

# CHEMICAL PROCESSING

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Steam Systems eHandbook

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# Improve Insulation

Hot surfaces can lead to significant energy losses and pose personal injury risks

By Riyaz Papar, Energy Columnist

**I SPEND** a significant amount of time in petrochemical plants, refineries and process plants. When I review the major on-site energy consumers at these sites, I find myself looking at steam generation and direct-fired process heaters. Depending on the specific plant, these two behemoths can use 70–80% of the total onsite energy. Thermal energy is the engine that drives our processes; plants can implement several energy conservation measures and best practices to optimize its use. Not only does this month's column deal energy efficiency, but the topic also has a close connection to personnel safety.

## THE NEED FOR INSULATION

Personnel safety is of prime importance and should not be compromised at any cost. We want to return home safe and sound to our families and friends every day. Every plant has a safety protocol and all of us abide by that protocol when on site. On a daily basis, it's typical to find, in addition to plant personnel, several contractors on site, as well as other visitors. Our industry's heavy dependence on thermal energy leads to extremely high temperatures in plants. Hence, we must ensure all high-temperature equipment, components, piping, instrumentation, etc. are properly insulated so their surface temperatures are such that no personnel can be injured if they accidentally or unknowingly happen to touch a hot surface. Note that process heaters, boilers, etc. have refractory on the inside and hot spots on the outside skin can pose a significant burn risk.

## ENERGY EFFICIENCY MEASURES

Now, let's talk about the energy-efficiency aspect. Radiation and convection energy losses can be significant. They are a function of several factors but primarily process temperature, surface area, geometry, wind speed, ambient temperature and insulation/refractory heat-transfer resistance. Interestingly, the energy loss due to lack of insulation is fixed and does not depend on operating rates. For example, a boiler on hot standby has the same amount of fixed radiation and convection loss (MBtu/hr) as a similar boiler operating at full load with other factors being the same. When I am doing an energy assessment, I see several areas where insulation is damaged or missing and in some instances no insulation is specified at all. Adding

insulation reduces surface temperature and minimizes the energy loss, thereby improving energy efficiency. One of the challenges in the field is to be able to estimate the energy loss due to missing or damaged insulation.

## REAL WORLD EXAMPLE

To illustrate, consider an uninsulated 10-in. pipe with a 350°F process fluid (or steam). From a personnel safety perspective, adding 1 in. of insulation will bring the outside surface temperature to below 120°F. From an energy-efficiency perspective, this 1 in. of insulation will save ~90% of the energy loss compared to uninsulated pipe. You can even do these types of analyses very easily using the free 3EPlus Insulation Evaluation software ([www.pipeinsulation.org/](http://www.pipeinsulation.org/)). One other tool I would highly recommend you have on hand is an infrared thermography camera; use it every time you walk into a plant. (For more on thermography, see "Use Thermal Imagery for Process Problems," <http://goo.gl/hQ0mXD>.)

In addition to piping runs, some of the most common places where I see missing insulation are valves, channel heads of heat exchangers, inspection manways, steam turbines, condensate tanks, level indication and control assemblies, etc. When I ask why these are not insulated, the most common answers include "they need to be serviced often and insulation is always in the way" or "the fittings leak." In most such cases, I recommend removable insulation materials that can be easily used and wrapped using clips or hook-and-loop bands. The reason for doing this is that ½ in. of insulation can save 70–80% of the energy loss compared to the bare surface. This brings down the outer surface temperature significantly and enhances both personnel safety and energy efficiency.

Improving insulation and adding refractory are low-hanging fruits and should be implemented immediately. As we have discussed, improving energy efficiency by adding insulation leads to improved personnel safety, which is paramount and should never be sacrificed. Insulation projects are like gold filings — collect all of them and you're bound to end up with a gold nugget! ●

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# Don't Get Steamed

Avoid plant downtime and potential injuries by addressing steam-generation chemistry issues

By Brad Buecker, Kiewit Engineering & Design

**HIGH PURITY** water and the steam produced from it constitute the lifeblood of most process plants. Equipment failures and curtailed production due to water/steam issues can cost a site hundreds of thousands of dollars or more annually. Much worse, some failures can cause injury or death. So, here, we'll examine several of the most important issues related to proper water treatment and chemistry control in steam generators.

