

DECEMBER 2019

**Chemical
Engineering
Progress**

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A LOOK AT VERTICAL FARMING

- 24** Protect Tanks from Overpressure and Vacuum
- 32** Steam Tracing Design
- 41** Hybrid Distillation-Membrane Systems
- 50** Working with Local Government
- 55** AIChE Awards in Review: 2019

Tracing the Causes of Heat Maintenance Issues

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Steam tracing systems are used throughout oil and gas and chemical facilities. Common problems, such as steam locking caused by incorrect installation, can hinder the performance of these systems.

Stream tracing is a system of tubing or jacketing laid along the outside of piping and equipment (beneath the insulation) to maintain or raise the temperature of the fluid within (Figure 1).

Chemical process industries (CPI) facilities often use steam tracing to maintain a product's desired viscosity and control instrumentation reliability. Thermal maintenance is critical to production, because it prevents fluids from becoming too cool, which can change the viscosity of the stream and even lead to product solidification and stagnated flow. Steam tracing is also used to keep instrument boxes warm, which improves instrument accuracy.

Poor performance of steam tracing systems can often be attributed to ineffective design or routing of tracing, or to steam traps that are not suited to the application. If heat transfer from tracing is inadequate or a steam trap within the system is not performing, products can solidify (*i.e.*, freeze up) and cause a plant shutdown.

CPI facilities pay significant attention to equipment and piping, but often treat steam tracing lines like simple plumbing. Plant designers often neglect to provide detailed drawings for the installation of steam tracing lines in new plant construction, leaving the design up to the installation contractor. But in a typical refinery or chemical plant, 50–80% of the facility's steam traps can be found on steam tracing lines. This article reviews some common mistakes and problems encountered in heat tracing design and operation, and discusses how to improve existing steam tracing installations.

Where to begin?

Telltale signs of trace heat issues often appear well in advance of serious problems.

For example, an open bleed from a traced line may indicate incorrect trapping for condensate drainage (Figure 2). In these cases, operations personnel might have opened bleeders to help remove the condensate and increase the heat supply. However, in addition to wasting energy, this practice can create multiple issues, including burn risk, poor visibil-



▲ **Figure 1.** This pipe has multiple steam tracing lines installed to obtain high heat transfer.

ity (which obscures equipment), and slip hazards posed by algae or ice. If heat from the tracing system were adequate, bleeding steam would likely not be required (1).

Facilities that use steam tracing should establish a steam system optimization program (SSOP) that consists of three phases (Figure 3):

1. *Trap management.* Maintain a majority of steam traps in working condition to supply high-quality heat.
2. *Equipment management.* Identify causes of equipment issues and rectify them. Mitigate bottlenecks, including those caused by poor process fluid heating and transport.
3. *System balance.* Optimize the steam/condensate energy balance to improve the facility's overall energy efficiency.

When implementing a SSOP, equipment asset management plays a critical role in production performance. Efforts to improve the overall efficiency of a facility cannot begin until steam trap and fluid transport issues are mitigated.

Steam tracing design

Common methods to apply external steam heat to process piping include (Figure 4):

- *Tube tracing* is used for simple heating, such as preventing water from freezing. For additional heating, special heat-transfer cement can be applied.
- *Enhanced tube tracing* increases heat transfer from a tube. An example application is maintaining the desired viscosity in residual oil transport.
- *Channel tracing* partially jackets a heated product line with steam to increase heat transfer. This is commonly used on sulfur lines.
- *Jacketing* is needed when the goal is to increase the process temperature or eliminate corrosion, which requires even more heat than tube or channel tracing can provide.

