Activity 06: Steam Tank Design

MECH332 - Thermodynamics
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Define the Situation (5 Minutes)

• You work as an engineer at ACME Heating and Cooling. Your colleague is excited with their new steam tank design. They are sure that their approach is sound, and they want to review their solution with you.

• Design specifications require the rigid tank hold 2 kg of steam at 20 MPa and 520 °C and be cooled to 400 °C and it is critical that the tank pressure be above 16 MPa.

• Your colleague designs the tank and shows you the following calculations for the volume and final pressure.

\[
\begin{align*}
P v &= RT = \frac{R_u}{M} T \\
v &= \left(\frac{8.31447 \text{ kJ}}{\text{kmol} \cdot K}\right)(520 + 273 K) \\
&\quad \div (18.05 \text{ kg/kmol}) \cdot (20,000 \text{ kPa}) \\
v &= 0.01826 \text{ m}^3/\text{kg} \\
Tank_{volume} &= v \cdot m = 0.01826 \text{ m}^3/\text{kg} \cdot 2 \text{ kg} \\
&= 0.0365 \text{ m}^3
\end{align*}
\]

\[
\begin{align*}
P v &= RT = \frac{RT}{v} \\
&= \left(\frac{8.31447 \text{ kJ}}{\text{kmol} \cdot K}\right)(400 + 273 K) \\
&\quad \div (18.05 \text{ kg/kmol}) \cdot (0.01826 \text{ m}^3/\text{kg}) \\
P &= 16.98 \text{ MPa}
\end{align*}
\]

\[
\begin{align*}
R_u &= 8.31447 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} \\
M_{H_2O} &= 18.05 \frac{\text{kg}}{\text{kmol}} \\
P_{\text{CR}} &= 22.06 \text{ MPa} \\
T_{\text{CR}} &= 647.1 \text{ K}
\end{align*}
\]
5 Minutes - Consult with Neighbor

• What assumptions were made?
• Are there any mistakes? Verify units and fundamental laws.
• What possible improvements could be made?
5 Minutes - Class Discussion

• Assumptions?
• Mistakes?
• Improvements?
10 Minutes - Review
\[
P_R = \frac{P}{P_{CR}} = \frac{20.00 \text{ MPa}}{22.06 \text{ MPa}} = 0.907
\]

\[
T_R = \frac{T}{T_{CR}} = \frac{793 \text{ K}}{647.1 \text{ K}} = 1.225
\]

\[
Z_1 = 0.83
\]

\[
v_R = \frac{\nu}{RT_{CR}/P_{CR}} = 1.122
\]

\[
T_R = \frac{673 \text{ K}}{647.1 \text{ K}} = 1.04
\]

\[
P_R = 0.7
\]

\[
P_2 = P_R \times P_{CR} = 15.4 \text{ MPa}
\]
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<th>$T$ °C</th>
<th>$v$ m$^3$/kg</th>
<th>$u$ kJ/kg</th>
<th>$h$ kJ/kg</th>
<th>$s$ kJ/kg · K</th>
<th>$v$ m$^3$/kg</th>
<th>$u$ kJ/kg</th>
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<th>$s$ kJ/kg · K</th>
<th>$v$ m$^3$/kg</th>
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</table>

$P = 15.0$ MPa (342.16°C), $P = 17.5$ MPa (354.67°C), $P = 20.0$ MPa (365.75°C)