Impact of Failed Steam Traps on Process Plants

The 4.x series Gateways have some different procedures than the 3.x version Gateway. The firmware version is found in the lower right corner of the Gateway web page. Also the 3.x series has a pale green motif to the web pages and the 4.x is blue. This document covers factory options and updates in 4.x Gateways.

1.1 Introduction

This paper is meant to give a background into the purpose of steam traps, failure modes and consequences, and current methods to detect failure. While we give a broad overview of legacy and new methods of implementing a steam trap health monitoring system, the desired outcome would be for Rosemount, Inc. to work with you in a collaborative relationship to find the solutions that best fit your needs.

1.2 Background

1.2.1 Purpose of steam traps

Steam leaves the boiler of a steam system with near 100% quality (fraction of a saturated mixture that is steam). As steam is distributed throughout the plant, heat is lost and some of this steam condenses and collects in low points. Condensate in steam piping has several consequences, which will be discussed further in the failed shut steam traps section.

The bottom line is that steam traps protect you from these adverse conditions:

- Safety concern for plant personnel and equipment
- Negative impact on plant throughput and quality
- Increased maintenance costs
- Increased fuel consumption leading to high fuel costs
- Reduces ability to meet environmental standards and goals

1.2.2 Failed shut steam traps

Water hammer

Water hammer is a condition where slugs of liquid become trapped between steam packets and then accelerate to a high velocity. When accelerated, the slugs of water can create a “hammer” like effect causing extreme damage to plant equipment.

Thermodynamic efficiency

Water that is not removed from the steam system will collect in the low points of the system and in plant equipment. One common place is in heat exchangers. This buildup will cover heat exchanger tubes causing heat transfer to be compromised. Less heat transfer will cause your process to slow down and have undesirable consequences on both product quality and throughput.

In one example, a manufacturer was unable to control temperature of their manufacturing process because of steam trap failure. When the process control temperature was out of tolerance entire batches had to be reprocessed costing millions of dollars.

Water impingement of plant equipment

If steam traps do not remove water from your steams system then droplets will be entrained in the steam. This entrained water can cause wear and tear on internal components of plant equipment, causing expensive repairs and possible placing plant personnel at risk.

- Leaks in heat exchanger tubes
- Turbines throwing blades
- Wall thinning on the outside edge of pipe bends

Figure 1. Water Impingement on Turbine Blades

Pressure surges/steam line rupture

Condensate that is at saturation temperature is susceptible to flashing to steam if pressure in the system drops. Any valve opening has the potential to drop pressure causing extreme pressure surges when the condensate flashes. This can lead to component and piping failure putting plant personnel and equipment at risk.

Figure 2. Steam Line Rupture Caused Four Deaths

1.2.3 Failed open steam traps

When steam traps fail in the open or blow-by condition, they constantly pass steam. Steam traps are built with an internal orifice to limit the amount of steam loss, but it can still be significant.

Increased fuel costs

The other failure mode of steam traps is a failed open or "blow-by" condition where the trap constantly passes steam. While this does not pose a direct threat to process or safety of plant personnel, there is a very large financial impact on the bottom line of the facility. Each steam trap has an internal orifice that limits the amount of steam/condensate that it will pass when open. Still, steam traps that are on large, high-pressure steam lines can pass greater than 600 lbs/hr of steam. Depending on the cost of steam at a facility, this can cost upwards of $30,000 per year.

Increased boiler load

As plants age, the number of steam leaks increase and plant efficiency decreases. Often this increase in load is known as the "phantom" load. One executive estimated that 20% of his boiler steam production went to this phantom load with a majority of it leaking through failed steam traps. Unless they had a plant to improve the health of the steam trap system, they would have to make a large investment to increase the capacity of their boilers or even add another boiler. Reducing steam loss through steam traps can reduce this phantom load and eliminate the need for capacity additions.

