COOLING SYSTEM

Cooling Tower Design and Computations

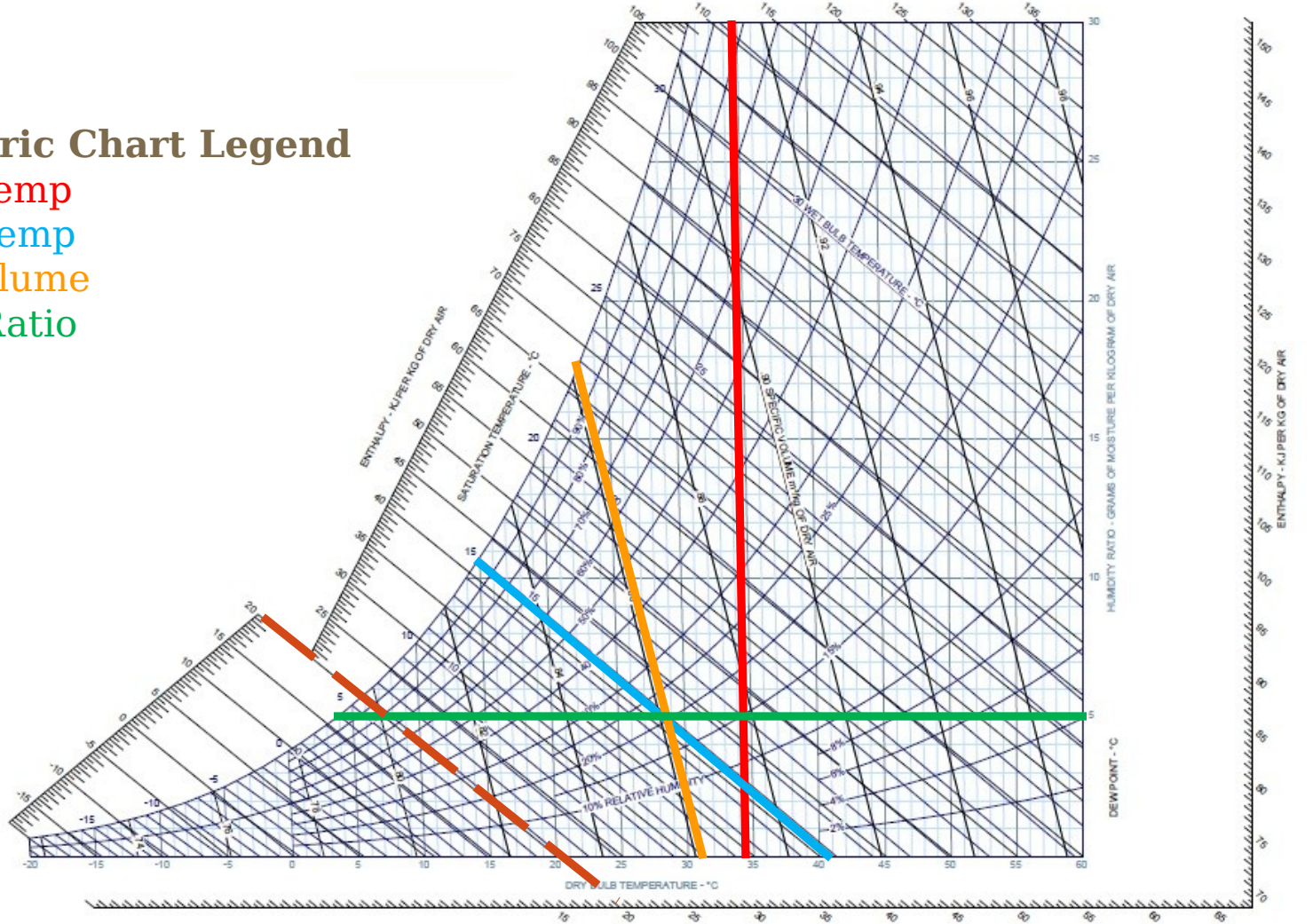
Psychrometric Chart

Will provide references for the following data for calculations:

- Dry Bulb Temperature
- Wet Bulb Temperature
- Relative Humidity
- Humidity Ratio (W)
- Enthalpy of air (kJ/kg of dry air)
- Specific Volume (m^3 per kg of dry air)

