How to Trap: Superheated Steam Lines
Say energy. Think environment. And vice versa.
Any company that is energy conscious is also environmentally conscious. Less energy consumed means less waste, fewer emissions and a healthier environment.

In short, bringing energy and environment together lowers the cost industry must pay for both. By helping companies manage energy, Armstrong products and services are also helping to protect the environment.

Armstrong has been sharing know-how since we invented the energy-efficient inverted bucket steam trap in 1911. In the years since, customers’ savings have proven again and again that knowledge not shared is energy wasted.

Armstrong’s developments and improvements in steam trap design and function have led to countless savings in energy, time and money. This section has grown out of our decades of sharing and expanding what we’ve learned. It deals with the operating principles of steam traps and outlines their specific applications to a wide variety of products and industries. You’ll find it a useful complement to other Armstrong literature and the Armstrong Steam-A-ware™ software program for sizing and selecting steam traps, pressure reducing valves and water heaters, which can be requested through Armstrong’s Web site, armstronginternational.com.

This section also includes Recommendation Charts that summarize our findings on which type of trap will give optimum performance in a given situation and why.

IMPORTANT: This section is intended to summarize general principles of installation and operation of steam traps, as outlined above. Actual installation and operation of steam trapping equipment should be performed only by experienced personnel. Selection or installation should always be accompanied by competent technical assistance or advice. This data should never be used as a substitute for such technical advice or assistance. We encourage you to contact Armstrong or its local representative for further details.
## Instructions for Using the Recommendation Charts

A quick reference Recommendation Chart appears throughout the “HOW TO TRAP” brochures (857-EN - 868-EN).

A feature code system (ranging from A to Q) supplies you with “at-a-glance” information.

The chart covers the type of steam traps and the major advantages that Armstrong feels are superior for each particular application.

For example, assume you are looking for information concerning the proper trap to use on a gravity drained jacketed kettle. You would:

1. Turn to the “How to Trap Jacketed Kettles” brochure, 864-EN, and look in the lower right-hand corner of page 10. The Recommendation Chart located there is reprinted below for your convenience. (Each section has a Recommendation Chart.)

2. Find “Jacketed Kettles, Gravity Drain” in the first column under “Equipment Being Trapped” and read to the right for Armstrong’s “1st Choice and Feature Code.” In this case, the first choice is an IBLV and the feature code letters B, C, E, K, N are listed.

3. Now refer to Chart 3-2 below, titled “How Various Types of Steam Traps Meet Specific Operating Requirements” and read down the extreme left-hand column to each of the letters B, C, E, K, N. The letter “B,” for example, refers to the trap’s ability to provide energy-conserving operation.

4. Follow the line for “B” to the right until you reach the column that corresponds to our first choice, in this case the inverted bucket. Based on tests and actual operating conditions, the energy-conserving performance of the inverted bucket steam trap has been rated “Excellent.” Follow this same procedure for the remaining letters.

### Abbreviations
- **IB** Inverted Bucket Trap
- **IBLV** Inverted Bucket Large Vent
- **BM** Bimetallic Trap
- **F&T** Float and Thermostatic Trap
- **CD** Controlled Disc Trap
- **DC** Automatic Differential Condensate Controller
- **CV** Check Valve
- **T** Thermic Bucket
- **PRV** Pressure Reducing Valve

---

**Chart 3-1. Recommendation Chart**  
(See chart below for “Feature Code” References.)

<table>
<thead>
<tr>
<th>Equipment Being Trapped</th>
<th>1st Choice and Feature Code</th>
<th>Alternate Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacketed Kettles</td>
<td>IBLV</td>
<td>F&amp;T or Thermostatic</td>
</tr>
<tr>
<td>Gravity Drain</td>
<td>B, C, E, K, N</td>
<td>IBLV</td>
</tr>
<tr>
<td>Jacketed Kettles</td>
<td>DC</td>
<td>IBLV</td>
</tr>
<tr>
<td>Syphon Drain</td>
<td>B, C, E, G, H, K, N, P</td>
<td></td>
</tr>
</tbody>
</table>