For any of these heating methods, the appropriate selection and installation of steam traps for effective condensate drainage plays a crucial role in achieving heat transfer. It is important that the traps are easily accessible so they can be inspected and maintained to the manufacturer's speci-

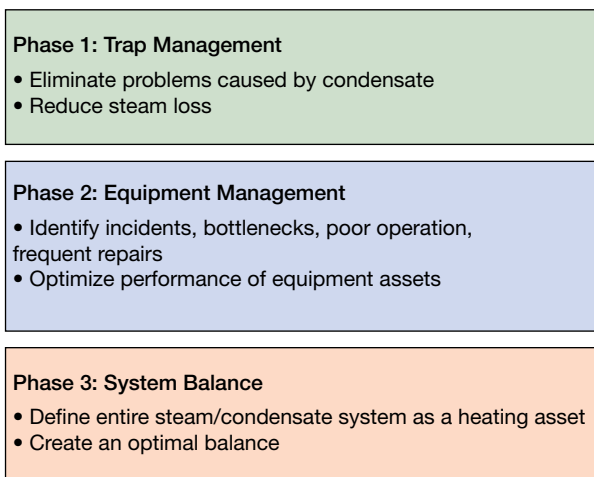


▲ **Figure 2.** Opened bleeds on steam tracing lines are a sign of poor heat transfer, and may be indicative of faulty steam traps.

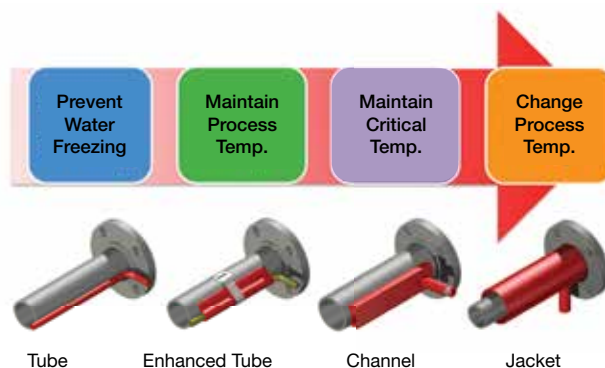
fications. Using manifolds for the steam supply and condensate return can accomplish this goal. A compact manifold installation should enable access for easy maintenance (considering unit ingress and egress), while occupying the smallest footprint possible (Figure 5).

Steam locking

When designing the steam tracing system, consider the orientation of flowing steam and condensate within the heating system. This information can help determine if condensate always flows downward to the trap — maintaining a water seal at the trap inlet — or if there are instances where condensate must rise to reach the trap. If condensate must rise, steam can fill a vertical portion of the piping and sit above incoming condensate (Figure 6). When steam creates a pocket at the trap inlet, the trap can lock shut, preventing it from discharging condensate while the steam is present. This phenomenon is known as a steam lock and can occur

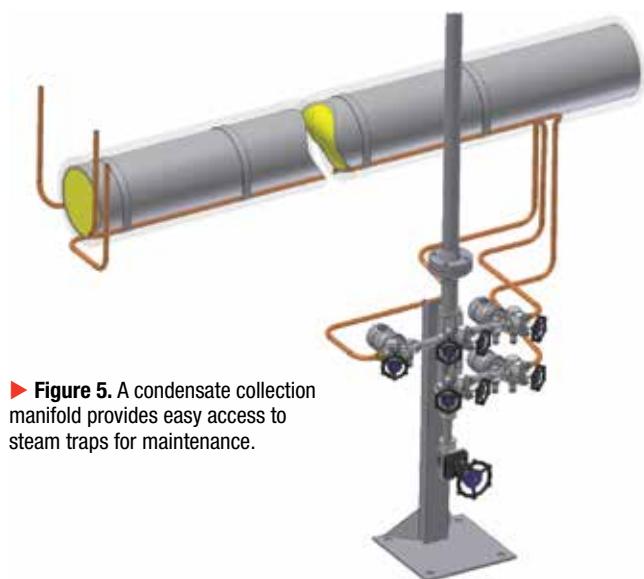


▲ **Figure 3.** Steam system optimization is a three-phase program, where the first step involves managing steam traps. Many of the heat maintenance issues discussed in this article are addressed in Phase 2.

