3 - AR No. 7 - Install Cooling Tower for Quench Tank

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Recommendation

Recycle quench water from the nine inch billet press through a cooling tower to maintain target quench water temperatures. This will reduce the need for city makeup water, and reduce sewage costs associated with dumping of hot quench water by 80%.

Annual Savings Summary

Source	*Quantity*	*Units*	*Cost Savings*
Electrical Consumption	-387,510	kWh (site)	-$21,460
Electrical Demand	-1,268	kW Months / yr	-$11,661
Water Consumption	-	-	$74,400
Total	**-1,321**	**MMBtu**	**$41,278**

Implementation Cost Summary

Description	*Cost*	*Payback (yrs)*
Before Incentives	$86,043	2.1
After Incentives	$81,043	2.0

Facility Background

Some aluminum extrusions from the nine inch press require a standing wave water quench to cool metals and allow safe handling. During normal operation, the nine-inch press extrudes approximately 46,000 pounds of aluminum per hour. This aluminum is approximately 1,000 °F and requires a rapid cooling temperature of 400 °F to obtain the desired properties. The facility currently maintains a quench temperature of less than 100 °F to allow comfortable handling of materials by workers. While processing hot aluminum, the facility overflows the quench tank with cold incoming city water to keep temperatures below 100 °F. This overflow valve allows 40 GPM of city water to cool the quench tank, however additional valves are opened during hot weather to keep the water temperature cool. According to the local water bureau, incoming water temperatures range from 38-75 °F [1].

Technology & Opportunity Background

Cooling towers use evaporative cooling in atmospheric conditions to achieve wet bulb temperatures (below dry bulb temperature) for a circulated water system. Circulation between the quench tank and the cooling tower allows excess heat to be expelled to atmosphere. Wet bulb temperatures are a function of dry bulb temperature and humidity. Lower humidity results in lower wet bulb temperatures for a given dry bulb temperature. Design wet bulb temperature in the facility's location is approximately 69°F [2].

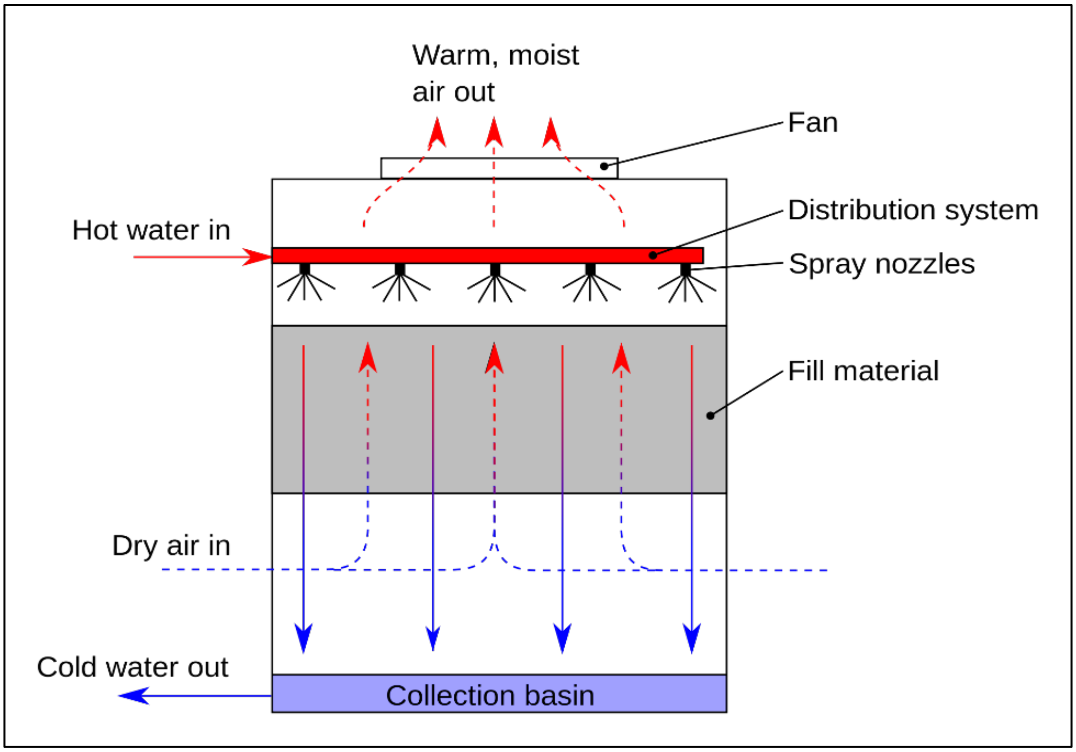

Diagram of a typical cooling tower system [3].

