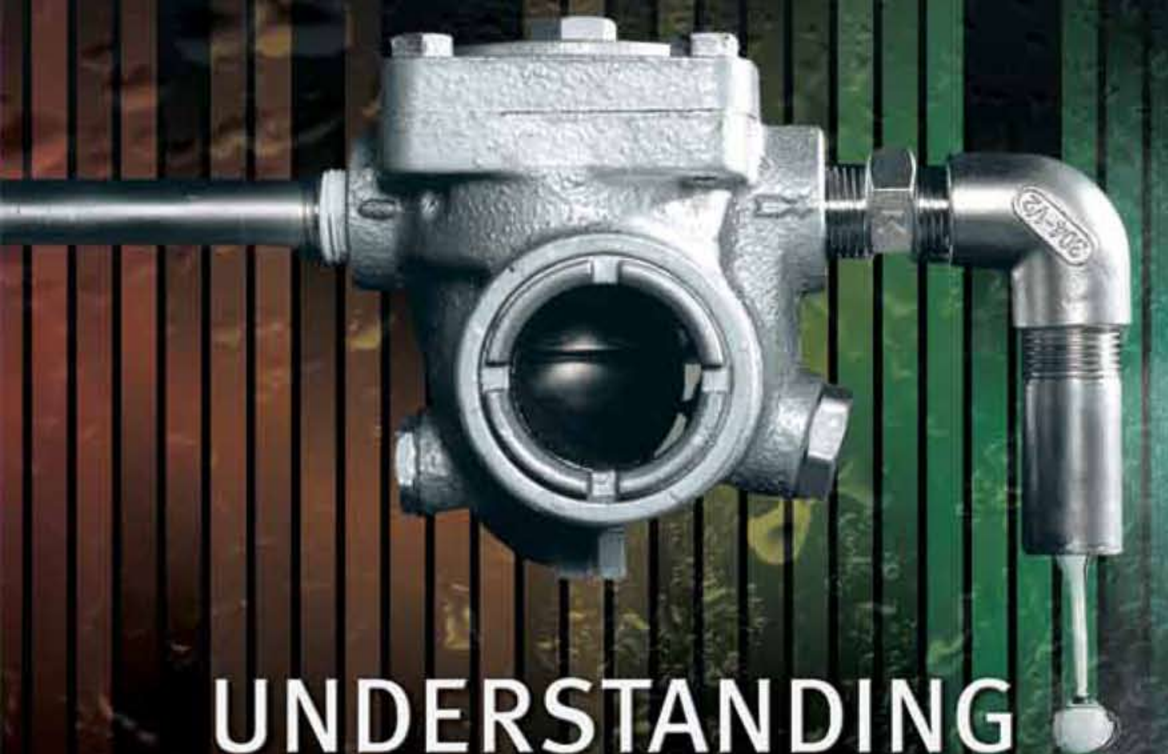
February 2011

CEP

Chemical Engineering Progress

An AIChE Publication

www.aiche.org/cep



UNDERSTANDING STEAM TRAPS

Understanding Steam Traps

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Steam trap failures can affect process operations and reduce profits. Choosing the right steam traps can improve reliability and reduce cost.

Steam traps and steam systems represent a large portion of a manufacturing plant's total operating cost, but methods to reduce spending in this area are not clearly defined. Problems may arise when engineers lack knowledge regarding such questions as: How do steam traps affect the steam system and process and product quality? What are the best types of traps to use? What differentiates the best manufacturers? What testing methods are used for determining trap failures?

The many considerations involved in selecting, installing, and maintaining steam traps can make it difficult to recognize what is important and what is not. Typical information sources such as manufacturers and the site's previous experiences may not provide all of the necessary information. It can be helpful to break down cost-reduction goals into smaller segments and analyze each separately.

▲ **Figure 1.** This normally functioning steam trap discharges condensate and noncondensable gases, with a negligible loss of live steam.

