lift condition needs to be analyzed and a solution — such as a small-bore lift fitting, drilled vent, or steam lock release — provided to prevent the steam lock. Otherwise, the CDL will fail cold and not drain the equipment adequately, even though the steam causing the lock may make the trap itself hot to the touch.

Steam locking due to distance. A similar phenomenon occurs when a trap is located too far away (horizontally) from the condensing source (Figure 4b). A trap may be located relatively far from the process equipment if there is not enough space available near the equipment to install a trap in close proximity. A trap might also be installed at a distance so it is more readily accessible or outside of a zone where special garments or permits are required.

In a distance-related steam-lock situation, the trap itself may be hot to the touch from the steam causing the lock, but condensate can pool on the inlet side and back up into the equipment, causing a cold condition. Condensate has a low specific volume (approximately 0.017 ft^3/lb) and occupies very little space in the pipe between the equipment and the steam trap. Steam can pass over the top of the condensate in the line and lock the trap, even though more condensate is being produced in the equipment.

To obtain the best performance from a steam trap, locate the trap as close to the vertical drop as possible. If it is not possible to move it closer, a simple solution to prevent steam locking is to install a vertical drop immediately before the trap, even if the trap is located a distance away from the equipment. The vertical drop usually helps to prevent a steam lock due to distance by allowing for a leg of condensate at the trap's entrance, as long as the condensate piping is pitched downward toward the trap.

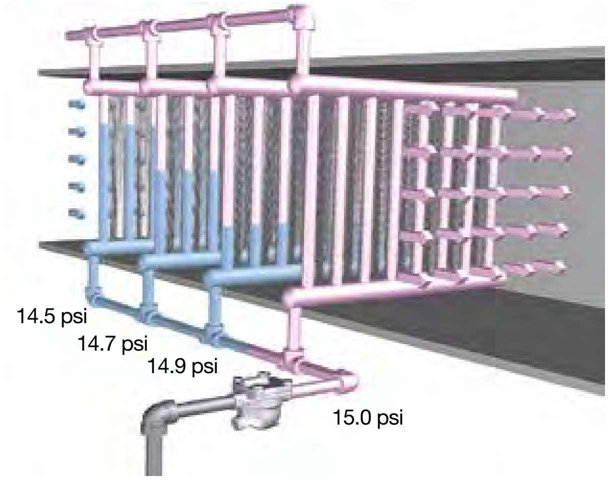
A third alternative is to install a balance line directly on or immediately before the locked trap at its inlet. This allows the steam that would normally be compressed to return to the steam line instead.

Group trapping

Collecting condensate from several sections of steam-heated equipment into one condensate line that discharges into a single steam trap is a practice known as group trapping. Reasons cited for group trapping include space limitations (real or perceived) and the desire to reduce installation costs. However, group trapping provides a false sense of economy. In most instances, it limits the performance of the heating system due to pressure differentials and short-circuiting.

It can be difficult to identify problems with group trapping at the trap itself. The trap condition might appear to be good — the trap is hot to the touch and is not leaking steam. However, the equipment being drained by the trap often suffers from significant thermal stratification. A trap in this condition is categorized as a cold failure.

Consider the four-coil air heater shown in Figure 5. The cool air encountering the first coil absorbs the largest



▲ **Figure 5.** The practice of group trapping may appear to be a reasonable measure. However having different condensing rates in the various sections causes short-circuiting, preventing lower-pressure condensate from flowing into the trap. This causes flooding and reduced heating in the affected equipment.

amount of heat and therefore creates the most condensation. When the steam condenses, the steam pressure in the coil drops simultaneously. The heated air reaching the last coil is much hotter and absorbs less heat, creating less condensation and a smaller pressure drop across that coil. Even though the inlet pressure to the four-coil system remains constant, the effective pressure drop from the inlet to the outlet of the first coil is larger than the pressure drop across the fourth coil. This pressure imbalance creates a short circuit. The second and third coils can also have outlet pressures lower than the fourth coil's outlet. The result is significant thermal stratification and reduced heat-transfer capacity of the coils.

Installing a single trap, instead of low-cost, individual traps for each coil, is a costly design decision, because it can significantly reduce the heating capability of the equipment and prevent it from performing at its maximum.