Psychrometric Chart Legend

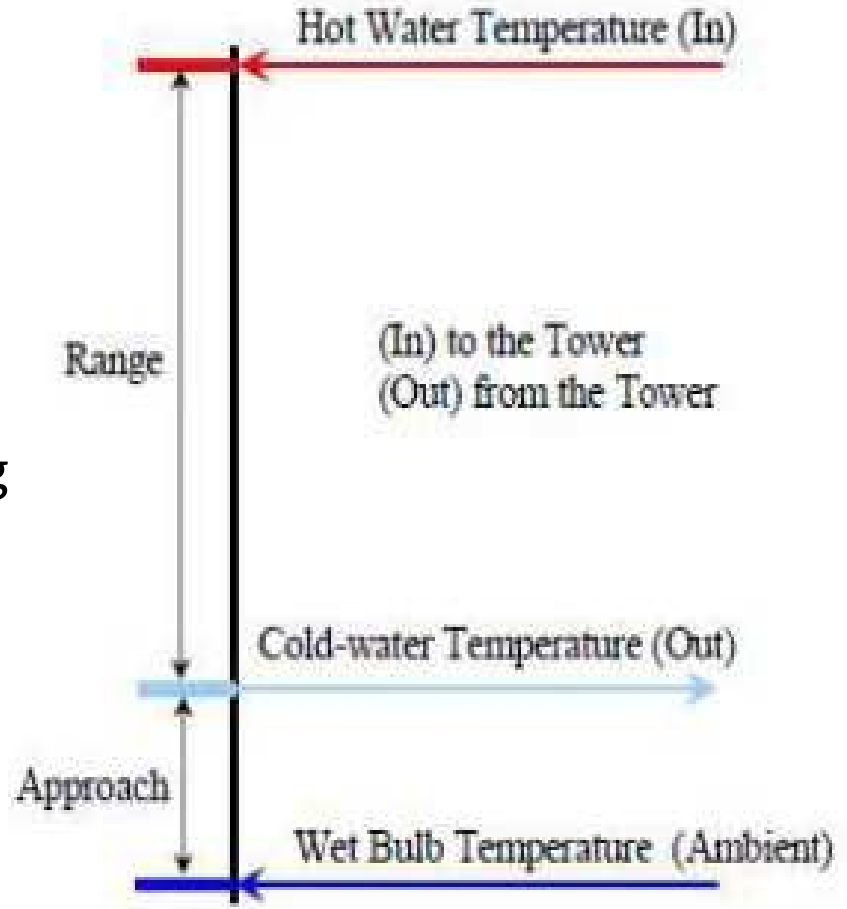
- Dry Bulb Temp
- Wet Bulb Temp
- Specific Volume
- Humidity Ratio
- Enthalpy



