

## SPECIAL REPORT

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# The Dangers of Uncontrolled Gases in Steam Systems

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**B**uild-up of air and other non-condensable gases such as carbon dioxide and oxygen in a steam system can be a serious, costly hazard. Left unattended, such accumulations accelerate corrosion and block flow, resulting in leaks, steam or water hammer, reduced heat transfer and, eventually, expensive repairs.

The real danger is in the corrosion potential of these gases when combined with condensate. Carbon dioxide combines with condensate below steam temperature to form carbonic acid, which can cause leaks at heat exchanger walls or tubes. It's also strong enough to eat away drain lines, leading to leaks in steam fittings and condensate return lines. Oxygen in the system speeds corrosion (oxidation) of piping through pitting action.

Corrosion is often so severe that condensate discharged from a steam trap may be bright red or dark brown from iron content. Under such conditions, components within the heat transfer equipment may not withstand the pressure of the system.

### **The root of many problems**

Corrosive condensate is only one of several hazards caused by air and non-condensibles in steam systems. Other potential problems include:

*System binding.* Even though they are compressed, air and non-condensable gases still occupy volume and can displace steam and condensate. When system binding occurs, flow of steam and condensate can be blocked. Since the condensate

## All boiler feedwaters contain elements that can produce non-condensable gases when the water is boiled.

cannot drain, it cools down. When it comes into contact with the hotter steam, it causes instantaneous condensation which unleashes severe velocity and pressure fluctuations within the system. Water is accelerated and impacts piping, elbows, fittings and valves in potentially destructive water or steam hammer. This may result in leaks, float collapse and other component failures.

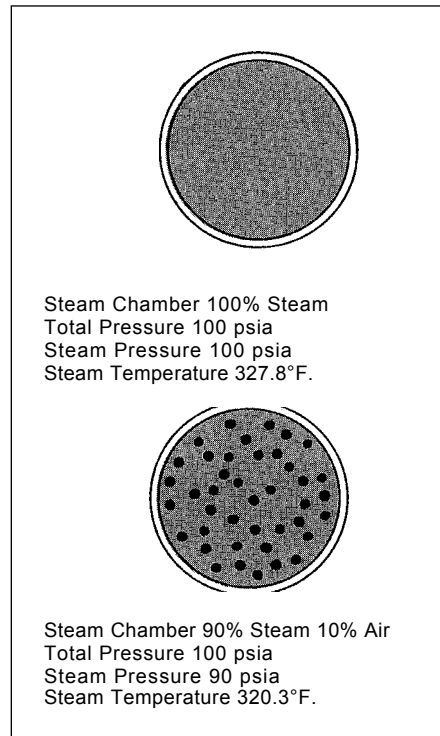
**Energy costs.** Most systems use steam to transfer heat. Any reduction in the capability of the steam to transfer heat is a potential inefficiency. When steam is distributed and flowing through the system, its pressure actually drops. Mains and branch lines are sized to distribute the steam without excessive pressure drop. To avoid the energy loss associated with steam pressure drop, these lines must be sized carefully. As steam pressure drops, so does the temperature. This could slow heat transfer, demanding more steam, increasing the pressure drop and wasting more total energy.

Air and non-condensable accumulations reduce heat transfer similarly to steam pressure drop: By 1) reducing effective steam temperature and 2) insulating heat transfer surfaces.

**Temperature drop.** Dalton's law of partial pressures states that "the pressure of a mixture of gases is equal to the sum of the partial pressures." In the case of air and non-condensibles with steam, the gases will exert part of the pressure and the pressure exerted by the steam will be reduced. As we have seen, there is a direct relationship between the temperature and pressure of steam. As the pressure of steam decreases so does the temperature, along with heat transfer efficiency (Figure 1).

**Insulating effect.** Air and non-condensable accumulations can also reduce heat transfer by insulating the heat exchanger. As steam flows within a heat exchanger tube, as shown in Figure 2, it moves from the center of the tube toward the wall.