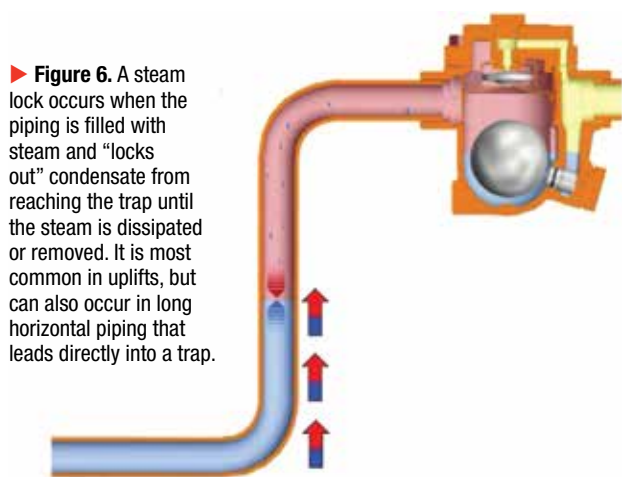


▲ **Figure 4.** Steam heat can be applied to product piping in four different ways.

Heat Transfer



► **Figure 5.** A condensate collection manifold provides easy access to steam traps for maintenance.



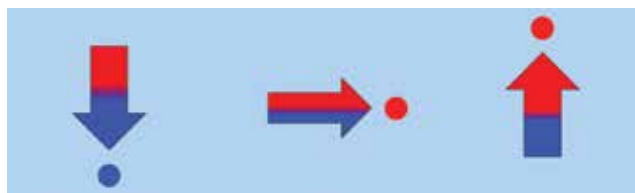
► **Figure 6.** A steam lock occurs when the piping is filled with steam and “locks out” condensate from reaching the trap until the steam is dissipated or removed. It is most common in uplifts, but can also occur in long horizontal piping that leads directly into a trap.

when condensate must be lifted to the trap (2, 3). It can also occur when steam resides above condensate in a long run of horizontal piping.

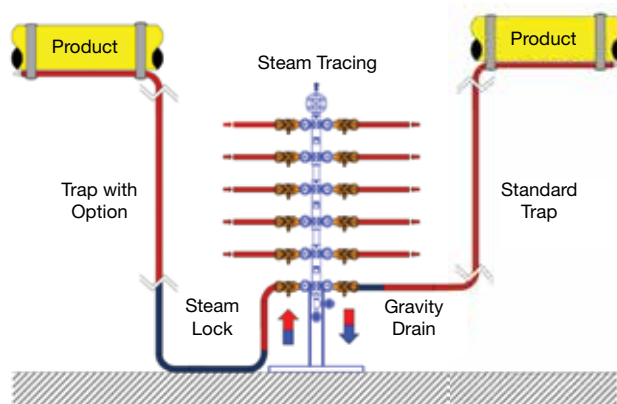
Flow arrows, like those in Figure 7, are a simple way to illustrate whether steam is ever above the condensate level during normal flow into a trap.

When a steam lock occurs, condensate may not reach the trap to be discharged until the locking steam has condensed and the flow interruption dissipates. For this reason, it is generally recommended to install steam tracing such that condensate flows downward (Figure 8). When upward flow to the trap cannot be eliminated, as shown on the left side of Figure 8, consider a trap that incorporates an optional feature that helps mitigate the steam lock.

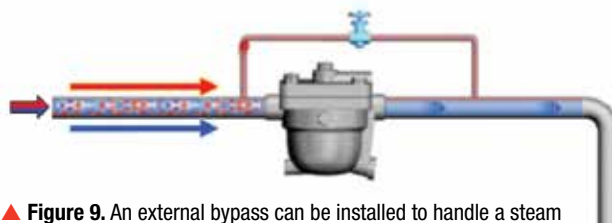
A steam lock naturally dissipates when the steam condenses, but this may require too much time relative to the heat transfer criticality of the process fluid being traced. An



▲ **Figure 7.** Consider condensate flow entering a steam trap. If the piping allows steam pockets above condensate in the flow direction to the trap, as in the two examples on the right, a steam lock can occur.



▲ **Figure 8.** Route condensate downward to a standard trap on a manifold (right side). If the condensate must be lifted to the trap (left side), a trap with an internal bypass may be needed to avoid steam lock.