For example, a common myth is that the purchase price of a new steam trap is a major component of system cost. Because the impact of operating cost is typically significantly higher than purchase price, it is important to understand the factors that negatively affect that cost. Total system operating cost is comprised of multiple components, including steam loss, generating cost, emissions-related credits, and maintenance charges. When calculating the cost per unit of production, productivity impact should also be considered.

This article describes the various failure states of steam traps and steam systems, as well as the potential consequences of not repairing failed steam traps. For a general overview of steam traps, see Ref. 1.

Functional steam loss

A steam trap is a device used to discharge condensate and noncondensable gases with negligible loss of live steam (Figure 1). Steam loss through non-failed steam traps is referred to as functional steam loss (FSL) — the amount of steam that is consumed during the operation of a properly functioning steam trap.

Steam traps with low functional steam loss rates can save money. For example (Table 1), a steam trap (Trap A) with an FSL of 0.1 lb/h will incur a \$9/yr cost for lost steam (assuming a steam cost of \$10/1,000 lb). A 3-lb/h increase in FSL (Trap C) can amount to \$272/yr in lost-

Table 1. Selecting steam traps with low functional steam loss rates can save a plant a significant amount of money.				
Steam Trap Model	**FSL, lb/h**	**FSL Annual Cost per Steam Trap (at $10/1,000 lb steam)**	**FSL Annual Cost for 4,000 Steam Traps**	**FSL Annual Cost Difference for 4,000 Steam Traps (Relative to Base Case)**
Steam Trap A	0.1	$9	$36,000	$0
Steam Trap B	1.2	$105	$420,000	$384,000
Steam Trap C	3.1	$272	$1,088,000	$1,052,000
Notes: Examples are for illustration only and do not refer to any particular steam trap. FSL is determined according to ISO 7841 *(2).*				

steam costs. A plant that has 4,000 steam traps of the Trap A design would require $36,000 of steam due to FSL per year, while 4,000 Trap C traps would require $1,088,000 per year. This represents a $1,052,000 difference.

Some manufacturers may report zero steam loss. Is a claim of zero steam loss a myth or fact, and is this an important factor to consider?

A high FSL can represent a sizeable portion of the total steam loss, significantly impacting cost. Thus, if a claim of zero steam loss for a certain trap is accurate, a major contributor to the total system cost is eliminated.

However, such claims of zero steam loss may be based on a manufacturer's internal testing methods rather than internationally recognized standards. Some internal methods might employ condensate loads during testing that are much higher than those handled by a typical steam trap during normal service.

Universally accepted methods of obtaining FSL data are described in two standards, "Determination of Steam Loss" (ISO 7841) *(2)* and "Steam Traps" (ASME PTC 39) *(3)*. These standards provide useful information for measuring the amount of FSL from traps operating within normal specification parameters.

A claim of zero FSL may not be relevant if it is not based on a standard test method, or if the testing apparatus was not sophisticated enough to perform the testing required by the standard. When evaluating FSL data, review the scientific methods used to obtain the data, particularly the quality of the measurement apparatus, independent verification that the measurement apparatus meets at least one of the referenced standards, and the credentials of the measurement witness.

Some companies may require trap manufacturers to submit only audited FSL data obtained by independently witnessed tests conducted in accordance with ISO 7841 or ASME PTC 39 standards on sophisticated equipment that has been independently validated by a globally recognized authority.

Failure steam loss

When a steam trap fails, the steam lost is referred to as failure steam loss (XSL). Since XSL only occurs when a steam trap fails, it is directly related to the reliability of a steam trap. Once failed, the amount of actual XSL per trap varies. Assuming for calculation purposes that all failed traps are leaking steam, a rule of thumb to approximate the annual steam loss for a population of traps is: estimate XSL as 4% of the specified maximum condensate load; multiply that by the number of steam traps in the population; and divide this by the expected life of that population. Average-quality traps may have just a 4-yr life expectancy (which implies a 25% average population failure rate), while higher-quality steam traps may have an 8-yr life expectancy (12.5% average population failure rate).

