Energy Conservation: Dealing With High Temperature Condensate

Improperly Designed Heat Transfer Systems Using Medium to High Pressure Steam Can Result in Energy Waste Due to Flash Steam

Flash Steam and Why it Occurs

Discharging high pressure/temperature condensate to a lower pressure receiver results in flash steam. The amount of flash steam depends on the temperature of the high temperature condensate and the pressure in the receiver.

The most common case occurs with atmospheric receivers (receivers that are vented to the atmosphere, therefore operating at 0 PSIG). At 0 PSIG water can exist at a maximum temperature of 212 °F. When condensate is discharged from a heat exchanger at a higher temperature, the excess energy causes some of the condensate to flash into 0 PSIG steam at 212 °F, as shown below in Figure 1.

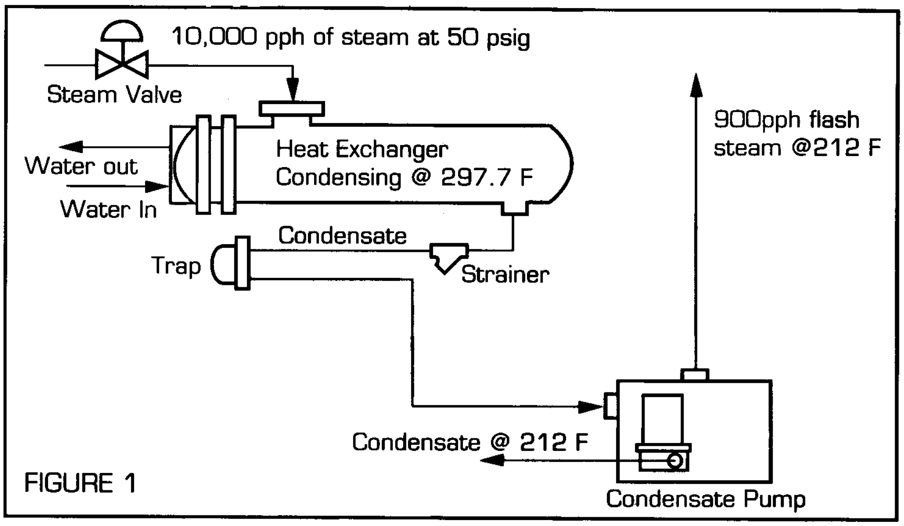

FIGURE 1

The amount that flash can be determined from the table below.

Table 1, Flash Steam

Steam Pressure psig	Atmosphere 0	Flash Tank Pressure-psig 2	5	10	15	20	30	40	60	80	100
5	1.7	1.0	0								
10	2.9	2.2	1.4	0							
15	4.0	3.2	2.4	1.1	0						
20	4.9	4.2	3.4	2.1	1.1	0					
30	6.5	5.8	5.0	3.8	2.6	1.7	0				
40	7.8	7.1	6.4	5.1	4.0	3.1	1.3	0			
60	10.0	9.3	8.6	7.3	6.3	5.4	3.6	2.2	0		
80	11.7	11.1	10.3	9.0	8.1	7.1	5.5	4.0	1.9	0	
100	13.3	12.6	11.8	10.6	9.7	8.8	7.0	5.7	3.5	1.7	0
125	14.8	14.2	13.4	12.2	11.3	10.3	8.6	7.4	5.2	3.4	1.8
160	16.8	16.2	15.4	14.1	13.2	12.4	10.6	9.5	7.4	5.6	4.0
200	18.6	18.0	17.3	16.1	15.2	14.3	12.8	11.5	9.3	7.5	5.9
250	20.6	20.0	19.3	18.1	17.2	16.3	14.7	13.6	11.2	9.8	8.2
300	22.7	21.8	21.1	19.9	19.0	18.2	16.7	15.4	13.4	11.8	10.1
350	24.0	23.3	22.6	21.6	20.5	19.8	18.3	17.2	15.1	13.5	11.9
400	25.3	24.7	24.0	22.9	22.0	21.1	19.7	18.5	16.5	15.0	13.4

Percent flash steam produced when high temperature condensate is discharged to atmosphere or into a flash tank controlled at various pressures.