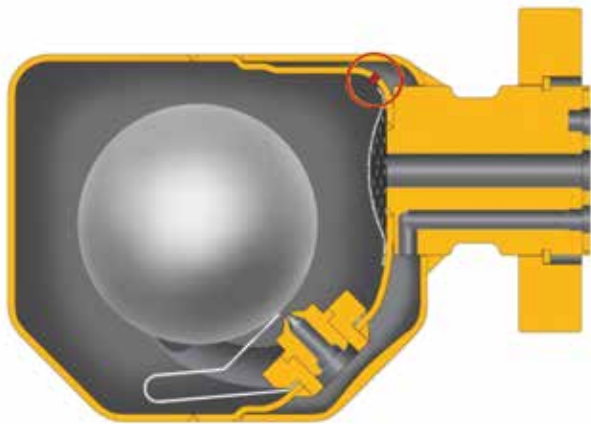
▲ **Figure 9.** An external bypass can be installed to handle a steam locking condition, but this can add unnecessary cost.

external bypass arrangement can be implemented to break a steam lock quickly (Figure 9) (2), but it can be costly to install and can make it easy for operators to bleed steam from the system. For that reason, a low-cost internal bypass arrangement is preferred (Figure 10).

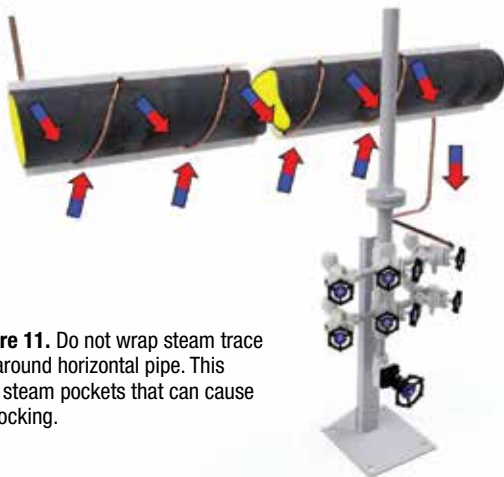
These methods of either eliminating or handling steam lock can be applied for each of the four methods of steam tracing.

Tube tracing. In a system that employs tube tracing, a standard model steam trap can be used whenever the condensate flows down via gravity.

However, when condensate is routed upward and steam may be present at the trap inlet, you must determine how critical it is to maintain the temperature of the process fluid. Specifically, evaluate the potential for serious effect on the traced product’s viscosity, temperature, or heat content dur-



▲ **Figure 10.** A trap that contains a small, internal bypass (shown within the red circle) can help break a steam lock.



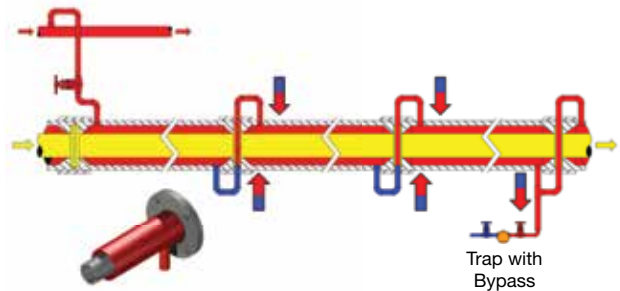
▶ **Figure 11.** Do not wrap steam trace tubing around horizontal pipe. This creates steam pockets that can cause steam locking.

ing the steam lock period. If this is not a key consideration, it may be possible to use a standard trap, even with an uplift. However, if there is any doubt, select a trap with the optional feature to mitigate the steam lock.

Installers who do not have experience with steam tracing may erroneously wrap tubing around horizontal piping (Figure 11). This creates steam pockets that can cause a serious steam lock issue.

Enhanced tube tracing. Whereas tube tracing is commonly employed for simple winterization, enhanced tube tracing is typically used to maintain an imperative product temperature. Because heat transfer in these applications is more critical, pay close attention to the condensate flow direction and eliminate as many upward lifts as possible.

Jacketed pipe heating. Installation of jacketed piping is far more capital-intensive than tube tracing. This heating method is reserved for product flows that require large heat-transfer capability. The goal may be to increase the product temperature, or to maintain the ideal product temperature or



▲ **Figure 12.** Jacketed piping is typically configured in an S-loop design. This necessitates steam traps with internal bypass.



