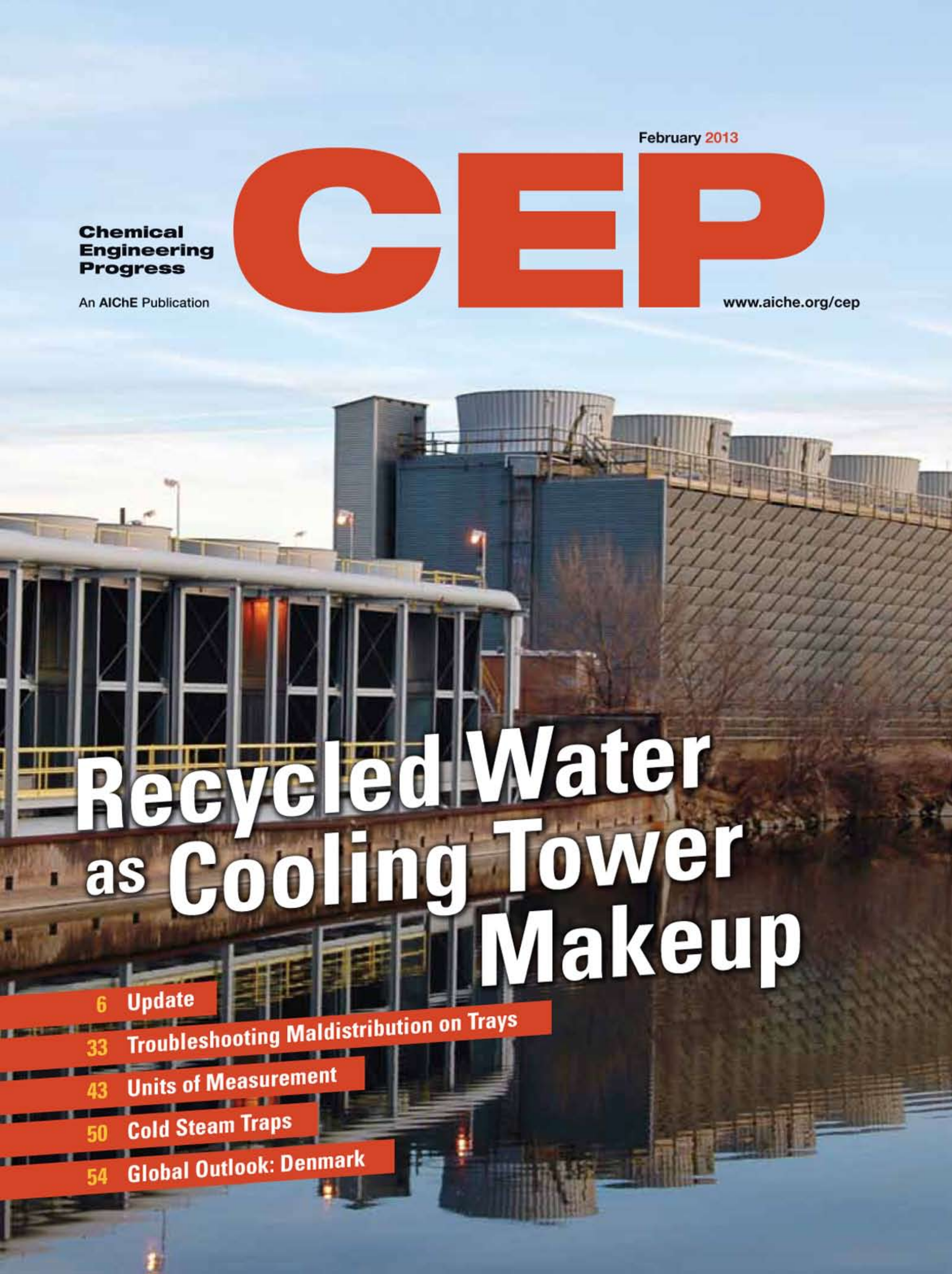

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Recycled Water as Cooling Tower Makeup

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Beware of the Dangers of Cold Traps

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Cold traps — steam traps that no longer drain condensate — are often ignored in lieu of less-critical leaking traps, until a catastrophic event, such as a plant shutdown or personal injury, occurs. Use historical data to accurately estimate the annual cost of these cold traps to justify their swift repair.