**Chart 3-2. How Various Types of Steam Traps Meet Specific Operating Requirements**

<table>
<thead>
<tr>
<th>Feature Code</th>
<th>Characteristic</th>
<th>IB</th>
<th>BM</th>
<th>F&amp;T</th>
<th>Disc</th>
<th>Thermostatic Wafer</th>
<th>DC</th>
<th>Orifice</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Method of Operation</td>
<td>(1) Intermittent</td>
<td>(2) Intermittent</td>
<td>Continuous</td>
<td>Intermittent</td>
<td>(2) Intermittent</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>B</td>
<td>Energy Conservation (Time in Service)</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Good</td>
<td>Poor</td>
<td>Fair</td>
<td>(3) Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>C</td>
<td>Resistance to Wear</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Good</td>
<td>Poor</td>
<td>Fair</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>D</td>
<td>Corrosion Resistance</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>E</td>
<td>Resistance to Hydraulic Shock</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
<td>Excellent</td>
<td>(4) Poor</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>F</td>
<td>Vents Air and CO₂ at Steam Temperature</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Poor</td>
</tr>
<tr>
<td>G</td>
<td>Ability to Vent Air at Very Low Pressure (1/4 psig)</td>
<td>Poor</td>
<td>(5) NR</td>
<td>Excellent</td>
<td>(5) NR</td>
<td>Good</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>H</td>
<td>Ability to Handle Start-Up Air Loads</td>
<td>Fair</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>I</td>
<td>Operation Against Back Pressure</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>J</td>
<td>Resistance to Damage From Freezing</td>
<td>(6) Good</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>K</td>
<td>Ability to Purge System</td>
<td>Excellent</td>
<td>Good</td>
<td>Fair</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>L</td>
<td>Performance on Very Light Loads</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>M</td>
<td>Responsiveness to Slugs of Condensate</td>
<td>Immediate</td>
<td>Delayed</td>
<td>Immediate</td>
<td>Delayed</td>
<td>Immediate</td>
<td>Immediate</td>
<td>Poor</td>
</tr>
<tr>
<td>N</td>
<td>Ability to Handle Dirt</td>
<td>Excellent</td>
<td>Fair</td>
<td>Poor</td>
<td>Poor</td>
<td>Fair</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>O</td>
<td>Comparative Physical Size (7)</td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td>P</td>
<td>Ability to Handle “Flash Steam”</td>
<td>Fair</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Q</td>
<td>Mechanical Failure (Open or Closed)</td>
<td>Open</td>
<td>Open</td>
<td>Closed</td>
<td>(8) Open</td>
<td>(9) Open</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

(1) Drainage of condensate is continuous. Discharge is intermittent.
(2) Can be continuous on low load.
(3) Excellent when “secondary steam” is utilized.
(4) Bimetallic and wafer traps – good.
(5) Not recommended for low pressure operations.
(6) Cast iron traps not recommended.
(7) In welded stainless steel construction – medium.
(8) Can fail closed due to dirt.
(9) Can fail either open or closed, depending upon the design of the bellows.
**What They Are…How to Use Them**

The heat quantities and temperature/pressure relationships referred to in this section are taken from the Properties of Saturated Steam table.

**Definitions of Terms Used**

**Saturated Steam** is pure steam at the temperature that corresponds to the boiling temperature of water at the existing pressure.

**Absolute and Gauge Pressures**

Absolute pressure is pressure in pounds per square inch (psia) above a perfect vacuum. Gauge pressure is pressure in pounds per square inch above atmospheric pressure, which is 14.7 pounds per square inch absolute. Gauge pressure (psig) plus 14.7 equals absolute pressure. Or, absolute pressure minus 14.7 equals gauge pressure.

**Pressure/temperature Relationship**

(Colks 1, 2 and 3). For every increase of pure steam there is a corresponding temperature. Example: The temperature of 250 psig pure steam is always 406°F.

**Heat of Saturated Liquid** (Column 4).

This is the amount of heat required to raise the temperature of a pound of water from 32°F to the boiling point of pressure and temperature shown. It is expressed in British thermal units (Btu).

**Latent Heat or Heat of Vaporization** (Column 5).

The amount of heat (expressed in Btu) required to change a pound of boiling water to a pound of steam. This same amount of heat is released when a pound of steam is condensed back into a pound of water. This heat quantity is different for every pressure/temperature combination, as shown in the steam table.

**Total Heat of Steam** (Column 6).

The sum of the Heat of the Liquid (Column 4) and Latent Heat (Column 5) in Btu. It is the total heat in steam above 32°F.

**Specific Volume of Liquid** (Column 7).

The volume per unit of mass in cubic feet per pound.

**Specific Volume of Steam** (Column 8).

The volume per unit of mass in cubic feet per pound.

**How the Table Is Used**

In addition to determining pressure/temperature relationships, you can compute the amount of steam that will be condensed by any heating unit of known Btu output. Conversely, the table can be used to determine Btu output if steam condensing rate is known. In the application portion of this section, there are several references to the use of the steam table.