Since air and non-condensibles do not condense, they behave as relatively lazy



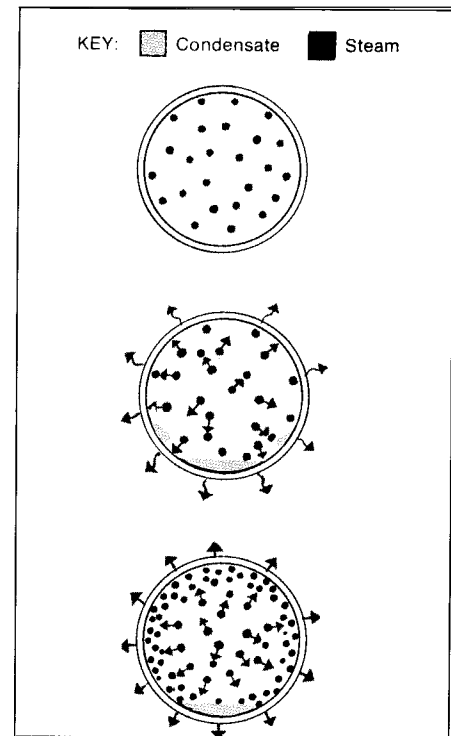
*Steam mixed with air delivers only the heat of the partial pressure of the steam, not the total pressure*

gases and can be pushed along by the flowing steam within the tube. The general steam flow is toward the walls of the heat exchanger, where the air and non-condensable gases can accumulate at the walls and form an insulating film.

### Sources of gases

Steam systems are full of air at start-up. As the steam enters the system, it condenses and will form high condensate loads. This liquid and steam mixture moving through the piping will force the air ahead of it into the far reaches of the system. Since the end of the system is the heat exchange equipment and the steam trap, the ability of these components to deal with high volumes of air at low pressures determines the effectiveness of air removal. Pockets within heat exchangers will normally form at the last place the steam and condensate flow reach. These air pockets are free to remain in the system unless steam or condensate flow sweeps them away.

All boiler feedwaters contain elements that can produce non-condensable gases when the water is boiled. These gases are transported into the system along with the steam. In addition



*Condensing steam moves air to the heat transfer surface where it collects to form an insulating film*

to the gases in solution, feedwaters usually contain carbonates and/or bicarbonates that are converted in the boiler drum to CO<sub>2</sub>.

### Removal and control

Most industrial and institutional steam systems are designed to reduce intake and accumulation of non-condensable gases. Understanding the operating principles of this equipment and how to manage the system can eliminate recurring hazards.

**Deaeration.** Deaerators are designed to do exactly what the name implies—remove gases from incoming boiler feedwater. As we saw earlier, CO<sub>2</sub> goes into solution when the temperature is decreased. Deaerators give the CO<sub>2</sub> and oxygen an opportunity to come out of solution, where they are under very low pressure and can be easily vented.

The equipment is designed to spread the feedwater out over an extended surface area and, at the same time, heat it up, encouraging the gas to come out of solution and vent to atmosphere. Returned condensate, often laden with CO<sub>2</sub>, is also typically deaerated.

**Thermostatic vents.** Thermostatic

**Condensate should be maintained as hot as possible in the return system to minimize the carbonic acid formation.**

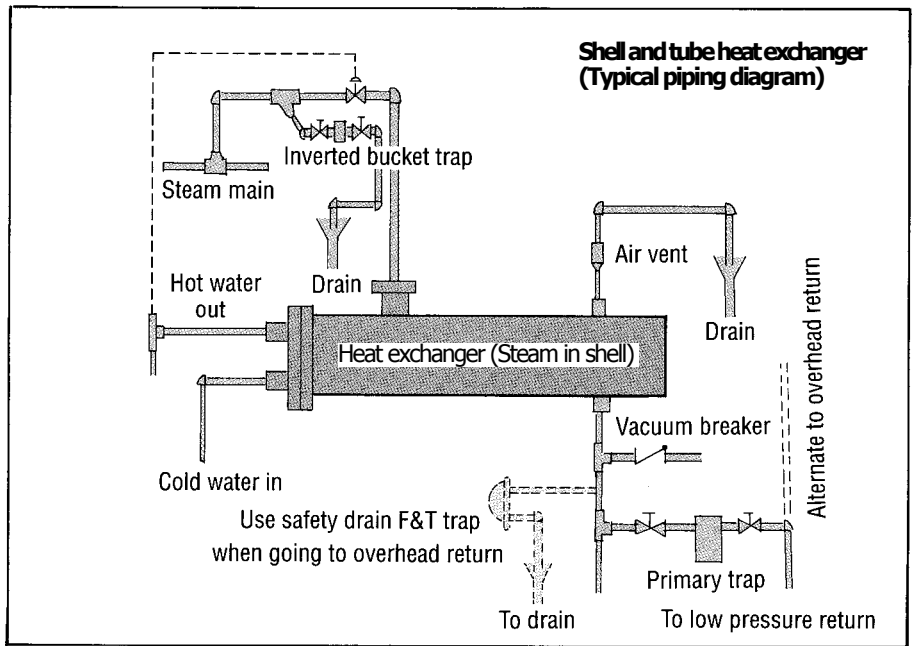
steam traps (particularly bellows type) can be used as automatic air vents on heat exchange equipment. Air and non-condensibles in the system do not condense so they get pushed to quiet zones by the flowing steam. At these locations the thermostatic device senses the temperature reduction caused by gas accumulation and vents it. Batch process autoclaves, large shell-and-tube heat exchangers and large steam coils should incorporate automatic air vents to eliminate gas accumulations.

