Performance Comparing of Cooling Towers by Varying Air and Water Flow Rate

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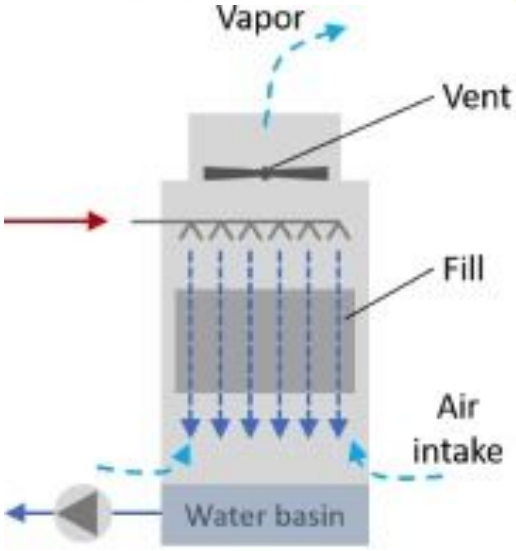
Background

Natural Draft Towers

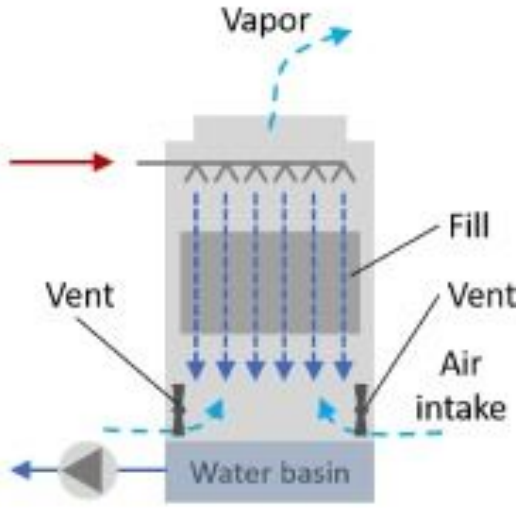
Atmospheric Tower

Induced Draft Towers

Forced Draft Towers



(A) Induced draft cooling tower



(B) Forced draft cooling tower

https://www.sciencedirect.com/

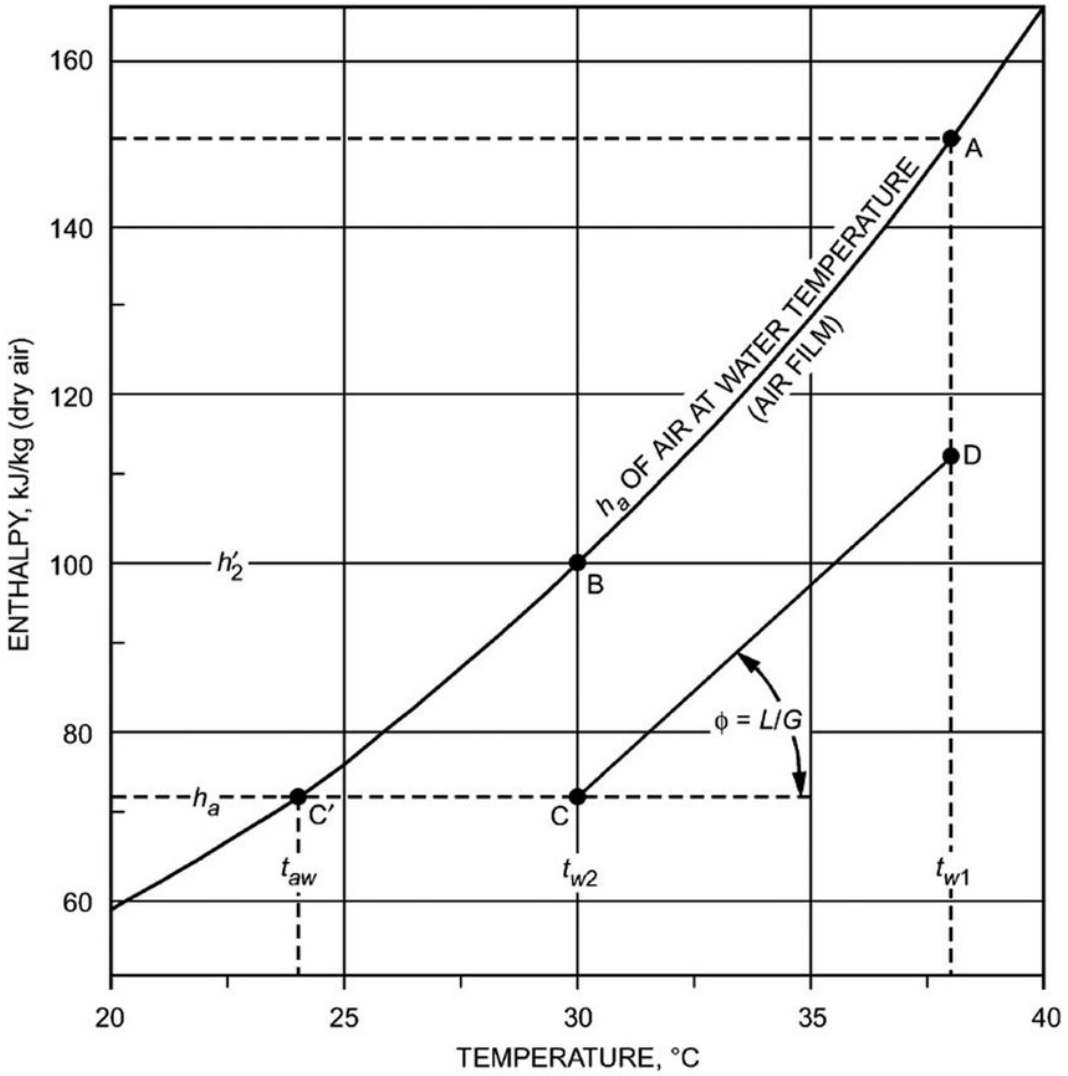
Theory: Merkel Equation

$$NTU = \frac{KaV}{L} = \int_{T_2}^{T_1} \frac{C_L}{h' - h} dT$$

$$h = h_{in} + \frac{L}{G} C_p (T - T_{out})$$

- KaV/L is the tower characteristics
  - K is mass transfer coefficient
  - a is contact area
  - V is volume of active cooling