Because of the safety and process issues caused by failed closed steam traps, many operators choose to open the bypass of failed cold steam traps. While this reduces the safety and process impact of the failure, it increases the fuel consumed by the boiler and eats in to any excess capacity. This has both a financial impact on your fuel bill and increases the impact on the environment from burning more fossil fuels.

1.2.4 Steam trap failure rates

When talking about failure rates it is useful to consider the underlying failure rate, or the rate at which your steam traps are actually failing. Aging plants may appear to have a higher failure rate from years of not identifying and/or replacing failed traps.

When talking with operators of process plants we often hear they are experiencing upwards of 20% failure rates on their annual audits.

> *"We know that if we don't take care of our steam traps on some routine basis, after a few years we could have anywhere between 25% and 35% in some failed condition... We would impact our fuel bill by anywhere between 8% and 10% a year."*
>
> *Dan Dvorak, DuPont Engineering Technology*
>
> *"Average-quality traps may have just a 4-year life expectancy (which implies a 25% failure rate), while higher-quality steam traps may have an 8-year life expectancy (12.5% average failure rate)."*
>
> *Risko, J., Understanding Steam Traps, Chemical Engineering Progress, Feb 2011*

1.3 Manual steam trap audits

Many plants perform steam audits on a yearly basis, which leaves the plant vulnerable to long periods of being exposed to the safety, process and financial impact of failed steam traps. The more insight that an operator has into the health of their steam traps system, the better they are able to manage their maintenance activities to lessen the impact of failures and improve the health of the system.

The best manual steam audit programs use an input of flow (usually through acoustic noise) and temperature. Field technicians or external personnel go from steam trap to steam trap performing each analysis individually. In the best case, trap type, size and operating pressure is entered into the instrument and actual parameters are compared to ideal parameters. Some instruments make this comparison in as little as 15 seconds.

A 15-second interval only allows for at most two cycles of a normally operating steam trap. In many cases, the flow noise will vary enough, even in a blow-through trap, to trick the equipment into believing that it is operating correctly. In addition, steam traps are only in service when those portions of the steam system they are installed on are in service. During an annual audit, only those traps that are on operating equipment can be checked. This can leave as many as 30% of the traps on a site not monitored until the next annual audit (at which time they might be offline again).

In the more common case, the individual compares flow noise and makes a judgment on the status of the trap. Since each type of steam trap operates differently and will have a different pattern of flow and temperature depending on loading, trap size, trap type and other factors Consistently getting steam trap audits that reflect actual health of the system is a problem. Further, the training and judgment of every technical will differ. Not only will the audit be inaccurate, but also it will be inconsistently inaccurate.

1.4 Real time monitoring of steam trap status

There are advancements in transmitter technology that now allows continuously monitoring of steam traps rather inexpensively. This new technology brings two significant benefits:

- Knowing the status of your steam traps in real time allows you to replace them before they have an impact on your plant processes and efficiency.
- Continuous monitoring is better at analyzing the status of steam traps since it does not rely on a 15 second "snapshot" of the traps operation.

1.5 Financial impact of failed steam traps

It is difficult to place a number on the financial impact of failed cold steam traps. Anecdotally it is easy to find examples of everything from steam line ruptures causing millions of dollars of damage to unplanned outages to repair equipment. One large company experienced severe water hammer because of four plugged steam traps. The damage resulted in a 6-hour site shutdown and $250,000 in repairs.

As cited before, a manufacturer was unable to control the temperature band of a vital manufacturing process when steam traps failed. This resulted in batches of product being reprocessed costing millions of dollars of lost production and time.

Steam line ruptures and failures in vital plant equipment can cause outages that last anywhere from days to months. The financial results can be huge. While it is impossible to predict the failure that can occur if water is not removed from the steam system, almost everyone agrees on one thing; the costs of a failed cold steam trap far outweigh the lost energy from blowing through steam traps. Intuition tells us this makes sense, after all that is why they were placed there in the first place. This is also evidenced by the practice of opening the bypass of a failed cold steam traps so that the condensate is removed at the expense of the knowingly increasing the lost steam.

