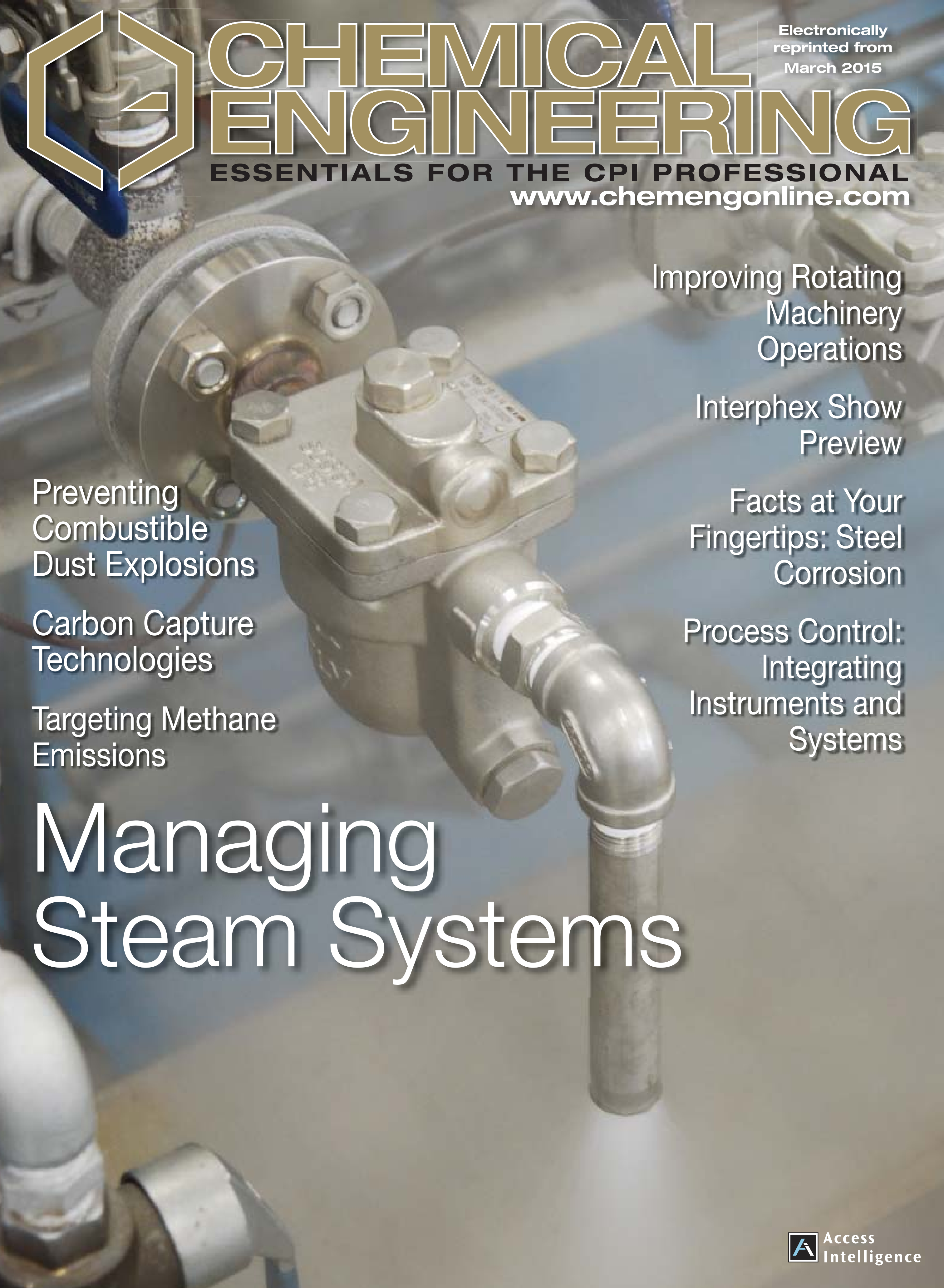
CHEMICAL
ENGINEERING
ESSENTIALS FOR THE CPI PROFESSIONAL
www.chemengonline.com

Electronically
reprinted from
March 2015



Improving Rotating Machinery Operations

Interphex Show Preview

Facts at Your Fingertips: Steel Corrosion

Process Control: Integrating Instruments and Systems

Preventing Combustible Dust Explosions

Carbon Capture Technologies

Targeting Methane Emissions

Managing Steam Systems

Access
Intelligence

Reprinted with permission from CHE (Chemical Engineering), March 2015.

Why Bad Things Happen to Good Steam Equipment

Part 1

Accounting for an entire steam-trap population is crucial to avoiding safety incidents and sub-optimal production — high-priority consideration must be given to steam-system management

James R. Risko
TLV Corp.

IN BRIEF

WHAT CAN GO WRONG IN A STEAM SYSTEM?

ANALYZING A STEAM-TRAP POPULATION

MANAGEMENT PRIORITIZATION

EVALUATING THE NUMBERS

SYSTEM GOALS

CREATING A NEW PARADIGM

Historically, steam systems have provided the most effective source of readily conveyable heat to industrial process applications, including those in the chemical process industries (CPI), and there is no similar low-cost substitute that can replace steam. Without steam, industrial production would be dramatically curtailed, and the low-cost manufactured products that are made from steam's heat or power-generation assistance would not exist. Without steam, our quality of life, economies and society in general would suffer.