Many chemical companies have maintenance programs to diagnose and repair unhealthy (*i.e.*, failed) steam traps. Unfortunately, these strategies often focus on leaking traps, while ignoring the more-critical drainage-failed ones, referred to as cold traps.

Steam traps can fail through two general modes: leakage, in which the trap continues to perform its job of removing condensate, but leaks steam; and drainage (*i.e.*, cold traps, low-temperature traps), in which the flow of condensate is blocked, preventing the removal or draining of condensate from the system. While most leakage-failed traps are easy to spot and their impacts easy to quantify, many engineers may not fully understand the potential hazards of cold traps.

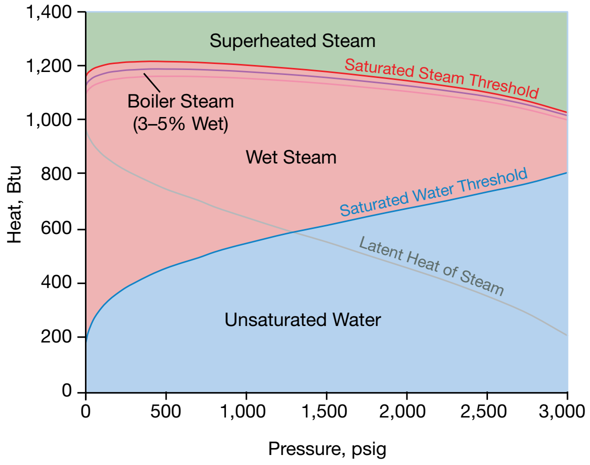
This article, which builds on the concepts presented in a previous *CEP* article (Feb. 2011, pp. 21–26), discusses drainage-failed steam traps. It dispels several common misunderstandings about steam and steam traps, explains how to identify cold traps, and emphasizes the importance of repairing these traps. It also introduces a method to estimate the costs associated with not repairing cold traps.

A misunderstanding about saturated steam

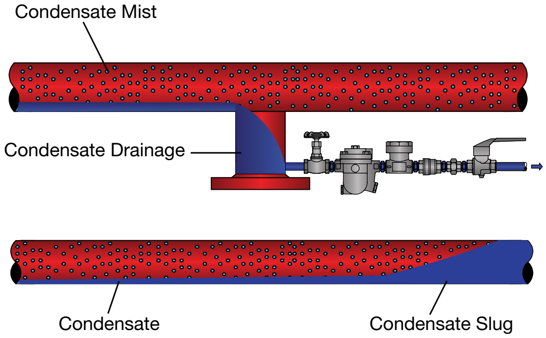
An inaccurate description of steam quality could be partly responsible for the lack of priority given to the repair of cold traps. For instance, the quality of steam generated by a plant's boiler is sometimes mistakenly referred to as saturated, but such a condition is impossible to obtain in a plant steam system. Steam systems contain either superheated steam or wet steam, but not saturated steam.

Saturated steam is produced when water is heated to its boiling point and then vaporized with additional heat (latent heating). It is a threshold — a singular point on a total heat scale, not a region. Superheated steam is generated when steam is heated above its saturation point. Conversely, wet steam, in which not all of the water has been evaporated, exists below saturation (Figure 1).

The steam produced by a typical boiler used in chemical manufacturing plants is wet steam (*i.e.*, less than 100% of the water has been evaporated). Wet steam contains



▲ **Figure 1.** The lack of understanding of steam systems and the quality of the steam produced may be responsible for the mishandling of cold traps. A typical boiler used in the chemical process industries produces wet steam containing 3–5% water, which requires removal through traps.



▲ **Figure 2.** Steam produced by a typical boiler contains condensate, which must be removed from the system via a steam trap (top). When not properly removed, the condensate will eventually form a slug of water (bottom) that will be thrust forward by the fast-moving steam.

water droplets attached to the vapor bubbles. While some boilers include devices to remove this water before it exits the boiler, not all of the water is removed and some remains entrained in the steam supplied to the plant. Even steam produced from state-of-the-art boilers can contain 3–5% water at the boiler exit.

A misunderstanding about superheated steam

Another common misconception is that condensate is not present in superheated steam systems. This can lead to inadequate maintenance of steam traps if maintenance personnel assign a low priority to the repair of cold traps.