Currently the facility uses city water to cool their quench tank. They do this by opening a valve to allow fresh, cold water to come in to the tank, while allowing water that is within the tank to overflow out into the drain. This results in approximately $93,000 in related water costs. Rather than using new, fresh water to cool the tank, there is an opportunity to recycle and cool the water that is already being used in the quench tank.

Proposal

Recycle the quench water from the nine-inch billet press through a cooling tower to maintain target quench water temperatures. This will reduce the need for city makeup water, and reduce purchase and sewage costs associated with dumping hot quench water by $41,278 after an implementation cost of $86,043 resulting in a simple payback of 2.1 years.

Calculation Methodology

The required heat rejection was calculated based on aluminum extrusion properties. An appropriately sized cooling tower was selected based on this heat rejection. Proposed water consumption was calculated assuming 20% of current water consumption as a bleed to prevent contaminate buildup. Finally, operating costs of the cooling tower were calculated based on vendor provided information. Savings are achieved by reducing the cost associated with running city water into the quench tanks.

Notes

20% of current system bleed off is assumed in this recommendation to avoid buildup of unwanted materials in the cooling tower pipes. City water should be used to makeup this bleedoff. An alternative would be to add a water filter to the circulation loop reducing the need to bleed city water.

Analysts assumed the cost of water and sewage was incremental to the amount of water used. Analysts did not have water utility bills to base the analysis on, but were provided the total water costs associated with operating the quench tank.

References

[1] "The City of Portland, Oregon." Water Quality RSS. N.p., 27 Feb. 2017. Web. 15 Mar. 2017.

[2] Design wet bulb temperature was included in vendor quote.

[3] Dreher, Eric. *Counterflow Diagram* . Digital image. N.p., 15 Aug. 2012. Web. 20 Mar. 2017. <https://commons.wikimedia.org/wiki/File:Counterflow_diagram.svg>.

[4] "Metals - Specific Heats." *The Engineering ToolBox* . N.p., n.d. Web. 15 Mar. 2017.

[5] "Density, Specific Weight and Specific Gravity." *The Engineering ToolBox* . N.p., n.d. Web. 15 Mar. 2017.

[6] "The City of Portland, Oregon." *Water Quality RSS* . N.p., 27 Feb. 2017. Web. 15 Mar. 2017.

[7] *Mechanical Cost Data: 2016* . N.p.: RSMeans, 2015. Print.

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Data Collected

Operating Conditions

Nine Inch Press Operation Hours	(t_P)	4,679	hrs	(N. 1, Rf. 1)
Water Quench Use Factor	(UF_{WQ})	60%		(Rf. 1)
Water Quench Operation Hours	(t_Q)	2,807	hrs	(Eq. 1)

Utility Data

Incremental Electricity Cost	(IC_E)	$0.05538	/kWh	(Rf. 2)
Incremental Demand Cost	(IC_D)	$9.20	/kW·mo.	(Rf. 2)

Material Properties

Specific Heat of Aluminum	(cp)	0.215	btu/lb-°F	(Rf. 3)
Specific Weight of Water	(γ)	62.4	lb/ft^3	(Rf. 4)

Aluminum Quench Data

Aluminum Process Rate	($\dot{m}$)	46,000	lb/hr	(Rf. 1)
Extrusion Exit Temperature	(T_E)	1,000	°F	(Rf. 1)
Target Quench Temperature	(T_Q)	100	°F	(Rf. 1)
Required Heat Rejection Rate	(P_H)	8,901,000	btu/hr	(Eq. 2)
Tons of Cooling Required	(P_C)	593	tons/hr	(N. 2, Eq. 3)

Cooling Tower Data

Water Bleed Percent	(BP)	20%		(N. 4)
Fan Power	(P_{Fan})	20	hp	(Rf. 5)
Fan Load Factor	(LF_{Fan})	70%		(N. 4)
Pump Total Dynamic Head	(L_{TDH})	100	ft	(Rf. 5)
Pump Flow Rate	(Q)	1,500	GPM	(Rf. 5)
Number of Pumps	(n_P)	2		(N. 5)
Pump Efficiency	(η)	60%		(Rf. 6)
Pump Power	(P_{Pump})	127.6	hp	(Rf. 7, Eq. 4)
Total Power	(P_{Tot})	138.0	kW	(Eq. 5)

Notes

N. 1) Analysts determined annual days of operation based on a weighted average provided by facility personnel. Facility personnel reported six days per week of operation nine months of the year, and five days per week of operation three months of the year. This weighted average of 5.75 days per week was used to determine annual operation days.