Let's begin with a case history. A number of years ago, a colleague and I visited an organic chemicals plant in the Midwest that every two years or so had to replace the steam superheater bundles in four 550-psig package boilers due to internal scaling. We first were shown a recently removed bundle; roughly 1/4-in.-thick deposits covered the internal tube surfaces. We then inspected the boilers and immediately noticed foam issuing from the saturated steam sample lines. Subsequent investigation revealed that total organic carbon (TOC) levels in the condensate return to the boilers sometimes reached 200 ppm — ASME guidelines [1] call for a maximum TOC concentration of 0.5 ppm in boilers of this pressure. So, it was easy to see why much foam existed in the boiler water and why impurities carried over to the superheaters on a continual basis.

## THE IMPACT OF IMPURITIES

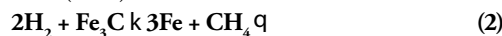
Impurities cause corrosion, scaling and other problems. These become more severe as boiler pressures and temperatures increase. Fortunately, the power industry has learned some lessons that directly apply to chemical plants, particularly ones that generate high-pressure steam for process needs or electrical generation. For example, Tables 1 and 2 summarize guidelines developed by the Electric Power Research Institute (EPRI) for makeup water effluent and condensate

pump discharge (CPD) for heat recovery steam generators (HRSGs) [2].

An examination of the effects of some of these impurities reveals why the limits are so low. Consider chlorides. Even small amounts that enter the steam generator, say, from a condenser tube leak or contaminated condensate return, if chronic and not neutralized by the boiler-water treatment program, will concentrate under deposits on boiler internals. Chloride salts in the high temperature boiler environment can react with water per:



The hydrochloric acid produced may cause general corrosion by itself — worse yet, the acid will accumulate under deposits, where it can react with iron to generate hydrogen. The hydrogen gas molecules penetrate into the metal wall where they then combine with carbon atoms in the steel to generate methane (CH<sub>4</sub>):



Formation of the gaseous methane and hydrogen molecules causes cracking in the steel, greatly weakening its strength (Figure 1).

**HYDROGEN DAMAGE**



Figure 1. Hydrogen gas molecules penetrate into the metal wall — notice the thick-lipped failure here. Source: ChemTreat.



Hydrogen damage is very troublesome because it's not easily detected. After such damage has occurred, the plant staff may replace tubes only to find that other tubes continue to rupture. I once was part of a team that had to deal with hydrogen damage in a 1,250-psig utility boiler. Operations personnel insisted on running the unit for several weeks with a known condenser leak. Even though the team did its best to maintain adequate boiler water chemistry, the ultimate outcome was extensive hydrogen damage that required a complete boiler retubing.

Measurements of conductivity and sodium are very straightforward and are excellent for detecting contaminant ingress to the steam generator. Of course, such monitoring only has real value if it leads to prompt remedial actions by chemists or operators [3]. Organic compounds, as already noted, can cause problems in the steam generator and can break down at high temperatures to form small-chain organic acids and carbon dioxide, which may significantly influence steam and condensate return chemistry.

Meeting the makeup water guidelines requires a reliable high-purity water treatment system. A very common approach employs two-pass reverse osmosis (RO) with either polishing mixed-bed ion exchange units or electrodeionization for final conditioning. Because RO membranes are very susceptible to particulate fouling,

upstream filtration is required — with micro- or ultrafiltration increasingly popular for this purpose [4].