The Cost of Flash Steam

Flash steam is surprisingly costly! Each pound of lost flash steam results in a pound of fresh water make up, which needs to be heated. The general formula for calculating the associated cost is:

Annual Cost = PPH Flash X (Hg at Flash Pressure – Hf at make up temperature) X HRS/YR X Energy Cost

Where:

Hg = Enthalpy in BTU/# of flash steam
Hf = Enthalpy in the make up water
Energy Cost = Net $/Million BTU

Example:

A heat exchanger operates with 60 PSIG steam. The condensate discharges to an atmospheric receiver. The steam flow is 5,000 PPH. What is the cost of flash steam, assuming an energy cost of $8.50/million BTU and 6,000 hours per year of operation?

Solution:

The first step is to calculate the amount of flash using the flash table. We can see that 10% of the condensate will flash, or 500 PPH. Next we need to look up the enthalpy of 0 PSIG steam (1151 BTU/#, from a steam table) and the enthalpy of 50 ° make up water. Recall that 32 degree water has an enthalpy of 0, and that it takes 1 BTU to raise a pound of water 1° F, so the enthalpy of 50 ° water is (50-32) = 18 BTU/#.

Annual Cost =

500 PPH X (1151 – 18 BTU/#) X 6000 HRS/YR X $8.50/1,000,000 BTU =
$28,893/YR

Methods of Avoiding the Cost of Flash Steam

Several methods can be used to avoid the cost of lost flash steam.

1. Use Low Pressure Steam in Heat Transfer Processes

This involves: 1) selecting the heat exchanger so that it can meet the process load using the lowest possible steam pressure and 2) providing a pressure reducing valve to create steam at that pressure. In certain high temperature processes, this is not possible, as low pressure steam will have insufficient temperature to achieve the desired result.

2. Subcool the Condensate

If the use of high pressure steam is unavoidable, flash steam can be prevented by using a secondary heat exchanger by ITT Standard called a subcooler. The subcooler is a smaller liquid-to-liquid heat exchanger that preheats the process solution with hot condensate. When properly selected, the subcooler will reduce the condensate temperature below the flash temperature, thereby eliminating the flash problem. Figure 2 below shows one arrangement for a primary heat exchanger and a condensate subcooler.

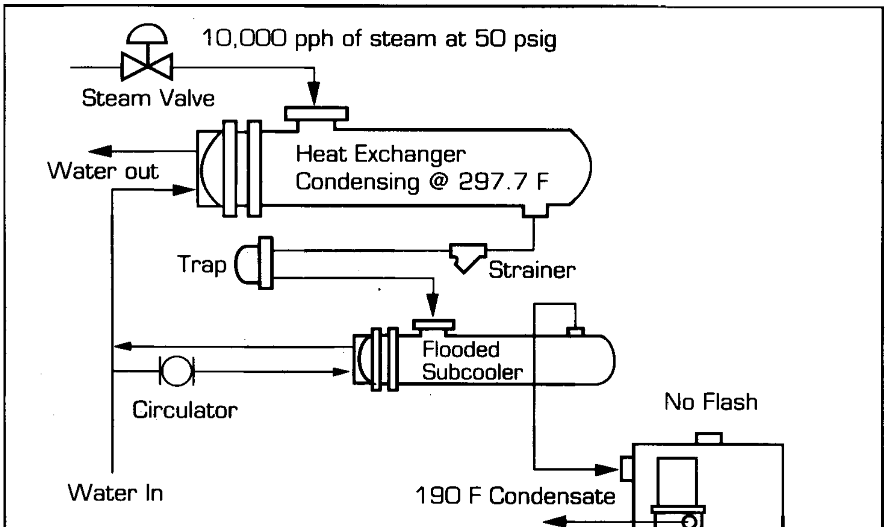

FIGURE 2

Subcooling can also be accomplished in a single, vertically mounted heat exchanger, as shown in Figure 3. In this arrangement, the placement of the pipe loop and the trap result in condensate retention in the lower portion of the heat exchanger shell. The retained condensate is subcooled by heat transfer with the tubes in this portion of the heat exchanger. Careful selection of this type of heat exchanger is required, as steam-to-liquid heat exchange occurs in the upper portion of the shell, while liquid-to-liquid heat transfer occurs in the lower portions.