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**Table 4-1. Properties of Saturated Steam**

(Abstracted from Keenan and Keyes. THERMODYNAMIC PROPERTIES OF STEAM, by permission of John Wiley & Sons, Inc.)

<table>
<thead>
<tr>
<th>Col. 1</th>
<th>Col. 2</th>
<th>Col. 3</th>
<th>Col. 4</th>
<th>Col. 5</th>
<th>Col. 6</th>
<th>Col. 7</th>
<th>Col. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge Pressure</td>
<td>Absolute Pressure (psia)</td>
<td>Steam Temp. (°F)</td>
<td>Heat of Sat. Liquid (Btu/lb)</td>
<td>Latent Heat (Btu/lb)</td>
<td>Total Heat of Steam (Btu/lb)</td>
<td>Specific Volume of Sat. Steam (cu ft/lb)</td>
<td>Specific Volume of Sat. Steam (cu ft/lb)</td>
</tr>
<tr>
<td>29.743</td>
<td>0.08854</td>
<td>32.00</td>
<td>0.00</td>
<td>1075.8</td>
<td>1075.8</td>
<td>0.016022</td>
<td>3306.00</td>
</tr>
<tr>
<td>29.515</td>
<td>0.2</td>
<td>53.14</td>
<td>21.21</td>
<td>1063.8</td>
<td>1085.0</td>
<td>0.016027</td>
<td>1526.00</td>
</tr>
<tr>
<td>27.886</td>
<td>1.0</td>
<td>101.74</td>
<td>69.70</td>
<td>1036.3</td>
<td>1106.0</td>
<td>0.016136</td>
<td>333.60</td>
</tr>
<tr>
<td>19.742</td>
<td>5.0</td>
<td>162.24</td>
<td>130.13</td>
<td>1001.0</td>
<td>1131.0</td>
<td>0.016407</td>
<td>33.52</td>
</tr>
<tr>
<td>9.562</td>
<td>10.0</td>
<td>193.21</td>
<td>161.17</td>
<td>982.1</td>
<td>1143.3</td>
<td>0.016590</td>
<td>38.42</td>
</tr>
<tr>
<td>7.536</td>
<td>11.0</td>
<td>197.75</td>
<td>165.73</td>
<td>979.3</td>
<td>1145.0</td>
<td>0.016620</td>
<td>35.14</td>
</tr>
<tr>
<td>5.490</td>
<td>12.0</td>
<td>201.96</td>
<td>169.96</td>
<td>976.6</td>
<td>1146.6</td>
<td>0.016647</td>
<td>32.40</td>
</tr>
<tr>
<td>3.454</td>
<td>13.0</td>
<td>205.88</td>
<td>173.91</td>
<td>974.2</td>
<td>1148.1</td>
<td>0.016674</td>
<td>30.06</td>
</tr>
<tr>
<td>1.418</td>
<td>14.0</td>
<td>209.56</td>
<td>177.61</td>
<td>971.9</td>
<td>1149.5</td>
<td>0.016699</td>
<td>28.04</td>
</tr>
</tbody>
</table>

Designs, materials, weights and performance ratings are approximate and subject to change without notice. Visit armstronginternational.com for up-to-date information.
**Steam Tables**

### Flash Steam (Secondary)

**What is flash steam?** When hot condensate or boiler water, under pressure, is released to a lower pressure, part of it is re-evaporated, becoming what is known as flash steam.

**Why is it important?** This flash steam is important because it contains heat units that can be used for economical plant operation—and which are otherwise wasted.

**How is it formed?** When water is heated at atmospheric pressure, its temperature rises until it reaches 212°F, the highest temperature at which water can exist at this pressure. Additional heat does not raise the temperature, but converts the water to steam.

The heat absorbed by the water in raising its temperature to boiling point is called “sensible heat” or heat of saturated liquid. The heat required to convert water at boiling point to steam at the same temperature is called “latent heat.” The unit of heat in common use is the Btu, which is the amount of heat required to raise the temperature of one pound of water 1°F at atmospheric pressure.

If water is heated under pressure, however, the boiling point is higher than 212°F, so the sensible heat required is greater. The higher the pressure, the higher the boiling temperature and the higher the heat content. If pressure is reduced, a certain amount of sensible heat is released. This excess heat will be absorbed in the form of latent heat, causing part of the water to “flash” into steam.