Several situations must be considered to determine whether condensate is present. The first is startup. Heating the cold pipeline of the steam system at startup generates condensate that must be drained via condensate discharge locations (CDLs) — *i.e.*, drainage systems consisting of a steam trap and the associated piping, check valves, blowdown valves, isolation valves, strainers, tees, etc. Once the start-up condensate has been drained and the system reaches superheated conditions, the vertical collection piping of the CDL, commonly known as drop legs, becomes a stagnant-flow heat sink that cools down the superheated steam, generating condensate.

Other situations can change the quality of the steam from superheated to wet, for instance, when desuperheaters go awry and inject too much water into the steam flow. One of the most prevalent failures in steam systems is damage to superheated-steam turbines from the release of retained condensate that site personnel thought would not be present in the system. This can occur when formerly closed valves are opened manually or automatically, thereby releasing a slug of condensate into the main piping that cannot be absorbed in time to prevent a catastrophic event.

Condensate dangers

As the steam travels through the distribution pipeline, various mechanical and thermodynamic influences can cause the entrained water to fall out of the steam (Figure 2). If not removed, the disentrained condensate can be propelled forward by the steam, which is flowing at high speeds, typically about 8,800 ft/min (100 mph). Slugs of condensate will eventually encounter an elbow, nozzle, valve, flange, etc. and come to an abrupt stop — causing water hammer. This pressure surge can damage equipment and cause personal injury.

The root cause of water hammer is often poor drainage from CDLs. However, CDLs are not typically repaired until a catastrophic event occurs. Some facilities seem to take an out of sight, out of mind approach to the handling of retained condensate. Unlike steam leaks that are visible, retained condensate is, in a sense, invisible as long as it is contained inside the pipeline, and steam can carry significant amounts of destructive condensate throughout the system.

Unless they are somehow related to safety, most leakage-failed steam traps should not be the first priority for repair. The worst-case impacts of leakage-failed traps are the pressurization of the condensate returns, excess CO_2 emission, and wasted energy. Even so, they still perform the basic function of a steam trap — removing condensate from the steam system. They are just inefficient at performing this basic task.

The really serious and potentially dangerous issue is the drainage-failed steam traps (cold traps) that no longer perform the basic function of removing condensate from the system. When a CDL is blocked, the condensate is retained in the system. Figure 3 shows a typical testing cycle that can be used to determine the presence of condensate in steam traps.

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▼ **Figure 3.** To look for condensate drainage, a trap should be taken through the four stages of operation (as shown in these images for a vertical trap with 580-psig steam).

Table 1. Cold steam traps can have expensive consequences.

Event	Cost
Flare Nozzle Replacement	$750,000
Analyzer Failure and Plant Shutdown	$1,000,000
Flare-Out Fine	$1,700,000
Gas Compressor Failure	$3,600,000
Main Turbine Failure	$20,000,000

A misunderstanding about unneeded steam traps

To eliminate the associated maintenance expense, an engineer or site manager might improperly consider decommissioning steam traps that they consider unnecessary. The problem with this thinking is that each CDL was designed into the system for a reason.

The design process for capital projects is budget-constrained, and engineers pay careful attention to avoid unnecessary equipment. The high initial cost for designing and installing a CDL reduces the likelihood of CDLs that are not needed for safe and reliable long-term operation. Therefore, it is reasonable to assume that all of the original CDLs were deemed to be necessary for plant operation.

This argument may convince engineers of the necessity of all CDLs designed and installed into their system. However, they may not be convinced of the urgency to fix drainage-failed traps.

Cost analysis

Perhaps the easiest way to understand the importance of swift maintenance of drainage failures is to imagine a steam system with no steam traps to repair. In this hypothetical example, a new construction project calls for 100 utility CDLs ($10,000 each) and 500 tracer CDLs at a cost of $5,000 each. If these CDLs are not installed, the capital costs would be reduced by $3.5 million. Furthermore, the cost of steam trap maintenance would be reduced to zero. While this could seem like a perfect hypothetical scenario to some, it would lead to catastrophic results.

What if a compromise is made and half of the originally designed CDLs are installed? This would reduce capital costs by $1.75 million. This might seem like an enticing option, but the system drainage requirements still would not be met, and the retained condensate could lead to disastrous consequences.

Table 2. Historical data can be used to estimate the costs associated with cold traps.

Event	Cost per Event	Number of Traps	Annual Cost per Trap*
Analyzer Failure	$1,000,000	1	$500,000
Analyzer Failure	$1,000,000	360	$1,389

*Assumes that the failure occurs once every two years.

