APP-509

Armstrong®

APPLICATION GUIDELINES

TRAPPING SUPERHEATED STEAM SYSTEMS

The purpose of this guideline is to discuss the need and importance of trapping steam and removing condensate from superheated steam lines. Trap sizing and selection, the operation of superheat traps, and cautionary measures will also be discussed.

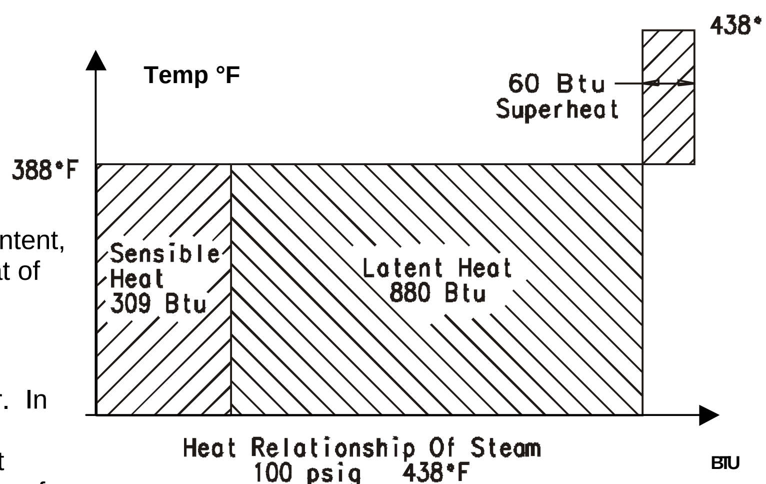
At first glance, this may seem confusing due to the idea that superheated steam produces no condensate, and therefore the steam lines carrying superheated steam should not have any condensate in them. This is true once the system is up to temperature and pressure, but condensate removal is necessary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

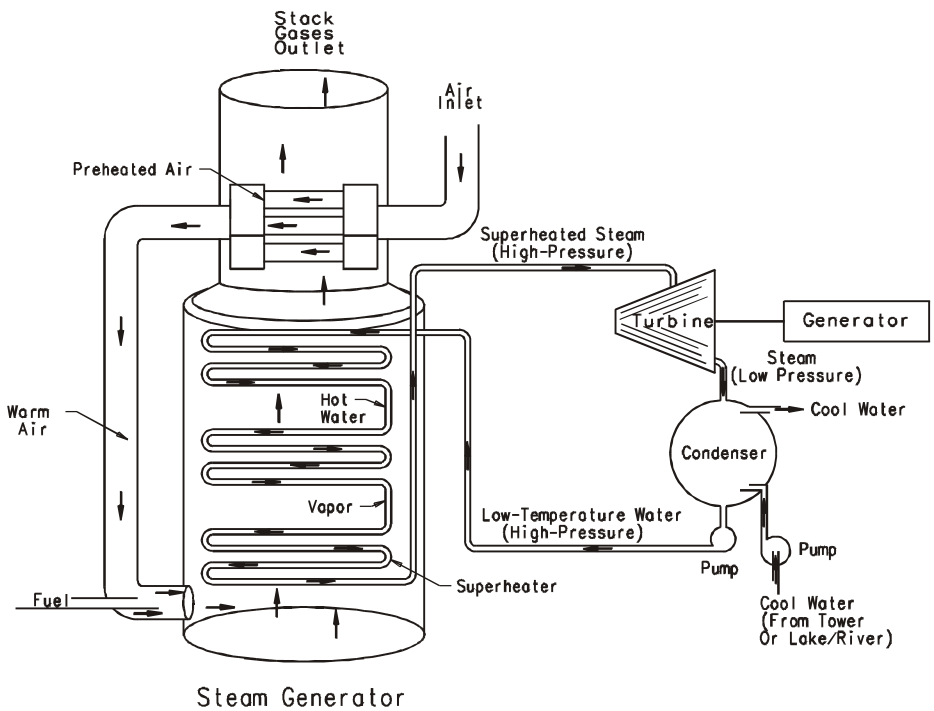
What is Superheated Steam?

Let's start with the production of steam from water and then examine how superheat is produced.

If we take one pound of water at atmospheric pressure and 32°F (0°C) and then add enough heat to bring it to the boiling point, it will take 180 Btu (British Thermal Units) (190 kiloJoules) to get the one pound of water to 212°F (100°C). The energy that is added to the water is in the form of sensible heat, meaning it can be sensed by touch or with a thermometer. If we continue to add heat at this condition, the temperature will not rise above 212°F (100°C) until we change the state of all of the water to vapor (steam). This steam is now in the saturated condition at 212°F (100°C) and occupies a volume of 27 cubic feet (1 cubic meter). We have added another 970 Btu (1023 kJ) to the boiling water in the form of latent heat to convert it to steam. The total amount of heat energy that was added to convert one pound of water at atmospheric pressure to steam was 1150 Btu (1213 kJ). If more heat is added to the steam at these conditions and the volume of the container is increased so that the pressure does not increase, the temperature will rise. The temperature rise of the steam above the saturation at a given pressure is called the superheat temperature.