Double trapping

Double trapping is the practice of installing a second trap in series immediately after another trap (Figure 6). It is sometimes intended to be a temporary measure, where a so-called master trap is installed on a condensate line downstream of a failed trap (or traps), or as a second trap to act as a backup in case the first trap fails. While installing two traps in series might seem to be a good safety measure, it can lead to trap blockage and waterlogging of all of the equipment the trap is supposed to drain.

Double trapping can cause a cold failure in two ways:

- live or flash steam exiting the first trap enters the second trap, causing the second trap to close
- the available pressure differential is split over two traps, and the driving force across the second is insufficient for the required load.

When a trap fails, it leaks live steam; when it functions properly, a portion of the discharged condensate flashes into steam because of the pressure differential. In either case, when two traps are set in series, live or flash steam exits the first trap, with multiple effects:

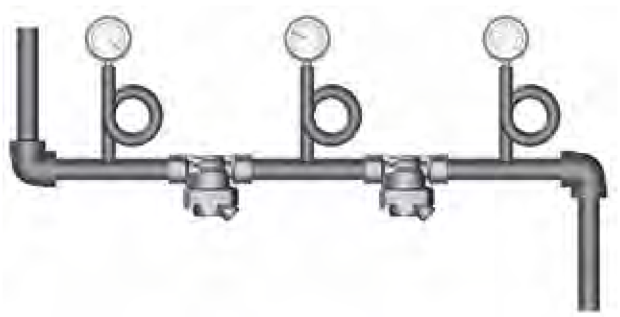
- system backpressure increases
- the second trap closes, interrupting flow
- waterlogging (*i.e.,* failure of the condensate to drain) and/or water hammer can occur.

The full pressure differential between the inlet and outlet is available for a single trap. Double trapping, on the other hand, divides the pressure differential between the two traps. If the pressure drop is not large enough for the condensate flow to overcome the outlet pressure, condensate will pool at the inlet of the first trap. To avoid this, both traps would need to be oversized. Additionally, in cases of higher backpressure in the return line, one of the traps may need to be substantially larger to account for the smaller differential pressure across it.

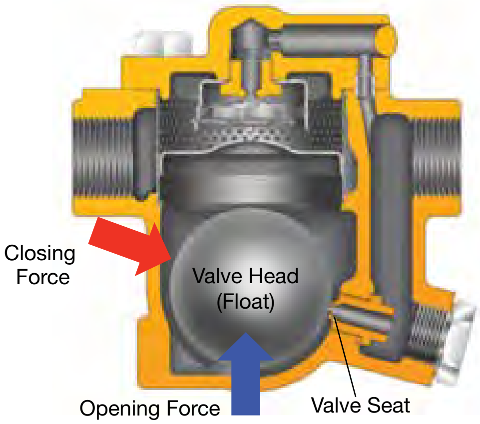
If trap failure is a concern, keep spare traps on hand and replace faulty traps promptly. In addition, install a block valve on the inlet and outlet sides of steam traps to allow for quick and easy replacement. A bypass valve that directs condensate to the plant's drain system is also useful. If a backup is required for a critical process, install a trap in parallel, not in series, and switch flow to it if necessary.

Pressure blockage

When the steam trap's valve head is located on the inlet side of the valve seat (Figure 7), thermodynamic action easily closes the trap's automatic-opening mechanism. This type of trap needs a mechanical advantage to overcome the closing force created by steam pressure on the valve head. For example, traps that operate based on the density principle (*i.e.,* the difference between the densities of the steam and the condensate), such as float and inverted-bucket mechanical traps, open to discharge condensate when the buoyancy of the float or bucket overcomes the closure force. The mechanical advantage needed to allow this is



▲ **Figure 6.** The full pressure differential between the inlet and outlet is split between traps that are double-trapped. This reduces the capacity of the second trap. Additionally, flash/live steam can close the second trap.



▲ **Figure 7.** A pressure blockage occurs when the difference between the inlet pressure and the backpressure exceeds the trap's differential pressure rating.

obtained by operating the trap below its specified maximum operating pressure (PMO) and maximum differential pressure (PMX).