#### CHEMICAL TREATMENT ISSUES

A couple of decades ago, the common belief was that all oxygen should be eliminated from boiler feedwater, as otherwise it would cause severe corrosion. This often is true when a unit is offline and air can enter the system. However, during normal operation, this idea has been proven false unless the condensate/feedwater system contains copper alloys. Regardless, this belief led to a chemical program for feedwater conditioning that became known as all-volatile treatment reducing, AVT(R), with ammonia or amine feed to establish a mildly basic pH and reducing agent (oxygen scavenger) injection to eliminate any oxygen that escaped a mechanical deaerator. For high-pressure units, the common reducing agent once was hydrazine but safer chemicals now have supplanted it.

It now is known that AVT(R) chemistry will induce flow-accelerated corrosion (FAC) in feedwater systems; this can cause wall thinning (Figure 2) and ultimately lead to catastrophic failures. In the last 30 years, several FAC-induced failures in the U.S. have resulted in fatalities.

In brief, when steam generators go into service, the carbon steel develops a thin layer of magnetite,  $Fe_3O_4$ . The combination of a flow disturbance and

#### WALL THINNING



Fig. 2. Single-phase FAC caused the substantial wall thinning shown. Source: ChemTreat.

the reducing environment causes iron ions to leach out of the steel/magnetite matrix, resulting in the wall thinning. Temperature and pH affect the extent of the dissolution; it usually reaches a peak at a temperature of about 150°C and increases with lower pH (e.g., 9 and below).

So, the areas most prone to this attack are the feedwater/economizer system of conventional steam generators and the low-pressure and, sometimes, intermediate-pressure economizers and evaporators in HRSGs.

For units that contain no copper alloys in the feedwater system — which almost always is the case for HRSGs — the recommended



#### NORMAL CHEMISTRY LIMITS FOR HRSG CONDENSATE PUMP DISCHARGE\*

PARAMETER	NORMAL LIMIT OR RANGE
pH (C)	9.2–9.8
Specific conductivity (C)	Consistent with pH established by ammonia or amine feed
Cation conductivity (C)	≤0.1 μS/cm
Dissolved oxygen (C)	≤20 ppb
Sodium (C)	≤2 ppb
Total organic carbon (P)	≤200 ppb

\* Adapted from Reference 2. C = continuous sampling and P = periodic sampling.

Table 2. Organics can break down into small-chain organic acids that impact fluid chemistry.

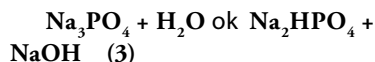
feedwater treatment has become all-volatile treatment oxidizing, AVT(O). This program allows the small amount of oxygen that (normally) leaks in through a condenser to remain, with perhaps even a bit of supplemental oxygen injected, such that the feedwater dissolved oxygen levels stay in a 5–10 ppb range. Addition of ammonia or an amine maintains the pH in a mid- to upper-9 range. Under these conditions, the magnetite layer becomes interspersed and overlaid with a layer of ferric oxide hydrate (FeOOH) that, with elimination of the reducing environment, is very protective. However, this program only is effective in high purity water with a cation conductivity of less than 0.2 μS/cm. Otherwise, oxygen corrosion would result. So, plants where condensate return could produce elevated conductivity shouldn't use AVT(O).

Regarding feedwater chemistry

monitoring, the normal limits cited in Table 2 for cation conductivity, pH and sodium for CPD apply. This is understandable because many modern industrial steam generators and virtually all HRSGs don't have feedwater heaters; thus, the condensate chemistry should change very little in its passage to the steam generator. However, the suggested dissolved oxygen range for HRSG feedwater is 5–10 ppb. Also recommended is total iron monitoring, preferably with a corrosion product sampler, to ensure the program, whether AVT(O) or an alternative, is adequately protecting the condensate and feedwater piping. With proper chemistry, the total iron content in the feedwater should remain less than 2 ppb. If, for some reason, AVT(R) is necessary, a corrosion product sampler also will collect copper corrosion products, which provide critical data on copper corrosion control.

