CE427 | Professor Weber
Unit Operations Lab 3 | Fall, 1998

COOLING TOWER SPREADSHEET DETAILS

Details of the Excel Spreadsheet are presented here. There are five sections, as follows:

Section 1 Laboratory Data
Data from the Laboratory Data Sheet are entered into the spreadsheet in the same order as they appear on the Data Sheet. Some parameters of the column operation are then calculated.

Section 2 NTU Calculation
An analytical calculation of the NTU's is performed using a 2nd order regression fit for the water line. The HTU's and K_ya's are also calculated.

Section 3 Evaporation Rate
The rate of evaporation is calculated.

Section 4 Khodaparast's NTU Calculation
This section uses the analytical integration of Khodaparast. This integration utilizes a different regression fit from that in Section 2.

Section 5 Summary
This section summarizes some of the results of the previous calculations.

A "Test Run" is included which serves as basis for copying all of the equations over into the adjacent columns. Data entires are shown in parenthese ( ) and calculation results are shown in brackets.

Cell	Cell Entry	Notes and Equation Numbers	Test Run Entries or Results
A1	Analysis of Cooling Tower Data		
A2	Damper Position = **Fill it in here**		
A3	Date due **Fill it in here**		
A4	See Word Spreadsheet File		
A5	for details.		
A6	# = Symbol for humidity		
A7	Laboratory Data	**Underline it or put a dashed line in Cell A8.**	
B7			
A8	A dashed line below the title in A7		
B8	Test Run		
A9	H_2O rate, liters/min		
B9	**A data entry**		(10.5)
A10	Hot water tank temp, ^oC		
B10	**A data entry**		
A11	Manometer Press. Drop, Inches of H_2O		
B11	**A data entry**		(19.5646)
A12	T_{xa}, Inlet water, ^oC		
B12	**A data entry**		(43.3)
A13	T_{xb}, Outlet water, ^oC		
B13	**A data entry**		(22.5)
A14	T_{yb}, Inlet air dry bulb, ^oC		
B14	**A data entry**		(21.0)
A15	T_{wbb},Inlet air wet bulb, ^oC		

B15	**A data entry**		(14.1)
A16	T_{ya}, Outlet air dry bulb, ^oC		
B16	**A data entry**		(44.0)
A17		This is a blank row.	
B17			
A18	T_{xa}, Inlet water, ^oF		
B18	=(B$12+40)*1.8-40	Equation to convert ^oC to ^oF	[109.9]
A19	T_{xb}, Outlet water, ^oF		
B19	=(B$13+40)*1.8-40	Equation to convert ^oC to ^oF	[72.5]
A20	T_{yb}, Inlet air dry bulb, ^oF		
B20	=(B$14+40)*1.8-40	Equation to convert ^oC to ^oF	[69.8]
A21	T_{wbb}, Inlet air wet bulb, ^oF		
B21	=(B$15+40)*1.8-40	Equation to convert ^oC to ^oF	[57.4]
A22	T_{ya}, Outlet air dry bulb, ^oF		
B22	=(B$16+40)*1.8-40	Equation to convert ^oC to ^oF	[111.2]
A23		This is a blank row.	
B23			
A24	G_x, lb H_2O/(h,ft^2)		
B24	=B9*0.035315*62.4*60	Liters/min x 0.35315 ft^3/liter x 62.4 lb/ft^3 x 60 min/hr	[1388]
A25	$\#_b$, lb H_2O/lb DA		
B25	$\#_b = \#_{wb} + 0.000231(B21-B20)$	See details below	[0.0070]

The following equations are involved in calculating $\#_{wb}$:

$$\#_{wb} = \frac{M_A P'_A}{M_B(1-P'_A)} = \frac{M_A}{M_B\left(\frac{1}{P'_A}-1\right)} \qquad \text{Equation (23.3) in MS\&H}$$

where $M_A = 18.02$ Molecular weight of water

$M_B = 28.97$ Molecular weight of air

and $$P'_A = \exp\left(18.3036 - \frac{6869.592}{T_{wb}+376.666}\right) \qquad \text{Antoine's Equation}$$

