Recommendation

Install a flash steam recovery tank to capture the boiler flash steam and preheat the feed water, rather than using boiler steam, reducing hog fuel use by 14.5%.

Annual Savings Summary

Source	*Quantity*	*Units*	*Cost Savings*
Hog Fuel	896	BDT	$17,929

Implementation Cost Summary

Description	*Cost*	*Payback (yrs)*
Implementation Cost	$8,549	0.5

Facility Background

The facility operates a hog fuel boiler as its primary source of steam and maintains a backup natural gas boiler to provide additional steam when the primary boiler cannot keep up with demand. The hog fuel boiler has an average firing rate of 25.5 MMBtu per hour, with an average steam supply rate of approximately 25,000 pounds per hour. Hog fuel is typically sold at a cost of $20/BDT and annual fuel use is approximately 9,547 BDT (bone-dry tons) of hog fuel, the total value of the fuel is approximately $190,940. The natural gas boiler's maximum steam supply is 12,700 pounds per hour, and the incremental cost of natural gas is $3.20/MMBtu. Steam pressure is maintained at 190 psig and temperature is assumed to be 384 °F for saturated steam at that pressure. During the assessment, analysts observed that flash steam from the condensate was vented directly to the atmosphere.

Opportunity Background

When condensate returns from the process, the pressure typically drops after the steam trap to atmospheric pressure. However, the condensate contains more energy than can be contained as liquid at reduced pressure. During this transition, excess energy turns a portion of the condensate into flash steam. Many facilities simply vent this flash steam to the atmosphere, losing the mass of steam and associated energy. Energy that is released in the flash steam could be used to pre-heat water to the boiler, lowering make-up energy usage. Recapturing the flash steam can also reduce make-up water and treatment costs, as well as reducing required blowdown. Energy recapture can be accomplished through direct injection of steam into the incoming water stream or a mixing tank, or through the use of a heat exchanger.

Proposal

Install a mixing tank to capture the condensate flash steam to pre-heat boiler makeup water. This will save $17,929 annually after an implementation cost of $8,549, resulting in a simple payback of 0.5 years.

Vendor Data

Analysts contacted Armstrong International in Three Rivers, MI, Cole Industrial in Lynnwood, WA, Penn Separator in Brookville, PA, and Spirax Sarco in Blythewood, SC, and received one quote from a vendor for a flash separator tank priced at $1,717. Related equipment is an additional $579 for a total of $2,296. This does not include labor estimates or site-specific piping.

Implementation

High-pressure condensate returning from the process is routed into a flash separator (Figure 3.2.1), which reduces pressure to the deaerator tank pressure. The deaerator is where dissolved oxygen and carbon dioxide are removed from boiler feedwater. The flash separator tank captures the flash steam at this lower pressure and routes it to low-pressure steam uses, such as wood block conditioning. Low-pressure steam can also be used to preheat boiler water [1].