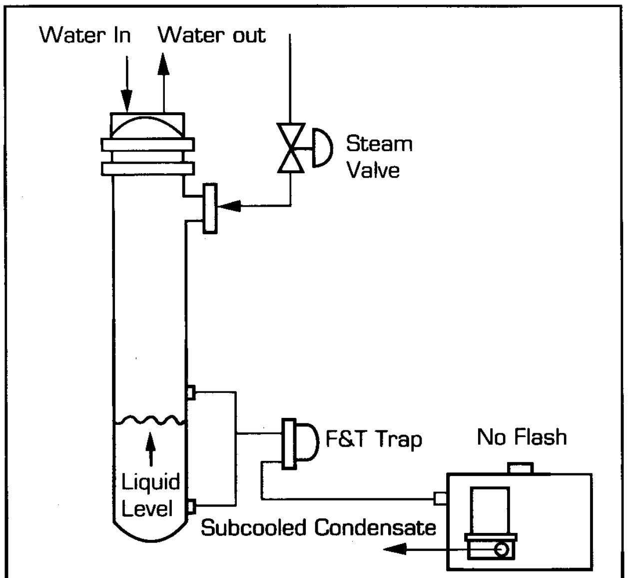

FIGURE 3

3. Use High Temperature Condensate Return Units (CRU's)

An alternate solution is to use a pressurized condensate return unit in lieu of a vented CRU. Shipco style "HT" units are similar in function to standard units, but they have ASME pressurized (non-vented) receivers, which allows handling of condensate at essentially the pressure/temperature that exists in the heat exchanger. They also have elevated receivers and low NPSH pumps to overcome the potential NPSH problem. Standard pump seals allow operation to 250 °F. Tungsten carbide seals allow operation to 300° F.

With high condensate temperatures, it is a good idea to consider flushing the seals with cool water, if available. Flush coolers are available from Elanco. Note that when sizing traps for HT units, the receiver pressure will be essentially the same as the heat exchanger pressure. That means that the only head available across the trap is static head in the drip leg. *In other words, size the trap at a ½ to ¼ PSI differential.*

4. Use Pressure Motive Pumps

Pressure motive pumps from Watson McDaniel or Shipco may be piped to handle high temperature condensate in non-vented applications (they may also be piped to handle vented situations). PMP’s utilize steam pressure rather than electric pumps to move condensate, so seal life is not an issue.

System Considerations When Pumping High Temperature Condensate

If the designer is considering using high temperature condensate return units or pressure motive pumps to return high temperature condensate, there are two important considerations:

1.   Avoid Multiple Heat Exchangers Draining to One HT or PMP Unit

When the heat exchangers are equipped with modulating valves, more than one heat exchanger should not be drained into one pressurized condensate return unit. This is because the condensate receiver pressure could be higher than the modulated pressure in a given heat exchanger, which would prevent free drainage and cause water hammer damage to the heat exchanger.

2.   Heat Balance Considerations

Handling high temperature condensate may be a wonderful idea----*or it may be an expensive way to simply move the flash problem downstream.* Here is the reason: Condensate pumps generally return condensate to a boiler feed unit (BFU) or a deaerator (DA). Most simple boiler feed units operate at atmospheric pressure (212 °F max.). Typical pressurized DA’s run at 5-8 PSIG, which corresponds to a saturation temperature of 227° - 235 °F. Atmospheric DA’s run at very close to 212° F.

The application of a high temperature condensate unit results in hot condensate being returned to the BFU unit or DA. This may cause flashing at the BFU or DA unit! To determine whether a potential problem exists, the following formula is used to calculate the mixture temperature:

Mix Temp =(% HT Return X HT Return Temp) + (% LT Returns X LT Return Temp) + (% Make Up X Make Up Temp)

The calculated Mix Temp must be lower than the saturation temperature at the desired pressure in the BFU or DA vessel.

If the mixture temperature is in excess of the saturation temperature, flash steam will result at the BFU or DA.

Summary

Heat transfer systems utilizing medium to high pressure steam must be carefully designed to avoid energy waste. The system designer may choose from the following methods to achieve optimal energy usage.

- Reduce the steam pressure to the lowest pressure that will achieve the desired fluid temperature
- Subcool the condensate using a separate subcooler or a vertically mounted heat exchanger with a subcooing section.
- Use high temperature condensate return units with electric pumps.
- Use pressure motive pumps piped for non-vented application

A fifth method, use of a flash tank, may or may not work properly when used in heat transfer applications. Watch this WEB site for a future article on this topic, or contact Fluid Handling to discuss it.