Condensate at steam temperature and under 100 psig pressure has a heat content of 308.8 Btu per pound. (See Column 4 in Steam Table.) If this condensate is discharged to atmospheric pressure (0 psig), its heat content instantly drops to 180 Btu per pound. The surplus of 128.8 Btu re-evaporates or flashes a portion of the condensate. The percentage that will flash to steam can be computed using the formula:

\[
\% \text{ flash steam} = \frac{SH - SL}{H} \times 100
\]

- \(SH\) = Sensible heat in the condensate at the higher pressure before discharge.
- \(SL\) = Sensible heat in the condensate at the lower pressure to which discharge takes place.
- \(H\) = Latent heat in the steam at the lower pressure to which the condensate has been discharged.

\[
\% \text{ flash steam} = \frac{308.8 - 180}{970.3} \times 100 = 13.3\%
\]

Chart 5-3 shows the amount of secondary steam that will be formed when discharging condensate to different pressures. Other useful tables will be found in brochure 873-EN (Useful Engineering Tables).

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**Chart 5-3.**
Percentage of flash steam formed when discharging condensate to reduced pressure.

**Chart 5-4.**
Volume of flash steam formed when one cubic foot of condensate is discharged to atmospheric pressure.
Steam is an invisible gas generated by adding heat energy to water in a boiler. Enough energy must be added to raise the temperature of the water to the boiling point. Then additional energy—without any further increase in temperature—changes the water to steam.

Steam is a very efficient and easily controlled heat transfer medium. It is most often used for transporting energy from a central location (the boiler) to any number of locations in the plant where it is used to heat air, water or process applications.

As noted, additional Btu are required to make boiling water change to steam. These Btu are not lost but stored in the steam ready to be released to heat air, cook tomatoes, press pants or dry a roll of paper.

The heat required to change boiling water into steam is called the heat of vaporization or latent heat. The quantity is different for every pressure/temperature combination, as shown in the steam tables.

**Steam at Work…**

**How the Heat of Steam Is Utilized**

Heat flows from a higher temperature level to a lower temperature level in a process known as heat transfer. Starting in the combustion chamber of the boiler, heat flows through the boiler tubes to the water. When the higher pressure in the boiler pushes steam out, it heats the pipes of the distribution system. Heat flows from the steam through the walls of the pipes into the cooler surrounding air. This heat transfer changes some of the steam back into water. That’s why distribution lines are usually insulated to minimize this wasteful and undesirable heat transfer.

When steam reaches the heat exchangers in the system, the story is different. Here the transfer of heat from the steam is desirable. Heat flows to the air in an air heater, to the water in a water heater or to food in a cooking kettle. Nothing should interfere with this heat transfer.

**Condensate Drainage…**

**Why It’s Necessary**

Condensate is the by-product of heat transfer in a steam system. It forms in the distribution system due to unavoidable radiation. It also forms in heating and process equipment as a result of desirable heat transfer from the steam to the substance heated. Once the steam has condensed and given up its valuable latent heat, the hot condensate must be removed immediately. Although the available heat in a pound of condensate is negligible as compared to a pound of steam, condensate is still valuable hot water and should be returned to the boiler.

**Definitions**

- **The Btu.** A Btu—British thermal unit—is the amount of heat energy required to raise the temperature of one pound of cold water by 1°F. Or, a Btu is the amount of heat energy given off by one pound of water in cooling, say, from 70°F to 69°F.

- **Temperature.** The degree of hotness with no implication of the amount of heat energy available.

- **Heat.** A measure of energy available with no implication of temperature. To illustrate, the one Btu that raises one pound of water from 39°F to 40°F could come from the surrounding air at a temperature of 70°F or from a flame at a temperature of 1,000°F.

**Figure 6-1.** These drawings show how much heat is required to generate one pound of steam at atmospheric pressure. Note that it takes 1 Btu for every 1°F increase in temperature up to the boiling point, but that it takes more Btu to change water at 212°F to steam at 212°F.

**Figure 6-2.** These drawings show how much heat is required to generate one pound of steam at 100 pounds per square inch pressure. Note the extra heat and higher temperature required to make water boil at 100 pounds pressure than at atmospheric pressure. Note, too, the lesser amount of heat required to change water to steam at the higher temperature.
Steam...Basic Concepts

The need to drain the distribution system. Condensate lying in the bottom of steam lines can be the cause of one kind of water hammer. Steam traveling at up to 100 miles per hour makes "waves" as it passes over this condensate (Fig. 7-4). If enough condensate forms, high-speed steam pushes it along, creating a dangerous slug that grows larger and larger as it picks up liquid in front of it. Anything that changes the direction—pipe fittings, regulating valves, tees, elbows, blind flanges—can be destroyed. In addition to damage from this "battering ram," high-velocity water may erode fittings by chipping away at metal surfaces.