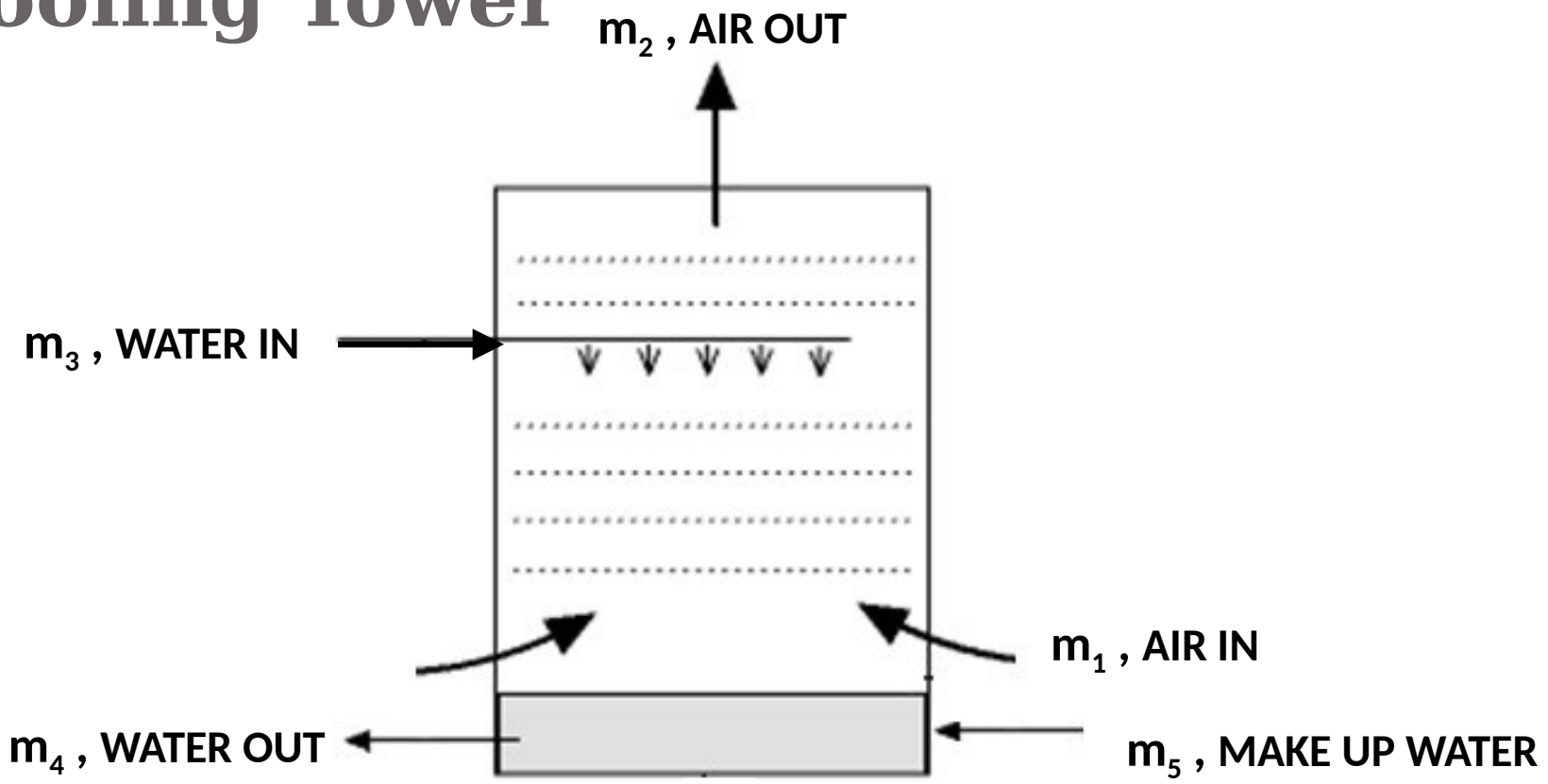
Cooling Tower

Rated in terms of APPROACH and RANGE

- **APPROACH** is the difference in temperature between the cooled water temperature and the entering air wet bulb temperature
- **RANGE** is the temperature difference between the water inlet and water exit



Cooling Tower



Cooling Tower

Rated in terms of APPROACH and RANGE

- **APPROACH** = $T_A = t_4 - t_{WB}$
- **RANGE** = $T_R = t_3 - t_4$

Where : t_4 = temperature of cooled water (water out)