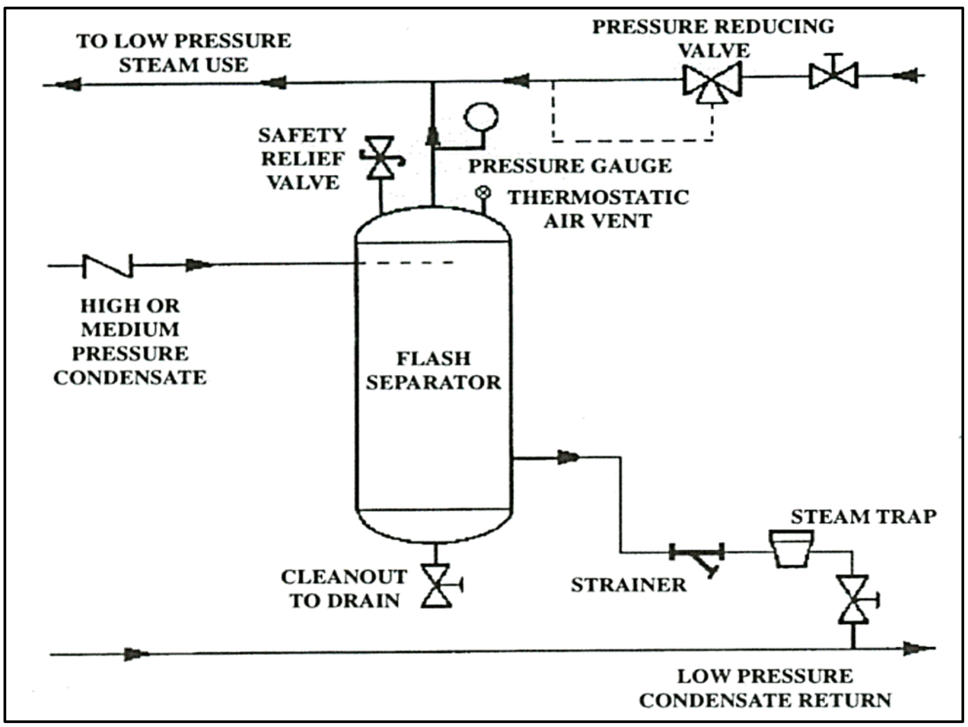

Figure 3.2.1: Schematic of a flash separation system. [1]

Incentives

This recommendation does not reduce utility consumption and will likely not qualify for typical incentives. This does not necessarily mean incentives are unavailable; custom incentives can sometimes be arranged.

Calculation Methodology

Data on typical steam production, steam temperature, condensate return volume, and feedwater temperature were collected on site. Annual steam production and makeup water were calculated from production data, which allowed analysts to calculate total energy use for the boiler. The available heating load is calculated based on the difference between the target temperature of water coming out of the boiler and temperature of water coming into the boiler. Available heating load is the quantity of heat needed to raise the water to its desired temperature. Available flash energy is the quantity of heat within the steam that is flashed based on the ratio of high and low-pressure condensate enthalpies. This ratio is a percentage of the condensate that is lost due to the flashing process. These data are included on the Data Preparation page, and available flash energy is calculated on the Analysis page. The available heat remaining in the low-pressure flash steam was calculated on the Analysis page. It is assumed that this heat has value for low-pressure steam applications, and analysts calculated savings based on the ratio of flash steam waste heat over total heat produced.

Next Steps

The next step in pursuing the savings outlined in this report is to confirm that estimates and calculations made in this report are accurate. Capturing flash steam can also reduce the treatment cost of make up water, therefore savings may be more than estimated in this report. Providing vendors with steam production and pressure will allow them to recommend an appropriately sized flash steam recovery tank.

Note

Analysts assumed the boiler is operating year-round at the steam production capacity stated in Data Preparation. Confirm annual steam production rates for a more accurate savings estimate.

References

[1] Penn Separator, "Condensate Handling and Flash Steam Recovery," *Literature Library by Penn Separator* . [Online]. Available: http://www.pennseparator.com/pdf/psc_flash_separators.pdf. [Accessed: 24 Apr 2018].

[2] R. B. Avery, P. L. Wilson, and J. W. Funck, *Fuelwood Characteristics of Northwestern Conifers and Hardwoods.* Research Bulletin 60. Corvallis, OR: Forest Research Laboratory, College of Forestry, Oregon State University, 1987, 21-22.

[3] M. Mossman, Ed., *RSMeans Mechanical Cost Data 2016* , 39th ed. RSMeans, 2015.

[4] "Properties of Saturated Steam - Imperial Units," *Engineering ToolBox,* (2003). [Online]. Available: https://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html [Accessed 30 May 2018].

[5] "Water - Heat Capacity (Specific Heat)," *Engineering ToolBox,* (2004). [Online]. Available: https://engineeringtoolbox.com/specific-heat-capacity-water-d_660.html [Accessed 11 May 2018].

[6] "Water - Enthalpy (H) and Entropy (S)," *Engineering Toolbox,* (2009). [Online] Available: https://www.engineeringtoolbox.com/water-properties-d_1508.html [Accessed 20 May 2018].