For instance, if steam at 100 psi gage (7 bar), is further heated above its 338°F (170°C) saturation temperature to 438°F (225°C), it is said to have 100°F (55°C) of superheat, 438 - 338 = 100°F (225 - 170 = 55°C). This extra 100°F (55°C) rise in temperature can be achieved with only a small increase in heat content, 60 Btu per pound (27 kJ/kg). The specific heat of superheated steam is only 0.6 Btu/ lb°F (2.51 kJ/kg°C) as compared to 1.0 Btu/lb°F (4.19kJ/kg°C). Only 4.8% of the total heat is superheat, but the temperature is much higher. In other words, increasing the temperature of superheated steam takes only 60% of the heat energy that it takes to increase the temperature of water the same number of degrees.





The Specific Heat of any substance (using Btu standards) is the quantity of heat required to raise the temperature of one pound by one 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 superheater section of coil is shown above.

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 of each other. 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.

Since superheated steam has such a low quantity of heat that it can give up 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 dryer 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 Superheat Systems?

As mentioned previously, superheat lines do not theoretically have condensate in them, and therefore should not require the use of a steam trap. The facts are that condensate is produced when starting up the system and in the event of the loss of superheat. As the piping comes up to temperature, condensate is produced mostly due to the heat that is absorbed by the cold pipe.

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 bypass 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 keep damaging water hammer and erosion to a minimum.

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 of time so as not to stress the lines. Large condensate flows combined with low pressure, to move through the traps, 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:

$$C = \frac{0.114\ \mathrm{Wp}\,(t2 - t1)}{\mathrm{H}}$$

Where: C = Amount of condensate in pounds
Wp = Total weight of pipe (from Table 17-3 of Handbook N-101)
H = Total Heat of X Pressure - Sensible Heat of Y 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

For example:

Assuming a 100°F/hr (37°C/hr) -Heat up
14" (35cm) 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 (61m) of run in between traps

For the first two hours:

W = (200 ft) (107 lb/ft) = 21,400 lb (= 9727 kg)
t(2) - t (1) = 270 - 70 = 200°F (= 93°C)
H = 1184.8 Btu/lb. - 196.27 Btu/lb. = 988.5 Btu/lb. (= 474 kJ)

$$C = \frac{(0.114\ \mathrm{Btu/lb}\ ^\circ\mathrm{F})(21{,}400\ \mathrm{lb})(200\ ^\circ\mathrm{F})}{988.5\ \mathrm{Btu/lb}} = 493\,\mathrm{lb} \quad (224\,\mathrm{kg})$$

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.

$$C = \frac{(0.114\ \mathrm{Btu/lb}\ ^\circ\mathrm{F})(21{,}400\,\mathrm{lb})(200^\circ\mathrm{F})}{851.5\,\mathrm{Btu/lb}} = 573\,\mathrm{lb} \quad (260\,\mathrm{kg})$$

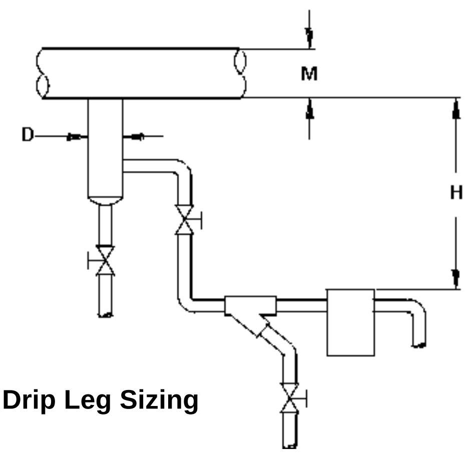
Time Period	Average Pressure psig (BAR)	Temperature at end of time period °F (°C)	14" Line Condensation Rate lb/hr (kg/hr)
1st 2 hours	5 (.35)	270 (132)	247 (112)
2nd 2 hours	140 (9.8)	470 (243)	286 (130)
3rd 2 hours	700 (49)	670 (354)	352 (160)
4th 2 hours	1200 (85)	870 (465)	288 (131)
5th 2 hours	1200 (85)	1070 (577)	260 (118)

NOTE: For the average pressure of 1200 psig (85 BAR), assume H to be the latent heat of 1200 psig (85 BAR) steam plus superheat at temperature at the end of the period.

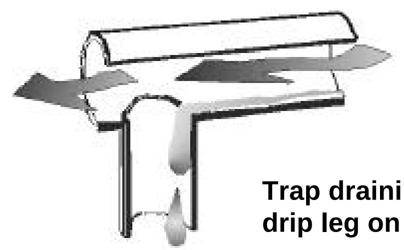
To ensure the condensate is removed efficiently, proper drip leg sizing and piping recommendations should also be followed when installing traps on superheat systems. The following table lists the proper drip leg size for given pipe sizes, while the following diagrams show proper trap piping configurations.

Recommended Steam Main and Branch Line Drip Leg Sizing

M	D	H	
Steam Main Size (in)	**Drip Leg Diameter (in)**	**Drip Leg Length Min. (in)**	
		Supervised Warm-Up	**Automatic Warm-Up**
½	½	10	28
¾	¾	10	28
1	1	10	28
2	2	10	28
3	3	10	28
4	4	10	28
6	4	10	28
8	4	12	28
10	6	15	28
12	6	18	28
14	8	21	28
16	8	24	28
18	10	27	28
20	10	30	30
24	12	36	36



Drip Leg Sizing



Trap draining drip leg on main.

