White Paper 7800-002
Steam Management
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DISTRICT HEATING STEAM CONDENSATE ENERGY AND WATER SAVINGS OPPORTUNITY

1.01 BACKGROUND

A. This paper is meant to give a background into the potential energy and water savings methods associated with steam condensate recovery. While we give a broad overview of legacy and new methods of implementing such methods, the desired outcome would be for Steam Management, Inc. to work with you in a collaborative relationship to find the solutions that best fit your needs.

1.02 INTRODUCTION

A. Large Cities, Medical Complexes and Universities that are served by district heating systems have the potential to provide significant water and energy savings for the end users of these systems. In some systems the end users of a steam supplied district heating system are not required to return the steam condensate. In other systems the steam condensate is required to be returned but there is no cost penalty for the temperature of the condensate being returned.

1.03 SAVINGS

A. Non-Returned Steam Condensate

1. For district steam heating systems that do not require returning the condensate to the central district heating plant, the condensate typically is discharged to the sanitary sewer. Building Codes require that the condensate be cooled before being discharged to the sewer. This cooling is typically being done by mixing potable water with the condensate. This represents a potential opportunity to recover not only the condensate water but also the cooling water being discharged. All of which represent cost savings for the end user of the district heating system.

2. The steam condensate water is essentially distilled water since the steam generating process eliminates most of the total solids in the water. The mixing of the steam condensate with potable water to lower its temperature ends up with an ideal water quality to be used for end user purposes such as cooling tower makeup water, toilet flush water and landscape irrigation water thus offsetting part of the costs for purchased water.

B. Returned Steam Condensate

1. For district steam heating systems that require the condensate to be returned but no penalty for low temperature of condensate being returned, the energy in the condensate can be recovered before being sent back to the district heating plant. This recovered energy can be used to offset space heating and domestic hot water heating.

1.04 ENERGY RECOVERY

A. Since steam condensate water is at a high temperature, it represents a considerable potential energy source for the end user. The energy in the steam condensate can be recovered using a water-to-water heat exchanger. The hot condensate energy is transferred to a lower temperature water source and that is used to offset a process heating need. This transfer of energy is accomplished by the end user before pumping the steam condensate back to the district heating plant.

B. The concept behind a heat exchanger is the use of pipes or other containment vessels to heat or cool one fluid by transferring heat between it and another fluid. In most cases, the exchanger consists of a coiled pipe containing one fluid that passes through a chamber containing another fluid. The walls of the pipe are usually made of metal, or another substance with a high thermal conductivity, to facilitate the interchange, whereas the outer casing of the larger chamber is made of a plastic or coated with thermal insulation, to discourage heat from escaping from the exchanger.

C. Most of the heat exchangers used in industry are shell and tube, or plate and frame. Typically, plate and frame heat exchangers are used for liquid-liquid exchange at low to medium pressures. However, gasket-free plate and frame heat exchangers can safely operate at high temperatures and pressures. Plate and frame heat exchangers offer flexibility because plates can be either added or compressed for each different situation.

D. Plate and frame heat exchangers are made of corrugated plates on a frame. This design creates high turbulence and high wall shear stress, both of which lead to a high heat transfer coefficient and a high fouling resistance. Fluids travel within the heat exchanger. The two streams flow counter currently. The hot fluid flows down one plate while the cold fluid flows up the other plate.

E. Shell and tube heat exchangers are suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc.

1.05 WATER RECOVERY

A. In lieu of cooling the steam condensate and then discharging it to the sewer, the steam condensate thermal energy should be evaluated for potential uses by the end user. It should be noted that this evaluation may involve the assessment of using the thermal energy as discussed above in addition to the water recovery.

B. After the water is cooled either by transferring the thermal energy or mixing it with potable water for cooling, it needs to have some type of storage with a pumping and conveyance for the intended use.

1.06 EXAMPLE

A. This example project is for an art museum being supplied with steam by a district heating plant. Main Building steam condensate is being discharged to sewer. The Building codes requires that the condensate be cooled before being discharged to the sewer. This cooling is being done by mixing potable water with the condensate. This cost saving opportunity is to use the water being sent to drain for makeup water in the museum air conditioning cooling towers. The following data applies to the project.

1. Water Rate: $3.81/1,000 gallons.
2. Sewer Rate: $4.34/1,000 gallons.
3. Steam/Energy Cost Rate: @20.54/1,000 pounds.
4. Electric Rate: $0.0553/KWH.
5. Annual Operating Hours (AOH): 8,760.
6. Condensate Temperature: 180°F.
7. Potable Water Temperature: 55°F.
8. Condensate Is Being Cooled To: 110°F.
9. Annual Average Steam Flow: 9,178 pounds/hour.
10. Cooling Tower Condenser Water Flow Rate: 2,800 gallons per minute.
11. Cooling Tower Drift Rate: 0.005%.
12. Cooling Tower Operating Power: 0.4 KW/Ton.

13. Cooling Tower Condenser Water Supply Temperature: 75°F.

14. Cooling Tower Evaporation Rate: 1% of flow rate.

B. Estimated Annual Savings:

1. Total Annual Cost Savings: $111,200.00.

2. Total Annual Water Savings: 14,680,000 gallons.

3. Total Annual Sewer Savings: 14,680,000 gallons.

4. Total Annual Increase in Electric Use: 153,300 KWH.

C. Calculations are attached.

STEAM CONDENSATE RECOVERY OPPORTUNITY:

Museum Main Building steam condensate is being discharged to sewer. The plumbing code requires that the condensate be cooled before being discharged to the sewer. This cooling is being done by mixing potable water with the condensate. This cost saving opportunity is to use the water being sent to drain for makeup water in the cooling towers. This opportunity would result in water, and sewer cost savings.

