Tech Sheet #SPD 208

Don't Overlook the Value of Returning Condensate

It seems obvious to assume that returning condensate from a steam system will result in cost savings. In some cases, it can be a significant cost savings. Most people associate the cost savings of returning condensate primarily with energy reduction (energy savings). Energy savings are a significant benefit for returning condensate, but there are also many other additional benefits. The fuel savings of returning condensate is not the only benefit at the boiler house. Less burned fuel also means less CO_2 emissions from the boiler. Also returning condensate leads to less make-up water needed for boiler feedwater, and less chemicals needed to treat boiler feedwater. In addition, in some cases (when there is NOT returning condensate) the cost to treat and/or cool the condensate before the condensate is released to the city drains is eliminated.

Assuming a natural gas cost of $3.00/MMBTU, let's examine how much of that cost can be recovered by returning 1,000 lb/hr of condensate to the deaerator and boiler.

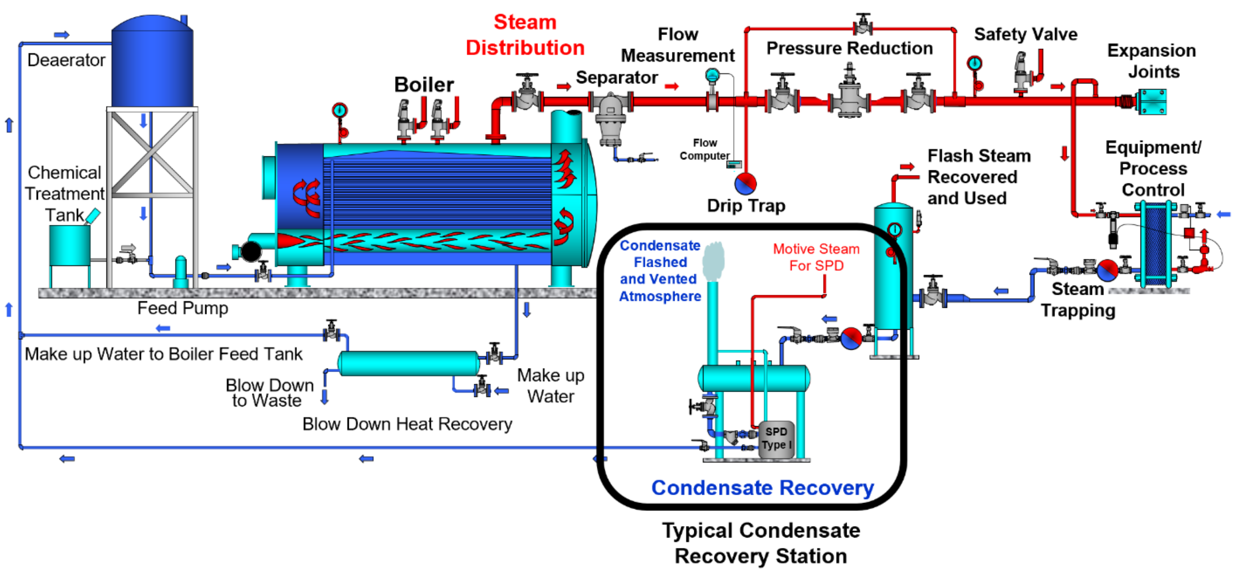
Energy Reduction Fuel Savings

City water or well water is typically at a temperature of around 60°F. However, returned condensate is typically returning to the deaerator and boiler at temperatures near 180°F. The returned condensate has an approximate 120°F "headstart" for heating boiler feedwater to make steam. By returning hot condensate to a boiler, significant energy cost savings can be realized due to the reduced need to heat large volumes of cold makeup water (starting at 60°F), thereby lowering the overall heating load on the boiler system.

From an energy point of view, it takes approximately 120 BTU of sensible heat to raise one (1) lb. of water 120°F, from 60°F city water temperature to 180°F (typical returned condensate temperature). The energy reduction and savings from returning condensate results from not having to heat city water/well water from this lower temperature of 60°F and instead recovering and returning condensate to the boiler at temperatures near 180°F (thereby saving the fuel needed to generate this 120 BTU of sensible heat to raise the temperature of every 1 lb. of water by 120°F).