  - L is water flow rate
- T_1 and T_2 is inlet and outlet water temperature
- C_L is water heat capacity
- h' is specific enthalpy of saturated air at water temperature (Water operating line
- h is enthalpy of air (Air operating line)
- h_{in} is inlet air enthalpy
- L is the mass flow rate of water
- G is the mass flow rate of air

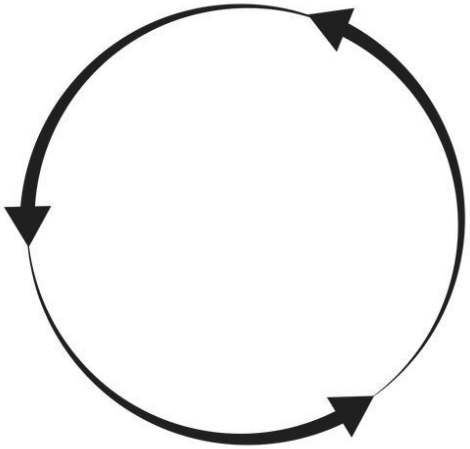
Theory: Enthalpy Balance



POINT A = Enthalpy of air film surrounding water droplet at hot-water temperature
POINT B = Enthalpy of air film surrounding water droplet at cold-water temperature
POINT C = Entering air
POINT D = Exit air

Methods - Cooling Tower Operation

1) Vary Air and Water Flow Rates (L/G ratio)