While many CPI workers may appreciate that steam systems are a necessity, the same individuals may have also experienced negative steam-related incidents throughout their careers, making them harbor unfavorable thoughts. Specifically, these events may have resulted in safety issues, equipment failures and unscheduled shutdowns of a unit or a full production line. Safety events are extremely challenging and sorrowful issues if someone is injured, and shutdowns can be disruptive to the entire workforce. It is not surprising, then, that people lack an enthusiastic attitude when it comes to steam.


FIGURE 1. Effective steam traps keep heat in the system to optimize production rates and heat quality, and they also discharge condensate to provide for system safety and reliability. Major problems can occur if condensate is not readily drained from the system

What can go wrong in a steam system?

What types of issues can arise in a steam system, and can listing and classifying these items help to determine an executable prevention path or risk-mitigation procedure? Of course, it is relatively easy to identify the most common maladies seen in a steam system. There can be waterhammer, erosion damage and steam leaks in utility systems or equipment. Such destruction may render critical process equipment, such as turbines, flares or heat exchangers, unusable. Additionally, high return-system backpressure caused by steam leakage or blowthrough from bypass steam might restrict production quantity or quality through heat-exchange equipment. Backpressure can also cause the heat-exchange application to be put on bypass or to waste condensate by routing to ground level. While some steam-system failures are common, the challenge then is to identify the

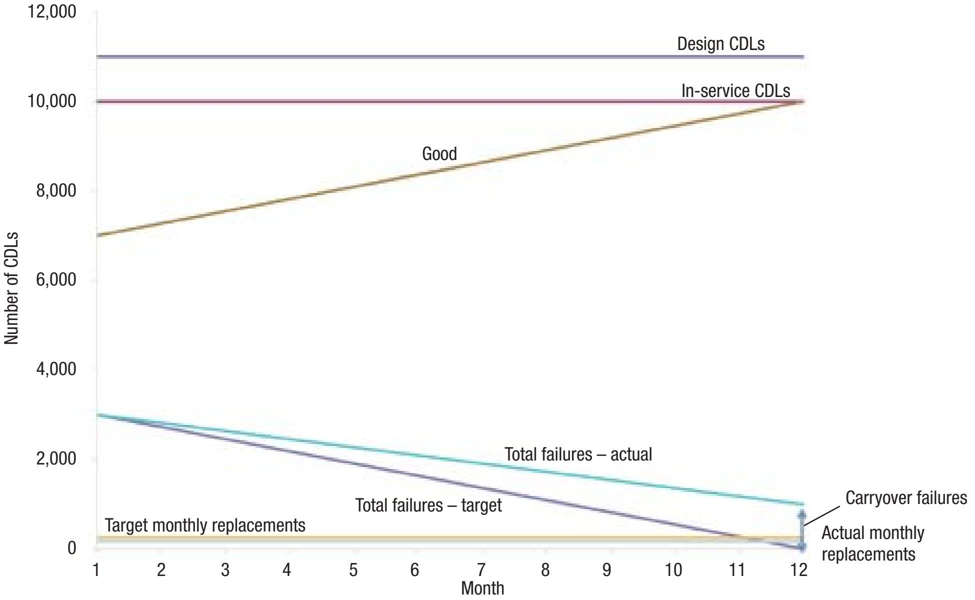


FIGURE 2. A typical steam plant has less in-service condensate discharge locations (CDLs) than the original design. As total failures are reduced through monthly replacements, the number of "good" CDLs increases. If actual replacements are less than known total failures, carryover failures result, thereby reducing available good CDLs to effectively drain the system in the subsequent year. For more details, see the calculation box on p. 26

sources of these incidents. This leads to the larger question, "Why do bad things happen to good steam equipment?"

The technical answer lies in understanding that the cause for a large percentage of failures might be due to the steam system not being maintained to the "as-built" or "design" specification. The original designers analyzed the plant requirements and determined the most suitable design, according to their expertise and standards. That original design included the correct number of steam traps and the assemblage of piping and components that help to drain condensate from the system. Commonly referred to as a condensate discharge location (CDL), the total assembly is required to remove condensate and effectively maintain the design performance of the steam system. Once built, the plant is handed over to the end user for operation and maintenance — with the expectation of sustaining the initial design. Unfortunately, that is when operational budgets, personnel turnover and, in some cases, inexperience with steam systems may play a causal role in negative events.

Analyzing a steam-trap population

Steam traps (Figure 1) are ubiquitous in steam systems, and when operating effectively, they can efficiently retain heat in the system. Consider the analysis of a hypothetical plant's steam-trap population shown in Figure 2. Based on this plant's "state of the population" summary, it is seen that the original design (and as-built) condition included 11,000 CDLs. Over time, the plant's management decided to decommission and remove 1,000 steam traps from service, leaving only 10,000 in-service CDLs. In this example, no plant personnel could find documentation to support why 1,000 steam traps were decommissioned, because no part of the plant had been shut down.

When the in-service quantity of CDLs is lower than the design calls for, then it may be that the reduction was due to a misunderstanding of the importance in maintaining the design total, or possibly from general neglect of the trap population. If the discrepancy is not explainable, then the system's drainage is restricted from the originally required capability. Here, the target for total in-service CDLs should be increased to equal the original design total of 11,000 CDLs.

