PROBLEM 3.101

Determine the percent error in using the ideal gas model to determine the specific volume of
(a) water vapor at 4000 lbf/in.^{2}, 1000°F.
(b) water vapor at 5 lbf/in.^{2}, 250°F.
(c) ammonia at 40 lbf/in.^{2}, 60°F.
(d) air at 1 atm, 560°R.
(e) Refrigerant 134a at 300 lbf/in.^{2}, 180°F.

Solution:

Analysis:

(a) Water vapor at 4000 lbf/in.^{2}, 1000°F
From Table A-4E: $v_{\text{table}} = 0.1752$ ft^3/lb
Using ideal gas model

$$v_{\text{ideal gas}} = \frac{RT}{p} = \frac{\left(\dfrac{1545\dfrac{\text{ft}\cdot\text{lbf}}{\text{lbmol}\cdot{}^\circ\text{R}}}{18.02\dfrac{\text{lb}}{\text{lbmol}}}\right)1460^\circ\text{R}}{4000\dfrac{\text{lbf}}{\text{in.}^2}\left|\dfrac{144\text{ in.}^2}{1\text{ ft}^2}\right|} = 0.2173\frac{\text{ft}^3}{\text{lb}}$$

The percent error follows

$$\%\text{ error} = \frac{v_{\text{ideal gas}} - v_{\text{table}}}{v_{\text{table}}}\times 100 = \frac{0.2173 - 0.1752}{0.1752}\times 100 = 24\% \quad \longleftarrow$$

(b) Water vapor at 5 lbf/in.^{2}, 250°F
From Table A-4E: $v_{\text{table}} = 84.21$ ft^3/lb
Using ideal gas model

$$v_{\text{ideal gas}} = \frac{RT}{p} = \frac{\left(\dfrac{1545}{18.02}\dfrac{\text{ft}\cdot\text{lbf}}{\text{lb}\cdot{}^\circ\text{R}}\right)710^\circ\text{R}}{5\dfrac{\text{lbf}}{\text{in.}^2}\left|\dfrac{144\text{ in.}^2}{1\text{ ft}^2}\right|} = 84.55\frac{\text{ft}^3}{\text{lb}}$$

The percent error follows

$$\%\text{ error} = \frac{v_{\text{ideal gas}} - v_{\text{table}}}{v_{\text{table}}}\times 100 = \frac{84.55 - 84.21}{84.21}\times 100 = 0.40\% \quad \longleftarrow$$

PROBLEM 3.101 (Continued)

(c) Ammonia at 40 lbf/in.^{2}, 60°F
From Table A-15E: v_{table} = 7.9134 ft^3/lb
Using ideal gas model

$$v_{\text{ideal gas}} = \frac{RT}{p} = \frac{\left(\dfrac{1545}{17.03}\dfrac{\text{ft}\cdot\text{lbf}}{\text{lb}\cdot{}^\circ\text{R}}\right)520^\circ\text{R}}{40\dfrac{\text{lbf}}{\text{in.}^2}\left|\dfrac{144\ \text{in.}^2}{1\ \text{ft}^2}\right|} = 8.19\frac{\text{ft}^3}{\text{lb}}$$

The percent error follows

$$\%\ \text{error} = \frac{v_{\text{ideal gas}} - v_{\text{table}}}{v_{\text{table}}}\times 100 = \frac{8.19 - 7.9134}{7.9134}\times 100 = 3.5\%$$ ←

(d) Air at 1 atm, 560°R
Using Table A-1E and Figure A-2:

$$p_R = \frac{p}{p_c} = \frac{1\ \text{atm}}{37.2\ \text{atm}} = 0.027$$

$$T_R = \frac{T}{T_c} = \frac{560\ {}^\circ\text{R}}{239\ {}^\circ\text{R}} = 2.34$$

$$Z \approx 1.0$$

At this state air is closely modeled as an ideal gas. ←

(e) Refrigerant 134a at 300 lbf/in.^{2}, 180°F
From Table A-12E: v_{table} = 0.1633 ft^3/lb
Using ideal gas model

$$v_{\text{ideal gas}} = \frac{RT}{p} = \frac{\left(\dfrac{1545}{102.03}\dfrac{\text{ft}\cdot\text{lbf}}{\text{lb}\cdot{}^\circ\text{R}}\right)640^\circ\text{R}}{300\dfrac{\text{lbf}}{\text{in.}^2}\left|\dfrac{144\ \text{in.}^2}{1\ \text{ft}^2}\right|} = 0.2243\frac{\text{ft}^3}{\text{lb}}$$

The percent error follows

$$\%\ \text{error} = \frac{v_{\text{ideal gas}} - v_{\text{table}}}{v_{\text{table}}}\times 100 = \frac{0.2243 - 0.1633}{0.1633}\times 100 = 37.4\%$$ ←