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Impact plant performance by improving the steam system

Petrochemical plants and refineries face production and profitability challenges on multiple fronts. Some of the typical difficulties encountered include:

- An unnecessarily poor energy intensity index or a low-energy efficiency index
- Unplanned maintenance expenditures to fix damaged and unreliable steam-using equipment (e.g., turbines, flares, reboilers and ejectors)
- Wasted operating expenditures and experiencing product loss on avoidable items (e.g., turbine trips, product lines freezing, reboiler control issues or equipment failures)
- Hassles working around process problems, such as production bottlenecks, low cutpoints and degrading vacuum levels
- Concerns on safety and environmental pollution
- Lack of sufficient steam specialist knowledge to address problems and opportunities
- Trouble applying limited resources to make improvements when the priority is to keep the plant running within budget
- Difficulties accurately predicting and demonstrating the true savings of improvements.

Plant operations are commonly focused on production, and so they tend to accept energy losses and poor reliability as accepted practices. As a result, substantial economic opportunities become invisible. Plants may not know where to start to improve in areas such as safety, environmental impact, production rates, product quality, equipment reliability and/or energy efficiency. One way of impacting all these areas is to treat the plant's steam system as a crucial heat asset, recognize the importance of the steam trap population to its health, and to implement a simple four-step program to protect and improve it.

Four effective steps that impact plant performance. The following steps are important for improving a plant's steam heat asset:[1]

1. Select the right steam trap for the application
2. Install the steam trap correctly
3. Implement a sustainable steam trap management program
4. Optimize the performance of steam-using equipment.

Select the right steam trap for the application. To properly select a steam trap, it is important to understand:

- The purpose of a steam trap
- How normal operation and failure may affect the purpose of a trap
- How generic steam trap types operate
- How steam traps can fail (common failure modes)
- Special requirements for specific steam trap applications that should be considered when selecting steam traps
- A site's experience and bias regarding steam trap performance
- Factors affecting lifecycle costs (for reliability and total cost of ownership)
- Specific performance criteria for individual steam trap models
- How to accurately model steam trap lifecycle costs.

Application-specific guidance. One of the most critical areas for steam trap selection is considering the application to account for specific challenges. The most common steam applications in hydrocarbon processing facilities that require careful trap selection include steam distribution lines, steam turbines, process heaters, flares, sulfur pit coils and steam tracing lines (particularly in the transport of high-viscosity products like sulfur or resid).[2]

Steam distribution. Steam is generated—as either superheated or wet quality—and then distributed throughout the facility to provide process heat to equipment.[3] It is essential that condensate forming in the steam distribution system is drained immediately and not allowed to back up, as this could result in water hammer damage and the reduction of process equipment reliability.[4] In general, for these applications, steam traps with near-instantaneous discharge provide the best performance. There is commonly the need for these traps to vent air, so the selection process should consider all requirements. Subsequently, float and thermostatic traps, as well as thermodynamic traps containing thermostatic air vents, and thermostatic balanced-pressure capsules, are recommended.[5] Bimetal traps should never be used for draining steam mains due to their operating principle requiring deep levels of subcooling, which can lead to condensate backup. There may also be some special requirements for steam main drainage (e.g., to drain the boiler header piping, which follows immediately after steam boilers/steam generators, for high-temperature super-heated steam lines or where traps are widely spaced).

Steam tracing. Steam tracing typically accounts for most steam trap installations in a hydrocarbon processing facility.

One key purpose of steam tracing is to maintain temperatures of process fluids and, in critical cases, to keep product in a process fluid transfer line from freezing (or solidifying). The heat load is typically about the same as the radiant, convective and conductive heat loss from the line. As lines are usually well insulated, the heat loss and resulting condensate loads may be minimal. This may present challenges and also opportunities for steam trap selection, particularly when there are loops or lifts that flow steam and condensate upward.

Steam tracing can generally be categorized as high temperature or low temperature. In critical high-temperature applications, condensate backup is undesirable. A steam trap with an instantaneous and continuous discharge with a tight shutoff may be preferred for maintaining the lowest lifecycle costs, and thermodynamic disc traps or balanced-pressure thermostatic traps may be acceptable for lowest-initial-cost installations. Copper tracing lines experience corrosion over time and may, therefore, present plugging difficulties. This scenario is best mitigated by using a thermodynamic trap with enlarged ports and short passages, or, for low-temperature applications, a bimetallic steam trap. Bimetal traps with a low set temperature can also be used for instrument enclosures to mitigate damage to the instrument by excess temperatures.