As an example, a steam trap with an 800 lb/h capacity may lose 32 lb/h steam when failed blowing (*i.e.,* losing, or blowing, live steam). If there are 1,000 such failed blowing traps, the estimated total steam loss could be 32,000 lb/h. At $10 per 1,000 lb steam, the value of this loss is $320/h or $2.8 million annually (Table 2) *(4).*

Sites often focus on FSL, but not XSL — even though XSL usually represents a far greater impact on system cost. Furthermore, many plants do not adhere to, or even have, a proactive steam-

Table 2. Steam traps that fail blowing can cost a company every year.			
Steam Trap Model and Condition	**XSL in Each Failure Cycle, lb/h**	**XSL Annual Cost in Each Failure Cycle (at $10/1,000 lb steam)**	**XSL Total Annual Cost for 1,000 Failed Traps**
Steam Trap A Good	Base Case	$0	$0
Steam Trap B Failed, Small Leak	6.85	$600	$600,000
Steam Trap C Failed, Blowing	32.0	$2,803	$2,803,000

trap management program that includes annual testing and repair of failures. By not maintaining a proactive program to minimize XSL, such sites incur significant and unnecessary costs.

Common concerns about testing and replacement costs are misguided. A population of 4,000 steam traps can typically be tested for under $80,000/yr. If the traps' average life expectancy is 4 yr, roughly 1,000 steam traps will need to be replaced each year, at a cost of approximately $500,000 annually. The sum of the testing cost ($80,000) and the annualized replacement cost ($500,000) is just over $580,000 for 4,000 traps. Spending $580,000 to identify and repair failed traps that can impact system operating cost by up to $2.8 million is often an easy investment to justify.

However, if the 1,000 blowing traps that fail in one year are not returned to a good state, and the next year another 1,000 steam traps fail, the site then has a total of 2,000 failed steam traps representing an annual steam loss of up to $5.6 million (assuming all the failed traps are blowing steam). Neglecting to spend the maintenance cost associated with testing all traps and replacing 1,000 blowing traps annually could increase operational costs almost five times the replacement cost — for each year the failed traps continue to operate.

Table 3 demonstrates what could happen if Steam Traps B and C failed, but no repairs were made, and both traps eventually deteriorated to blowing failures by Years 2 through 4. It is most likely not a plausible scenario for all steam traps to be in a failed blowing condition, but the consequences should be considered as a worst-case scenario if a decision is made to not repair failed steam traps. This is a real-life situation often experienced when sites identify leaking trap failures but take no action to repair them.

Table 3 also provides opportunity value estimates. If the same traps are repaired in a timely fashion after they are identified, the opportunity values for Traps B and C are reduced drastically because steam loss in Years 2–4 is eliminated (although the value of the recoverable steam is still significant). Additional opportunities exist because the repair scenario reduces costs by correcting XSL issues. Higher-reliability traps to reduce incidence of XSL, and more-efficient traps to lower FSL, should be selected to optimize savings.

The goal of repairing Steam Trap B in Table 3 is most likely not to gain a $300 value, but instead to avoid losing $8,395 if no repair were made.

The focus thus far has been on blowing traps. Most

Table 3. When failed steam traps are not repaired, they can deteriorate to a blowing condition and continue to lose steam (worst-case scenario). Repairing the failed steam traps promptly will save money by mitigating steam loss in Years 2–4 (repair scenario).