The need to drain the heat transfer unit. When steam comes in contact with condensate cooled below the temperature of steam, it can produce another kind of water hammer known as thermal shock. Steam occupies a much greater volume than condensate, and when it collapses suddenly, it can send shock waves throughout the system. This form of water hammer can damage equipment, and it signals that condensate is not being drained from the system. Obviously, condensate in the heat transfer unit takes up space and reduces the physical size and capacity of the equipment. Removing it quickly keeps the unit full of steam (Fig. 7-5). As steam condenses, it forms a film of water on the inside of the heat exchanger. Non-condensable gases do not change into liquid and flow away by gravity. Instead, they accumulate as a thin film on the surface of the heat exchanger—along with dirt and scale. All are potential barriers to heat transfer (Fig. 7-3).

The need to remove air and CO₂. Air is always present during equipment start-up and in the boiler feedwater. Feedwater may also contain dissolved carbonates, which release carbon dioxide gas. The steam velocity pushes the gases to the walls of the heat exchangers, where they may block heat transfer. This compounds the condensate drainage problem, because these gases must be removed along with the condensate.

Figure 7-3. Potential barriers to heat transfer: steam heat and temperature must penetrate these potential barriers to do their work.

Figure 7-4. Condensate allowed to collect in pipes or tubes is blown into waves by steam passing over it until it blocks steam flow at point A. Condensate in area B causes a pressure differential that allows steam pressure to push the slug of condensate along like a battering ram.

Figure 7-5. Coil half full of condensate can’t work at full capacity.

Figure 7-6. Note that heat radiation from the distribution system causes condensate to form and, therefore, requires steam traps at natural low points or ahead of control valves. In the heat exchangers, traps perform the vital function of removing the condensate before it becomes a barrier to heat transfer. Hot condensate is returned through the traps to the boiler for reuse.


**Effect of Air on Steam Temperature**

When air and other gases enter the steam system, they consume part of the volume that steam would otherwise occupy. The temperature of the air/steam mixture falls below that of pure steam. Figure 8-7 explains the effect of air in steam lines. Table 8-2 and Chart 8-5 show the various temperature reductions caused by air at various percentages and pressures.

**Effect of Air on Heat Transfer**

The normal flow of steam toward the heat exchanger surface carries air and other gases with it. Since they do not condense and drain by gravity, these non-condensable gases set up a barrier between the steam and the heat exchanger surface. The excellent insulating properties of air reduce heat transfer. In fact, under certain conditions as little as 1/2 of 1% by volume of air in steam can reduce heat transfer efficiency by 50% (Fig. 9-8).

**Corrosion**

Two primary causes of scale and corrosion are carbon dioxide (CO₂) and oxygen. CO₂ enters the system as carbonates dissolved in feedwater and, when mixed with cooled condensate, creates carbonic acid. Extremely corrosive, carbonic acid can eat through piping and heat exchangers (Fig. 9-9). Oxygen enters the system as gas dissolved in the cold feedwater. It aggravates the action of carbonic acid, speeding corrosion and pitting iron and steel surfaces (Fig. 9-10).

**Eliminating the Undesirables**

To summarize, traps must drain condensate because it can reduce heat transfer and cause water hammer. Traps should evacuate air and other non-condensable gases because they can reduce heat transfer by reducing steam temperature and insulating the system. They can also foster destructive corrosion. It’s essential to remove condensate, air and CO₂ as quickly and completely as possible. A steam trap, which is simply an automatic valve that opens for condensate, air and CO₂ and closes for steam, does this job. For economic reasons, the steam trap should do its work for long periods with minimum attention.

---

**Table 8-2. Temperature Reduction Caused by Air**

<table>
<thead>
<tr>
<th>Pressure (psig)</th>
<th>Temp. of Steam, No Air Present (°F)</th>
<th>Temp. of Steam Mixed With Various Percentages of Air (by Volume) (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>10.3</td>
<td>240.1</td>
<td>234.3</td>
</tr>
<tr>
<td>25.3</td>
<td>267.3</td>
<td>261.0</td>
</tr>
<tr>
<td>50.3</td>
<td>298.0</td>
<td>291.0</td>
</tr>
<tr>
<td>75.3</td>
<td>320.3</td>
<td>312.9</td>
</tr>
<tr>
<td>100.3</td>
<td>338.1</td>
<td>330.3</td>
</tr>
</tbody>
</table>

**Chart 8-5. Air Steam Mixture**

Temperature reduction caused by various percentages of air at differing pressures. This chart determines the percentage of air with known pressure and temperature by determining the point of intersection between pressure, temperature and percentage of air by volume. As an example, assume system pressure of 250 psig with a temperature at the heat exchanger of 375°F. From the chart, it is determined that there is 30% air by volume in the steam.