▲ **Figure 13.** If standard traps are used on jacketed piping with S-loop connectors (red), steam bleeds (like the one shown on the right) likely indicate heating issues.

viscosity, such as in sulfur transport applications.

Although jacketed pipe is very expensive (and therefore expected to be effective), the way in which the jacketed sections are connected may actually hinder the heat transfer. Consider an installation where steam and condensate are transferred from one jacket section to the next, in a sort of daisy-chain (linear series) connection on horizontal piping. Steam flows throughout the jacket and into the jumpers on the top of the piping, while condensate flows easily along the bottom of the jacket through bottom jumpers. Even though there is a small uplift on the bottom jumpers, condensate fills the lower loops and little, if any, steam passes through the bottom connectors. This is an ideal condensate flow arrangement, which regrettably is not commonly utilized.

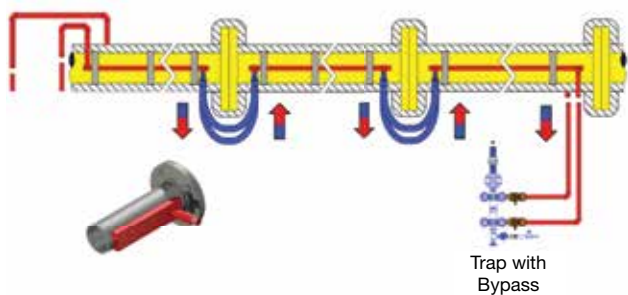
Unfortunately, much jacketed piping is installed in an S-loop connector configuration (Figure 12). A single bottom connection at the end of one jacket section transports both steam and condensate to a single connection at the top of the next jacket section. Several sections of jacketed pipe may be connected together in this manner. Invariably, steam pockets can get caught between the condensate and trap on the last piping section in the series, causing steam locking. Operators often attempt to mitigate steam locking in S-loop configurations by opening bleed valves (Figure 13), blowdown valves, or pipe unions (4). In these instances, heat transfer may not meet the process requirements, or steam may be discharged

Heat Transfer

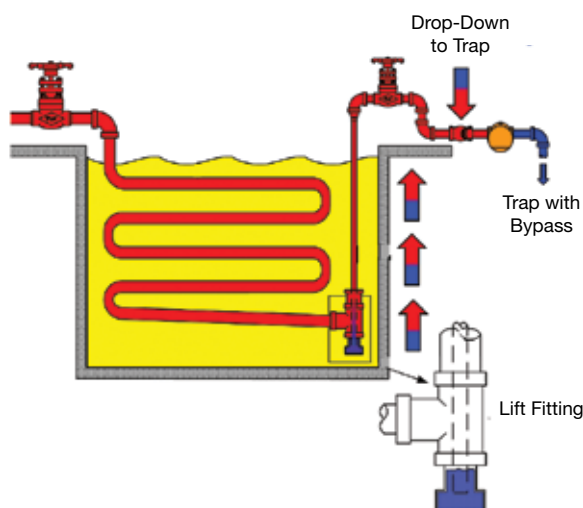
to the atmosphere. Steam locking and its associated effects can be mitigated by installing traps with an internal bypass.

Channel tracing. Channel tracing can also achieve significant heat transfer, but at a lower installed cost than jacketed pipe. It is common to see channel tracing used on sulfur lines due to the critical heat required for this service.

U-loops are commonly employed to connect sections of channel tracing (Figure 14). In these cases, a single connection at the end of one channel transports both steam and condensate through the U-loop to a single connection at the next channel. The arrangement causes both condensate and steam to flow through the loop, invariably with steam sometimes getting caught between the condensate and the trap on the last piping section in the series. Similar to jacketed pipe, steam locking can be mitigated by installing traps with an internal bypass.



▲ **Figure 14.** Strap-on channel jacketing can help maintain critical process temperatures. The jacketing is commonly configured with U-loop connections between sections.



▲ **Figure 15.** Condensate discharge from bottom coils in a sulfur pit must travel vertically to the steam trap, creating the potential for steam lock. Effects are mitigated with a lift fitting and drop-down to the trap, but a trap with internal bypass is recommended for best sulfur heating.

