Removal of Non-condensable Gases and Air Is Critical In A Steam System

Air and non-condensable gases are one of the major problems in a steam system. Both can cause production problems for a steam system's operation and performance. For example, the thermal conductivity of air is 0.000049, compared with 0.002 for water, 0.20 for iron, and 0.96 for copper. Not removing air and non-condensable gases from the steam system can reduce heat transfer efficiencies by 21 % or more depending on the air concentration in the steam system. Because air is one of the greatest insulators, a major steam operation objective is elimination of air from a steam system.

Adding to the problem is the fact that steam systems are typically not designed to eliminate air at startup or during operation. During shutdown of a steam system or its components, the system depressurizes, with the steam condensing and reducing in volume by as much as 1,600 times. This reduction in volume produces a vacuum in the steam system or steam components. Air is drawn into the steam system through steam components, such as air vents, valve packing, and flanges, and the air drawn in fills the vacuum. When energizing a steam system or steam heat transfer components, one of the first goals should be to vent the air out of the steam system or components.

I. Where do non-condensable gases and air come from?

Feedwater contains a small percentage of non-condensable gases in solution. When the boiler water changes state (liquid to vapor), the non-condensable gases are released and carried with the steam into the plant. Steam will release the latent energy to the process and condense down to condensate in the heat transfer area, but the non-condensable gases do not condense. These gases stay in the heat transfer component unless some method or action removes them.

During the steam system operation, the percentage of steam in the system will be close to 100 % steam vapor with a small percentage of non-condensable gases.

When steam is shut down to the heat transfer unit or steam supply line for maintenance or process changes, the steam will condense and decrease in volume, which will open the vacuum breakers on the steam heat transfer unit, allowing air to flow into the system. On heat transfer units, it is extremely important to have functional vacuum breakers on the heat transfer units to enable the condensate to drain out of the unit by gravity. If vacuum breakers are not on the heat transfer unit, the vacuum will hold the condensate in the unit and cause another set of issues. A steam line that does not have vacuum breakers, will draw air in from components on the system (such as valve packing or flanges), and fill the void in the line.

II. How does air affect the system?

A. Air Reduces the Heat Transfer Efficiency

The release of latent energy (change of state) to condensate in the steam components takes place on the heat transfer surface, which is where heat is being transferred due to the temperature difference (steam to the process). The steam component transfer is consuming the latent energy, and the steam is condensing to a liquid (condensate); the condensate is drained away by gravity, but the non-condensable gases and air remain.

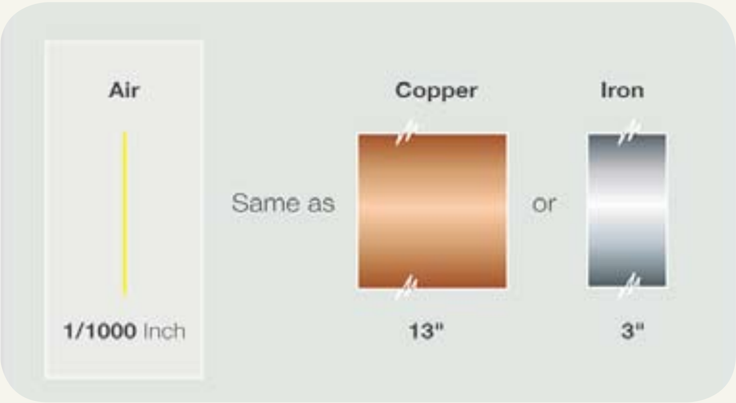

Figure 1 Resistance of Air Compared to Copper and Iron

The non-condensable gases form a stagnant film on the walls of the heat transfer surface which creates a resistance. Heat energy transmitting through the heat transfer surface has to pass by conduction through these films of resistance. A film of air or non-condensable gases that is only one thousandth of an inch thick has the resistance of a three-inch wall of iron. See Figure 1.