A26	H_{yb}, Btu/lb DA		
B26	=0.24*B20+B25*1075.8+0.45*(B20-32)		[24.432]
A27	v_H, ft^3/lb DA		
B27	Equation (23.7a)	Note that T here is in ^oR	[13.487]
A28	Vol. air rate, ft^3/h		
B28	=(1.3328*LN(B11)+5.9569)*3600	Regression fit of Pitot Tube Calibration	[35713]
A29	G'_y, lb DA/(h,ft^2)		
B29	=B28/B27	Entering air rate/v_H	[2648]
A30	$s=G_x c_L/G'_y$, Btu/(lb DA,^oF)		
B30	=B24/B29	Operating Line Slope Equation (12)	[0.5243]
A31		This row is blank	
B31			
A32	Analytical Integration	**Underline it or put a dashed line in cell A32**	
B32			
A33	===============		
B33	**This cell is blank**		

A34	$s=G_xc_L/G'_y$, Btu/(lb DA, ^oF)		
B34	=B30		[0.5243]
A35	gamma		
B35	100.081		[100.081]
A36	alpha		
B36	-2.52683		[-2.52683]
A37	beta		
B37	0.0022464		[0.022464]
A38	T_{xb}, ^oF		
B38	=B19		[72.5]
A39	H_{yb}, Btu/lb DA		
B39	=B26		[24.432]
A40	f		
B40	=B26-B34*B38	$f = H_{yb} – sT_{xb}$ Equation (14)	[-13.581]
A41	a = gamma – f		
B41	=B35 – B40	Equation (16)	[113.662]
A42	b = alpha – s		
B42	=B36-B34	Equation (17)	[-3.051]
A43	c = beta		
B43	=B37	Equation (18)	[0.022464]
A44	sqrt delta		
B44	=SQRT((4*B41*B43)-B42^2)	Square Root of ($4ac-b^2$)	[0.951]
A45	T_{xa}, ^oF		
B45	=B18		[109.9]
A46	Numer1		
B46	=2*B43*B38+B42	Numerator of 1st $\tan^{-1}$ term of Equation (20)	[0.206]
A47	Numer2		
B47	=2*B43*B45+B42	Numerator of 2nd $\tan^{-1}$ term of Equation (20)	[1.888]
A48	NTU		
B48	=B34*2/B44*(ATAN2(B44,B47)-ATAN2(B44,B46))	Equation (20)	[0.983]
A49		This row is blank.	
B49			
A50	HTU, ft		
B50	=6/B48	Equation (21) where Z_T = 6 ft	[6.106]
A51	K_ya, lb DA/(h,ft^3)		
B51	=B29/B50	Equation (24)	[433.7]
A52		This row is blank	
B52			
A53	Evaporation Rate	**Underline it or put a dashed line in cell A54**	
B53			
A54	=============		
B54			
A55	T_{yb}		
B55	=B20		[69.8]
A56	T_{wbb}		
B56	=B21		[57.4]
A57	$\#_b$		
B57	=B25		[0.0070]
A58	H_{yb}		
B58	=B26		[24.432]
A59	Cal'd H_{ya}, Btu/lb DA		

B59	=B58+B30*(B18-B19)	$H_{ya} = H_{yb} + s(T_{xa} – T_{xb})$	[0.01563]
A60	Cal'd $\#_a$, lb H_2O/Lb DA		
B60	=(B59-0.24*B22)/(1075.8+0.45(B22-32))	$\#_a=(H_{ya}-0.24T_{ya})/(1075.8+0.45(T_{ya}-32))$	[0.01563]
A61	$G_{xe} = G'_y(\#_a - \#_b)$	This is the evaporation, lb $H_2O/(h,ft^2)$	
B61	=B29*(B60-B25)		[22.783]
A62	Percent Evaporation		
B62	=B61/B24*100	$(G_{xe}/G_x)*100$	[1.641]

Enter all of your data, beginning in Column C and copy all of the equations from Column B across. Retain the "test run" in Column B.