Steam locking in sulfur seal units

Sulfur vapors are a byproduct of the refining process. Vapors are condensed to liquid sulfur and drained to a pit for storage and ultimately sale and transport. However, the vapor side of the process can contain extremely toxic gases such as H_2S and SO_2 . A sulfur seal leg — similar to a home plumbing system's P-trap that isolates the home and keeps sewer gases out — prevents the gases from escaping into the atmosphere.

Because sulfur is stored in a pit, steam coils must be located at the lower levels of the pit to keep the sulfur hot and molten. If the high temperature is not maintained, the sulfur in the pit can solidify. Sulfur pits are notorious for difficulties in draining condensate from the bottom coils. Even if appropriate lift fittings (*i.e.*, a specialized combination of a small-bore riser pipe contained in a larger-bore tee) are used, steam pockets may still precede condensate up the riser piping and cause steam locking at the trap inlet (Figure 15). A vertical drop (*i.e.*, drop-down) at the trap inlet can somewhat mitigate this effect, but a trap with an internal bypass is recommended. The internal bypass expels steam that has built up in the vertical riser, while the drop-down provides a water seal at the trap inlet, which minimizes steam pocketing before the trap.

Long horizontal piping runs in front of the trap inlet and dips in inlet piping can also increase the potential for steam locking. In these situations, it is best to move the trap closer to the application, correct any dip in the horizontal piping, and install a small drop-down to the trap inlet (2).

Figure 16 shows an example of steam locking on a sulfur seal leg that was experiencing heating issues. The traps were located on a horizontal plane too far from the vertical feed. Engineers installed steam traps with internal bypasses to mitigate the steam locking. However, they could have also moved the traps closer to the feed, but this would have necessitated major piping changes.

One of the newest and preferred methods for creating a seal leg is to use an aboveground sulfur seal unit (5). These seal pots are heated by multiple external sections of chan-



▲ **Figure 16.** Long horizontal piping runs to the traps created steam locking issues, which were resolved by adding a steam trap with an internal bypass.

nel tracing. Connector hoses transfer steam and condensate between channels. Steam traps with an internal bypass are recommended (Figure 17) to handle the upward steam and condensate flow. The advantage of aboveground sulfur seal units is that multiple pots can be located close together with a very small footprint. However, the units require cleaning and other maintenance, so layouts should accommodate egress and ingress.

Other tracing and heat maintenance issues

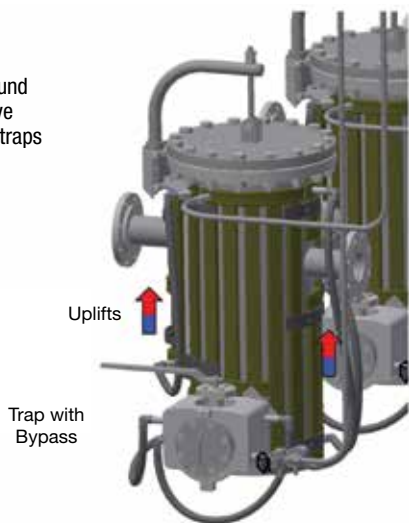
Copper leaching. When copper tube tracing has deteriorated (either over time or as a result of chemical treatment), copper can leach into a solution of hot condensate. As the condensate discharges through the steam trap orifice, some of it will flash, leaving behind copper precipitate that can stick to surfaces, such as the trap orifice outlet canal. Regardless of orifice material, a precipitate buildup can create a blockage (Figure 18).

Several steam trapping methods can mitigate the effects of copper leaching and precipitate buildup:

- High-subcooling traps can reduce the condensate temperature if the heating need is low. Traps with high subcooling reduce or eliminate steam flash, which can prevent much of the precipitate from depositing at the trap orifice.
- Dirt channel design improvements, such as wide discharge passages in steam traps, can reduce buildup.
- Some traps contain an auger that can eliminate copper precipitate without needing to remove the trap from the line.