Steam Trap Model and Condition	FSL*	XSL*	FSL + XSL*	Cost of Steam Trap Survey	Net Opportunity Value (at $500/replacement)
Worst-Case Scenario: No maintenance occurs on failed traps for 4 yr. Steam Trap B develops a small leak in Year 1, which worsens to blowing conditions in Years 2–4.					
Steam Trap A Good	$35	$0	$35	$80	Base Case (not failed)
Steam Trap B Failed, Small Leak	$420	$9,010	$9,430	$80	$8,395
Steam Trap C Failed, Blowing	$1,086	$11,213	$11,213	$80	$10,598
Repair Scenario: When a trap is already leaking steam, FSL is not considered. Thus, since Trap B is leaking in Year 1, FSL is not added. In Year 2, the trap is repaired and FSL is added for Years 2–4. Steam Traps B and C leak in Year 1, so FSL is added to the cost for only Years 2–4.					
Steam Trap A Good	$35	$0	$35	$80	Base Case (not failed)
Steam Trap B Failed, Small Leak	$420	$600	$915	$80	$300
Steam Trap C Failed, Blowing	$1,086	$2,803	$3,618	$80	$3,003

* FSL and XSL are calculated based on a steam cost of $10/1,000 lb.

leaking traps will eventually begin blowing as a result of erosion over time. Another failure mode, blocked/low-temperature traps (*i.e.,* when condensate flow is blocked, preventing drainage) can create significant safety or operational issues, which can have a far greater impact on operations. Therefore, the examples only use blowing traps to provide simplified scenarios and tables for economic comparison.

Coincident steam loss

Although significant, FSL and XSL might not have the highest impact on operating costs. Coincident steam loss (CSL) is often the highest-value steam, making it important to recover. CSL occurs when some component of the steam system does not function properly — for example, the drainage mechanism of a heat exchanger or reboiler might malfunction and a bypass valve open, or there may be an open bleeder on a pipe or steam trap. Although a failed tracer trap might lose XSL worth as much as $2,800 annually through a relatively tiny leak, a single open 2-in. bypass valve can have a far greater impact — CSL up to hundreds of thousands of dollars annually *(4)*. Sitewide, open bypass valves can represent a loss of well over $1 million annually.

Any open bypass on equipment is an indication that the steam trap or drainage device probably does not meet the requirements of the application — a bypass is opened to compensate for poor system drainage. Fixing the cause by replacing the drainage component with one that is appropriately sized can eliminate waste and significantly reduce costs.

Wasted condensate is another type of coincident steam loss. If the system cannot drain condensate properly, either a bypass valve will be opened to bleed steam and condensate, or a drain will be opened to discharge condensate to the ground or to the sewer. In addition to the obvious environmental consequences, wasted condensate must be treated before it can be sent to a sewer system, placing an unnecessary burden on the water treatment process. Furthermore, the resulting make-up water must be treated and heated, unnecessarily consuming more chemicals and steam.

Dumping 10,000 lb/h of condensate can increase costs by more than $100,000/yr. Consider the value of all wasted, yet reasonably recoverable, condensate sitewide when determining the facility's priorities.

External steam loss

The cost of external steam loss (ESL) — the steam lost through piping, flanges, and valve packing — is high. It is not always obvious that the root cause of ESL is often poorly functioning condensate discharge locations (CDLs). A CDL is the drainage system consisting of the steam trap and all piping and valves associated with it. The CDL allows condensate to be effectively and efficiently discharged from that location. If the CDL does not drain, the resulting corrosion, erosion, and water hammer often lead to ESL.

If a system is experiencing excessive ESL, examine its CDLs to confirm that a proper drainage system exists. For example, if there is a large number of flange leaks, consider whether the flanges are being impacted by water hammer conditions.

ESLs are often caused by insufficient CDLs or non-functional steam traps within the CDLs. One site repaired hundreds of ESL failures — only to have new ESLs occur as soon as the repairs were complete. The cause of the ESLs was found to be water hammer that was traced back to insufficient CDLs and blocked steam traps in some CDLs. Identifying the cause enabled corrective actions to be taken.

Piping steam leaks have a significant negative cost impact, and the cause is often found to be a steam trap population in need of proactive attention and repair.