[7] "Water - Heat of Vaporization," *Engineering Toolbox,* (2010). [Online]. Available: https://www.engineeringtoolbox.com/water-properties-d_1573.html [Accessed 30 May 2018].

3 - AR No. 2 - Data Preparation

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Flash Steam Recovery, style 2018 v1.0

Available Heating Load Analysis

Operational Data

Hourly Steam Production	(m_S)	*25,000*	lbm/hr	**(N. 1)**
Operation hours	(t_{OH})	*7,488*	hrs	**(N. 1)**
Condensate Return Ratio	(C_R)	*40%*		**(N. 1)**
Make-up Water Use	(m_w)	*112,320,000*	lbm/yr	**(Eq. 1, N. 1)**
Steam Pressure	(P_{SC})	*190*	psig	**(N. 1)**
Feedwater Temperature	(T_i)	*210*	°F	**(N. 1)**
Steam Temperature	(T_{hw})	*384*	°F	**(N. 2)**
Hourly Boiler Energy	(E_B)	*25.5*	MMBtu/hr	**(Eq. 2)**
Boiler Efficiency	(η_B)	*71%*		**(N. 3)**
Total Hog Fuel Use (energy)	(E_H)	*190,789*	MMBtu/yr	**(Eq. 3, N. 1)**

Water Properties

Specific Heat of Water	(c_P)	*1.01*	Btu/lbm·°F	**(N. 4)**
Steam Enthalpy	(h_S)	*1,199*	Btu/lbm	**(N. 5)**
Feedwater Enthalpy	(h_F)	*180*	Btu/lbm	**(N. 5)**

Heating Load

Available Heating Load	(q_W)	*27,720*	MMBtu/yr	**(Eq. 4)**

Equations

Eq. 1) Makeup Water (m_W)

$$m_S \times t_{OH} \times (1 - C_R)$$

Eq. 2) Hourly Boiler Energy (E_B)

$$m_S \times (h_S - h_F) \times \frac{1MMBtu}{1{,}000{,}000Btu}$$

Eq. 3) Total Hog Fuel Usage (energy) (E_H)

$$E_B \times t_{OH}$$

Eq. 4) Available Heating Load (q_W)

$$\frac{(T_{hw} - T_i) \times c_P \times m_W}{\eta_B} \times \frac{1MMBtu}{1{,}000{,}000Btu}$$

Notes

N. 1) Based on production data provided by boiler operations personnel.

N. 2) Temperature of saturated steam at current steam pressure. [4]

N. 3) Boiler efficiency calculated internally based on data collected on site.

N. 4) Specific heat for feedwater temperature T_i [5].

N. 5) Enthalpy of saturated steam at P_{SC} [4] and condensate at T_i and atmospheric pressure [6].

Key Input Data

Operational Data

Condensate Return	(m_{RC})	*112,320,000*	lbm/yr	**(N. 6)**
Hog Fuel HHV	(HHV_H)	*20*	MMBtu/BDT	**(N. 7)**
Total Hog Fuel Usage (mass)	(m_H)	*9,539*	BDT/yr	**(Eq. 5)**

Incremental Energy Data

Hog Fuel Cost	(C_F)	*$20.00*	/BDT	**(N. 1)**
Incremental Steam Cost	(IC_H)	*$1.00*	/MMBtu	**(Eq. 6)**

Water Properties

Fraction of Condensate Flash Steam	($m_{\%}$)	*16.6%*		**(Eq. 7)**
Proposed Condensate Pressure	(P_{CP})	*6.0*	psig	**(N. 8)**
High Pressure Condensate Enthalpy	(H_{HP})	*358*	Btu/lbm	**(N. 9)**
Low Pressure Condensate Enthalpy	(H_{LP})	*198*	Btu/lbm	**(N. 9)**
Low Pressure Heat of Vaporization	(H_V)	*959*	Btu/lbm	**(N. 9)**

Energy Analysis

Current Conditions

Available Heating Load	(q_W)	*27,720*	MMBtu/yr	**(N. 6)**
Current Energy Consumption	(E_H)	*190,789*	MMBtu/yr	**(Eq. 3)**
Current Energy Cost	(C_C)	*$190,789*	/yr	**(Eq. 8)**