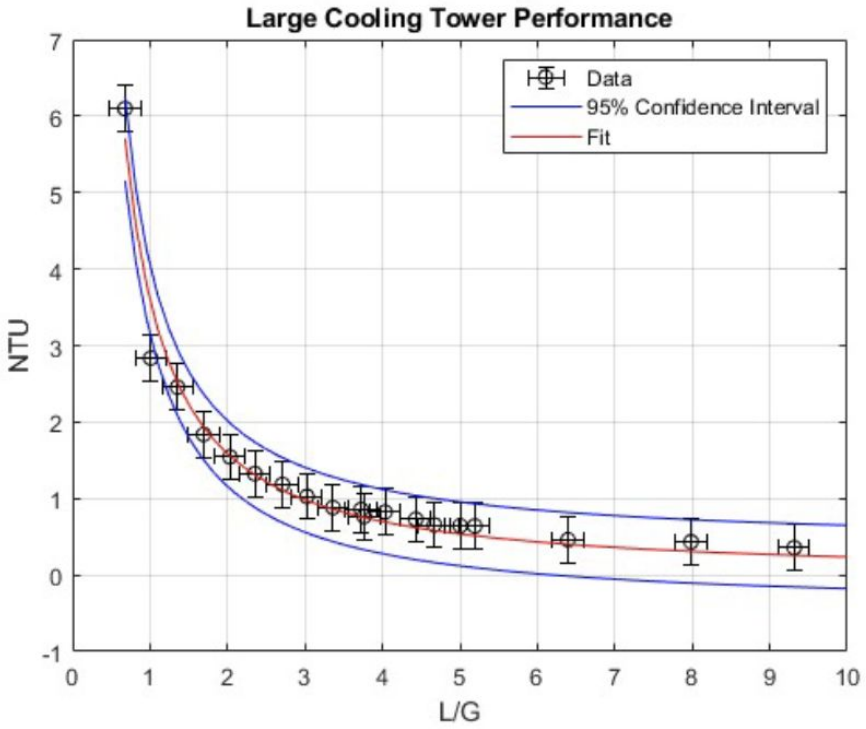
2) Record Steady State Temperatures

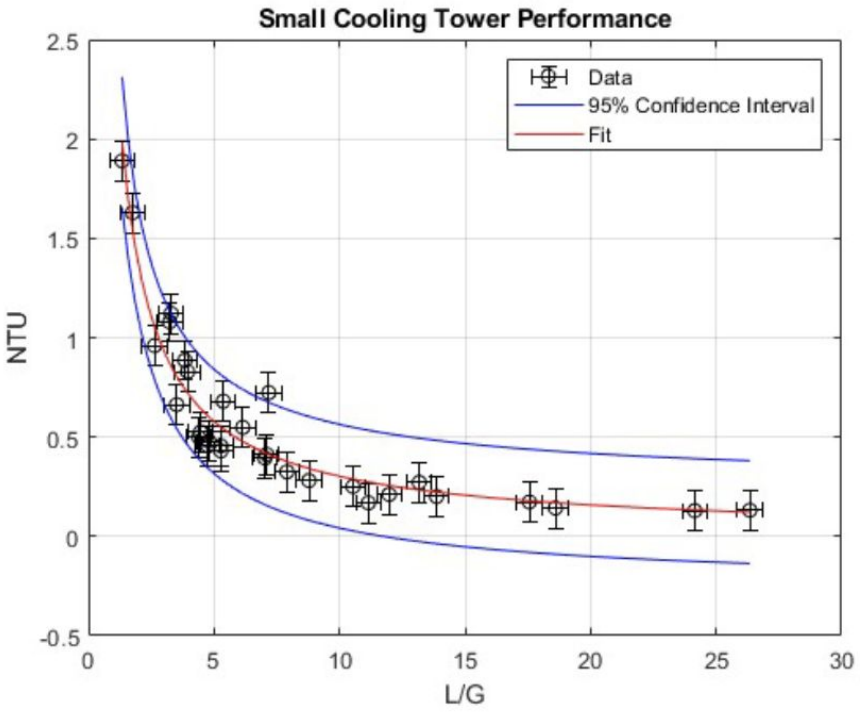
3) Tabulate Data

Small tower (Pull from top)