Maintenance considerations

Performing an annual physical plant examination is essential to understanding the plant's health. This exam should include a survey of all the steam traps to determine the failure state of the population (also sometimes called failure rate, although rate should imply a time period). Until all failed steam traps are repaired or replaced, it is reasonable to expect 25% of a plant's steam trap population to be in a failure state at a site that has traps with a life expectancy of 4 yr.

It is important to understand the difference between annualized failure rate — the number of steam trap failures in one year as a percentage of the total population — and failure state — which describes the current population's health. The annualized failure rate provides useful reliability information, and an indication of the life expectancy of various steam traps. Failure state correlates directly to a site's dedication to maintaining its steam trap population, and provides quantified estimates that can be useful for identifying cost-reduction opportunities.

Reliability and trap life

Asking a trap manufacturer or a distributor to estimate steam trap life expectancy might not yield the most accurate information. Although manufacturers will provide their best estimates, the plant's own data — because they are based on a large, diverse trap population — are a better source of reliability information. However, obtaining these data requires a consistent effort to conduct an annual survey and return the population to a zero failure state — *i.e.,* a zero reset.

To better understand zero reset, first consider that the original steam system designers used the most readily available data to determine the need for CDLs and their placement. The amount of redundancy built into a steam system is typically only enough to assure drainage for steam traps that might fail due to being blocked. The actual extent of redundancy might be known only to the original designers (or buried in the design documentation). Obtaining that information now might require a total steam system audit to analyze each CDL. Such a project might be worth undertaking at a site whose engineers think it has too many steam traps. In the absence of such a study, however, facilities should be cautious about removing CDLs because of the safety and reliability implications of doing so.

Zero reset involves restoring all failed traps to a properly functioning condition to ensure that the original design intent for system integrity, safety, and reliability is maintained. A facility with a limited maintenance budget might continue to operate knowing that some traps are in a state of failure — however, this practice of failure carryover should be avoided.

Failure carryover has obvious negative safety and cost implications, whereas the implementation of zero reset, together with accurate testing, can help a plant determine the actual annualized failure rate of its trap population. Instead of relying on outside sources to estimate trap reliability based on other sites' populations, use your own site-specific data accumulated over several years of consistent testing, combined with zero reset of failed traps, to obtain accurate, verifiable empirical data that can be trusted.

Are some failures more critical than others?

There are three causes of steam trap failures — wear, blockage, and improper selection. Wear-caused failures occur naturally during normal operation. Blockage-caused failures occur when excessive debris carried by the condensate, or left behind when condensate flashes, blocks an orifice or strainer screen, impeding flow. Both wear and blockage indicate that a trap is no longer functioning according to specifications. Selection-related failures occur because the traps installed do not fully meet the application's requirements for proper drainage, even though the traps may be in perfect working order.

To understand which failures are the most critical, it is important to recognize the difference between drainage failures — the failure to remove condensate from the system — and leakage failures — failed traps that remove condensate but also leak steam.

Drainage failures are the most critical to address because the traps have stopped performing their primary function — draining condensate from the system. Drainage failures are often caused by a blockage, but they can also be caused by improper selection (*e.g.,* choosing a steam trap to operate outside its pressure differential capability, or one that is too small or that has too much subcooling for the application). Whatever the cause, drainage failures tend to create the most danger and havoc in a system and should be corrected as a first priority.

Leakage failures impact the bottom line by reducing system efficiency, but leaking traps still perform the primary function of draining condensate. Leakage failures may be caused by wear, debris, or improper selection. Whatever the cause, leakage failures represent a quick opportunity for cost reduction.

Accurately identifying failures

There are several ways to identify steam trap failures, but a combination of temperature measurement (to determine drainage failures) and ultrasonic technologies (to determine leakage failures) has proven to be very effective. High-quality temperature measurement at the trap inlet will reveal whether the trap is backing up condensate — which usually indicates some form of drainage failure. Identifying leakage failures is more difficult.