However, a trap operating below its PMO/PMX specifications might experience a line pressure increase, for example, due to a combination of higher boiler pressure and reduced demand elsewhere in the system, or to a drop in system backpressure. If that increased differential pressure causes the steam trap to exceed its PMX, the trap may not develop sufficient mechanical advantage to open, and the trap fails cold. If a new trap of the same model is installed to replace the failed one, the trap will continue to experience cold failures. The trap needs to be replaced by one with a higher PMX rating. Often the PMX is exceeded in error — for example, if someone unfamiliar with the system's nominal pressure and its variance installs a trap with an inadequate PMX rating.

Traps with an outlet valve head do not experience this type of problem. Rather, the high pressure forces the valve open — and it does not have sufficient capability to close the valve when its PMX is exceeded. This creates a hot failure.

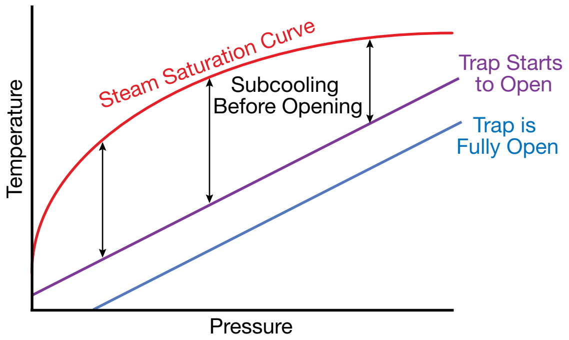
Incorrect low temperature setpoint

Bimetallic (and expansion-type thermostatic traps) tend to have a sluggish response. Thus, the temperature setting at which the trap begins to open must be significantly lower than the temperature of saturated steam (Figure 8) to prevent the trap from blowing live steam into the condensate return header. This setpoint may be as much as 50°F lower than the saturated steam temperature, depending on the system pressure and the return header backpressure.

Metal strip(s) or plate(s) in a bimetal trap expand and contract in response to temperature changes, and this deflection causes the trap to open and close. When the condensate temperature is above the setpoint temperature, the deflection is minimal and the trap remains closed. When the condensate has cooled to the setpoint temperature, the amount of deflection is sufficient to open the trap slightly, allowing the condensate to begin draining slowly.

Depending on the capacity that needs to be drained, condensate can back up at the trap's inlet, where it continues to cool and further increases the condensate load. The additional subcooling causes the metal strip to bend more, gradually increasing the size of the opening and the condensate discharge flowrate, until the trap is fully open and condensate is discharging at its full-open rate. The amount of additional subcooling required to reach the full-open position may be an additional 50°F, which represents 100°F of subcooling below the saturated steam temperature.

If the opening temperature is set too low, the trap closes tight early, and then an even larger degree of subcooling is needed to deflect the element and fully open the valve.

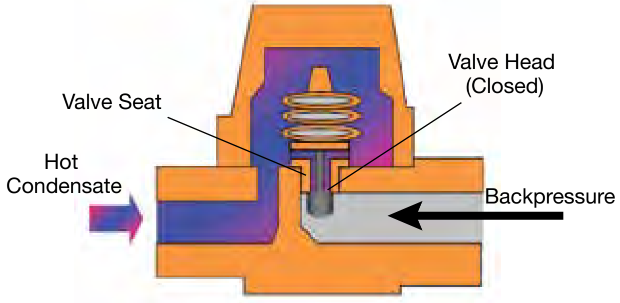


▲ **Figure 8.** The temperature setpoint at which a bimetallic trap starts to open must be significantly below the temperature of saturated steam. If it is too low, the trap closes early, causing a cold failure. If it is too high, the trap will blow steam (a hot failure).

High backpressure

Many bimetallic and some balanced-pressure thermostatic steam traps have a downstream valve head design, where the valve head is downstream of the valve seat (Figure 9). High backpressure pushes the valve head toward the seat. Thus, dynamic system conditions that significantly increase the backpressure can increase the closure force from the downstream side, closing the steam trap early and causing a cold condition.