Unless there is a closed (not vented) condensate return system, not all the condensate from the1000 lb/hr of condensed steam will return to the boiler in liquid form. A typical steam system will recover condensate in open or vented flash vessels before pumping and returning this condensate to the boiler. The hot condensate recovered from the steam system will partially "flash" or vaporize back to steam when it is exposed to atmospheric pressure and vented (lost) to the atmosphere. An exact calculation of how much condensate is flashed (to steam vapor) and lost in this process can be made through a detailed flash steam calculation, but as a rule of thumb it can be assumed that approximately 10% of the recovered condensate will flash and vent to the atmosphere as steam vapor and 90% of the condensate will remain liquid and be pumped and returned to the boiler when evaluating steam systems that operate in the 50 – 100 psig range.

Basic Steam System Layout



Open Condensate Recovery System

The formula below can be used to calculate the annual fuel savings of returning condensate.

$$\text{Annual Fuel Savings (\$/yr)} = (1 - \text{Flash Loss\%}) \times \frac{\text{Returned Condensate (lb/hr)} \times \text{Annual Hours Operation (hr/yr)} \times \text{Make-Up Water Temp Rise (}^{\circ}\text{F)} \times \text{Fuel Cost}}{\text{Boiler Efficiency} \times \text{Net BTU per Unit of Fuel}}$$

For this example, let's examine the fuel savings to recover 1,000 lb/hr of condensed steam. The variables for this example are:

- Returned Condensate = 1,000 lb/hr (approximately 2 GPM)
- Flash Loss = 10%
- Annual Hours Operation = 8,760 hr
- Make Up Water Temp Rise = 120ºF (heating raw water from 60ºF to 180ºF)
- Fuel Cost (natural gas) = \$3.00/MMBTU = \$3.00/1000ft^3 = \$0.003/ft^3
- Net BTU per Unit of Fuel (natural gas) = 1000 BTU/ft^3
- Boiler Efficiency = 80%

$$\text{Annual Fuel Savings (\$/yr)} = (1 - 10\%) \times \frac{1{,}000 \text{ lb/hr} \times 8760 \text{ hr/yr} \times 120^{o}\text{F} \times \$0.003/\text{ft}^3}{80\% \times 1000 \text{ BTU/ft}^3}$$

Annual Fuel Savings = $3,548/yr

In summary, the amount above is saved by avoiding the need to purchase fuel (natural gas) to add 120 BTU/lb to heat raw water from 60°F to 180°F and instead receive and return condensate to the deaerator and boiler at a temperature of 180°F.

Water & Chemical Savings

Raw water (city or well water) needs to be chemically treated to eliminate dissolved oxygen, as dissolved oxygen in boiler feedwater can lead to oxygen infused pitting/corrosion in the steam system piping and components. Chemical treatment also helps to minimize scale and corrosion at the boiler and throughout the steam and condensate systems. Condensate is boiler feedwater which has already been treated (and heated). Recovering condensate can dramatically reduce the chemical treatment of boiler feedwater. Also, raw water (used for make-up feedwater) in and of itself may represent an additional cost to purchase city water or pump well water. Also, in some jurisdictions any condensate that is dumped or drained into a sewer may need to be cooled and treated, which will add even greater cost. Water and chemical savings can be calculated by using the formula below:

$$\text{Annual Water \& Chemical Savings (\$/yr)} = (1 - \text{Flash Loss\%}) \times \frac{\text{Returned Condensate (lb/hr)} \times \text{Annual Hours Operation (hr/yr)} \times \text{Total Water Cost}}{8.34 \text{ lb/gal}}$$

For this example, let’s examine the water and chemical savings to recover 1,000 lb/hr of condensed steam. The variables for this example are:

- Returned Condensate = 1,000 lb/hr (approximately 2 GPM)
- Flash Loss = 10%
- Annual Hours Operation = 8,760 hr
- Raw Water/Make-up Water Cost = $0.007/gal
- Water Treatment Cost = $0.008/gal
- Sewage Cost = $0.004/gal

$$\text{Annual Water \& Chemical Savings (\$/yr)} = (1 - 10\%) \times \frac{1{,}000 \text{ lb/hr} \times 8{,}760 \text{ hr/yr} \times (\$0.007 + \$0.008 + \$0.004) \text{ \$/gal}}{8.34 \text{ lb/gal}}$$

Annual Water & Chemical Savings ($/yr) = $17,961/yr

CO_2 Emissions Reduction

We previously reviewed the energy reduction cost savings that can be achieved by returning 1,000 lb/hr of condensed steam, which is actually 900 lb/hr of condensate received as boiler feedwater when you consider that 10% of the condensate will flash and vent to atmosphere. This savings is achieved by eliminating the need to heat raw water from 60°F to a typical condensate return temperature of 180°F. This will save burning the fuel necessary to generate 120 BTU sensible heat for raising the temperature of 1 lb. of raw water by 120°F (60°F to 180°F).