When routinely administered, steam-trap surveys conducted by plant personnel (Figure 3) provide invaluable information for evaluating the health of the steam system. As it turns out, in this hypothetical example, several years had passed since the last trap survey was completed. So, when the current survey was finished, it was found that there were 3,000 trap failures (both hot leaking failures and cold-blocked low-temperature failures occurred); and 7,000 traps were considered to be in good condition. This sit-

FIGURE 3. Accurate and regularly sustained diagnosis of steam traps' operating conditions is essential to determining the population's current health (state of the population). Once failures are identified, the information is valuable for allocating resources to restore all condensate discharge locations to an "as designed" operating condition for safety and reliable performance

CALCULATION EXAMPLES

Estimating annual new failures

(Reported failures – Carryover failures) / Years between surveys

Example: (3,000 reported failures – 1,000 carryover failures) / 2 years = 1,000 annual new failures

Average trap life

(Total in-service population) / (Annual new failures)

Example: 10,000 traps / 1,000 traps failed in a year = 10 year trap life expectancy

Annual Failure Rate

(Annual new failures) / (Total in-service population)

Example: 1,000 traps / 10,000 traps = 10% annual failure rate

State of the Population

(Failures) / (Total in-service population)
(Good traps) / (Total in-service population)

Example: 3,000 failures / 10,000 traps = 30% state of failure
7,000 good traps / 10,000 traps = 70% good state

uation creates a significant operational and maintenance dilemma for the site.

If the goal is to have a "zero reset" scenario, in which all failed traps must be repaired, and the cost to repair the average failure is $600, then $1.8 million is needed from the year's budget to accomplish the target. To achieve this goal, 250 steam traps must be replaced each month, which represents two or three maintenance crews working full time for a year, assuming that every trap is accessible and can be isolated for repair or replacement. It is certainly a monumental task that may have been caused by an improper course of action a number of years before, when trap replacements were not completed in sufficient quantity to keep pace with the annual failure rate (amount of failures per year) of the population.

Consider that the average annual failure rate of a steam trap population in a mature plant can be estimated from historical records, provided that there are at least two survey events within a period of 4–5 years. Simply subtract the carryover failures (failed traps recorded from a prior survey for which no action was taken to repair) from the reported failures that were recorded in the survey. The remainder is the quantity of new failures. The number of new failures can be divided by the number of years since the prior survey to provide an estimate of the average annual new failures of a steam trap population. Several related useful calculations are shown in the box above.

In this hypothetical plant history, if the management of the trap population had been continuous and sustainable at an annual failure rate of 1,000 (10%), then the plant should only have to support the repair of 84 traps per month, not 250 traps. However, in this case, the trap population was allowed to deteriorate to 3,000 failures (30% failure state), and this situation places a tremendous burden on resources. Worse still, if not corrected, the failures can be expected to grow until catastrophic events occur.

One takeaway from this example is that for every 1,000 traps that must be repaired in a year, there is a requirement for the planning and repair resources to correct 84 traps monthly without fail. That replacement requirement equates to repairing 4–5 CDLs per day, with any lesser amount creating a gap at year-end; the difference here equaling the next year's carryover failures.

Steam traps must be replenished or repaired in order to maintain a sustainable operation. Not taking the highest-priority corrective action with regard to steam trap failures is somewhat comparable to reusing a teabag even though it no longer dispenses flavor — although there is a teabag in service, it no longer provides a useful purpose. Similarly, if a steam trap has failed — particularly via a cold failure — then the CDL is no longer serving its intended purpose, and must be repaired.

Is there any question about what outcome should be expected if all of the steam traps and related CDLs in a system were simply isolated by valving, thereby completely removing their drainage capability? There would be no way to automatically remove condensate from the system, creating a highly dangerous situation. What about if just 30% were shut off, or 50%? It is akin to gambling with the safety of the plant, as the potential formation of condensate slugs in the pipeline can lead to unstable, hazardous conditions. It is extremely distressing to consider a site that is not replacing trap failures due to a budget constraint, because the timely repair of traps allows the system to operate at the intended conditions. This must be seen as an inflexible demand. Timely action should be mandatory, not optional, to optimize the operation of a steam system.

Management prioritization

In a properly drained and maintained steam system, it is critical that the steam flowing