Depending on the condensate load and the application, these traps can require a significant backup length to allow the condensate to subcool — sometimes as much as 40 ft or more. The risk of water hammer damage or personnel injury in the event of such backup is high in systems that may not be able to provide the necessary volume to hold the subcooled condensate without incident. Because of the large volume of condensate in the line, it is unwise to use these traps on steam main drips or process heating applications. They may be suitable, or in some cases recommended, for low-temperature trace heating or instrument enclosure warming. If the backup is too far from the trap and extends into the application being drained, then it becomes a cold failure.



▲ **Figure 9.** Backpressure on a bimetallic trap with a downstream valve head design pushes the valve toward the seat. If the backpressure is too high, the valve closes earlier than intended, causing condensate to back up and creating a cold condition.

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Backwards installation

Installing a steam trap with the flow arrow pointing in the downstream direction seems like a simple task. Nevertheless, it is not uncommon to find a trap that has been installed backwards.

When a trap with a downstream valve head or integral check valve (such as a bimetallic trap) is installed backwards, the inlet steam pressure can hold the valve shut, causing a blocked, cold condition. Density-based and thermodynamic traps do not have a valve that can be held closed by reverse flow, so if installed backwards they typically experience hot failures rather than cold failures.

Debris or deposits

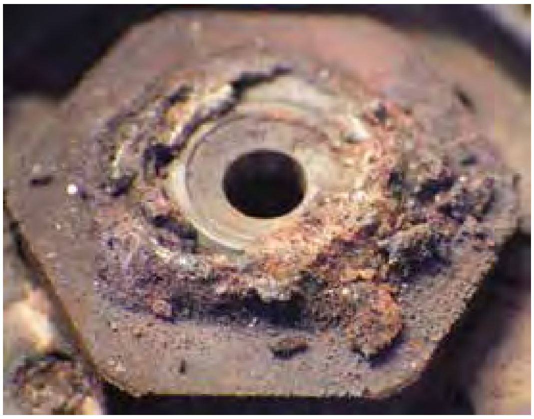
Mud legs should be blown down regularly — for example, at system startup or shutdown and before and after installing a new trap. If maintenance, operations, or contractor personnel do not do this, debris can accumulate quickly and be deposited in the new trap, creating a blockage.

A longer-term condition can occur when the condensate contains particulates, such as iron oxide or leached copper. Debris can accumulate at the entrance of the valve seat and prevent the trap from closing, thereby causing a hot failure (Figure 10). But, some condensate flashes as it passes through the steam trap's orifice. The incondensable particles that were in solution can simultaneously precipitate out of the flashed fluid. This precipitate forms deposits that can metallically bond to the orifice, build up, cause a blockage, and create a cold condition.

Inability to discharge air

Some steam traps that operate on the density or thermodynamic principle are not able to vent significant amounts of air. This can cause them to close when they encounter air upon startup or ingressed air (for instance, from vacuum breakers). Noncondensable air inside the trap body can lock the trap shut, creating a cold condition.

To avoid this problem, select traps that vent air. Thermostatic traps have this air-venting feature, as do float-and-thermostatic, disc-and-thermostatic, and inverted-bucket-and-thermostatic traps.



▲ **Figure 10.** Minerals in the condensate can build up at the orifice outlet and prevent the trap from closing.

Isolation or valving-out

This type of cold failure can involve one of two scenarios.

Scenario 1: After a new steam trap is installed, it needs to be put into service. If the installer leaves this task for the operations staff, but the operators do not realize they are expected to do it, the CDL will not be able to drain condensate.

Scenario 2: A leaking trap represents a hot failure, and although the trap is leaking steam, it is at least discharging condensate as intended. If a worker valves-out the CDL to stop the leak, what was an inefficient operation — leaking steam — becomes a dangerous cold failure.

HOT FAILURES

Many facilities assign the highest maintenance-response priority to hot failure — *i.e.,* leaking — steam traps. However, hot failures typically do not present the same safety issues as cold failures. Even though the drainage of leaking traps is inefficient, they nevertheless discharge condensate from a steam system. The main benefits to fixing hot failures are economics-related. Possible causes for hot failures of good steam traps include:

- backwards installation
- incorrect orientation
- oversizing
- high backpressure
- inability to handle superheat
- incorrect high temperature setpoint.