Given Data:

Water Rate $3.81/1000 gallons
Sewer Rate $4.34/1000 gallons
Steam/Energy Rate $20.54/1000 pounds
Electric Rate $0.0553/KWH
Annual Operating Hours (AOH) 8760
Annual Steam Consumed (ASC)
Average Steam Flow 9,178 pounds/hour

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$$WaterCost\$:= \frac{3.81 \cdot \$}{1000\ gal}$$

$$SewerCost\$:= \frac{4.34 \cdot \$}{1000 \cdot gal}$$

$$FuelCost\$:= \frac{20.54\ \$}{10^6 \cdot Btu}$$

$$AOH := 8760 \cdot hr$$

$$ElectricCost\$:= \frac{0.0553\ \$}{kW \cdot hr}$$

Assumptions:

1. Condensate is equal to 67% of steam use in 2016-2017 due to steam losses from steam vents and humidification steam and proposed reductions in the number of steam heating coils.
2. Condensate water recovery can be used in cooling towers.
3. Condensate Temperature 180 F.
4. Potable Water Temperature 55 F.
5. Condensate is cooled to 110 F for sewer discharge.
6. Cooling tower condenser water flow rate, 2800 GPM (TFR).
7. Cooling tower cycles of concentration, 3 (C).
8. Cooling tower drift rate, 0.005%, (D)
9. Cooling tower operating power, 0.4 kW/ton, (TP)
10. Evaporation Rate 1% of flow rate.
11. Cooling tower condenser water supply temperature to chiller, 75 F.

$$ASC := 9178 \cdot \frac{lb}{hr} \cdot AOH$$

$$ASC = \left(8.04 \cdot 10^7\right)\ lb$$

$$Condensate := 0.67 \cdot \frac{ASC}{8.34 \cdot \frac{lb}{gal}}$$

$$Condensate = 6458935\ gal$$

$$TFR := 2800 \cdot \frac{gal}{min}$$

$$C := 3 \qquad D := 0.00005$$

$$TP := 0.4 \cdot \frac{kW}{12000 \cdot \frac{Btu}{hr}}$$

Cooling Tower Water Use (TWU):

$Evaporation := 0.01 \cdot TFR$ $Evaporation = 28\ \frac{gal}{min}$

$Blowdown := \frac{Evaporation}{(C-1)}$ $Blowdown = 14\ \frac{gal}{min}$

$Drift := D \cdot TFR$ $Drift = 0.14\ \frac{gal}{min}$

$TWU := Evaporation + Blowdown + Drift$ $TWU = 42.14\ \frac{gal}{min}$

Condensate Cooling Water/Sewer (CWS):

Cooling water and sewer required to cool condensate from 180 F to 110 F using potable water at 55 F. Required by plumbing code before condensate can be sent to drain system.

$CWS := \frac{Condensate}{AOH}\left(\frac{180-110}{110-55}\right)$ $CWS = 15.64\ \frac{gal}{min}$ $CWS \cdot AOH$

$CWS \cdot AOH = \left(8.22 \cdot 10^{6}\right)\ gal$

Available Cooling Water plus Condensate (AW):

$AW := CWS + \frac{Condensate}{AOH}$ $AW = 27.929\ \frac{gal}{min}$

Annual Water/Sewer Cost Savings:

$WaterSewerCost\$:= WaterCost\$ + SewerCost\$$

$Savings\$:= CWS \cdot AOH \cdot (WaterSewerCost\$) + Condensate \cdot (WaterSewerCost\$)$

$Savings\$ = \left(1.196 \cdot 10^{5}\right)\ \$$ $119,637.09

Electric cost to run water pumps to pump condensate to tower $ (EC) :

Pump break horsepower, GPM=pump gallons per minute, TDH=pump total dynamic head feet water, SG=specific gravity of water 1 and E= pump efficiency 50 percent

$TDH := 115$ $SG := 1$ $E := 0.5$

$gpm_{avg} := 27.93$ $BHP_{pump} := \frac{gpm_{avg} \cdot TDH \cdot SG}{3960 \cdot E}$ $BHP_{pump} = 1.622$

$EC_{PC} := \left(BHP_{pump}\right) \cdot 0.746\ kW\ AOH \cdot ElectricCost\$$ $EC_{PC} = 586.235\ \$$

$PumpElectric := BHP_{pump} \cdot 0.746 \cdot kW$ $PumpElectric = 1.21\ kW$

Cooling tower energy required for cooling condensate CTE:

$CTE := 27.93 \cdot 500 \cdot (110 - 75) \cdot \frac{Btu}{hr} \cdot TP \qquad CTE = 16.293\ kW$

$EC_{CT} := CTE \cdot AOH \cdot ElectricCost\$ \qquad EC_{CT} = \left(7.893 \cdot 10^{3}\right)\ \$$

Net Annual Cost Savings $ (NAS):

$NAS := Savings\$ - \left(EC_{PC} + EC_{CT}\right) = \left(1.112 \cdot 10^{5}\right)\ \$$ $111,200.00

Net Annual Water and Sewer Savings (Water/Sewer):

$WaterSewer := CWS \cdot AOH + Condensate \qquad WaterSewer = \left(1.468 \cdot 10^{7}\right)\ gal$

Net Annual Increase in Electric Use (EU):

$EU := (PumpElectric + CTE) \cdot AOH \qquad EU = \left(1.533 \cdot 10^{5}\right)\ kW \cdot hr$

SUMMARY:

ANNUAL COST SAVINGS: $111,200.00
ANNUAL WATER SAVINGS: 14,680,000 GALLONS
ANNUAL SEWER SAVINGS: 14,680,000 GALLONS
ANNUAL INCREASE IN ELECTRIC USE: 153,300 KWH