N. 2) Tons of cooling is used to compare required heat rejection to cooling tower sizes.

N. 3) Analysts made a conservative estimate to percent system water bleed off to help prevent buildup of unwanted material in the system piping. Installing a filter would be an alternative to bleeding city water. By doing so, there would be no need for additional system water bleed off and only makeup water from evaporation would be required.

N. 4) Analysts assume a load factor of 70% is typical of cooling tower fan performance.

N. 5) Two pumps are required to operate the cooling tower. The first pump drives warm water from the quench tank to the cooling tower, while the second pump drives the cool water back to the quench tank.

Equations

Analysis Equations

Eq. 1) Quench Operation Hours (P_H)

$$t_P \times UF_{WQ}$$

Eq. 2) Required Heat Rejection Rate (P_H)

$$\dot{m} \times cp \times (T_E - T_Q)$$

Eq. 3) Tons of Cooling Required (P_C)

$$P_H \times \left(\frac{1\text{ ton cooling}}{15,000\text{ btu}} \right)$$

Eq. 4) Pump Power (P_{Pump})

$$\frac{n_P \times L_{TDH} \times \gamma \times Q \times \left(\text{ft}^3 / 7.48\text{ gal} \right)}{33,000 \times \eta}$$

Eq. 5) Total Power (P_{Tot})

$$(P_{Fan} \times LF_{Fan} + P_{Pump}) \times \left(\frac{0.746\text{ kW}}{\text{hp}} \right)$$

References

Rf. 1) Information provided by facility personnel the day of the assessment.

Rf. 2) Average incremental energy costs developed in the Utility Analysis, located in the Site Data section of this report.

Rf. 3) Specific heat of aluminum found at The Engineering ToolBox [4].

Rf. 4) Specific weight of water found at The Engineering ToolBox [5].

Rf. 5) Cooling tower details provided by vendor.

Rf. 6) Pump efficiency is based on a conservative estimate by analyst.

Rf. 7) Details regarding pump power consumption calculations at The Engineering ToolBox [6].

Energy Analysis

Current Conditions

Energy Consumption	(E_C)	*0*	kWh/yr	**(N. 3)**
Electrical Demand	(D_C)	*0*	kW-mo/yr	**(N. 3)**

Proposed Conditions

Energy Consumption	(E_P)	*387,510*	kWh/yr	**(Eq. 6)**
Electrical Demand	(D_P)	*1,267.5*	kW-mo/yr	**(Eq. 7)**

Savings

Energy	(E_S)	*-387,510*	kWh/yr	**(Eq. 8)**
Electrical Demand	(D_S)	*-1,267.5*	kW-mo/yr	**(Eq. 9)**
Energy Cost	(C_{ES})	*-$21,460*	/yr	**(Eq. 10)**
Demand Cost	(C_{DS})	*-$11,661*	/yr	**(Eq. 11)**

Water Cost Analysis

Current Conditions

Water Cost	(C_{WC})	*$93,000*	/yr	**(Rf. 1)**

Proposed Conditions

Water Cost	(C_{WP})	*$18,600*	/yr	**(Eq. 12)**

Savings

Water Cost	(C_{WS})	*$74,400*	/yr	**(Eq. 13)**

Implementation Cost Analysis

Piping

8" PVC Pipe	(L_P)	*200*	ft	**(Rf. 8)**
Cost 8" PVC	(IC_P)	*$80.50*	/10 ft	**(N. 5, Rf. 9)**
Piping Cost	(C_{Pipe})	*$1,610*		**(Eq. 14)**

Material Costs

Cooling Tower Package	(C_{CT})	*$48,131*		**(N. 6, Rf. 5)**
Pump Cost	(C_P)	*$8,700*		**(Rf. 5)**
Total Pump Quantity	(n_P)	*3*		**(N. 7)**
Total Pump Cost	(C_{PT})	*$26,100*		**(Eq. 15)**

Labor Cost

Labor Rate	(C_{LR})	*$87.20*	/hr	**(Rf. 10)**
Labor Time	(t_L)	*117*	hr	**(Rf. 11)**
Labor Cost	(C_L)	*$10,202*		**(Eq. 16)**

Notes

N. 5) Cost of 8" PVC piping includes installation and all hangers and pipe fittings.

N. 6) Cost of cooling tower package includes resistive heating to prevent freezing during down times, outlet strainer to prevent debris from entering pipes, variable frequency drive to allow for speed control of tower fan motors, and vibration cut-out switch in case of seismic activity.