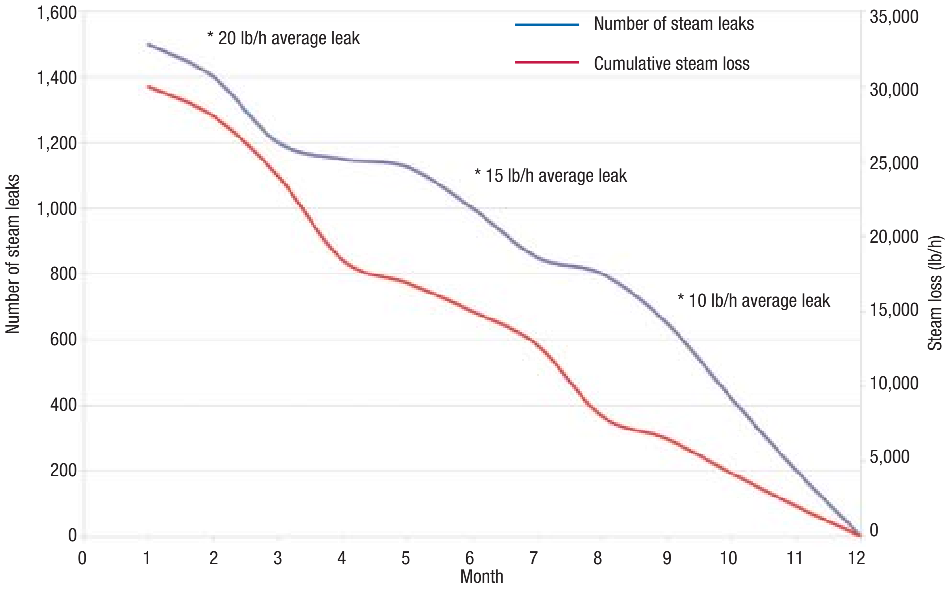


FIGURE 4. Often, high priority is given to fixing the leakage failures or hot failures to reduce steam loss and increase profit. Commonly, the repair of hot failures with high-value loss is given first priority in instances other than very critical applications. A representative example of the correlation of yearly repairs to reduction in steam loss is shown here

within the system remains at near-saturated quality and that avoidable backpressure in the return header is reduced, in order to diminish the likelihood of waterhammer, erosion, corrosion and plating. Superheated steam or steam with near-saturation quality normally cannot cause hammer or high erosion at normal velocities because there is not enough condensate to be propelled downstream. Hammer and erosion occur when liquid pools in the system are thrust at high speeds, but when a system is properly drained, the damaging component is missing. Once again, it is evident that steam-trap failure rates are reduced in successfully maintained steam systems, enabling efficient condensate removal from the system.

Maintaining CDLs to manufacturer specifications helps to eliminate steam leakage (hot failures) and blocked discharge conditions (cold failures). When CDL failures — both hot and cold — are minimized, insulation is maintained and boilers are not pushed beyond their specified limits, the steam system can be optimized with regards to condensate drainage, as well as the ability to sustain steam quality when transported throughout the system.

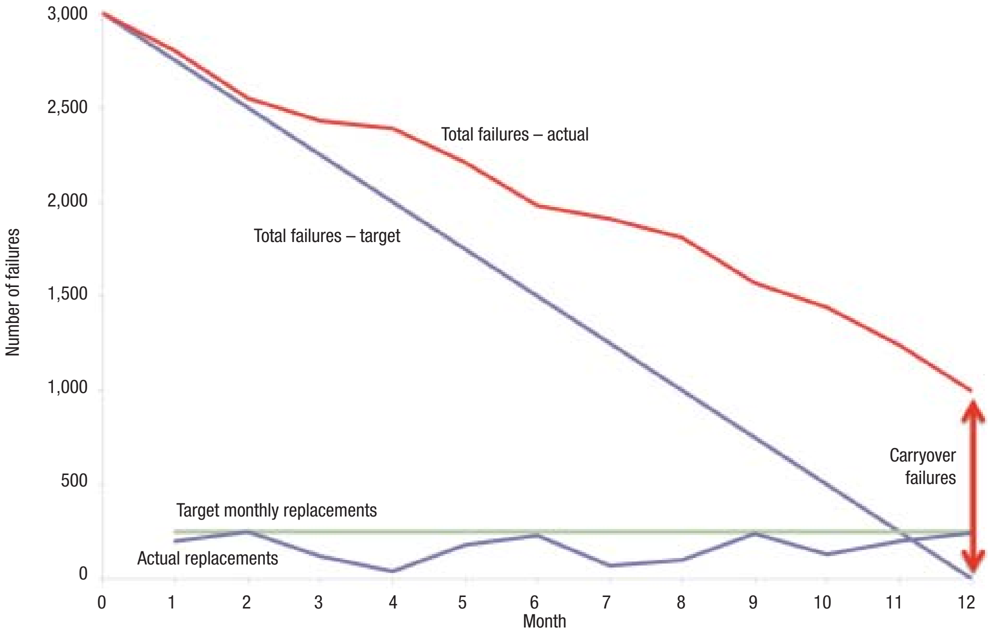
It sounds simple enough — maintain the insulation, keep the boiler within its limits and ensure that the steam trap population provides for quality condensate drainage. It certainly sounds straightforward in concept. If it were so readily attainable, then why isn't this goal accomplished more often?

Evaluating the numbers

In many plants, the typical program to manage the steam trap population may be controlled by budget constraints, by changing responsibilities or by a lack of priority. Although plant operations can be critically affected, the budget may be controlled by maintenance that requires close collaboration and coordination between departments. However, regardless of the circumstance or cause, it sometimes seems that once a system has reached a manageable level after years of cooperation and dedication, then the operational problems are minimized and some portion of the trap maintenance budget is reassigned to a different project not related to trap repair. Then, the portion of the trap population considered to be "good" suffers by seeing an increase in carryover failures, and often no survey action takes place for an extended time. All the while, new failures are accumulating, thereby reducing the safety, reliability and performance of the system. This situation is unfortunate, because the system had finally reached a relatively sustainable condition. Subsequently, after several years of inaction, the plant's trap population may deteriorate so much that a significant negative incident occurs. At this point, the follow-up (some might say knee-jerk) reaction may be to fix the steam system very hastily. This is an all-too-frequent scenario that can lead to the previously presented example where 3,000 traps failed at a single site.