Instrument enclosures. Control instrumentation needs to be warmed during cold months, but must be shielded from excessive temperature above specification limits. Temperatures that are too hot or too cold can cause incorrect readings or damage the instruments. False instrument readings have been known to cause plant shutdowns. Steam traps with high subcooling characteristics can be employed

► **Figure 17.** Aboveground sulfur seal units can have uplifts and benefit from traps with internal bypasses.



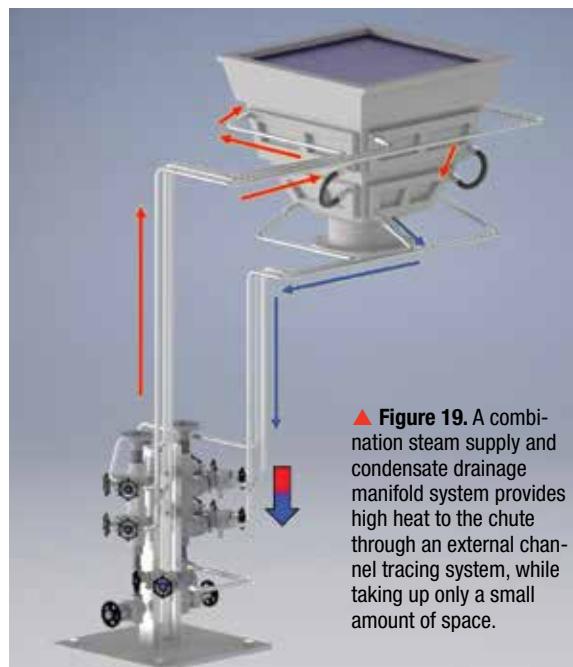
so that the instrument enclosure's steam trace tubing contains warm condensate rather than steam to provide a more moderate temperature.

Chute heating. Some chutes that handle viscous liquids have geometries that create stagnant areas on the edges of the chute, which causes heat loss, solids buildup, and chute plugging. With certain products, such as paraxylene, this can cause multiple process interruptions throughout the year. High heat applied by properly installed exterior channel tracing can help maintain liquid viscosity to mitigate plugging. Both steam and condensate manifolds can be combined in a small footprint to optimize the heat transfer without impacting access to the chute (Figure 19).

Storage tank heating. In a tank coil heating system, a steam lock can form when steam traps are located on the



▲ **Figure 18.** Leached copper from tracing lines can fall out of solution during condensate flashing, build up inside the steam trap, and then block the trap's orifice.



▲ **Figure 19.** A combination steam supply and condensate drainage manifold system provides high heat to the chute through an external channel tracing system, while taking up only a small amount of space.

Heat Transfer

same horizontal plane as the tank coil outlet (Figure 20). As steam condenses within a coil, the remaining steam is able to flow over the condensate and reach the trap simultaneously with the condensate. Over long horizontal distances, this can cause a steam lock, and even create significant water hammer and shock events in the coil. It is possible to eliminate steam locking at the coil outlet by installing the traps with a drop-down on the trap inlet (6).

On a related note: Many storage tanks' internal or external skin heater coils have modulating steam control on their supply line. High condensate return line pressure can cause backup and hammering into the coil. If backpressure is a consideration, a simple pumping system should be used to recover condensate. The loads are typically small enough to drain the condensate into a manifold, which can also be used to vent flashing steam. In these cases, a compact trapping, collection, and return system can be installed.

Closing thoughts

Steam tracing systems are capital-intensive, and their performance should be optimized by:

- designing systems to eliminate condensate uplifts wherever possible
- selecting steam traps with an internal bypass whenever uplifts or long horizontal inlet runs to the traps cannot be eliminated.

Careful consideration in the design of external heating methods and steam trap selection can return significant production benefits — including improved product viscosity and transport reliability.

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ACKNOWLEDGMENTS

Special thanks to CSI Ametek for use of graphics pertaining to aboveground sulfur seal units and the four other heat maintenance methods, as well as TLV's Drew Mohr, Justin McFarland, Alec Newell, and Nick Skahill for creating the custom illustrations used herein.



▲ **Figure 20.** Storage tanks can experience water hammer caused by steam locking when the trap is located on the same plane as the coil outlet.

ADDITIONAL RESOURCES

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