The financial impact of a failed open steam trap is much easier to calculate. Since the financial impact is so much smaller than that of a failed cold steam trap, we often make a simplifying and conservative assumption of applying the cost of a failed open steam trap to a failed cold steam trap.

1.5.1 Napier's Equation

John Napier discovered the equation for calculating steam flow through an orifice. Since every steam trap has an internal orifice to reduce steam loss in the case of a failed open steam trap, the equation is widely used to estimate the losses through a failed trap.

$$W = 24.24 \times P_{abs} \times D^2$$

W = steam loss in lbm/hr
24.24 = constant
P_{abs} = Steam pressure in psia
D = Diameter of the internal orifice

If we take the example of a steam trap operating on a 250-psi steam system with an internal orifice of 3/16 inches, we can calculate the steam loss through a blow-through trap.

$$W = 24.24 \times P_{abs} \times D^2$$

$$W = 24.24 \times (250psi + 14.7psi) \times \left(\frac{3}{16} in\right)^2$$

$$W = 225.6 \frac{lbm}{hr}$$

We can then apply the cost of steam for a process unit to find the financial impact of a blow-through trap. A typical cost of steam is $10/1,000lbm so this is what we will use in our example.

Cost ($/yr) = Steam Loss (lbm/hr) * Cost of Steam ($/1,000 lbm) * 8,760 (hrs/yr)

$$\text{Cost (\$/yr)} = \frac{225.6\ lbm}{hr} * \frac{\$10}{1{,}000\ lbm} * \frac{8{,}760\ hrs}{yr}$$

Cost = $(19,762) / yr

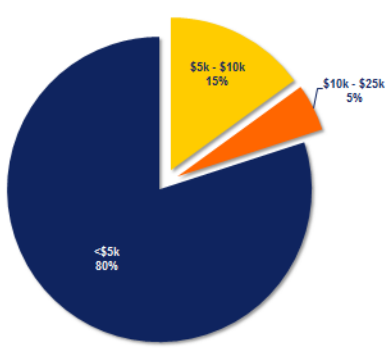
As you can see, the cost for this particular trap is nearly $20k/yr.

1.5.2 Distribution of steam trap sizes

The above example is useful for a couple of reasons. First, it shows how the impact of individual steam plants can be known and calculated. This is valuable information when deciding where to allocate valuable maintenance resources. Second, it shows a typical financial impact of a failed trap... but is it typical? Well, yes and no.

It makes sense that not all traps are created equal. As you can see in Napier's formula, the flow through an orifice is dependent on both the pressure of the steam and the size of the steam trap. While each plant is designed individually, we can generalize on the number and size of steam traps in a facility. For simplicity, we can break down the distribution into the financial impact of a failed trap.

Figure 3. Steam Traps by Failure Cost



The above chart shows that the majority of steam traps in a plant do not have nearly the financial impact as the one in the example. There is a significant amount of traps with a very large financial impact. We refer to these as "high value" steam traps. This is only one aspect that one should consider when identifying their high value traps.

1.5.3 High value steam traps

There are several factors to consider for identifying high value steam traps. It is important to be reminded that the energy loss through failed steam trap is one of the smaller impacts of steam trap system that has sub-optimal health. We should consider high value steam traps those that:

- protect important plant equipment
- would have a large impact on plant processes in the event of failure
- are located on larger, higher pressure steam line
- have a known high failure rate

1.6 Examples of process plants

The following are specific examples of real world people that were seeing specific problems caused by their steam trap system and an analysis of the problems. In each example, we identify the high value traps and give a recommendation on the benefits of real-time monitoring would have on their operations.