Steam turbines. Among the most common steam equipment applications in a petrochemical facility are steam turbines providing power to pumps, compressors or power generators. Turbines are very sensitive to condensate in the steam supply and to condensate backup in the governor casing, body or exhaust lines. Consequently, the best choice for this application is a steam trap with instantaneous and continuous discharge, such as a float and thermostatic design. However, thermodynamic disc traps may be used with appropriate drainage pockets and drain lines. Bimetal steam traps should never be used because of the possibility of condensate backup or steam loss.

Turbine condensate drainage should be carefully considered to ensure that all appropriate points on the upstream steam supply, governor, casing and exhaust lines are all properly drained.[4] A slug-tolerant separator should be considered on the steam supply line immediately before critical turbines. Traps on the exhaust should be appropriately sized for the turbine's efficiency and operation, considering that the exhaust steam may be significantly wet or may contain a substantial condensate load.

Process heating equipment. Process heating equipment may include applications such as reboilers, heat exchangers, air heaters, evaporators, concentrators, dryers and aboveground storage tank coils. These applications may have various control strategies and operating conditions that may affect the range of steam pressures and flowrates. In some cases, a steam trap may not work correctly due to a stall condition.[6,7] This may occur when the ideal steam pressure in the equipment for steady-

TABLE 1. Recommended trap type according to application—Legend: First choice (1), second choice (2) and third choice (3)

Service/application	Free float and thermostatic	Thermodynamic	Bimetal adjust-temp	Balanced pressure thermostatic	Non-electric pump/trap	Non-electric pump	Level pot with outlet control
			Tracing				
Tracing lines[9]							
Low temperature, < 200°F	–	–	1	2	–	–	–
High temperature, > 200°F	1	3	–	2	–	–	–
Jacketed pipe	1	2	–	–	–	–	–
			Drip				
Saturated steam main: ≥ 20, ≤ 650	1	2	–	–	–	–	–
Superheated steam—all services[6]: ≥ 20, ≤ 650	1	2	–	–	–	–	–
Flare stack steam lines							
Steam to control valve	1	–	–	–	–	–	–
Control valve outlet to flare stack	1	–	–	–	1	–	–
Turbine supply lines	1	2	–	–	–	–	–
Turbine casing drains:[7,8] ≥ 20, ≤ 650	1	–	–	–	–	–	–
Turbine exhaust steam lines: > 0, ≤ 150	1	–	–	–	–	–	–
			Process				
Process heaters: ≤ 200 supply							
Stall condition	2	–	–	–	1	2	–
No stall condition	1	–	–	–	–	–	–

state operation is lower than the discharge pressure after the steam trap. In these conditions, a secondary pressure drainer pump/trap combination may be necessary.

When steam traps are appropriate, the best selection is a float and thermostatic-style trap with instantaneous continuous discharge, incorporating reinforced components to avoid water hammer damage. Disc traps may sometimes be utilized for tank coils, comfort heaters and small noncritical heat exchangers, but they are not suitable for other process heating applications. Inverted buckets may not be suitable because of their cyclical operating characteristics or because of challenges faced with non-condensable air in the system. Bimetal traps are generally not recommended due to their operational reliance on subcooling and their sensitivity to changes in back pressure, which may result in condensate backup. This, in turn, may flood equipment, reducing the heat transfer area.[8] Bimetals may be considered for small storage tank coils, where only approximate temperature regulation is required, and also where it is not practical to install a steam control valve and control system.

Flares. A steam-assisted flare requires a continuous low volume of steam that is often supplied through an orifice plate bypass around control valves to keep the flare tips hot while the flare is not burning vapors. When flare gas is supplied to the flare, the steam control valves open to supply steam for atomization and flame stability. If wet steam is supplied, the flare tips may become eroded. This can reduce the effectiveness of the steam distribution at the tip and may cause unclean "sooty" burning that could result in environmental issues. If the flare steam lines upstream and downstream of the control valves are not properly drained, then water slugs may be propelled to the flare tip. This may severely damage the flare tip or extinguish the pilot light before the flare gas is ignited. Both conditions may result in environmental issues. Repair of the flare tips or complete candelabra replacement may also be costly.

Due to the criticality and design of flare steam lines and control stations, the best choice of steam trap, such as a float and thermostatic style, will instantaneously and continuously discharge condensate. Bimetal traps must not be used. Thermostatic traps and inverted buckets are not a first choice. Disc traps upstream of the control valve station may be acceptable if the condensate collection pockets and the drain lines are properly sized and designed. Special selections may be required for drain locations after the control valve stations, which may have extremely low operating pressures in standby operation and may be close to grade.

Sulfur pit coils. Sulfur pit coils are below ground, and steam traps usually must be installed above ground. Condensate must be lifted from the coil to the trap. This can commonly cause steam locking of the trap, which may prevent condensate discharge and result in lowered temperatures, coil damage and possible solidifications. Operators may then have to open drainage location bypasses and blowdown valves to maintain sulfur temperatures, which can cause energy loss and safety issues. Steam locking of the sulfur pit coil may be mitigated by the installation design and by selecting a trap with a small vent hole to address steam locking.[2]

Structured approach to selection and documentation.

