Final Exam ME 40 Spring 2020

1. (30) Installation of a ventless dishwasher is proposed for a commercial kitchen. Typically, commercial dishwashers vent to the exterior so that condensation of water on the interior of the kitchen does not occur. Evaluate the proposed installation and determine whether it will result in condensation. Air flows from the exterior (i.e. ambient conditions) at a rate of 0.5 m^3/s. The exterior conditions may be assumed to be at 10 °C and 80% relative humidity. The manufacturer of the dishwasher reports sensible and latent heat for the dishwasher of 4.386 and 0.731 kW respectively (15,000 and 2500 BTU/hr). You may assume the air flow into the kitchen is large relative to the size of the kitchen so that uniform mixing is occurring[1].

   a) Show using calculations and the psychrometric chart as necessary, the change in initial air temperature, relative humidity, and specific humidity resulting from complete mixing of the incoming air with the heat and moisture output from the dishwasher. Does condensation occur? Draw lines and points on the psychrometric chart to illustrate the initial and final conditions. What temperature would the kitchen surfaces (e.g. windows) need to be for condensation to occur on them?

   b) Now assume it is the end of the day and the inlet air is shut off before the dishwasher is started to do one last load of dishes. You provide any additional variables and assume values needed to determine whether condensation would occur under these conditions? Draw lines and points on the psychrometric chart to illustrate the initial and final conditions.

   c) What types of systems (as we have defined systems in this class) are given in parts (a) and (b)? Briefly explain.

[1] This is a good assumption as kitchens have the highest "air change per hour (ACH)" requirements of any common occupancy, 15-60 ACH. This means the entire volume of air is changed once every 1-4 minutes. This is background and is not required to solve the problem.

2. (30) The variation of saturation pressure with saturation temperature can be derived from our knowledge of the fact that the liquid and vapor phases of a mixture in equilibrium have the same the same Gibbs value, i.e. $g_f = g_g$. And since g_f and g_g are functions of the saturation temperature only, it follows that $\frac{dg_f}{dT_{sat}} = \frac{dg_g}{dT_{sat}}$.

   a. Starting from the equations above, develop an expression for the change in vapor pressure (dP_{sat}) with saturation temperature (dT_{sat}) as a function of (h_{fg}), (v_{fg}), and T. Show all steps taken.

   b. Find the partial pressure of water vapor in air at 30 °C using your equation from part (a). Compare with the tabulated value.

   c. Show using tabulated values, that $g_f = g_g$ at 30 °C, thereby satisfying the $g_f = g_g$ condition used in part (a).

   d. Short essay (150 words max) – In your own words, briefly describe the process of evaporation from a liquid surface into air above at a relative humidity of 50%. You could consider, among other things, heat transfer, vapor pressure, partial pressure, its difference from boiling, and hypothesize on the role that Gibbs may have.

3. (40) Propane gas (C_3H_8) is burned steadily with 85% theoretical air. It enters a combustion chamber at 25°C and 1 atm and after combustion the products are allowed to cool to 25°C. The water is released as water vapor and some of the carbon burns to produce CO.

   a. After the propane combustion, the carbon monoxide is removed and combusted with 100% excess air at 1 atm.

   b. Write the balanced combustion equation for the propane reaction for 85% theoretical air.

   c. Is energy released or absorbed during propane combustion? Show with calculations.

   d. Determine the air to fuel ratio for the propane combustion. Compare this value to the air to fuel ratio of propane with 100% theoretical air.

   e. Determine the volume flow rate of air that is required to burn propane at a rate of 4kg/min.

   f. Determine the equilibrium constant for the actual CO reaction when 80% of the carbon monoxide has burned to carbon dioxide when in equilibrium.

   g. If we lower the temperature at which the removed carbon monoxide is combusted, what happens to the reaction?