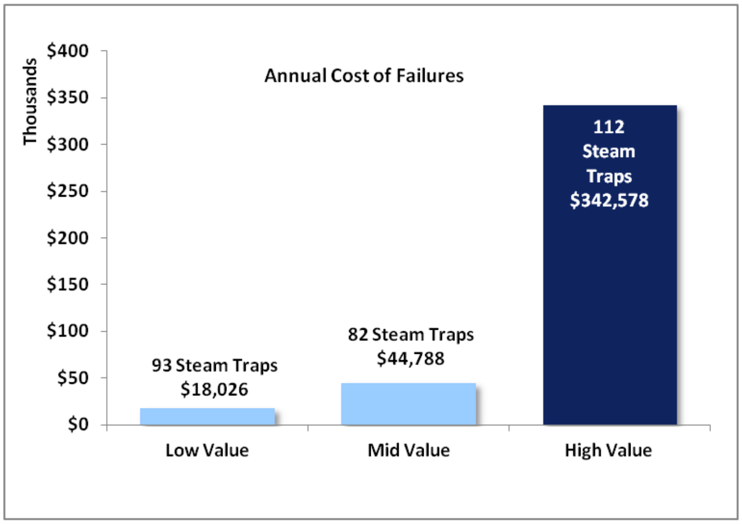
1.6.1 Ethylene cracker

Ethylene crackers are a very large user of steam. Anything they can do to lower their fuel cost has a large impact on the bottom line. We performed an analysis on their steam trap system to help them identify their high value steam traps, their impact on the bottom line, and the financial impact of real-time monitoring and maintenance program.

The current practice on this site was to have a third party do a manual audit every six months. Not every trap was analyzed during the semi-annual audit, only the ones they believed to have the highest value. The results were that they were experiencing an 18.6% annual failure rate.

Given their failure rates and the size of the steam traps in their plant, we can calculate that the financial impact of those failures is $405,392 per year. Further if we only look at the high value traps in the system we found that the top 112 steam traps (39% of the total being audited), were responsible for $342,578 of those losses (or 84.5% of those losses). Implementing a real-time monitoring system on just those 112 high value steam traps would allow them to start capturing those savings immediately and the investment would pay for itself in a matter of months.

Traps in service	247
New Failed Cold Traps	12
New Failed Hot Traps	11
Total Failed Traps	23
6-Month Failure Rate	9.3%
Annual Failure Rate	18.6%

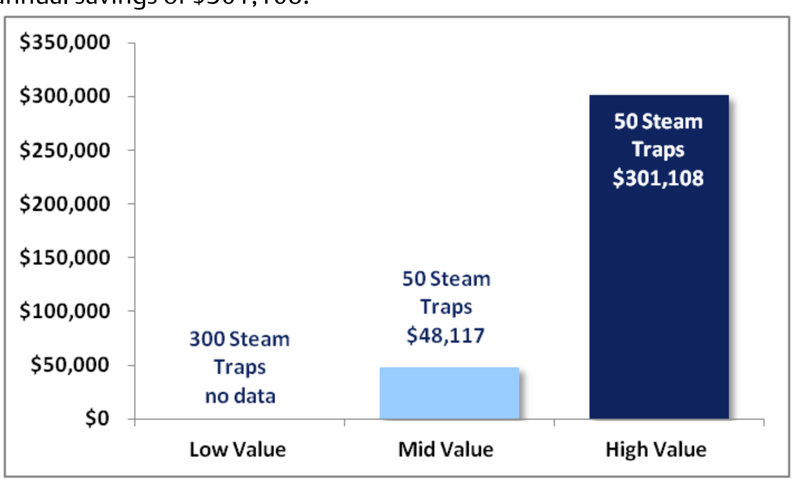


1.6.2 Corn milling plant

Anything food and beverage companies can do to lower their fuel cost has a large impact on the bottom line. We performed an analysis on their steam trap system to help them identify their high value steam traps, their impact on the bottom line, and the financial impact of a real-time monitoring and maintenance program. We looked at the information they gave us about their top 100 steam traps (in a plant with 400+ steam traps). They had two sizes of steam traps on their 150-psi distribution system. When looking at the cost of failure, it becomes apparent where the best place to start a continuous monitoring program is.

