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Thanks for visiting our site,

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Content Based
Chemical Engineering

Batch Heating/Cooling Calculations

This calculation procedure will assist in finding the necessary time and heat transfer surface area to perform your batch heating or cooling duties.
Applicable cases include:
Non-isothermal batch heating
Isothermal batch heating (steam)
Non-isothermal batch cooling

Both english and metric units of measure are available.

Do not rename sheets in this workbook

Sheets are protected, but protection may be turned off.

Revision History :

The Chemical Engineers' Resource Page
www.cheresources.com

Batch Heating/Cooling Calculations

Applicable to : Batch calculations for tanks that can be considered well mixed with submerged plate style coils or integral jackets.

References:
Process Heat Transfer, Kern, D.Q., McGraw-Hill, 1990.

Handbook of Chemical Engineering Calculations, Chopey, N.P., McGraw-Hill, 2nd Ed., 1994

Assumptions of Method:

-U-Value is considered constant
-Service side flow rates are considered constant
-Specific heats are considered constant
-Service side inlet temperature is considered constant
-Batch fluid temperature is considered uniform
-No batch side phase change occurs
-Heat losses must be compensated for through overdesign

Calculation Details:

Basis of calculation is derived from:

Heating

$$\frac{dQ'}{d\theta} = M c \frac{dT}{d\theta} = W C (T_1-T_2) = U A \Delta t \quad (1a)$$

Cooling

$$\frac{dQ'}{dq} = -MC \frac{dT}{dq} = w c (t_2-t_1) = U A \Delta t \quad (1b)$$

Substituting and integration yield the working equations:

Heating

$$\ln \frac{T_1-t_1}{T_1-t_2} = \frac{WC}{Mc} \frac{(K_1-1)}{K_1} \theta \quad (2a)$$

where $K_1 = \exp(UA/WC)$

For steam heating, Equation 1a simplifies to:

$$\ln \frac{T_1-t_1}{T_1-t_2} = \frac{(UA)}{(Mc)} \theta \quad (2a_2)$$

Cooling

$$\ln \frac{T_1-t_1}{T_2-t_1} = \frac{wc}{MC} \frac{(K_2-1)}{K_2} \theta \quad (2b)$$

where $K_2 = \exp(UA/wc)$

Nomenclature

Q' = heat (btu)
θ = time (h)
M = weight of batch liquid (lbs)
C = specific heat of hot fluid (Btu/lb °F)
c = specific heat of cold fluid (Btu/lb °F)
T_1 = initial temperature of hot fluid (°F)
T_2 = final temperature of hot fluid (°F)
t_1 = initial temperature of cold fluid (°F)
t_2 = final temperature of cold fluid (°F)
W = mass flow rate of hot fluid (lb/h)
w = mass flow rate of cold fluid (lb/h)
U = overall heat transfer coefficient (Btu/h ft^2 °F)
A = heat transfer surface area (ft^2)

Define Problem:

Select the batch heating/cooling scenario applicable to your process:

( ) Steam Heating (•) Non-isothermal Heating ( ) Non-isothermal Cooling

then enter data at yellow cells		Steam Table Steam Heating	Non-isothermal Heating	Non-isothermal Cooling
Weight of Batch	(lb)		10000	
Initial Batch Temp.	(°F)		50	
Final Batch Temp.	(°F)		150	
Initial Service Side Temp.	(°F)		250	
Mass Flow Rate of Service Fluid	(lb/h)		30000	
Specific Heat of Batch Fluid	(Btu/lb °F)		1	
Specific Heat of Service Fluid	(Btu/lb °F)		0.65	
Overall Heat Transfer Coefficient	(Btu/h ft^2 °F)		80	
Look Up on Chart				
Heat Transfer Area (initial guess)	(ft^2)		200	

Results :

Non-Isothermal Heating

K_1 = exp (UA/WC) = 2.272

$\frac{K_1-1}{K_1}$ = 0.560

Time for Heating	=	0.63	hours
		38	minutes
Heat Load	=	1600	kBtu/h
Service Side outlet temp @ startup	=	138	°F
Service Side outlet temp @ final batch temp.	=	194	°F

Be sure that the required area will fit inside the tank
Adjust area above to meet your time requirements
Consult manufacturer of coils for service side pressure drop calculations