Once failures have been identified, then the focus is often placed on fixing

FIGURE 5. For zero reset of all 3,000 failures, monthly replacement of 250 CDLs is required. If actual replacemnents monthly are reduced, the gap results in year-end carryover failures that reduce the effective good in-service CDLs in the next year



the hot failures, because these repairs can be readily justified by simple energy-cost analysis. Figure 4 illustrates a typical close relationship between hot-failure traps and reduced steam loss. Especially in times of very high energy prices, incredible emphasis is placed on reducing the cost of operations by fixing leaking steam traps. A progress chart, similar to the one shown in Figure 4, can be generated and tracked. Thus, if the project plan is to eliminate 3,000 failures from the hypothetical plant, then the corresponding requirement is to repair 250 CDLs per month, otherwise there will be a carryover failures gap (see Figure 5 for additional analysis).

The carryover failures represent the real world; rarely do plants correct all or even nearly all of the failures. The result is that a significant number of CDLs are not restored to proper drainage operation, and it is not uncommon to carry a sizable number of failures over to the following year. Once carryover failures are accepted in a plant's operations, the steam system becomes destined for sub-optimal and potentially unreliable operation.

What follows when 1,000 carryover failures are extended into the following year? Instead of correcting all 3,000 failed steam traps (a zero reset mentality), suppose that the plant management allocated a budget for repair of only 2,000 failures instead. Perhaps this thought process stems from the expectation that with 2,000 failures corrected, the next annual period will only require budget for 1,000 failures. However, that is not an accurate scenario, because those 1,000 CDLs represent carryover failures only, and the plant also must consider new failures. In a plant with an average steam-trap lifecycle of ten years, the actual failures could be estimated as 2,000, consisting of the 1,000 carryover failures just identified and 1,000 new failures. While the diagnosis of each trap in the population is performed at regular intervals (usually annually or semi-annually), new failures are constantly occurring, as illustrated in Figure 6.

If carryover failures are included as part of the repair strategy, a significant number of CDLs will be operating improperly, thereby increasing the chances of a debilitating incident occurring within the plant. For this reason, it is not recommended to adopt a work process that allows carryover failures and focuses only on those traps that have already been fixed. Instead, a paradigm shift is required.

System goals

Applying maintenance action to individual steam traps is a path action, but not an overarching system goal. Risk lies in the false sense of security that is given when the goal is simply to repair a given number of steam traps, and the real goal of achieving an optimized steam system is neglected. So, if the annual target is established to fix 2,000 steam traps and only 1,000 traps are repaired, there might be some explanation of mitigating events that explains the lapse. In such a situation, the carryover failures might be considered acceptable under the circumstances, and a new goal is assigned for the next year. However, this is a dangerous situation, because while the potential for damage is not visible, it is prevalent in the unaddressed sections of the steam system, and

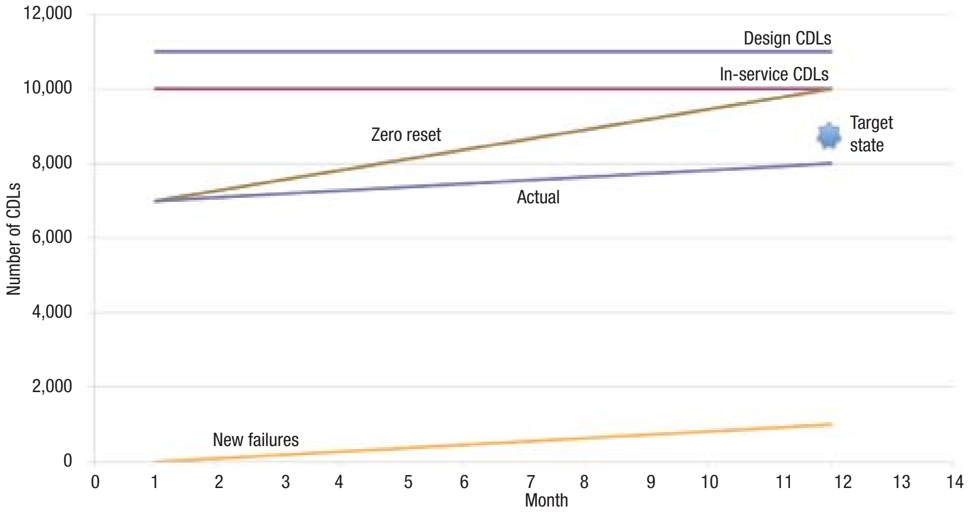


FIGURE 6. There is always an identification-repair response-time lag between diagnosis and maintenance action. Although a site may elect to perform sufficient repairs to reach a target state of the CDL population at year-end, new failures occuring during the repair period always lower the actual year-end state. It is just one of many justifications for adopting a zero reset mentality for maintenance-response planning

the downstream recipients of that steam. The potential for peril can increase in severity over time.

Without a full understanding of the long-term impact on a steam system, there can exist a false impression that a system can be well managed, even if there is allowance for carryover failures. Figure 7 provides additional insight into a longer-term view. As it turns out, the best possible theoretical state of the population occurs only after a zero reset condition is experienced from the prior survey report, and when accumulated repairs equal new accumulated failures. After the midway point, zero reset has been theoretically reached, and new replacements cease, as there are no known failures that remain to be repaired. However, unidentified new failures are still occurring and will not be recognized until the next survey.

The result is that the best state deteriorates between the prior and new surveys, with the theoretical "best sustainable" condition being realized at the beginning date of the next survey. This theoretical point occurs midway between the prior survey and the next survey date — if annual surveys are conducted, and repair is immediate and linear, then the best good state occurs at midyear.

