THERMODYNAMICS QUALIFYING EXAM

August 2015

OPEN BOOK (only one book allowed) & CLOSED NOTES

Answer all four questions

All questions have equal weight

TIME: 3.0 hrs

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• Take any required property from your book, approximate values if necessary.
• If you make any assumption to reach a solution state it clearly

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Question # 1

a) A piston/cylinder of total 1 kg steel contains 0.5 kg ammonia at 1600 kPa both masses at 120°C. Some stops are placed so a minimum volume is 0.02 m³, as shown. Now the whole system is cooled down to 30°C by heat transfer to the ambient at 20°C, and during the process the steel keeps same temperature as the ammonia. Find:

i. The total work,
ii. The heat transfer, and
iii. The total entropy generation in the process.
iv. Sketch the process for on a T-S diagram

b) One kg water at 500°C and 1 kg saturated water vapor both at 200 kPa are mixed in a constant pressure and adiabatic process. Find:

i. The final temperature, and
ii. The entropy generation for the process.
Question # 2

a) A 0.2-m\(^3\) rigid tank equipped with a pressure regulator contains steam at 2 MPa and 300°C. The steam in the tank is now heated. The regulator keeps the steam pressure constant by letting out some steam, but the temperature inside rises. Determine the amount of heat transferred when the steam temperature reaches 500°C. The enthalpy of the steam leaving the tank is changing during the process. But for simplicity, we can assume the enthalpy for the exiting steam is constant and has the value:

\[ h_{\text{out}} = \left[ \frac{(h_1 + h_2)}{2} \right]_{\text{steam}} \]

b) An insulated rigid tank is divided into two compartments of different volumes. Initially, each compartment contains the same ideal gas at identical pressure but at different temperatures and masses. The wall separating the two compartments is removed and the two gases are allowed to mix. Assuming constant specific heats, find the simplest expression for the mixture temperature written in the form below and where \(m_3\) and \(T_3\) are the mass and temperature of the final mixture, respectively:

\[ T_3 = f\left(\frac{m_1}{m_3}, \frac{m_2}{m_3}, T_1, T_2\right) \]
**Question # 3**

A room contains 200m³ of an air-water vapor mixture at .01MPa, 35°C and 70% relative humidity. Calculate the humidity ratio, dew point, mass of air and mass of vapor. On a T-S diagram, show the liquid-vapor dome of relevance, lines of constant pressure and label T, P for the initial condition and the dew point for this mixture.
**Question # 4**

Methane is burned with atmospheric air. The analysis of the products on a dry basis is:

<table>
<thead>
<tr>
<th>Product</th>
<th>Percent by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>10.0</td>
</tr>
<tr>
<td>O₂</td>
<td>2.37</td>
</tr>
<tr>
<td>CO</td>
<td>0.53</td>
</tr>
<tr>
<td>N₂</td>
<td>87.10</td>
</tr>
</tbody>
</table>

Calculate the air-fuel ratio, the percentage of theoretical air and determine the combustion equation.