*Steam traps.* Steam traps should discharge condensate from a process application at or near saturation temperature. Selection of traps that back up or subcool condensate will accelerate carbonic acid corrosion, cause steam leaks, reduce heat transfer and possibly increase maintenance. Subcooling traps are typically thermostatic traps that are designed to back up condensate. These traps may be of thermal expansion design, balanced pressure bellows, bi-metal, wafer or diaphragm type. How much these traps will subcool depends mainly on the mechanical characteristics of the trap. The degree of subcooling also depends on the steam pressure and condensate load.

It's important to locate steam traps properly because one of their functions is to vent the air and non-condensable gases as in Figure 3. When installing steam traps, follow the ABCs of trap location:

- A—ACCESSIBLE for inspection and repair,
- B —BELOW drip points whenever possible, and
- C— CLOSE to the drip point.

Steam traps are like thermostatic air vents in that they do not reach into the system to draw out air and non-condensibles for venting. They will vent only whatever reaches them; unless they are located so they see air and non-condensibles, they will not vent them. A properly located non-subcooling steam trap can usually take care of the lower quiet zones within a heat exchanger since the trap will vent air also. Properly sized



*Traps should be located close to and below drip points whenever possible*

non-subcooling traps, such as inverted-bucket and float-and-thermostatic types, will help maximize heat energy transfer in the system.

CO<sub>2</sub> and oxygen corrosion can also be a major cause of problems in steam traps with small orifices. If copper or iron products of corrosion are in the condensate flowing to the steam trap (as they are in many older systems), they go into solution in the carbonic acid. When they pass through an orifice of small size to a lower pressure, the condensate flashes and these corrosion products can be deposited as oxides that may plug small orifices. Even when larger orifices are used, plugging can occur in the outlet piping of the steam trap.

*Insulated condensate returns.* When condensate is at a higher temperature, corrosion is slowed because CO<sub>2</sub> goes into solution best in cooler condensate. Condensate should be maintained as hot as possible in the return system to minimize the carbonic acid formation.

*Chemical treatment.* The proper makeup treatment is essential to remove as much CO<sub>2</sub> as possible from the boiler feedwater. However, even with proper deaeration and alkalinity control of makeup water and condensate return, it's impossible to eliminate all CO<sub>2</sub> from the system. At some point the condensate will become corrosive. The addition

of amines can be helpful by neutralizing carbonic acid and thus controlling corrosion.

**Taking action**

Uncontrolled air and non-condensable gases in steam systems can cause corrosion, water hammer, heat transfer and drainage problems in steam systems and steam heat exchange equipment. Therefore a program to minimize gas introduction rates, to vent gases where they accumulate, to drain condensate before it subcools, to prevent cooling of condensate return systems and to minimize the corrosive effects of carbonic acid should be implemented.

A complete action plan would entail:

- Studying deaerator piping design and existing piping practices,
- Analysis of major heat exchange equipment for air vent inclusion and piping practices,
- Analysis of steam trap selection and piping practices,
- Analysis of maintenance records on heat exchanger tube bundles and steam coil repairs and replacement for persistent corrosion or water hammer problems,
- Surveying condensate return lines for adequate insulation, and
- Analysis of chemical treatment practices and problems. ■