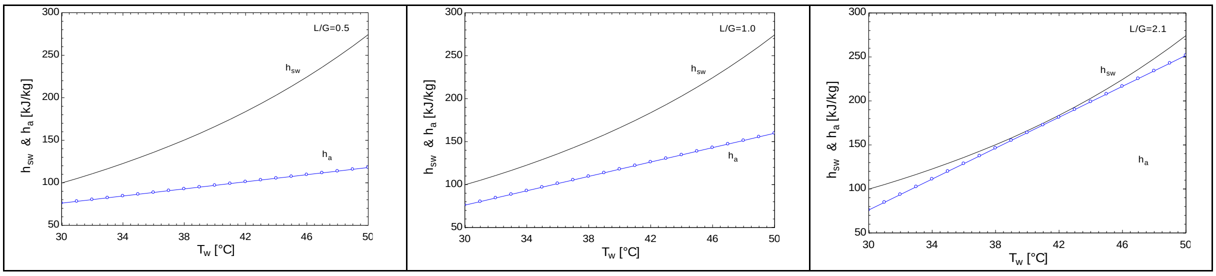
King Abdulaziz University
Faculty of Engineering
Mechanical Engineering

MEP 460
Heat Exchanger Design
Spring 2022
HW. # 13 (Cooling Towers)

1- Consider a counter current force draft cooling tower with inlet water temperature of 45° C. Use both Fraas approximate method and Chebyshev integration method to find the cooling tower characteristics CTC for water to air mass ratio of 0.5, 1.5, 1 and 2, and fill the table below. Show your calculations

L/G	tw_i	tw_o	t^*_{ai}	Range	Approach	CTC Fraas	CTC Chebyshev
0.5	45	30	25	**15**	**5**	**1.296**	**1.304**
1.0	45	30	25	**15**	**5**	**1.634**	**1.673**
2.0	45	30	25	**15**	**5**	**5.454**	**6.750**
1.5	45	35	25	**10**	**10**	**0.693**	**0.702**
1.5	45	35	20	**10**	**15**	**0.5266**	**0.532**

2-For the first case considered above it is required to study the effect of changing the ratio L/G on the air operation line. Assume the mass flow rate of water to be 10 kg/s, draw the variation of saturated air enthalpy at the water temperature with the temperature variations. On the same figure draw the air operation line for different values of L/G, then calculate the maximum L/G ratio, and form it find G_{min}. Assume G is 1.4 G_{min}, calculate the mass flow rate of air, and find CTC at this condition.



G_{min}=10/2.10=4.762 kg/s, G=1.4*G_{min}=6.667 kg/s, L/G=10/6.667=1.50, CTC=2.7

3-Using Fraas approximate method for finding the cooling tower characteristic CTC to find the water outlet temperature exiting (i.e. t_{wo}) the cooling tower. Take the following data:

t_{wi}=45 °C, t_a=40°C, $t^*_{ai} = 22$ °C, L/G=1.3. CTC=0.60

T_{wo}=34.56 °C

4-Use the cooling tower effectiveness method to find the exit condition of air and water from a counter current cooling tower. The following information is given

t_{wi}=45 °C, t_a=35°C $t^*_{ai} = 23$ °C, CTC=1.5, L/G=1.2 $\dot{m}_a = 10\ kg/s$

Also calculate approximately the rate of water evaporated in the air $\dot{m}_{evap}$

NTU	**C^* [kJ/kg]**	**ε [-]**	**h_{ao} [kJ/kg]**	**T_{wo} [°C]**	**W_{ai} [kgw/kgda]**	**W_{ao} [kgw/kgda]**	**$\dot{m}_{evap}$ [kg/s]**
1.8	**7.46**	**0.55**	**148**	**29.1**	**0.01269**	**0.04314**	**0.2945**

5-In designing a cooling tower the ratio L/G is found by matching CTC from thermal behavior i.e. by integrating (which is called Merkel Integration: I_m)

$$I_m = \frac{h_d a_v V}{\dot{m}_w} = \int \frac{Cp_w dt_w}{h_s - h_a} \tag{1}$$

and the cooling tower CTC from mass transfer characteristics of the packing. Consider one type of fill where the CTC is given by the following equation

$$I_{Fill} = \frac{h_d a_v V}{\dot{m}_w} = eH\left(\frac{\dot{m}_w}{\dot{m}_a}\right)^{-n} \tag{2}$$

for triangular slats with e=0.32 and n=0.45

Consider a cooling tower with inlet water temperature of **35°C**, outlet temperature of 20°C and inlet air condition of (dry bulb temperature t_{ai}=15°C and relative humidity φ_i=20%. Use Chebyshev and find CTC for several values of L/G (say 0.4, 0.6, 0.8, 1.0, 1.4, 1.8) and plot CTC vs L/G. Also use equation 2 (assumed height of cooling tower to be H=4 m) and find CTC for the same values of L/G and plot on the same graph, then find the design value of L/G which is the intersection of the two lines. You can use MATLAB to solve this problem. **[Ans. L/G≈1.1]**