The latent heat energy of steam must pass from the steam heat transfer area to the area where the process material is being heated. To do so, it must pass through several obstacles:

1. A stagnant film of air/steam on the steam side
2. Condensate film
3. Buildup of rust or corrosion material
4. Heat transfer metal wall
5. Product side—burned product or scale
6. Stagnant film of material on the process side of the wall

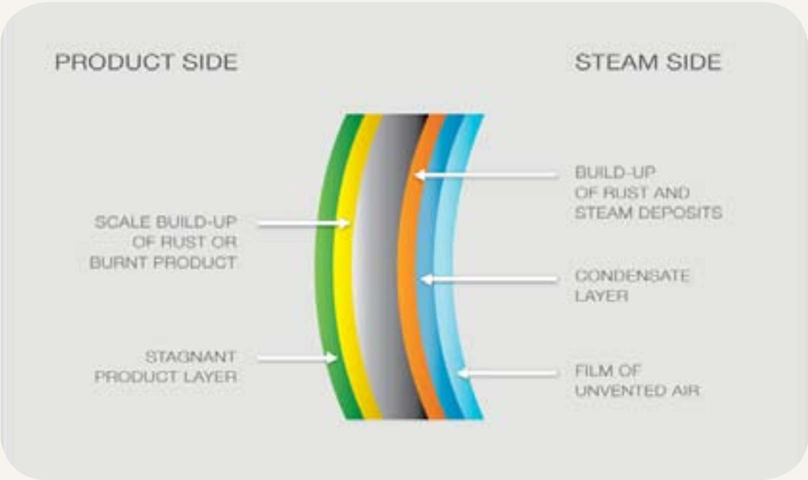

Figure 2 Obstacles to Energy Transfer

B. Air Reduces the Temperature of Steam

1. Dalton's Law of Partial Pressures

Dalton's law of partial pressures states that in a mixture of gases or vapors, the total pressure of the mixture is made up of the partial pressures exerted by each gas or vapor. The partial pressure exerted by each is the fraction of the total pressure equal to the fraction of the total volume of each.

The pressure reading is in absolute units. For example, the total pressure of a mixture of 25 % air and non-condensable gases and 75 % steam is 114.7 lbs. per sq. in. absolute (337.87°F).

The partial pressure of steam is 114.7 x 0.75 or 86.02 lbs. per sq. in. absolute (psia) (317°F).

Figure 3

The partial pressure of the air is 114.7 x 0.25 or 28.56 lbs. per sq. in. absolute (psia).

The temperature of saturated steam at 114.7 lbs. per sq. in. absolute is 317°F vs. 337.87°F for a steam line or steam component filled with a mixture consisting of 25 % air and non-condensable gases and 75 % steam.

There are other steam system issues with the concentration of air and non-condensable gases. The buildup or volume of air and non-condensable gases in the heat transfer area is not constant. The thickness of a stagnant film of air can vary due to velocities, baffles, flow direction, metal finish, and other heat transfer internal designs. This factor can also lead to problems with uneven heating of products.

Plants increase steam pressures to overcome the issues with air and non-condensable gases. In turn, the higher cost of producing higher steam pressures increases the plant's energy cost.

III. Eliminating the Non-Condensable Gases or Air from the System

A. Devices or Methods to Vent the Non-condensable Gas or Air There are several methods to vent air from the system or heat transfer unit.

1. ***Manual Valve***

   Negative:

   a. Requires an employee to operate the device

   Positives:

   a. Plant employee can ensure that all air has been vented from the system
   b. Plant employee can also drain condensate from the system during startup
   c. Typically used on steam and pressurized condensate lines

2. ***Automatic Valve***

   Negatives:

   a. Requires an automatic valve with electric or compressed air connections
   b. More complex
   c. No method of ensuring all the air has been removed

   Positive:

   a. Plant employee does not have to be at the location of each valve

3. ***Air Venting Device***

   Temperature is a key factor that differentiates an air/steam mixture from 100 % steam. Therefore, an automatic air vent which relies on a thermostatic device for operation is often used.

   The air venting device typically includes a thermostatic balance pressure bellows unit

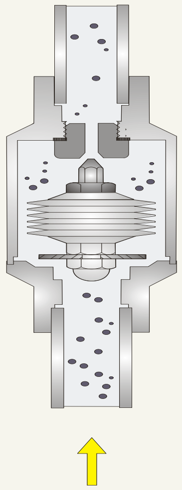

Figure 3 Air Venting Device

with a very low sub-cool. The device is able to sense air or non-condensable gases due to the resulting temperature suppression.

The air venting device is used on the heat transfer units that have shutdowns and startups during the operational week.