If the original goal of the designers is recalled, it was to have 11,000 fully functional CDLs at the site. For whatever reasons, the plant's management decided to decommission and remove 1,000 installations, leaving a population of only 10,000 in-service CDLs (a 9% reduction from the design). Even if there is perfect harmony

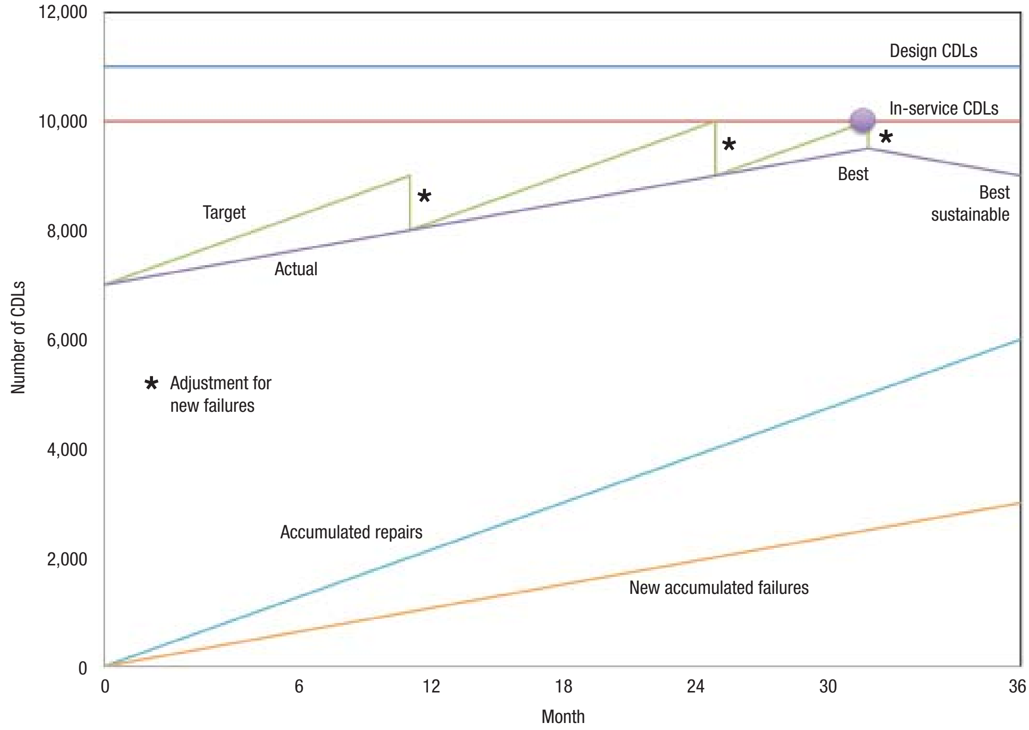


FIGURE 7. Sites sometimes decide upon a fixed number of annual repairs instead of striving for zero reset, thinking they can achieve a nearly 100% good in-service CDL population state over several years. However, due to new failures during the repair cycle, the theoretical "best sustainable" condition is reached midway through a perfectly correlated, linear inspection and repair term, after which the number of CDLs in good condition will decline

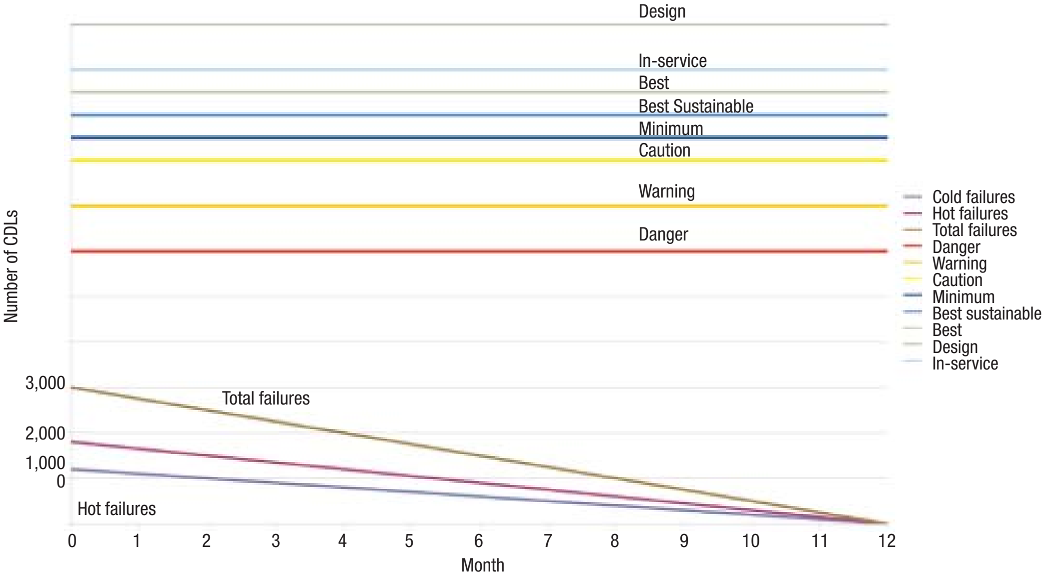


FIGURE 8. The number of in-service CDLs is already a reduction from the number of CDLs in the original design, which is not desirable unless clearly justified; and even with a zero reset focus and perfectly harmonized inspection and repair, the "best sustainable" condition is controlled by the number of annual failures. Establishing critical threshold values provides clear direction for sustainable steam-system performance

with replacement equipment to achieve a "best sustainable" state, that already represents an 18% drop in drainage capability from the design. At this point, it is also important to consider how much redundancy the professional engineering firm included in the original design. Understanding the effect of reducing the number of in-service good CDLs from the design, it can be seen that a key step is to increase the quantity of in-service CDLs until it reaches the design total, less any trap stations clearly suitable for decommissioning.