t_{WB} = wet bulb temperature of entering air

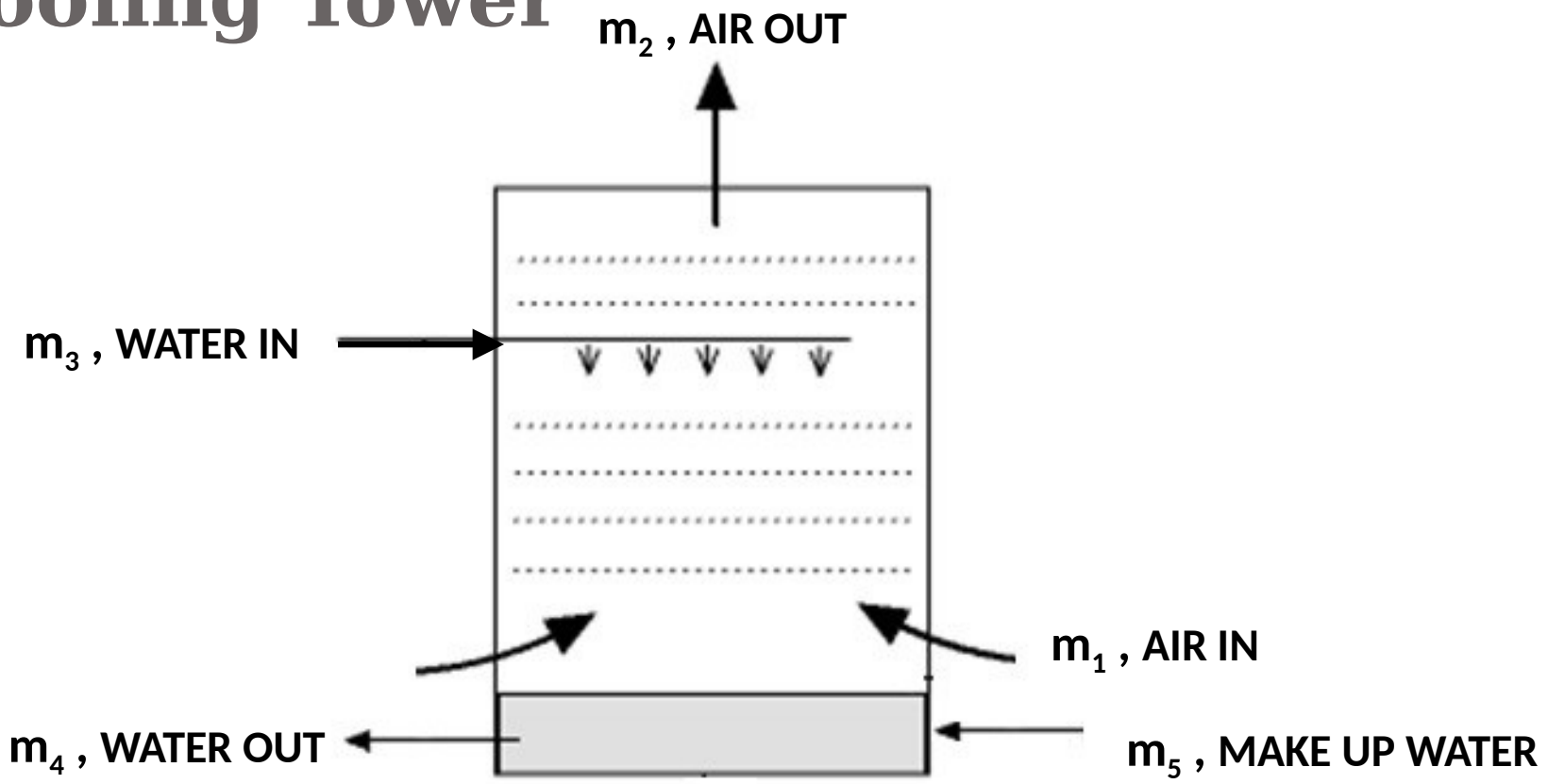
t_3 = temperature of hot water (water in)

Cooling Tower

Cooling tower efficiency, e

$$e = \frac{t_3 - t_4}{t_3 - t_{WB}}$$

Cooling Tower



Cooling Tower

MASS BALANCE

$$m_{IN} = m_{OUT}$$

$$m_1 W_1 + m_3 = m_2 W_2 + m_4$$

but $m_1 = m_2$

$$m_1 W_1 + m_3 = m_1 W_2 + m_4$$

$$m_3 - m_4 = m_1 (W_2 - W_1)$$

$$m_5 = m_1 (W_2 - W_1)$$

Where:

W_1 = humidity ratio of entering air

W_2 = humidity ratio of leaving air

Cooling Tower

HEAT BALANCE

heat absorbed by air = heat rejected by water

$$m_1 (h_2 - h_1) = m_3 C_P (t_3 - t_4)$$

ENERGY BALANCE

Energy in = Energy out

$$m_1 h_1 + m_3 h_3 + m_5 h_5 = m_1 h_2 + m_4 h_4$$

$$m_1 (h_1 - h_2) + (m_3 - m_4) h_5 = m_4 h_4 - m_3 h_3$$

SAMPLE PROBLEMS

1. The change of enthalpy of air in a cooling tower is 35 Btu/lb and the mass flow of air is 453.17 lb/min. Water enters the tower at the rate of 50 gpm and 115 °F. Determine the exit temperature.

2. The amount of water carried by air in a cooling tower is 15 lb/min. The change in humidity ratio in outlet and inlet is 0.025 lb/lb. Determine the volume flow of air needed if specific volume is 13 ft/lb.

3. A cooling tower has an efficiency of 65%. Water enters the tower at 55 . The wet bulb temperature of surrounding air is 27 . What is the temperature of water leaving the tower?

4. Water at 55°C is cooled in a cooling tower which has an efficiency of 65%. The temperature of the surrounding air is 32°C dry bulb and 70% relative humidity. The heat dissipated from the condenser is 2,300,000 kJ/hr. Find the capacity in L/s of the pump used in the cooling tower.