N. 7) Analysts recommend installing one extra pump as a backup pump to avoid complete shut down of the cooling tower system during maintenance to a primary pump.

Equations

Eq. 6) Proposed Energy Consumption (E_P)

$$P_{Tot} \times t_Q$$

Eq. 7) Proposed Electricity Demand (D_P)

$$P_{Tot} \times \left(\frac{12 \text{ mo}}{\text{yr}} \right)$$

Eq. 8) Energy Savings (E_S)

$$P_E \times IC_E$$

Eq. 9) Demand Savings (D_S)

$$D_C - D_P$$

Eq. 10) Energy Cost Savings (C_{ES})

$$E_S \times IC_E$$

Eq. 11) Demand Cost Savings (C_{DS})

$$D_S \times IC_D$$

Eq. 12) Proposed Water Cost (C_{WP})

$$C_{WC} \times BP$$

Eq. 13) Water Cost Savings (C_{WS})

$$C_{WC} - C_{WP}$$

Eq. 14) Piping Cost (C_{Pipe})

$$\left(\frac{IC_P}{10 \text{ ft}} \right) \times L_P$$

Eq. 15) Total Pump Cost (C_{PT})

$$C_P \times n_P$$

Eq. 16) Labor Cost (C_L)

$$C_{LR} \times t_L$$

References

Rf. 8) Analysts estimated the length of piping required to connect the cooling tower with the current quench tank.

Rf. 9) Cost per 10 ft of 8" PVC piping found in RSMeans 2016 Mechanical Cost Data (pg. 201, line 1970) [7].

Rf. 10) Average labor rate for installation found in RSMeans 2016 Mechanical Cost Data (pg. 652) [7].

Rf. 11) Estimate labor hours for a similarly sized system found in RSMeans 2016 Mechanical Cost Data (pg. 687, line 2564) [7].

3 - AR No. 7 - Analysis

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Economic Results

Annual Cost Savings	(S)	***$41,278***	/yr	**(Eq. 17)**
Implementation Cost	(C_I)	***$86,043***		**(Eq. 18)**
Simple Payback	(t_{PB})	***2.1***	yrs	**(Eq. 19)**

Equations

Eq. 17) Annual Cost Savings (S)

$$C_{CW} + C_{ES} + C_{DS}$$

Eq. 18) Implementation Cost (C_I)

$$C_{Pipe} + C_{CT} + C_{PT} + C_L$$

Eq. 19) Simple Payback (t_{PB})

$$\frac{C_I}{S}$$

3 - AR No. 7 - Incentive Analysis

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Incentive Data

Annual Cost Savings	(S)	***$41,278***	/yr	**(Rf. 1)**
Implementation Cost	(C_I)	***$86,043***		**(Rf. 1)**
Simple Payback	(t_{PB})	***2.1***	years	**(Rf. 1)**

Incentive Analysis Summary

Description	*Incentive*	*After Incentive*	*Payback*	*Notes*
			(yrs)	
Water Efficiency Incentive	***$5,000***	***$81,043***	***2.0***	***Maximum $5,000***

Portland Water Bureau

Applications for a non-residental water efficiency projects are available. Projects that are selected will receive an incentive of 50% of the approved project costs up to a maximum of $5,000.

References

Rf. 1) Developed in this recommendation on the previous pages.

Rf. 2) 1 MMBtu is approximately equivalent to 10 Therms.

3 - AR No. 7 - Financial Analysis

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Financial Analysis template September 2016, Style 2016

Recommendation Data

Economic Results

Annual Cost Savings	(S)	*$41,278*	/yr	**(Rf. 1)**
Implementation Cost	(C_I)	*$86,043*		**(Rf. 1)**
Incentives Total	(I)	*$5,000*		**(N. 1, Rf. 1)**
Cost Basis	(C_B)	*$81,043*		**(Eq. 1)**
Simple Payback	(t_{PB})	*2.1*	years	**(Rf. 1)**
Simple Payback after Incentives	(t_{PBI})	*2.0*	years	**(Rf. 1)**