Furthermore, once carryover failures and new failures are considered, it is possible to have only 7,000 or 8,000 correctly functioning CDLs; which in the case of the former, represents just 63% of the original design. Starting the next year with only 63% of the original design total considered to be in good condition is dangerous, especially if there is an additional lapse in repair action. It can be expected that another 1,000 traps would fail without any repair of previously failed traps. In such an instance, the portion of the population functioning correctly for system drainage could be reduced to 6,000 traps — only 54% of the original design.

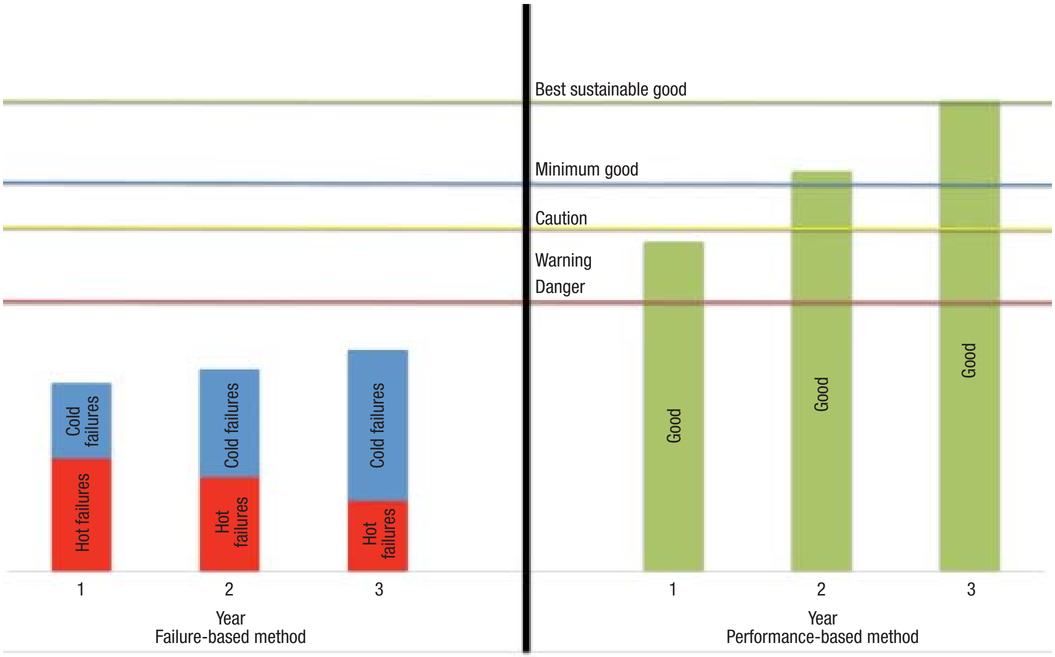


FIGURE 9. A paradigm shift directs full attention to the performance-based method, rather than focusing mainly on hot failures. Knowing the number of "good" CDLs relative to key threshold levels provides a clear indication of the steam system's health and performance expectations

Creating a new paradigm

This is where the necessity of a paradigm shift comes to the forefront. The goal is not to repair failed traps, but rather to maintain a minimum threshold of CDLs in functional condition. That quantity of good CDLs should always refer to the original design total, not to the quantity that are currently in service. Instead of the focus on hot failures, steam loss or accumulated repairs, a site should shift attention to sustaining an acceptable "good" threshold value for the state of the population — with specific, strict dates to start the survey every period. The established survey start date becomes sacrosanct and is held steadfast, regardless of daily interferences. The survey takes such a high priority simply because a steam system is indispensable to the production success of a safely operating plant. It should not be a second- or third-priority focus, but the key focus, thus helping to ensure an optimized steam system.

Another important factor that must be addressed is outsourcing, which is the allocation of responsibilities to third-party entities as contractors to perform certain work. In order to achieve a sustainable program under an outsourcing scenario, there are several crucial requirements: certified test personnel; validated equipment for making accurate condition judgments; and standardized application drawings for correct installation of repaired equipment. In some plants, testing and maintenance may be conducted by the same third-party entity. Regardless, whether a singular third-party or multiple entities are involved with activities that can affect the state of the population, it is important that the capability for each process is confirmed. For example, an incredibly capable contractor for piping repair may be insufficiently trained for testing activities, and must be suitably educated and certified for these tasks. Most critically, there should exist a regular audit process to check and confirm the accuracy of the surveyors' qualification certificates, the actual judgments performed by those surveyors, and in the case of maintenance contractors, the correct installation of each repaired CDL. In some instances at least, the engagement and dedication to a steam system by owner personnel can be higher than with contractors, so a regular and ongoing audit process is recommended to help obtain sustained high-quality work on such critical responsibilities.

