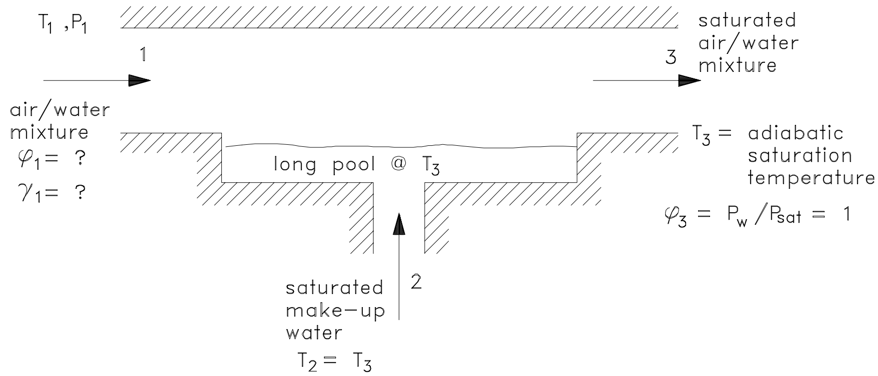
Week 11: Lecture 1

An Adiabatic Saturator



- used to measure humidity
- two inlet, single exit device through which moist air passes
- air-water mixture of unknown humidity enters at a known pressure and temperature
- if air/water mixture is not saturated, some water from the pool will evaporate
- the energy required to evaporate the water comes from the moist air → mixture temperature decreases
- for a sufficient long duct, the moisture exits with $\phi = 1$
- the temperature of the exiting mixture is called the adiabatic saturation temperature

Mass and energy balances lead to:

$$\gamma_1 = \frac{c_{p_a}(T_3 - T_1) + \gamma_3(h_{fg}(T_3))}{(h_{w_1} - h_{w_2})}$$

If we assume that h_{w_1} is very close to the enthalpy for the saturated vapour at T_1 and h_{w_2} is close to the enthalpy of the saturated liquid at T_1 (this assumption can be made with confidence since $h_f << h_g$), we can write γ_1 as

$$\gamma_1 = \frac{c_{p_a}(T_3 - T_1) + \gamma_3(h_{fg}(T_3))}{(h_{fg}(T_1))}$$

Week 11: Lecture 1

Dry Bulb Temperature - the temperature measured by a thermometer placed in a mixture of air and water vapour

Wet Bulb Temperature

- thermometer surrounded by a saturated wick
- if air/water vapour mixture is not saturated, some water in the wick evaporates and diffuses into the air $\rightarrow$ cooling the water in the wick
- at the temperature of the water drops, heat is transferred to the water from both the air and the thermometer
- the steady state temperature is the wet-bulb temperature

Sling Thermometer - a rotating set of thermometers one of which measures wet bulb temperature and the other dry bulb temperature. T_{DB} and T_{WB} are sufficient to fix the state of the mixture.

Week 11: Lecture 2

Applications

1. Simple Heating and Cooling

$$\frac{\dot{Q}}{\dot{m}_a} = (h_2^* - h_1^*) \quad (heating)$$

where

$$\begin{aligned} h_1^* &= h_{a,1} + \gamma_1 h_{w_1} \\ h_2^* &= h_{a,2} + \gamma_2 h_{w_2} \end{aligned}$$

2. Heating with Humidification

$$\dot{Q} = \dot{m}_a \; (h_2^* - h_1^*) \quad (heating)$$

where

$$\begin{aligned} \dot{m}_a &= \frac{\dot{V}}{v_{a_a}} \\ v_{a_a} &= \frac{R_a T_1}{P_{a_1}} = \frac{R_a T_1}{(P - P_{w_1})} = \frac{R_a T_1}{(P - \phi_1 P_{sat_1})} \end{aligned}$$

and

$$\dot{m}_{steam} = \dot{m}(\gamma_3 - \gamma_2)$$

3. Evaporative Cooling

$$h_1^* + \underbrace{(\gamma_2 - \gamma_1)h_\ell}_{\text{negligible}} = h_2^*$$

Therefore

$$h_1^* = h_2^*$$

Week 11: Lecture 2

4. Mixing of Two Moist Air Streams

$$\frac{\dot{m}_{a,1}}{\dot{m}_{a,2}} = \frac{h_2^* - h_3^*}{h_3^* - h_1^*} = \frac{\gamma_2 - \gamma_3}{\gamma_3 - \gamma_1}$$

where

$$\dot{m}_{a,1} = \rho_{a_1} \dot{V}_1$$

$$\dot{m}_{a,2} = \rho_{a_2} \dot{V}_2$$

Week 11: Lecture 3

Reacting Mixtures and Combustion

Definitions

Combustion Process

- a fuel made up of hydrocarbons is said to have burned completely if:
  - all the carbon present in the fuel is burned to carbon dioxide
  - all the hydrogen is burned to water
- if the conditions are not fulfilled the combustion is incomplete

Combustion Reactions

$$\text{reactants} \rightarrow \text{products}$$

or

$$\text{fuel} + \text{oxidizer} \rightarrow \text{products}$$

- in all cases the mass is conserved

  mass of products = mass of reactants

Fuels

- fuel is simply a combustible substance
- hydrocarbon fuels exist as liquids, gases and solids

Combustion Air

- oxygen is required in every combustion reaction
- in most combustion reactions air provides the needed oxygen

Week 11: Lecture 3

Air-Fuel Ratio

$$\frac{mass\ of\ air}{mass\ of\ fuel} = \frac{moles\ of\ air \times \tilde{M}_{air}}{moles\ of\ fuel \times \tilde{M}_{fuel}}$$

$$AF = \bar{AF}\left(\frac{\tilde{M}_{air}}{\tilde{M}_{fuel}}\right)$$

Theoretical or Stoichiometric Air

- the minimum amount of air that supplies sufficient oxygen for complete combustion of all carbon and hydrogen in the fuel
- no free oxygen would appear in the products
- normally the amount of air supplied is given as a percentage of the theoretical value
  i.e. 150% = 1.5 × the theoretical air
- the equivalence ratio is defined as

$$equivalence\ ratio = \frac{AF_{actual}}{AF_{theoretical}}$$

- if the equivalence ratio is:
  - $> 1 \quad \rightarrow$ lean mixture
  - $< 1 \quad \rightarrow$ rich mixture