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When non-condensable gases (primarily air) continue to accumulate and are not removed, they may gradually fill the heat exchanger with gases and stop the flow of steam altogether. The unit is then “air bound.”

**Figure 8-7.** Chamber containing air and steam delivers only the heat of the partial pressure of the steam, not the total pressure.

Steam chamber 100% steam
Total pressure 100 psia
Steam pressure 100 psia
Steam temperature 327.8°F

Steam chamber 90% steam and 10% air
Total pressure 100 psia
Steam pressure 90 psia
Steam temperature 320.3°F
Steam...Basic Concepts

What the Steam Trap Must Do

The job of the steam trap is to get condensate, air and CO₂ out of the system as quickly as they accumulate. In addition, for overall efficiency and economy, the trap must also provide:

1. **Minimal steam loss.** Table 9-3 shows how costly unattended steam leaks can be.

2. **Long life and dependable service.** Rapid wear of parts quickly brings a trap to the point of undependability. An efficient trap saves money by minimizing trap testing, repair, cleaning, downtime and associated losses.

3. **Corrosion resistance.** Working trap parts should be corrosion-resistant in order to combat the damaging effects of acidic or oxygen-laden condensate.

4. **Air venting.** Air can be present in steam at any time and especially on start-up. Air must be vented for efficient heat transfer and to prevent system binding.

5. **CO₂ venting.** Venting CO₂ at steam temperature will prevent the formation of carbonic acid. Therefore, the steam trap must function at or near steam temperature since CO₂ dissolves in condensate that has cooled below steam temperature.

6. **Operation against back pressure.** Pressurized return lines can occur both by design and unintentionally. A steam trap should be able to operate against the actual back pressure in its return system.

7. **Freedom from dirt problems.** Dirt is an ever-present concern since traps are located at low points in the steam system. Condensate picks up dirt and scale in the piping, and solids may carry over from the boiler. Even particles passing through strainer screens are erosive and, therefore, the steam trap must be able to operate in the presence of dirt.

A trap delivering anything less than all these desirable operating/design features will reduce the efficiency of the system and increase costs. When a trap delivers all these features the system can achieve:

1. Fast heat-up of heat transfer equipment
2. Maximum equipment temperature for enhanced steam heat transfer
3. Maximum equipment capacity
4. Maximum fuel economy
5. Reduced labor per unit of output
6. Minimum maintenance and a long trouble-free service life

A steam trap without these design features will reduce the efficiency of the system and increase costs. When a trap delivers all these features the system can achieve:

Sometimes an application may demand a trap without these design features, but in the vast majority of applications the trap which meets all the requirements will deliver the best results.

### Table 9-3. Cost of Various Sized Steam Leaks at 100 psi

<table>
<thead>
<tr>
<th>Size of Orifice</th>
<th>Lbs Steam Wasted Per Month</th>
<th>Total Cost Per Month (USD)</th>
<th>Total Cost Per Year (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2”</td>
<td>12, 7 mm</td>
<td>553,000</td>
<td>$5,530.00</td>
</tr>
<tr>
<td>7/16”</td>
<td>11, 2 mm</td>
<td>423,500</td>
<td>4,235.00</td>
</tr>
<tr>
<td>3/8”</td>
<td>9, 5 mm</td>
<td>311,000</td>
<td>3,110.00</td>
</tr>
<tr>
<td>5/16”</td>
<td>7, 9 mm</td>
<td>216,000</td>
<td>2,160.00</td>
</tr>
<tr>
<td>1/4”</td>
<td>6, 4 mm</td>
<td>138,000</td>
<td>1,380.00</td>
</tr>
<tr>
<td>3/16”</td>
<td>4, 8 mm</td>
<td>78,000</td>
<td>780.00</td>
</tr>
<tr>
<td>1/8”</td>
<td>3, 2 mm</td>
<td>34,500</td>
<td>345.00</td>
</tr>
</tbody>
</table>

The steam loss values assume typical condensate load for drip trap applications. Armstrong methodology for steam trap management and condensate return is sanctioned by the Clean Development Mechanism of the United Nations Framework Convention on Climate Change.