Negative:

a. Reliability can be a issue if the proper air venting device is not purchased

Positives:

a. No plant personnel have to be at the location during startup
b. Greatly improves the operation of the heat transfer system

4. Steam Trap

Steam traps are never considered to be primary air venting mechanisms due to the methods incorporated into their design to accomplish this task. Therefore, steam traps are always considered secondary air vent mechanisms. There are two methods to vent air in any steam trap: a leak path and a thermostatic mechanism.

A. Create a leak path

The steam trap design has a leak path incorporated into the operational design. The steam trap leak path is very small to ensure no significant steam loss occurs during operation. Due to the small leak path, the steam trap is not able to provide sufficient air venting capabilities.

B. Thermostatic mechanism

The other method is to use a thermostatic element inside of the steam trap that can offer a high capacity of venting air at startup due to the orifice size. In process applications, the preferred steam trap is a float and thermostatic steam trap, which incorporates a thermostatic air venting mechanism. Plants often employ one or more of the above items to remove the air from the steam system during startup or operation.

IV. Installation of Air Venting and Devices

A. Steam Lines

When steam lines are activated or started up, one of the main tasks is to remove the non-condensable gases. During startup, the drain valve off the steam line drip pocket is opened, venting air from the steam line and removing condensate. In some cases, a second manual air venting valve is installed on top of the steam line to ensure removal of air from the system. See Figure 4.

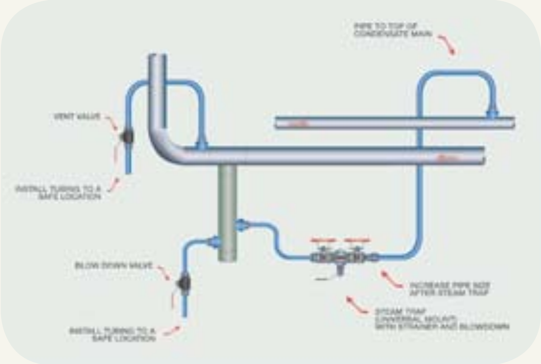

Figure 4 Steam Lines

Note: the strainer blowdown valve is also open at startup to allow the strainer to be blown down.

B. Examples of Process Equipment Placement of Air Vents and Vacuum Breakers

A key factor in the location of air vents on process equipment is to understand the design of the unit. For example, a shell and tube heat exchanger has a port typically on the top of the shell for the placement of a vacuum breaker and air vent. The process steam side needs to have the air purged to ensure proper startup and temperature control. See Figure 5.

Steam coils have a vacuum breaker located at the entrance of the steam into the coils, usually located on the port on the top header of the device. See Figure 6.

For process application steam traps, the preferred steam trap design is the float and thermostatic, which incorporates a thermostatic air vent mechanism. The steam trap thermostatic air vent mechanism becomes the secondary air venting device.

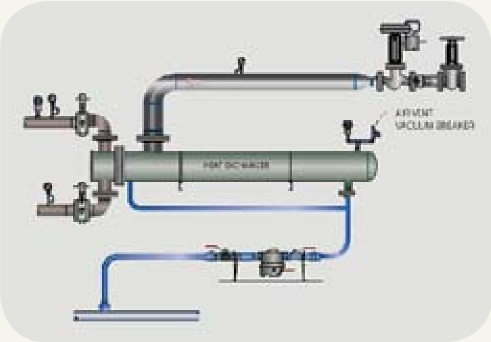

Figure 5 Shell and Tube Heat Exchanger

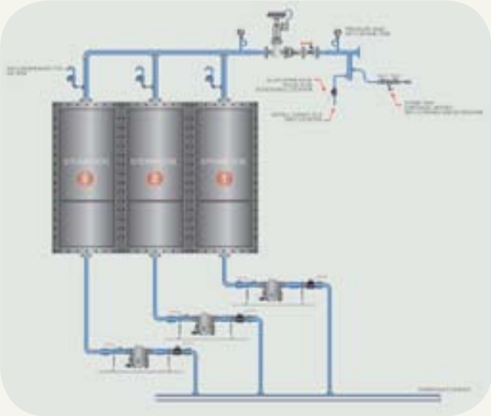

Figure 6 Steam Coils

Roadmap:

1. *Survey all process equipment and ensure units have air vents and vacuum breakers.*

2. *Survey all steam line drip legs and ensure proper blowdown valves are installed.*

3. *Have Standard Operating Procedures (SOP) for the use of manual air vents on steam lines and process applications.*