Given:

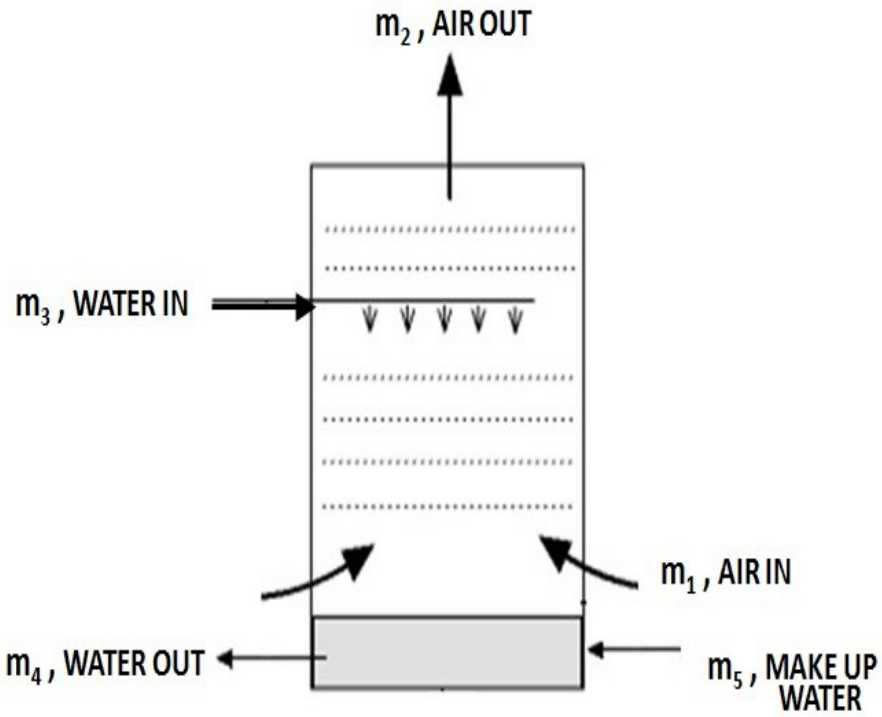
$t_3 = 55^oC$

e = 65%

@entering air: 32°C dry bulb

70% RH

Q = 2,300,000 kJ/hr



Req'd:

Pump Capacity (L/s)

Solution:

$Q = m_3 C_P (t_3 - t_4)$; $e = \frac{t_3 - t_4}{t_3 - t_{WB}}$

$t_4 = -[e(t_3 - t_{WB}) - t_3]$

$= t_3 - e(t_3 - t_{WB})$

from psychrometric chart @32^{o}C dry bulb 70% RH

$t_{WB} = 27.4^oC$, then

$t_4 = 55^oC - 0.65(55^oC - 27.4^oC)$

$t_4 = 37.06^oC$

Solution:

$$Q = m_3 C_P (t_3 - t_4)$$

$2{,}300{,}000\ kJ/hr = m_3 (4.187\ kJ/kg\text{-}K)(55^oC - 37.06^oC)$

$$m_3 = 30619.80612\ kg/hr$$

$$m_3 = 8.5055\ kg/s$$

from steam tables @ 37.06^oC : $v_f = 1.0068\ L/kg$

Pump capacity $= m_3 v_f$

$$= 8.5055\ kg/s(1.0068\ L/kg)$$

Pump capacity = 8.5633 L/s

5. A cooling tower is used to cool a jacket water loss from an engine. The heat generated by the fuel is 2500 kW and cooling loss is 30%. If temperature range of the tower is 15^{o}C. Determine the mass flow rate of water entering the tower.

6. An atmospheric cooling tower is to provide cooling for the jacket water of four stroke, 800 kW diesel generator with useful output of 34% and cooling loss of 30%. The cooling tower efficiency is 60% at a temperature of approach of 10◦C. If ambient air has a relative humidity of 70% and dry bulb temperature of 32◦C, determine the cooling water supplied to the diesel engine in L/hr. Generator efficiency is 97%.

7. At 30◦C, air-vapor mixture has a relative humidity of 70%. Find the humidity ratio if the barometric pressure reading is 101.325 kPa.

8. Fifty gallons per minute of water enters a cooling tower at 115◦F, atmospheric air at 60◦F and 55% RH enters the tower at 6,000 cfm and leaves at 90◦F saturated. Determine the volume of water that leaves the tower in gpm.