Capital Information

Terminal Dep. Yr. (Recovery Period)	(t_T)	*7*	years	**(N. 2, Rf. 2)**
Class Life	(t_L)	*12*	years	**(N. 2, Rf. 2)**
Estimated WACC^{ADJ}	(r)	*8.40%*		**(Rf. 3, N. 3)**
Estimated Corporate Tax Rate	(T_C)	*35.00%*		**(Rf. 4)**

Economic Analysis

No Depreciation Schedule

Initial After Tax Cash Flow (t = 0)	($CF_{N,0}$)	*-$52,678*		**(Eq. 2)**
After Tax Cash Flow (t = 1, 2,…t_L)	($CF_{N,t}$)	*$26,831*		**(Eq. 3)**
Net Present Value	(NPV_N)	*$145,398*		**(Eq. 4)**
Annual Internal Rate of Return	(IRR_N)	*50.6%*		**(N. 4, Eq. 5)**

Straight-Line Depreciation Schedule

Depreciation	(DEP)	*$11,577.63*		**(Eq. 6)**
After Tax Benefit	(CF_{TB})	*$4,052*		**(Eq. 7)**
Initial After Tax Cash Flow (t = 0)	($CF_{S,0}$)	*-$81,043*		**(Rf. 5)**
After Tax Cash Flow (t = 1, 2,…t_T)	($CF_{S,t}$)	*$30,883*	/yr	**(Eq. 8)**
After Tax Cash Flow (t = t_{T+1}...tL)	($CF_{S,t}$)	*$26,831*	/yr	**(Eq. 9)**
Net Present Value	(NPV_S)	*$137,844*		**(Eq. 4)**
Annual Internal Rate of Return	(IRR_S)	*36.8%*		**(N. 4, Eq. 5)**

Notes

N. 1) No incentives were considered for this recommendation.

N. 2) The General Depreciation Schedule is used. Recovery Period and Class Life may differ if analysts found a better known estimate. The Salvage Value of any equipment is assumed to be zero as it is out of the scope of this analysis and provides a further conservative estimate.

N. 3) WACC^{ADJ} is Weighted Average Cost of Capital Adjusted for Taxes. Cost of Capital is different for every business, and accurately estimating it for this facility is beyond the scope of this analysis. An industry average of WACC^{ADJ} is used **(Rf. 3)**, and is considered a conservative estimate. Analysts may adjust the WACC^{ADJ} if a more accurate estimate is identified in **(Rf. 3)** or it is given.

N. 4) An IRR greater than the WACC^{ADJ} (r) is an attractive investment option.

Equations

Eq. 1) Cost Basis (C_B)

$$C_I - I$$

Eq. 2) Initial A.T. Cash Flow (t = 0) ($CF_{N,0}$)

$$(-C_B)\times(1-T_C)$$

Eq. 3) A.T. Cash Flow (t =1, 2,...t_T) ($CF_{N,t}$)

$$S\times(1-T_C)$$

Eq. 4) Net Present Value (NPV$_{[N,S]}$)

$$CF_{[i],0} + \sum_{t=1}^{t_L} \frac{CF_{[i],t}}{(1+r)^t}$$

Eq. 5) Internal Rate of Return (IRR$_{[N,S]}$)

$$NPV = 0 =$$

$$CF_{[i],0} + \sum_{t=1}^{t_L} \frac{CF_{[i],t}}{(1+IRR)^t}$$

Eq. 6) Depreciation (DEP)

$$C_B / t_T$$

Eq. 7) After Tax Benefit (CF_{TB})

$$DEP \times T_C$$

Eq. 8) A.T. Cash Flow (t =1, 2,...t_T) ($CF_{S,t}$)

$$C_B \times (1-T_C) + CF_{TB}$$

Eq. 9) A.T. Cash Flow (t =t_{T+1},...t_L) ($CF_{S,t}$)

$$C_B \times (1-T_C)$$

References

Rf. 1) Developed in this recommendation on the previous pages.

Rf. 2) Recovery Period and Class Life are referenced from IRS publication 946, Table B-2, based on the best-fit industry sector. https://www.irs.gov/pub/irs-pdf/p946.pdf.

Rf. 3) Cost of Capital is based on New York University's Stern School of Business' *Cost of Capital by Sector*, data from January 2016. Industries not related to the IAC were omitted, and an average was calculated. http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/wacc.htm

Rf. 4) Based on Tax Rate Schedule from: www.irs.gov/pub/irs-pdf/i1120.pdf

Rf. 5) Initial A.T. Cash Flow is the negative of the above Implementation Cost.