While this may seem to be a ridiculous way to determine the number of steam traps needed for a steam system, this type of iterative calculation is done during the design phase so that the installed traps in a system represent the most economically feasible design. Steam traps should not be decommissioned without careful study by engineers who have knowledge of the entire steam system.

Quantifying the cost of cold traps

Even many site personnel who realize the negative impact of cold traps do not know how to economically justify the repair of these traps. Calculating the cost of not fixing a leakage-failed steam trap is relatively straightforward. Estimating the costs associated with a drainage-failed trap, on the other hand, is not as simple.

However, it is possible to use historical data to quantify these costs. Once an average cost value is determined, future investments to repair cold traps will be easier to justify.

The first part of this estimation is identifying the negative impacts of cold traps, such as:

- personnel injury from flying pipe shrapnel
- pipeline detachment from supports
- turbine compressor, generator, and pump failures
- flare tip or flare ring destruction
- flare outage or loss of flare control (which could trigger regulatory citations and fines)
- frequent steam line leaks due to water hammer of valve packings, fittings, and flanges, or erosion of piping elbows
- high operating costs due to open bypass valves, excessive steam leaks and steam bleeds, and wasted condensate
- atomization or process problems caused by the injection of wet steam
- gradual deterioration of vacuum systems.

Table 1 provides estimates of the potential costs associated with some of these events.

In some cases, cold traps can cause a shattered steam pipe or failure of critical equipment, such as a turbine or analyzer, that requires the plant to shut down. The costs of plant shutdowns can easily exceed $1 million per day, so any major equipment failure can be economically catastrophic.

To determine the cost of cold traps for your particular system, identify events that were caused by retained condensate over the past three to five years, the costs associated with these events, the frequency with which these events occur, and the number of steam traps located in each unit supplying the damaged equipment.

Consider an operating unit with 360 traps that is part of a manufacturing plant with a total of 8,000 steam traps. Over the past two years, an analyzer on this operating unit has failed as a result of a single cold trap. Table 2 shows

Table 3. Cold traps can cause expensive equipment failures and plant shutdowns. Here are some of the events that could be attributed to cold traps.

Event	Frequency, yr	Cost per Event	Annual Cost	Annual Cost per Trap
Analyzer Failure	2	$1,000,000	$500,000	$63
Flare Replacement	3	$750,000	$250,000	$31
Flare-Out Fine	1.5	$1,700,000	$1,133,333	$142
Turbine Failure	2	$3,600,000	$1,800,000	$225
Main Turbine Failure	5	$20,000,000	$4,000,000	$500
Total	n/a	$27,050,000	$7,683,333	$960

the cost of the analyzer failure. Since only one trap was responsible for the event, the entire event cost could be attributed to a single trap; on an annual basis this would place the value at $500,000. However, it is not possible to predict which cold trap is responsible for safety and reliability issues, so a better approach for estimating the cost of such a failure in order to justify the repair of all cold traps on the unit is to allocate the cost of the event over all of the traps in the operating unit.

To estimate the cost per cold trap, divide the cost of the event by the number of traps in the unit (360), then divide that by the number of years between repeat events (in this case 2 yr) to determine a per-year cost. The allocated cost per trap for each such analyzer failure ($1,389 in this example) can then be determined for the total trap population in the operating unit on an annual basis (Table 2).

This same analysis can be used to estimate the negative impact of cold traps across the entire plant. The analyzer failure is one of many events in the plant that can be attributed to cold traps. Table 3 lists these events along with their associated costs and frequencies. To estimate the cost per cold trap for the plant, divide the total annual cost of actual historical events by the total number of traps (8,000) in the plant. The example's total allocated cost of $960 per trap provides a useful valuation to justify repair of all cold traps.

Be aware of cold traps

Not fixing cold traps can be dangerous. These failed CDLs cannot drain condensate from the system as required for safe and reliable operation, and can result in consequences ranging from equipment damage to personnel injury to plant shutdown. Thus, the highest priority should be given to the repair of cold steam traps.

Cold traps must be identified, and then funds and resources should be allocated for their quick repair. One approach is to test all steam traps in the plant every year, and test those in critical applications more often. Once cold traps have been identified, the guidance provided here can be used to help plant personnel estimate the economic losses associated with these cold traps, which will be necessary to justify their repair. CEP

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