A structured approach is necessary to select the trap, and then to document the selection and communicate it to maintenance personnel, engineering contractors and capital project teams. A trusted steam system specialist can help to guide steam trap selection for any type of application and to provide established procedures for documenting and communicating selection standards. **TABLE 1** shows an extract from a typical selection document reviewing steam trap selections.

Install the steam trap correctly.

Steam traps must be properly installed so they can function correctly. Installation details depend on the application, along with the existing factors in the field and the type of steam trap selected. A steam trap is typically installed as part of a condensate discharge location (CDL), which includes other items such as an inlet isolation valve, a strainer with blowdown, the steam trap, an outlet isolation valve, a check valve, a disassembly component such as a

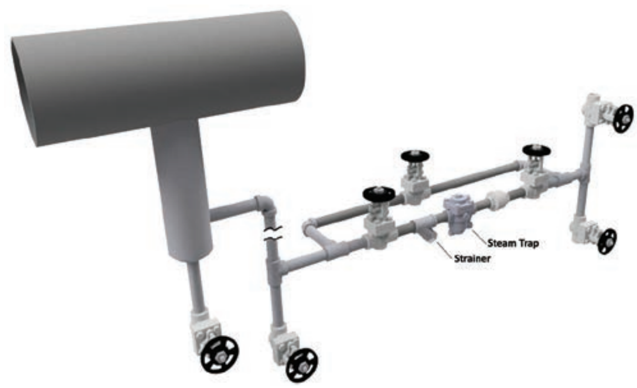

FIG. 1. A properly designed collecting leg/CDL has multiple components that require correct installation.

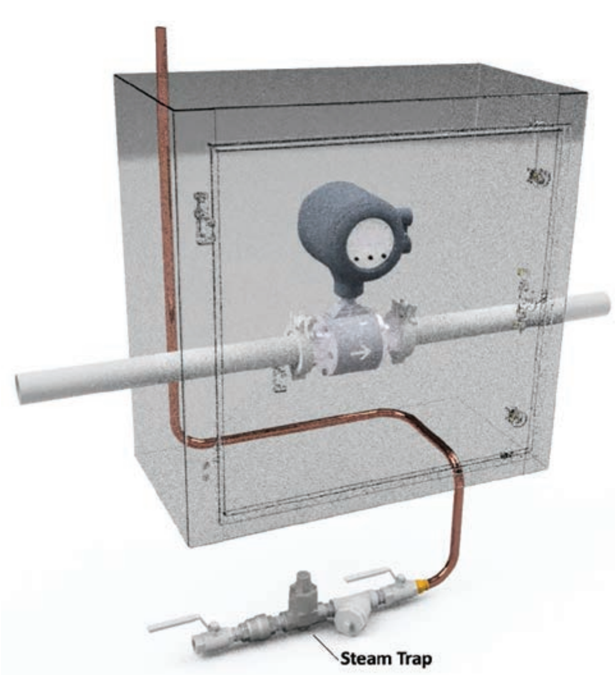

FIG. 2. Instrument enclosures require subcooling traps to avoid burning instruments.

flange or union, valves for depressurizing the steam trap body to a safe zero-energy state to allow for trap replacement, and valves to allow flow to the atmosphere for testing or troubleshooting. The configuration of all these elements critically impacts the performance of the steam trap. **FIGS. 1–6** show typical arrangements for some of the more common types of condensate drainage locations.

For pressures up to 650 psig, the piping and individual components for a CDL may be replaced by a single steam trap station to reduce installation space, complexity, labor and leak points. In some situations, several condensate discharge locations may be in proximity, and there may be a requirement to return condensate. In these cases, it may be appropriate to utilize steam supply manifolds and condensate collection manifolds with trap stations (**FIG. 6**).

It is essential to generate a documented standard for installing steam traps that can be used to:

- Define the trap selection guide
- Provide data to office-based personnel (e.g., planners, procurement personnel and project engineers)

FIG. 3. A heat exchanger sustaining positive pressure differential from equipment to condensate return header may only require a trap for condensate.