#### BOILER WATER TREATMENT

For eighty years, steam-generation chemists have utilized sodium phosphate compounds for corrosion control and prevention of solids deposition in the waterwall circuits of drum-type boilers. Today, for high-pressure units, tri-sodium phosphate (TSP — Na<sub>3</sub>PO<sub>4</sub>), is the only recommended species, perhaps with a small amount of supplemental caustic (NaOH) for pH elevation at startups. TSP generates mild alkalinity in the boiler via :



The alkalinity to some extent will mitigate the effects outlined in Eq. 2. TSP also provides benefit by reacting with hardness ions (calcium and magnesium) to form a soft sludge that can be blown down.

A drawback to TSP is that its solubility greatly decreases as temperatures exceed 300°F. Thus, in high-pressure units at full load, most of the phosphate precipitates on waterwall tubes and other internals. This phenomenon commonly is known as “hideout.” Many plant chemists now operate units with a bulk water phosphate concentration of ≈1–2 ppm, knowing that most of the original phosphate dose has hidden out and will redissolve at reduced boiler load or shutdown.

Boiler-water chemical treatment and monitoring in large measure is designed to protect steam purity. This

#### REFERENCES

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#### RECOMMENDED HRSG BOILER-WATER MONITORING POINTS\*

PARAMETER	GUIDELINES
pH (C)	See Reference 2 for a control chart. Dosage is based on TSP feed only, with a maximum free caustic concentration of 1 ppm. Immediate unit shutdown is required if the boiler pH starts dropping and reaches 8.0.
Phosphate (C)	See note above.
Specific conductivity (C)	Measures the overall impurity level in the boiler water. Control range is unit- and pressure-dependent.
Silica (C)	Can be coordinated with steam silica analyses to prevent carryover to turbines. Control range is unit- and pressure-dependent.
Sodium (C)	Important to determine the free caustic concentration.
Cation conductivity (C)	Provides a general measurement of anions in the boiler water, including the very harmful chloride ion. Control range is unit- and pressure-dependent.
Chloride (P)	Important for corrosion prevention. Control range is unit- and pressure-dependent.
Sulfate (P)	Important for corrosion prevention. Control range is unit- and pressure-dependent.

\* Adapted from Reference 2. C = continuous sampling and P = periodic sampling.

Table 3. Monitoring of these parameters is essential for protecting steam purity.

#### RECOMMENDED STEAM SAMPLE PARAMETERS\*

PARAMETER	NORMAL LIMIT	NOTES
Cation conductivity (C)	≤0.2 μS/cm	A general indicator of total impurities in the steam.
Sodium (C)	≤2 ppb	An excellent analysis to determine mechanical carryover from the boiler drum. If sodium is entering the turbine, so, too, may other harmful impurities including chloride and sulfate. These salts can cause pitting, stress corrosion cracking and corrosion fatigue in a low-pressure turbine.
Silica (C)	≤10 ppb	Silica in water vaporizes, with such vaporous carryover into steam very pressure-dependent. Silica will coat turbine blades and reduce efficiency. On-line monitoring is a must.

\* Adapted from Reference 5. C = continuous sampling and P = periodic sampling.

Table 4. Monitoring of these parameters is especially important if the steam drives a turbine.

is particularly true for plants that generate electricity via steam turbines. Table 3 summarizes the most important measurements.

To a large extent, the chemistry guidelines for feedwater and boiler water chemistry aim to prevent excess impurity carryover to the steam — this is especially critical if the steam drives a turbine or turbines. Steam turbines are precision machines that require careful installation, balancing and operation. (For more on steam turbines, see: “Count on Steam Turbines,” <http://goo.gl/fXS2OD>.) Table 4 details the most crucial guidelines.

#### PREVENT PROBLEMS

Proper steam generation chemistry is critically important, as is the need to monitor and control chemistry at all times. Neglect of condensate return, boiler feedwater, boiler water or steam chemistry can prove quite costly

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both from a monetary and a safety standpoint.