The question arises on 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. The reason for this is to ensure that some condensate is continuously being formed ahead of the trap. This will ensure that the trap has some condensate going to it at all times, thus prolonging the trap's life.

Types of Superheat Traps

Now that the problems have been defined, a look at the various types of traps and their characteristics is in order, to ensure that the best type is used with superheat.

Thermostatic Bimetallic

A thermostatic bimetallic can be set so it will 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 would tend to seal the valve better. For these reasons, this trap looks like 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. The result can be a long back up of condensate behind the trap. Condensate may back-up into the line and cause damage to the lines, valves, and equipment if there is not a sufficient length of drip leg before the trap. For this reason, proper drip leg sizing and layout is mandatory.

Testing of bimetallic types of traps has verified that traps from different manufacturers have definite disadvantages in certain applications. They can be erratic with response time lags, set-point shifts, susceptibility to dirt, and tendencies to increase corrosion in lines and traps. To limit these types of problems when using bimetallic traps, verification of the proper bimetallic trap for each application is a must.

Thermodynamic Disc

The disc type of trap is a time cycle device. As soon as the pressure above the disc is dissipated, the trap will open. It cycles whether or not there is condensate behind it. Since very little condensate will be present even at the trap in superheat applications, any small amount will blow through quickly. The disc does not drop in time to prevent some steam passage. Essentially, the trap is opening and closing with little or no condensate passage. This causes a quicker cycle rate on low or absent load. The result is a very rapid cycle rate with steam passage at high temperatures and pressures causing excessive wear with the result of steam waste and extremely short life.

Float and Thermostatic

If a high pressure float could be found, you still would have the problem of the thermostatic air vent. We have already discussed bi-metal element shortcomings and standard thermostatic elements are not designed to handle extreme superheat conditions. Therefore, a Float and Thermostatic trap can not be used on superheated steam applications.

Float

The float trap will not open unless condensate is present, so it would appear to be a good choice, but there are drawbacks for this type of trap also. High-pressure floats are not common, air can not be removed, and dirt can hang the valve open, thus causing steam loss and rapid wear on the seating surface.

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 still accommodate small running loads. It appears to be the ideal choice, but there are problems associated with its application on superheat, mostly associated with the necessity to maintain its water seal or “prime”. The loss of prime in an inverted bucket trap will result in the valve opening and blowing of live steam. There are several ways in which this can happen; likewise, there are means for preventing this occurrence. Sudden pressure changes can cause backflow out of the trap or flashing of the prime. The means for preventing this is to specify an inlet tube with a check valve at the inlet to the trap. If superheated steam flows into the trap, the extra heat can boil the prime water. There are two ways in which superheated steam can enter the trap; as replacement for the steam passing through the vent, and as replacement for steam condensed by radiation from the trap. If the vent flow provides more heat than the trap radiates, this extra heat can boil away the prime. It has been shown during testing that there is enough radiation loss from the surface area of an inverted bucket trap with a standard bucket vent size so as to not lose the prime in the trap even if there is superheat entering the trap. A comparison of vent flow and radiation losses, assuming superheated steam entering the trap, shows that radiation losses far exceed the vent flow for standard size bucket vents.

In sizing a superheat trap, size for start-up load with no safety factor. Select the main valve on the basis of the maximum pressure differential, but use restricted orifices to suit the trap to the load. Always specify burnished valve and seat. Body materials should be selected on the basis of the maximum pressure of the steam and the steam temperature, including superheat. The allowable maximum conditions in Table 6-2 of the Trap Catalog No. 108, and the Superheat Bulletin No.135 should be used.

Specify the following options when ordering inverted bucket traps for superheat.

1. Inlet tube
2. Check valve at inlet
3. Burnished seats and valves
4. Use smallest orifice possible, restricted orifices if necessary
    a. Size main orifice for pressure
    b. Size restricted orifice for start-up load
5. Avoid insulating the trap and the drip leg if possible

Stainless Steel Traps on Superheat

Stainless steel inverted bucket traps can be used on superheat within their pressure and temperature limitations using the same guidelines suggested for all inverted bucket traps.

Conclusion

To summarize, a properly sized and tight shut-off Inverted Bucket steam trap is the best choice for superheat applications. A possible second choice would be a suitable Bimetallic trap.

Armstrong®

Armstrong International, Inc. www.armstrong-intl.com

816 Maple Street, P.O. Box 408, Three Rivers, MI 49093 - USA Phone: (616) 273-1415

Parc Industriel Des Hauts-Sarts, B-4040 Herstal/Liege, Belgium Phone: (041) 480152

Steam Traps \ Humidifiers \ Steam Coils \ Valves \ Water Heaters \ Strainers Drainers \ Air Vents \ Purgers \ Pumping Traps \ Hose Stations \ Mixing Valves

APP-509 5/98 2.5M **Printed in U.S.A.**