Backwards installation

Depending on the type of trap, backwards installation can cause either a cold failure as discussed earlier or a hot failure.

When density-based or thermodynamic traps are installed backwards, it is usually not possible for the valve mechanism to close. Steam loss occurs until the installation is corrected.

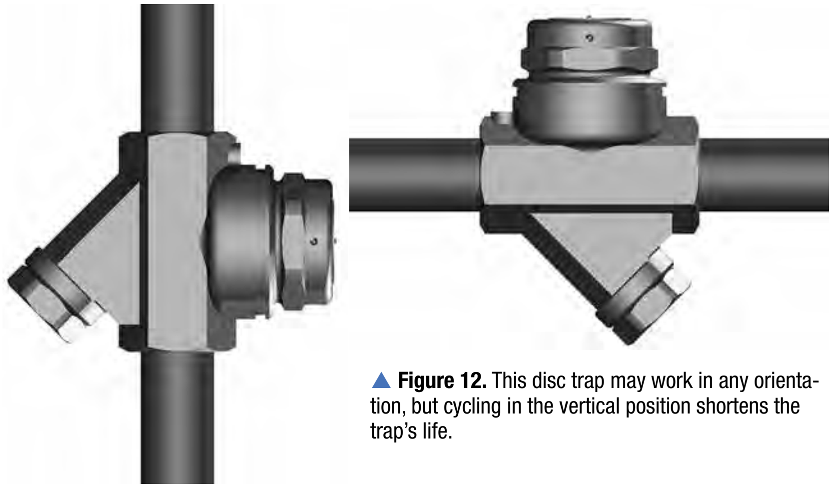
Incorrect orientation

A steam trap installed in the wrong orientation may experience a hot failure in two ways.

If a density-principle trap is installed in an incorrect orientation, the valve mechanism may be unable to close, and steam will leak. For example, the horizontal trap installed vertically in Figure 11 may experience steam blow-through (*i.e.,* the steam blows through the open valve). Blow-through could also occur if the trap were installed upside down.

Most inline steam traps have a preferred orientation, usually either horizontal or vertical. Although an inline trap might function acceptably in any direction, its life expectancy might be longer in one orientation than the other. For example, disc traps installed in a non-optimal orientation can experience more-frequent cycling and more-rapid internal wear that reduces the trap's lifespan and causes hot-failure leakage in a shorter period of time.

The disc trap in Figure 12 may have been installed vertically in an attempt to improve drainage under shutdown. However, in this position the disc is vertical, which shortens the life of the trap. The same trap in a horizontal application would have a longer useful life. A different type of disc trap (*e.g.,* a costlier two-bolt, swivel-connector type that maintains a horizontal disc when installed vertically or in any other orientation) would be a better choice for this line.



▲ **Figure 12.** This disc trap may work in any orientation, but cycling in the vertical position shortens the trap's life.

Oversizing

Except for float-type designs, an oversized steam trap also typically has a shorter life than one that is properly sized. Inverted-bucket, thermostatic, and thermodynamic traps can be more prone to early failure than float traps when oversized. The result of shortened life is premature hot failure.

Technically speaking, if an oversized trap experiences a hot failure, its condition would not be considered good. However, the user may consider the trap to be relatively new and wonder why it failed sooner than expected.

◀ **Figure 11.** Many traps require (or operate better in) a specific orientation. This horizontal density trap installed vertically is likely to experience blow-through.

High backpressure

High backpressure can cause a cold failure in some trap designs, but it can also cause a hot failure in others. Thermodynamic steam traps, in particular, are susceptible to hot failure due to high backpressure. Many thermodynamic traps cannot operate with backpressure above 80% of the inlet pressure (some can tolerate only 50%). This is because the small differential does not allow the trap to develop the necessary velocity on the underside of the disc to obtain and maintain tight closure. As a disc trap wears or becomes fouled, its ability to operate with high backpressure tends to decrease.