In addition, proper steam generator shutdown, layup and startup procedures are critical issues, particularly to prevent offline oxygen corrosion [6,7]. ●

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# Change Your Approach to Steam System Management

Improve plant productivity and reduce unplanned downtime with this three-step process

By Justin Grubka, Armstrong International

**REAL-TIME ASSET** information is becoming increasingly valuable in evaluating, analyzing and trending equipment performance, and the same holds true when it is used for steam traps. Steam traps play a crucial role in plantwide safety, equipment reliability and product quality. Failed steam traps account for millions of dollars in wasted energy, CO<sub>2</sub> emissions, unscheduled maintenance and production losses.

In a typical refinery or chemical plant, a facility without a steam trap management program has an average failure rate of 15%–25%. Steam trap failures are inevitable, and failure mode has a direct effect on plant operations. It can be a daunting task to manage the typical 2,000 to 5,000 traps, along with the required data.

Using a combination of real-time monitors for critical service applications and scheduled survey frequencies for the remainder of the plant can impact significantly total overall facility performance. Instead, consider segregating these applications and integrating automated system tools to manage the overall reliability and maintenance needs for both. This can provide a complete maintenance and operational protocol for small and large plants.

Three steps — surveying equipment, completing a techni-

cal review and performing required maintenance — can help plants keep on top of steam system management demands (Figure 1).

## 1. SURVEY THE EQUIPMENT

The first step of any maintenance program is to identify and qualify the equipment you have and determine where it is located. This information is obtained by performing an initial comprehensive steam trap survey. Collecting this critical application data is the baseline for future efficiency improvements. A simple “good or bad” approach is common; however, documented piping arrangements, valve locations and application assessments should be included in the baseline data.

Many plants continue to use technologies initially provided by the builder, most likely because of their cheaper initial costs, even though poor performance or failures are frequent. Identifying the equipment and their locations is critical to overall plant reliability, long-term costs, and future energy and maintenance reductions. Direct effects on equipment and plant reliability should be prioritized based on these trap technology choices. Traps that fail safe, or open, always should be used when potential equipment failures such as steam turbine or exchanger malfunctions could be caused by a trap that failed in the closed position.

To begin the survey, pick a contractor. Independents typically are less biased than manufacturers. The contractor should do the following:

- Identify the location.
- Identify the application.
- Identify failure repercussions.
- Define operational and design system parameters (pressures and temperatures).
- Identify the trap manufacturer, type and model.
- Document and record steam system leaks.
- Validate piping design (isolation, bypass, drip leg, insulation, etc.).
- Determine the trap condition.
- Use a monitoring tool to track, trend and document operational and safety issues specific to the trap location.

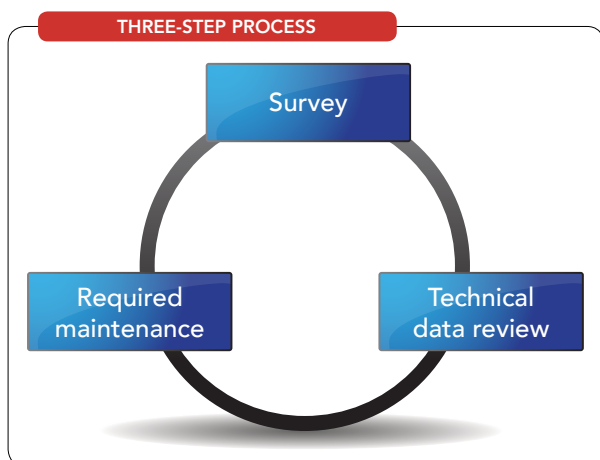


Figure 1. Surveying equipment, completing a technical review and performing required maintenance can help plants manage their steam system demands.



#### INTELLIGENT MONITORING SYSTEM



Figure 2. Non-intrusive intelligent monitoring systems can provide immediate notification of faulty steam traps while pinpointing the exact location and nature of the failure.