Let's step back and focus on the fuel side. How much natural gas is consumed to heat 900 lb/hr of condensate (considering that 10% of recovered condensate to flash steam/ atmosphere has been lost) from 60°F to 180°F?

The variables for this example are:

- Returned Condensate = 1,000 lb/hr (approximately 2 GPM)
- Flash Loss = 10%
- Annual Hours Operation = 8,760 hr
- Sensible Heat to Increase 1 lb Water by 120°F (60°F to 180°F) = 120 BTU/lb
- Net BTU per Unit of Fuel (natural gas) = 1000 BTU/ft^3

$$\text{Annual Fuel Consumed (Mcf/yr)} = (1 - \text{Flash Loss\%}) \times \frac{\text{Returned Condensate (lb/hr)} \times \text{Annual Hours Operation (hr/yr)} \times \text{Sensible Heat (BTU/lb)}}{\text{Net BTU per Unit of Fuel (natural gas)} \times (1000\ \text{ft}^3 = 1\ \text{Mcf})}$$

$$\text{Annual Fuel Consumed (Mcf/yr)} = (1 - 10\%) \times \frac{1{,}000\ \text{lb/hr} \times 8{,}760\ \text{hr/yr} \times 120\ \text{BTU/lb}}{1000\ \text{BTU/ft}^3 \times (1000\ \text{ft}^3 / 1\ \text{Mcf})}$$

Annual Fuel Consumed = 946.1 Mcf/yr

According to the United States Environmental Protection Agency (EPA) Greenhouse Gas Equivalency Calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator), there are 55 metric tons of CO2 released to the atmosphere for every 1,000 Mcf of natural gas that is burned/consumed. Now we can calculate the amount of CO2 emissions that can be saved/reduced by returning 1,000 lb/hr of condensate.

Annual CO_2 Impact = (946.1 Mcf/yr) X (0.055 metric ton CO2/Mcf) = 52.3 metric ton/yr

Conclusion - Summary

The costs of operation a steam utility system typically range between $8.00 - $10.00 to produce 1000 lb. of steam (with natural gas cost at $3.00/MMBtu). If plant steam demand is 20,000 – 30,000 lb/hr, the costs are between $1.5 - $2.5 MUSD per year to generate steam for delivering heat to the process. Returning the condensate generated from a steam system allows the recovery of some of that heat and investment in boiler feedwater chemical treatment. Recovering condensate can represent significant cost savings and reduce boiler plant CO_2 emissions. Consider that for every 1,000 lb/hr of condensate that is returned:

- Returning high temperature condensate will save the energy needed to heat cold raw city/well water (approximately 60°F). This energy savings and reduction in fuel consumption results in an approximate savings of $3,548/yr.
- Returning condensate will reduce the need for boiler make-up feedwater and its associated chemical treatment, as well as reducing sewer costs, resulting in an additional savings of $17,961/yr.
- The fuel that is consumed and combusted to heat city/well water (60°F) to typical condensate return temperatures (180°F) results in 57.8 metric tons of annual CO_2 emissions to the atmosphere.

These savings and benefits will typically justify the cost of installing and operating condensate return pumps as well as installing the other infrastructure associated with a condensate return system.

The example and calculations outlined in this tech sheet apply to a relatively simple steam system. In the case of more complex systems with integrated heat recovery (for example a flue gas economizer to preheat boiler feedwater) or a system that is vent balanced (venting low pressure steam to compensate for heavy high pressure steam demand) a more involved steam system balance is required to determine the exact energy impact and savings of condensate recovery projects.

To learn more about condensate return pumps, visit the Secondary Pressure Drainer Section of the FCI website at https://www.fluidcontrolsinstitute.org/fci-secondary-pressure-drainers.asp.

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