The steam loss values assume typical condensate load for drip trap applications. Armstrong methodology for steam trap management and condensate return is sanctioned by the Clean Development Mechanism of the United Nations Framework Convention on Climate Change.

**Figure 9-8.** Steam condensing in a heat transfer unit moves air to the heat transfer surface, where it collects or “plates out” to form effective insulation.

**Figure 9-9.** CO₂ gas combines with condensate allowed to cool below steam temperature to form carbonic acid, which corrodes pipes and heat transfer units. Note groove eaten away in the pipe illustrated.

**Figure 9-10.** Oxygen in the system speeds corrosion (oxidation) of pipes, causing pitting such as shown here.

Figs. 9-9 and 9-10 courtesy of Dearborn Chemical Company.
At first glance, this may seem confusing due to the idea that superheated steam produces no condensate; therefore, the steam lines carrying superheated steam should not have any condensate in them. This is true once the system is up to temperature and pressure, but condensate removal is necessary up to this point. This section will explain what superheated steam is and the applications for its use.

The specific heat of any substance (using Btu standards) is the quantity of heat required to raise the temperature of 1 pound by 1 degree F. With this definition, the specific heat of water is 1, and the specific heat of superheated steam varies according to temperature and pressure. Specific heat decreases as the temperature rises but increases as the pressure goes up.

Superheated steam is customarily made by the addition of an extra set of coils inside the boiler or in the exhaust area of the boiler so as to use the “waste” heat from the boiler. Or, by the addition of a superheat chamber somewhere after the boiler, attached to the steam main. A schematic diagram of a steam generator with a superheated section of coil is shown below.

Properties of Superheated Steam
Superheated steam has several properties that make it unsuitable as a heat energy exchange medium yet ideal for work and mass transfer. Unlike saturated steam, the pressure and temperature of superheated steam are independent. As superheat is formed at the same pressure as the saturated steam, the temperature and volume increase.

In high heat release boilers with relatively small drums, separation of steam from water is extremely difficult. The combination of the small volume of water in the drums and rapid load swings produces severe shrink and swell conditions in the drum, which promotes water carryover.

This water can be removed with separators and traps in the steam outlets, but they are not 100% efficient. In applications where dry steam is a necessity, additional superheating coils are placed in the boiler furnace as convection passes. More heat is added to the steam to vaporize the water carryover, which adds a small amount of superheat to guarantee absolutely dry steam.

Because superheated steam can give up so little heat before it converts back to saturated steam, it is not a good heat-transfer medium. Some processes, such as power plants, require a dry heat in order to do work. Whatever the type of power unit, superheat helps reduce the amount of condensation when starting from cold. Superheat also increases the power output by delaying condensation during the expansion stages in the equipment. Having drier steam at the exhaust end will increase the life of turbine blades.

Superheated steam can lose heat without condensing whereas saturated steam cannot. Therefore, superheated steam can be transported through very long steam lines without losing sufficient heat to condense. This permits the delivery of dry steam throughout the entire steam system.

Why Trap Superheated Systems?
The primary reason for traps on superheat systems is the start-up load. It can be heavy because of the large size of the mains. On start-up, manual valves will most likely be used since time is available to open and to close the valves. This is known as supervised start-up. A second reason for steam traps is to handle emergencies such as superheater loss or by-pass, which might require operation on saturated steam. In these unscheduled events, there is no time available for manually opening valves; therefore, steam traps are a necessity.

These are the situations for which proper trap sizing is a must. Condensate must be removed as it forms in any steam system to keep efficiency high and to minimize damaging water hammer and erosion.

Figure 10-39. Steam Generator
How to Trap Superheated Steam Lines

Sizing Superheat Loads to Traps

The condensate load to a trap used on superheat will vary widely from severe start-up loads to virtually no load during operation. Consequently, this is a demanding application for any steam trap.

During start-up, very large lines are being filled with steam from cold conditions. At this time, only saturated steam at low pressure is in the lines until the line temperature can be increased. This is done slowly over a long period so the lines are not stressed. Large condensate flow combined with low pressure is the start-up condition that requires the use of large capacity traps. These oversized traps are then required to operate at very high pressures with very low capacity requirements during normal superheat operation.