The movement of fluid in a closed system develops ultrasonic noise. An ultrasonic testing instrument recognizes the noise created by flowing condensate or steam, or both, and can be used to determine a trap's operating condition based on the difference between the ultrasonic profiles of leaking steam and discharging condensate.

Some instruments recognize the difference in amplitude between the ultrasonic levels generated by steam and condensate, providing information about the trap's condition but not necessarily the source of the leak. Some instruments provide an audible output that requires the tester to make a subjective judgment, the accuracy of which depends on the experience of the tester. Any measurement should be compared to a reference standard to identify the source of the ultrasonic noise and determine the condition of the trap. At least one company makes an ultrasonic testing instrument that indicates trap condition by comparing the actual ultrasonic readings to empirical data that reflect known values.

Knowing what failures exist and what actions to take to correct them requires an accurate diagnosis of every steam trap's actual condition. Otherwise, cost-recovery opportunities to correct leakage failures might be missed, or maintenance funds might be wasted replacing properly functioning traps. Consider implementing routine testing using diagnostic instrumentation that has been independently validated by a recognized authority in order to accurately assess the condition of your plant's steam traps.

Article continues on next page

Table 4. Typical characteristics for specific steam trap applications.			
Steam Trap Application	**Condensate Flow**	**Condensate Backup Length**	**Condensate Subcooling Amount**
Utility/Distribution Steam	Small	None to a Short Trail	None to a Small Amount
Heating, Ventilating, and Air Conditioning	Small to Large	None to a Short Trail	None to a Small Amount
Rotating Equipment	Small to Large	None to a Short Trail	None to a Small Amount
Process Equipment	Small to Large	None to a Short Trail	None to a Small Amount
High-Temperature Tracing	Very Small	None to a Short Trail	None to a Small Amount
Low-Temperature Tracing	Very Small	Long Trail	Large Amount

Selecting steam traps for best performance

Even though a steam trap can be of the very highest quality, it will not necessarily work well in a particular application. Similarly, a lesser-quality trap might perform better than the highest-quality trap if the operating characteristics of the selected trap more closely match the requirements of the application.

Typical steam trap characteristics include:

- modulating vs. cyclic discharge
- narrow vs. wide operating pressure range
- small vs. large capacity
- horizontal, vertical, or angled orientation
- insulated vs. bare.

For a more detailed explanation of steam trap principles, types, and characteristics, see Ref. 1, and for more information on draining steam-using process equipment, see Ref. 5.

Every trap is expected to have a long life and low cost of operation. Each application also usually has very specific requirements, a few of which are listed in Table 4.

For example, process or other heating equipment can have condensate flow requirements ranging from small to large, depending on process demand and how much steam the equipment condenses. The general rule of thumb is that there should be no condensate backup in order to keep steam on the entire condensing surface.

Utility or distribution steam is used to deliver heat and power steam to processing equipment. The condensate loads are typically small, but one of the main requirements is that there is no backup in order to prevent the carryover or slugs that can create water hammer and dangerous conditions or equipment damage.

Tracing loads are typically very small, but the differences between high-temperature and low-temperature requirements can often determine the amount of acceptable backup. Backup and subcooling are directly related — high subcooling means that condensate will experience a long backup leg.

Table 4 provides general guidelines, not absolute mandates, as each installation needs to be evaluated individually. As stated earlier, a trap on a steam-distribution line should, in general, have little backup. However, an application with a steam main located 30 ft overhead and a trap at grade might be able to tolerate more condensate backup if it can be assured that condensate will not remain in the steam header (which could lead to downstream water hammer damage).

Steam traps should be selected specifically for each application. It is rare that one type of trap can be used for all traps throughout a plant.

The responsibility to select appropriate steam traps and maintain them may appear overwhelming at first. The information in this article should prove helpful in choosing the right equipment and operating it efficiently and at the lowest overall cost. CEP

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