With consideration for the site employees who manage the steam system — because responsibilities and personnel change — guidelines must be established. In order to implement clear ongoing parameters for safe and reliable operation, a plant should determine required threshold target and notification values that can be used as the primary focus for the team responsible for maintaining system performance. Figure 8 shows the different key threshold levels of "good" CDLs as: "minimum," "caution," "warning" and "danger." Note that "best sustainable" is a theoretical condition for which it is possible to approach this level, and "minimum" is the determined threshold below which safe and reliable operation of the steam system can be adversely affected. Other tiers provide information to operations and maintenance personnel on the reasonable expectations of increased risk, should appropriate action not be executed.

If a plant wants to have a secondary focus on cold failures to reduce problems caused by condensate in the system, or to repair hot failures to reduce backpressure and recover profits lost to unnecessary energy production, that is certainly a fine approach to fixing failed CDLs. However, when the big picture is to achieve safe and reliable plant operations, the primary focus, as shown in Figure 9, must be to measure the number of good CDLs that are draining the system. Plants should establish the target of keeping the good CDLs between the "minimum good" and "best sustainable good" state threshold values.

When the goal is to maintain a state of the population at or above "minimum good" levels for safety and reliability considerations, the target is straightforward. Now, the repair of failures becomes just a path, not a goal. With a clear message to personnel, the steam-system drainage can be optimized and sustained for best plant performance. ■

Edited by Mary Page Bailey

For suggested additional reading on steam systems, see the online version of this article at www.chemengonline.com.

Author

James R. Risko is the president of TLV Corp. (13901 South Lakes Dr., Charlotte, N.C. 29873; Phone: (704) 597-9070; Email: risko@tlvengineering.com). The author of more than 30 articles related to steam and condensate systems, Risko is active in both the standards and technical-writing activities of the Fluid Controls Institute (FCI), and has previously served as the organization's chairman, standards chair, and chair of the Secondary Pressure and Steam Trap sections. He has earned three energy-management certifications, from the Association of Energy Engineers, North Carolina State Univ., and the Institute of Energy Professionals. He holds an M.B.A from Wilkes University, and two B.S. degrees, in mathematics/education and business administration/accounting, from Kutztown University. He is also licensed as a Certified Energy Manager (CEM) and a Professional Energy Manager (PEM).

ADDITIONAL READING

1. **"Steam Heat Exchangers are Underworked and Over-Surfaced"**
   Risko, J. R. (TLV Corporation), *Chem. Eng.*, Nov. 2004, 58–62.
   http://www.tlv.com/global/US/articles/steam-heat-exchangers-are-underworked-and-over-surfaced.html

2. **"Handle Steam More Intelligently"**
   Risko, J. R. (TLV Corporation), *Chem. Eng.*, Nov. 2006, 44–49.
   http://www.tlv.com/global/US/articles/handle-steam-more-intelligently.html

3. **"Steam Traps – Operating Principles and Types"**
   Risko, J. R. (TLV Corporation), *Fluid Controls Institute*, Technical Sheet #ST 107, April 2008,
   http://www.fluidcontrolsinstitute.org/pdf/resource/steam/st107operatingprinciplesandtypes.pdf

4. **"Understanding Steam Traps"**
   Risko, J. R. (TLV Corporation), *Chem. Eng. Progress*, Feb. 2011, 21–26.
   http://www.tlv.com/global/US/articles/understanding-steam-traps.html

5. **"Use Available Data to Lower System Cost"**
   Risko, J. R. (TLV Corporation), Paper presented at the Industrial Energy Technology Conference,
   New Orleans, La., May 18, 2011,
   http://www.tlv.com/global/US/articles/use-available-data-to-lower-system-cost.html

6. **"Beware of the Dangers of Cold Traps"**
   Risko, J. R. (TLV Corporation), *Chem. Eng. Progress*, Feb. 2013, 50–53.
   http://www.tlv.com/global/US/articles/cold-steam-traps.html

7. **"Implement a Sustainable Steam-Trap Management Program"**
   Walter, J. P. (TLV Corporation), *Chem. Eng. Progress*, Jan. 2014, 43–49.
   http://www.tlv.com/global/US/articles/sustainable-steam-trap-management-program.html

8. **"Outsourcing Energy Performance:**
   Its Potential for Industrial Energy Efficiency Programs"
   Russell, Christopher, *American Council for an Energy-Efficient Economy*, Report IE1402,
   last accessed March 18, 2014,
   http://aceee.org/research-report/ie1402

9. **"What Causes Stall to Occur?"**
   TLV Co. Ltd. Kakogawa Japan, last modified 2010,
   http://www.tlv.com/global/US/steam-theory/stall-phenomenon-pt1.html

10. **"Steam Trap Management System"**
    TLV Co. Ltd. Kakogawa Japan, last modified 2010,
    http://www.tlv.com/global/US/products/070800.html

11. **"What is Water Hammer?"**
    TLV Co. Ltd. Kakogawa Japan, last modified 2011,
    http://www.tlv.com/global/US/steam-theory/what-is-waterhammer.html

12. **"Group Trapping"**
    TLV Co. Ltd. Kakogawa Japan, last modified 2013,
    http://www.tlv.com/global/US/steam-theory/group-trapping.html

13. **"Steam Locking"**
    TLV Co. Ltd. Kakogawa Japan, last modified 2014,
    http://www.tlv.com/global/US/steam-theory/steam-locking.html

---

Reprinted with permission from CHE (Chemical Engineering), March 2015.