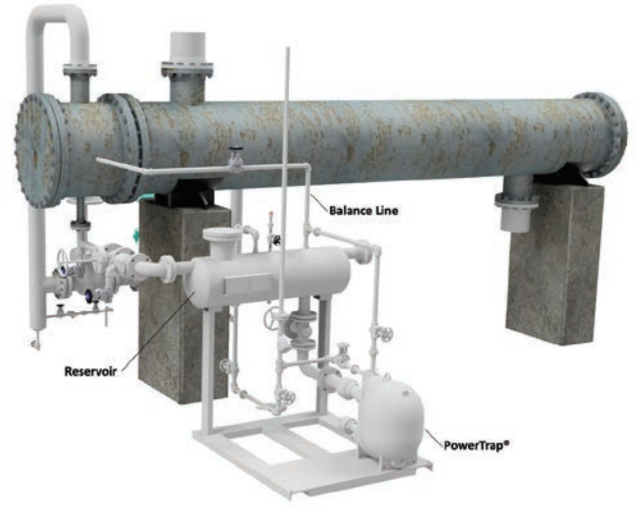

FIG. 4. A heat exchanger experiencing stall conditions may require a combination pump/trap system for condensate discharge.

- Convey selection and installation information to capital project groups or to external engineering, procurement and construction (EPC) companies
- Train maintenance and operations personnel.

It is also helpful to generate the same information in the form of laminated posters for maintenance workshops and as pocket-sized flip books.

Implement a sustainable steam trap management program. Even when a steam trap is correctly selected and installed, it will have a finite life. A sustainable steam trap management program is essential to maintain an acceptable failure rate and to monitor the current state of failures and the number of good in-service drainage locations.[9] An effective trap management program should cover the following:

- Accurately and consistently identify steam trap failures; these actions can have a critical impact on program costs, and are especially essential when multiple sites are being compared
- Track survey progress to ensure that all drainage locations are inspected
- Record failure and maintenance data
- Track replacement/maintenance actions

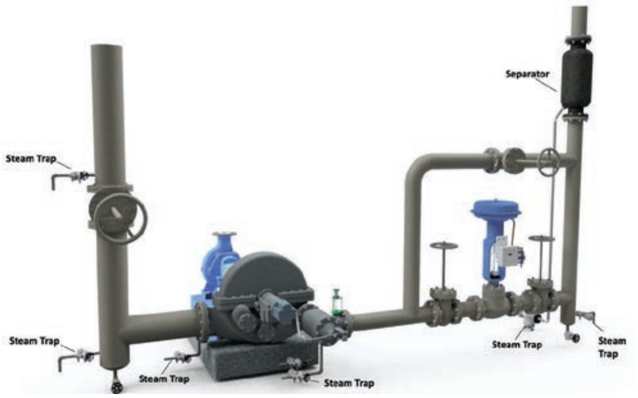

FIG. 5. Turbines may only have a few traps (or none), and this can lead to premature failure.

FIG. 6. Tracing systems may require special trap options to mitigate steam locking from uplifts.

- Use recorded data to identify bad actors and root causes of failures
- Generate information on savings to justify expenditures and return on investment (ROI)
- Ensure that the program continues to run smoothly and make continuous improvements year after year.

Optimize steam-using equipment performance. Further steam system asset improvements can be made once the steam trap population is under control, after high-quality steam is supplied to production and effective condensate drainage for steam-using equipment is deployed throughout the facility. The investigative steps for this typically include:

1. Conduct a one-day plant walkthrough and a consultation session with a steam specialist to identify opportunities and potential value. The plant can assess priority and potential ROIs to decide which options to progress. Sometimes, a plant may already have specific challenges for the event to review.
2. Obtain detailed technical assessments of a specific opportunity or challenge onsite to identify the root cause of the issue and collect data to engineer a solution and more accurately calculate potential benefits. This action is usually followed by offsite work to design a solution. Several technical assessments may be combined to create a larger event.
3. Work with plant personnel to complete an implementation proposal to gain funding.
4. Provide equipment, engineering, construction and commissioning support for the solution.

High-value targets for steam-using applications in hydrocarbon processing facilities typically include:

- Steam turbines to reduce trips, increase reliability, decrease damage incidents and reduce plant steam generation
- Reboilers to decrease plant steam generation, reduce failures (gaskets, corrosion of tube bundles and piping erosion), and increase performance to improve production rates and product quality by fixing operating problems, reconfiguring processes to use lower-pressure steam that may be vented and by recovering condensate
- Flares to reduce risk of flare tip damage from erosion or water slugs, and to decrease condensate backflow down the flare gas line
- Condensate recovery strategies to save energy, alleviate raw water treatment limits and reduce environmental impact.

Takeaway. Hydrocarbon processing plants are facing new challenges that are frequently changing, so the focus of these plants is often on the production process and keeping things running. Taking a strategic look at the steam system, treating it as an asset and following a simple four-step program to improve it can positively impact the plants' performance in many areas, including safety, environmental impact, production rates, product quality, equipment reliability and energy efficiency. This article has outlined the four steps to steam system improvement and provides references that provide more detail on implementation. HP

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