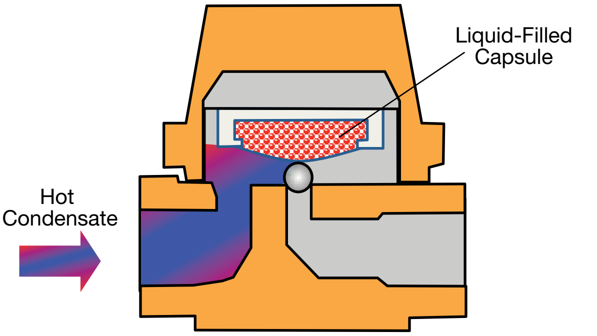
Avoid thermodynamic traps in applications where the backpressure is near the trap's specified tolerance limits.

On the other hand, when backpressure is removed from a bimetallic trap with a downstream valve head design, the valve can open and blow live steam. This is because the backpressure helps close the valve, and removing it allows the valve to stay open longer.

Inability to handle superheat

Some steam trap designs may not be suitable for use at elevated superheat temperatures.

Balanced-pressure thermostatic traps (Figure 13) have a liquid filling that vaporizes when the temperature of the condensate flowing through it approaches the temperature of saturated steam; the expansion of the liquid-filled chamber



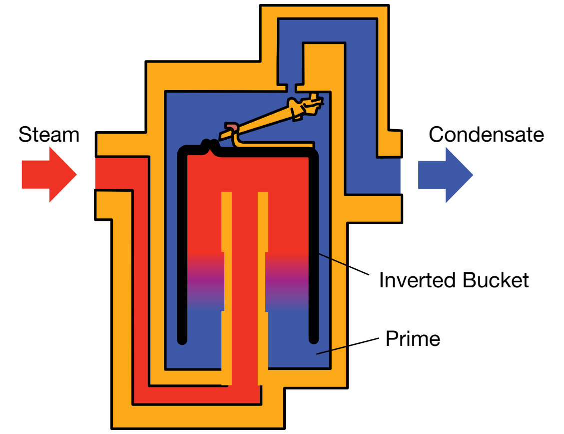
▲ **Figure 13.** Superheat conditions can cause the capsule inside a balanced-pressure trap to rupture, causing a hot failure.

closes the trap to prevent steam flow. If the trap encounters superheat temperatures above its rating, the element containing the liquid may rupture, causing live steam to leak.

Similarly, if the temperature rating of a bimetal element is exceeded (such as can occur during temporary leakage caused by debris holding a valve seat open), the element can fatigue or its dissimilar layers can separate. This can prevent the trap from closing, with the net effect of steam loss.

Even a new trap in good condition can be damaged by high superheat temperatures and experience a hot failure. No matter how many new, good traps of the same model are installed, the superheat condition will cause the same damage and hot failure.

A water prime in the bottom of an inverted-bucket trap provides for bucket flotation, which causes the valve to close. If the condensate load is insufficient, such as can occur if the trap experiences superheat or rapid pressure modulation by the control valve, the required water prime may be lost. If this happens, the bucket loses buoyancy and falls, and steam is lost (Figure 14).



▲ **Figure 14.** Inverted-bucket traps require a priming liquid to prevent steam loss. If this prime is lost, for instance, due to superheat, the result will be steam blow-through.

Incorrect high temperature setpoint

As discussed earlier, because bimetallic and expansion-type thermostatic traps can have a slow response, the setpoint at which the trap begins to open must be significantly lower than the temperature of saturated steam (Figure 8). If the setting is too close to the saturated steam temperature, the trap is likely to discharge live steam — a hot failure.

Inadequate subcooling can also occur as bimetal elements fatigue over time. Fatigue loosens the nut used to adjust the temperature setting; this raises the opening temperature, which has the effect of reducing subcooling. If this is allowed to continue, the trap will start to leak steam.

In closing

In almost all of the situations discussed (except those specifically related to shortened trap life), steam traps can be new and performing perfectly to the manufacturer's specifications before experiencing a hot or cold failure.

One way to avoid these problems is to conduct an annual steam trap survey to diagnose the operating condition of the trap population and identify potential areas of misapplication or faulty installation. It is also helpful to schedule an annual review meeting with the facility's preferred trap manufacturer to confirm that the traps are being selected and installed properly on specific applications as recommended. CEP

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