### 2. COMPLETE A TECHNICAL DATA REVIEW

To carry out the second step, facility personnel providing technical data reviews should be well-versed in plant operations system requirements and trap operational characteristics. Some companies provide training in steam system operations and principles. Such training would allow personnel to:

- Determine the need for continual operational validation (i.e. real-time monitoring and manual survey schedules).
- Assess the steam trap operation failure mode desired for an application (should it be open or closed?).
- Identify whether current equipment failure mode is consistent with current operational needs (if not, select the proper trap type for operational and reliability needs).
- Determine whether the technical validation technology or model should change based on overall life cycle cost and history.

### 3. PERFORM REQUIRED MAINTENANCE

The third step is to keep up with required maintenance.

- Prioritize replacements based on potential safety issues, operational and reliability exposure, and monetary and energy losses.

- Identify required equipment for changes.
- Procure necessary materials and compare initial cost vs. overall lifecycle cost to the plant.
- Generate work orders.

#### INCORPORATE MAINTENANCE SOFTWARE TOOLS

After a validated database has been generated and approved, ongoing system maintenance costs can be minimized by using maintenance software tools. Some systems use algorithms to analyze data to track behavior and performance for steam system management. They are designed to provide continual efficiency and maintenance updates to provide continual return on investment of labor-hours and equipment costs by improved plant efficiencies.

Additional labor savings and reduced contractor costs may be realized due to ease of ongoing survey and maintenance requirements. These systems also may help to eliminate additional data entry, decrease overall survey times and minimize continual investment in labor-hours and contractor costs.

#### VALIDATE CRITICAL APPLICATIONS CONTINUOUSLY

After the technical review has identified needs in critical areas for equipment and process reliability integration, use a monitoring system to validate ongoing operation and performance. By monitoring critical applications continuously, plants can mitigate potential shutdowns or process upsets before they occur.

Some intelligent monitoring systems are available on multiple instrumentation protocols such as WirelessHART and ISA100 Wireless (Figure 2). Installation is non-intrusive and is validated on any manufacturer's steam traps based on a steam trap algorithm that reads acoustic and temperature measurements on varying applications. Continual communication to multiple critical users can allow for live analysis of steam system integrity and operational characteristics.

By implementing the above best practices solutions, a U.S. refinery documented overall steam savings of 100,000 lbs/hr. This resulted in the ability to put one of their existing on-line boilers on standby. ●

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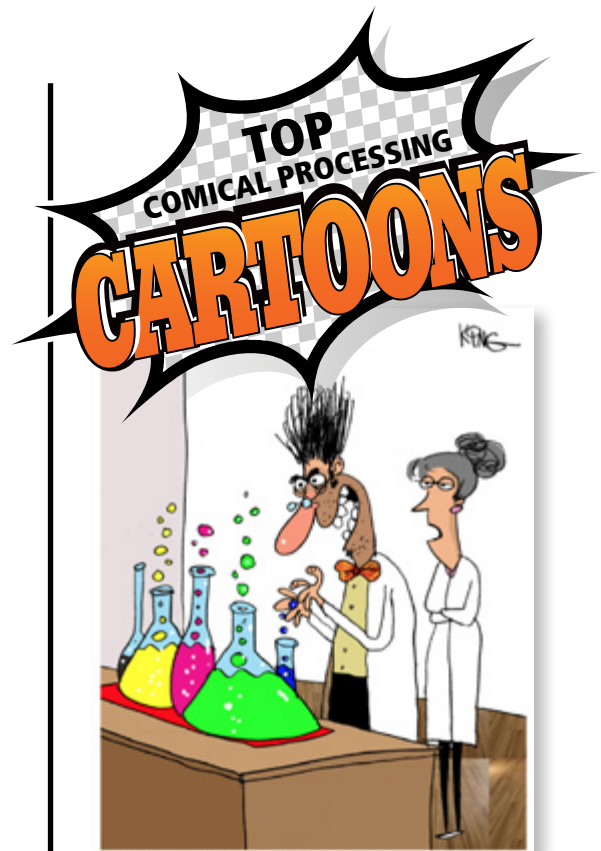
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