Typical start-up loads can be roughly calculated as follows:

Using:

\[
C = \frac{0.114 \times Wp (t2-t1)}{H}
\]

Where:

\[
C = \text{Amount of condensate in pounds}
\]

\[
Wp = \text{Total weight of pipe (from Table 11-12, page 12, brochure 857-EN)}
\]

\[
H = \text{Total heat of X pressure minus Sensible heat of Y}
\]

\[
\text{Pressure (Latent heat of steam. For long warm-up times, use the total heat of saturated steam at the superheat steam supply pressure (X) minus the sensible heat of saturated steam at the average pressure (Y) during the warm-up time involved.)}
\]

0.114 = Specific heat of steel pipe in btu/lb °F

EXAMPLE:

Assuming a 100°F/hr (37°C/hr) heat-up

14” (35 cm) diameter Schedule 80 line

Supply superheated steam at 1200 psig 1070°F (85 bar, 577°C)

Ambient temperature is 70°F (21°C)

200 feet (61 m) of run between traps

For the first two hours:

\[
W = (200 \text{ ft}) (107 \text{ lb/ft}) = 21,400 \text{ lb (9727 kg)}
\]

\[
t(2) - t(1) = 270 - 70 = 200°F (93°C)
\]

\[
H = 1184.8 \text{ btu/lb} - 196.27 \text{ btu/lb} = 988.5 \text{ btu/lb} = (474 \text{ kJ})
\]

\[
C = 0.114 \times (21,400 \text{ lb}) (200°F) = 493 \text{ lb (224 kg)}
\]

For the second two hours:

The only thing that changes is the sensible heat of the saturated steam at average pressure during the time involved.

\[
C = \frac{0.114 \times (21,400 \text{ lb}) (200°F)}{851.1 \text{ btu/lb}} = 573 \text{ lb (260 kg)}
\]

Table 11-15. Time Period Table

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Average Pressure psig (bar)</th>
<th>Temperature at End of Time Period °F (°C)</th>
<th>14” Line Condensation Rate lb/hr (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st 2 hours</td>
<td>5 (.35)</td>
<td>270 (132)</td>
<td>247 (112)</td>
</tr>
<tr>
<td>2nd 2 hours</td>
<td>140 (9.8)</td>
<td>470 (243)</td>
<td>286 (130)</td>
</tr>
<tr>
<td>3rd 2 hours</td>
<td>700 (49)</td>
<td>670 (354)</td>
<td>352 (160)</td>
</tr>
<tr>
<td>4th 2 hours</td>
<td>1200 (85)</td>
<td>870 (465)</td>
<td>288 (131)</td>
</tr>
<tr>
<td>5th 2 hours</td>
<td>1200 (85)</td>
<td>1070 (577)</td>
<td>260 (118)</td>
</tr>
</tbody>
</table>

NOTE: For the average pressure of 1,200 psig (85 bar), assume H to be the latent heat of 1,200 psig (85 bar) steam plus superheat at temperature at the end of the period.

To ensure the condensate is removed efficiently, proper drip leg sizing and piping recommendations should also be followed when installing traps on superheat systems. The Table 12-13 on page 12, brochure 857-EN lists the proper drip leg size for given pipe sizes.

The question arises whether insulation should be used on the drip leg, piping leading to the trap, and the trap. The answer is no; unless it is mandatory for safety reasons, this section of the steam system should not be insulated. This ensures that some condensate is continuously being formed ahead of the trap and going to it, thus prolonging the trap’s life.

Types of Superheat Traps

Bimetallic

A bimetallic trap is set to not open until condensate has cooled to a temperature below saturation. For the existing pressure, it will remain closed whenever steam of any temperature is in the trap. As the steam temperature rises, the pull of the bimetallic element becomes greater, providing a greater sealing force on the valve. Superheated steam tends to seal the valve better. The bimetallic trap also has the ability to handle large start-up loads. For these reasons, this trap is a good choice for superheat.

During superheat operation, the condensate in the trap must cool to a temperature below the saturation temperature before the trap can open. Condensate may back up into the line and cause damage to the lines, valves and equipment if drip leg size and length before the trap are insufficient.

Inverted Bucket

A water seal prevents steam from getting to the valve, promoting no live steam loss and long life. The valve at the top makes it impervious to dirt and permits removal of air. Large start-up loads can be handled, and the trap can still accommodate small running loads. There are problems associated with its application on superheat, mostly associated with the necessity of maintaining its water seal or “prime.” Proper piping is necessary to maintain a prime in the IB.

For proper inverted bucket piping on superheat, refer to Figure 12-31, page 12, brochure 857-EN. When sizing a superheat trap, size for start-up load with no safety factor. Body materials should be selected on the basis of maximum pressure and temperature, including superheat.

Designs, materials, weights and performance ratings are approximate and subject to change without notice. Visit armstronginternational.com for up-to-date information.
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