	150 psi	
Orifice Size	1/2-in.	1/5-in.
Number of Traps	50	50
Cost of Failure	$40,148	$6,424

Based on the 15% annual failure rate they were experiencing we are able to see the financial impact of the high value traps vs. the general population of steam traps. In this case, the top 12.5% of their steam traps are responsible for 38% of the steam loss on site. This represents an annual savings of $301,108.



1.6.3 Refinery (SRC)

A large refinery that recently installed 50 steam trap monitors was skeptical about a permanently installed real-time monitoring system being more accurate than their current method of an annual steam trap manual audit. They believed the manual system to have 95% - 97% reliability. They initially installed a real-time steam trap monitoring system of 24 steam traps, which had recently been audited and were found to be in good working condition. Of these 24 steam traps, 16 immediately indicated a failed condition. To check the validity of the results, the contracted third party was asked to come back and look at the valves to see whether they were failed. They confirmed that all 16 of the steam traps were in an actual failed condition.

The financial impact of these 16 failed traps was $526,992 per year, if the site did not repair them.

Trap Tag #	Trap Status	Stem Temp	Trap Type	Critical	State Change Timestamp	Monitor Tag
ST1-02	✖	144.2 °C	Float	☑	1/4/2013 1:39:22 PM	ST1-02
ST1-03	✖	129.7 °C	Float	☑	1/4/2013 1:38:14 PM	ST1-03
ST2-02	✖	159.3 °C	Thermostatic	☑	1/4/2013 1:41:59 PM	ST2-02
ST2-03	❄	33.3 °C	Thermostatic	☑	1/4/2013 1:32:59 PM	ST2-03
ST5-01	✖	118.7 °C	Float	☑	1/4/2013 1:28:15 PM	ST5-01
ST5-03	✖	129.8 °C	Thermostatic	☑	1/4/2013 1:27:42 PM	ST5-03
ST5-04	✖	149.1 °C	Float	☑	1/4/2013 1:28:33 PM	ST5-04
ST6-02	✖	126.4 °C	Float	☑	1/4/2013 1:28:31 PM	ST6-02
ST6-03	✖	146.3 °C	Float	☑	1/4/2013 1:28:21 PM	ST6-03
ST8-01	✖	216.1 °C	Float	☑	1/4/2013 1:37:05 PM	ST8-01
ST8-02	✖	137.8 °C	Float	☑	1/4/2013 1:37:02 PM	ST8-02
ST8-03	✖	229.6 °C	Float	☑	1/4/2013 1:36:49 PM	ST8-03
ST9-01	✖	121 °C	Float	☑	1/4/2013 1:37:10 PM	ST9-01
ST9-02	✖	132.3 °C	Float	☑	1/4/2013 1:37:33 PM	ST9-02
ST9-03	✖	216.4 °C	Float	☑	1/4/2013 1:37:17 PM	ST9-03
ST9-04	✖	221.5 °C	Float	☑	1/4/2013 1:37:35 PM	ST9-04

1.7 Conclusion

Steam systems are designed with steam traps to remove condensation from the piping to protect plant equipment and allow the efficient operation of plant equipment and processes. When they fail, there is a significant impact. The traditional method of checking those traps is to contract a third party to come in and do manual audits. Those audits consist of using ultrasonic level and temperature of the steam trap to make a determination on the condition of the traps. This method has drawbacks in that it only looks at a short snapshot of the operation and therefore cannot always be a good predictor of trap condition. In addition, the frequency of audits (either semi-annual or annual) leaves the plant operator susceptible to long periods of failed steam traps.

With the advent of wireless transmitter technology, continuously monitoring the health of your highest value steam traps is now cost effective. In order to implement a continuous monitoring program, it is important to know where the largest impact is on your process. The factors that decide where the impact is include both the size and failure rates of you steam traps, but also their location in the plant and the important plant equipment they are protecting.

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