For compressed liquid, if compressed liquid data are not available,

\[ u(P,T) \approx u_f(T) \]
\[ v(P,T) \approx v_f(T) \]
\[ S(P,T) \approx S_f(T) \]

\[ h(P,T) = ? \quad h = u + Pv \]
\[ h(P,T) \approx u_f(T) + v_f(T) \times (P - P_{sat}) \]

\[ h_f(T) + v_f(T) \times (P - P_{sat}) \]
2-phase mixture

\[ X = \text{quality} = \frac{\text{fraction of mixture that is vapor}}{\text{total mass}} \]

\[ X = \frac{M_{\text{vapor}}}{M_{\text{total}}} = \frac{M_{\text{vapor}}}{M_{\text{sat}} + M_{\text{vapor}}} \]

\[ h_{\text{mix}} = h_f + X(h_f - h_g) \]

\[ h_f = h_h - h_f \]

Note: \( X \) only defined for 2-phase region, \( 0 \leq X \leq 1 \)

- If compute \( X \geq 1.0 \) and no math error \( \rightarrow \) really superheated
- If compute \( X \leq 0.0 \) and no math error \( \rightarrow \) really compressed
Superheated region - value not exactly in table + linear interpolation

\[ S \]

\[ P = 500 \text{ kPa} \]

\[ S_1, S_2, S, S \]

\[ T_1, T, T_2, T \]

Slope = constant = \( \frac{S - S_1}{T - T_1} = \frac{S_2 - S_1}{T_2 - T_1} \)

Solve for 'S' as function

\[ S = S_1 + \left( \frac{T - T_1}{T_2 - T_1} \right) (S_2 - S_1) \]

---

CARNOT cycle

Fully reversible cycle

Four processes

1 \( \rightarrow \) 2 reversible adiabatic compression
2 \( \rightarrow \) 3 reversible isothermal expansion (heat addition)
3 \( \rightarrow \) 4 reversible adiabatic expansion
4 \( \rightarrow \) 1 reversible isothermal heat rejection
Second Law of Thermodynamics

\[ \eta_{th} < 1 \]

Maximum thermal efficiency is for a reversible cycle (such as Carnot) for which

\[ \frac{Q_L}{Q_H} = \frac{T_L}{T_H} \]

And

\[ \eta_{th}^{\text{rev}} = \frac{T_H - T_L}{T_H} = 1 - \frac{T_L}{T_H} \]

Carnot cycle on T-S diagram

Clockwise
OPEN BOOK/OPEN NOTES. Work this problem as you would any homework problem.

1. Determine the following properties. What phase(s) (compressed liquid, saturated mixture, superheated vapor) are present for each state?

<table>
<thead>
<tr>
<th>State Description</th>
<th>Property</th>
<th>Phase(s) present</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O at 120°C, 5MPa</td>
<td>( u = 501.9 \text{ kJ/kg} \text{kg} ) ( \approx 503.6 \text{ kJ/kg} \text{kg} )</td>
<td>Compressed Liq.</td>
</tr>
<tr>
<td>H₂O at 190°C, ( h = 1982.2 \text{ kJ/kg} )</td>
<td>( v = 0.09169 \text{ m}^3/\text{kg} )</td>
<td></td>
</tr>
<tr>
<td>H₂O at 300°C, 0.5 MPa</td>
<td>( s = 7.4614 \text{ kJ/kg-K} )</td>
<td>Superheated</td>
</tr>
</tbody>
</table>

a) \( P > P_{\text{sat}} \) \( T \Rightarrow \) Compressed Liq. \( P \quad s \quad L \quad V \)

b) \( x = \frac{1982.2 - 807.43}{1977.9} = 0.5939 \)

\( x = u + x \cdot s \frac{\text{d}u}{\text{d}s} \) \( = 0.001141 + (0.5939)(0.15636 - 0.001141) \)

\( h_f \text{LH} \text{P} \text{H} \text{G} \text{V} \Rightarrow \) two phase mixture \( P \quad Lg \quad Vap \)

c) \( T \quad P \quad s \quad L \quad V \)