Out Dry Bulb Temp [C]	Out Wet Bulb Temp [C]	Inlet Temp Water [C]	In Dry Bulb Temp [C]	In Wet Bulb Temp [C]	Outlet Temp Water [C]	Gas Flow [m/s]	Liquid Flow [GPM]	Vol Gas flow (m^3/s)	Mass Gas Flow (kg/s)
25.1	22.5	34.3	18.7	15.7	33.4	2.6	1.1	0.0184293679	0.02218895896
22.3	20.3	32.7	18.6	15.3	31	6.1	1.1	0.04323813239	0.0520587114
25.7	22.6	34.4	18.3	15.7	33.7	1.2	1.1	0.00850586211	0.01024105798
23.5	21.1	34.4	17.9	15.2	32.6	5.4	1.1	0.03827637949	0.04608476091
25.1	22.4	34.5	17.6	15.3	33	1.4	0.7	0.00992350795	0.01194790098
24.3	21.9	34	18.5	15.3	31.9	2.6	0.7	0.0184293679	0.02218895896
22.1	20.1	32.5	18.9	15.4	29.4	4.8	0.7	0.03402344844	0.04096423192
22	19.9	33.1	18.8	15.4	29.5	5.7	0.7	0.04040284502	0.0486450254
21.3	19.1	35.1	18.3	15.5	33.2	1.1	0.3	0.00779704026 7	0.009387636482
19.9	17.5	36.1	18.6	15.4	33.3	5.9	0.3	0.04182048871	0.0503518684
20.5	18	36	18.2	15.4	34	2.4	0.3	0.01701172422	0.0204821159 6
20.6	18.2	35.8	18	15.5	34.2	2	0.3	0.01417643685	0.01706842997
26.2	23.4	34.7	18.2	15.8	33.9	1	1	0.00708821842 5	0.008534214983
25.7	23	34.4	18.1	15.7	33.4	1.5	1	0.01063232764	0.01280132247
25.1	22.6	34.1	18	15.6	33	1.9	1	0.01346761501	0.01621500847
25	22.3	33.7	17.8	15.6	32.6	2.2	1	0.01559480853	0.01877527296
24.5	21.8	33.6	18	15.6	32.4	2.5	1	0.01772054606	0.02133553746
23.3	20.9	33.3	19	15.7	31.5	5	1	0.03544189212	0.04267107492
22.9	20.5	33.5	18.8	15.5	31.7	5.5	1	0.03898528134	0.04693818241
22.9	20.5	33.7	19.3	15.7	31.8	5.9	1	0.04182048871	0.0503518684
25	22.1	34.8	19	15.7	33.4	3	1	0.02126465527	0.02560264495
24.6	21.9	34.4	18.5	16.4	33	3	0.9	0.02126465527	0.02560264495
24.4	21.7	33.9	18.4	15.8	32.1	3	0.8	0.02126465527	0.02560264495
23.8	21.4	33.2	18.4	15.7	30.8	3	0.7	0.02126465527	0.02560264495
23.3	21.1	32.8	18.5	15.6	31	3	0.6	0.02126465527	0.02560264495
22.7	20.5	33.4	18.5	15.7	31.6	3	0.5	0.02126465527	0.02560264495
21.5	19.2	34.7	17.9	15.7	33	3	0.4	0.02126465527	0.02560264495
20.7	18.4	35.7	17.8	15.5	33.7	3	0.3	0.02126465527	0.02560264495
20.5	18	36.4	18	15.5	33.5	3	0.2	0.02126465527	0.02560264495
26.1	22.9	35.1	18.7	15.8	34.3	1.7	1.2	0.01204997132	0.01450816547

Results/ Discussion





Conclusion

A large cooling tower would be more effective when running with a smaller L/G ratio, while a small cooling tower would be more effective when running the cooling tower with a larger L/G ratio.

Question?