Proposed Conditions

Available Flash Energy	(q_F)	*17,929*	MMBtu/yr.	**(Eq. 9)**
Proposed Energy Consumption	(E_P)	*172,860*	MMBtu/yr	**(Eq. 10)**
Proposed Energy Cost	(C_P)	*$172,860*	/yr	**(Eq. 8)**

Energy Savings

Energy Savings	(E_S)	*17,929*	MMBtu/yr	**(N. 10)**
Fuel Savings	(F_S)	*896*	BDT/yr	**(Eq. 11)**
Cost Savings	(C_S)	*$17,929*	/year	**(N. 11)**

Equations

Eq. 5) Total Hog Fuel Usage (m_H)

$$\frac{E_H}{HHV_H}$$

Eq. 6) Incremental Steam Cost (IC_H)

$$\frac{C_F}{HHV_H}$$

Eq. 7) Condensate Flash Percent (m%)

$$\frac{H_{HP} - H_{LP}}{H_V}$$

Eq. 8) Energy Cost (C_C, C_P)

$$E_{H,P} \times IC_H$$

Eq. 9) Available Flash Energy (q_F)

$$H_V \times m_{\%} \times m_{RC} \times \frac{1\ MMBtu}{1{,}000{,}000\ Btu}$$

Eq. 10) Proposed Energy Consumption (E_P)

$$E_H - q_F$$

Eq. 11) Fuel savings (F_S)

$$\frac{E_S}{E_H} \times m_H$$

Notes

N. 6) Developed in Data Preparation on the previous page.

N. 7) Higher heating value of hog fuel based on assumption of primarily Douglas fir bark. Values taken from OSU Forest Research Lab Bulletin 60 [2].

N. 8) Pressure of deaerator tank, provided by boiler operations personnel.

N. 9) Condensate properties at P_{SC} and P_{CP} [4], [7].

N. 10) Energy savings is based on the minimum of the available heating load and flash steam energy values.

N. 11) Cost savings developed in Implementation on next page. Savings do not include reducing the make-up water purchased, reduced water treatment cost, or savings from make-up natural gas.

Flash Steam Recovery, style 2018 v1.0

Implementation Cost Analysis

Material Costs

Flash Steam Recovery Tank	(C_{M1})	*$2,296*	/unit	**(N. 12)**
Pipe Cost (incl. labor)	(C_P)	*$105*	/ft	**(N. 13)**
Required Pipe Length	(L_P)	*50*	ft	**(N. 14)**
Total Pipe Costs	(C_{M2})	*$5,253*	/unit	**(Eq. 12)**

Labor Costs

Labor Rate	(R_L)	*$50*	/hr	**(N. 12)**
Labor Hours	(t_L)	*20*	hours	**(N. 12)**
Total Labor Cost	(C_{L1})	*$1,000*		**(Eq. 13)**

Economic Results

Annual Cost Savings	(C_S)	*$17,929*	/year	**(N. 11, Eq. 14)**
Implementation Cost	(C_I)	*$8,549*		**(Eq. 15)**
Simple Payback	(t_{PB})	*0.5*	years	**(Eq. 16)**

Equations

Eq. 12) Total Pipe Installation Costs (C_{M2})

$$C_P \times L_P$$

Eq. 13) Total Labor Cost (C_{L1})

$$t_L \times R_L$$

Eq. 14) Annual Cost Savings (C_S)

$$E_S \times IC_H$$

Eq. 15) Implementation Costs (C_I)

$$C_{M1} + C_{L1} + C_{M2}$$

Eq. 16) Simple Payback (t_{PB})

$$\frac{C_I}{C_S}$$

Notes

N. 12) Third party quote for a pressure-rated, 15,000 pound per hour flash steam recovery tank.

N. 13) Value from RSMeans 2016 based on 4" copper pipe plus 10% for insulation, including labor and materials [3].

N. 14) Length based on rough estimate of distance from flash vessel to deaerator.