Rankine cycle at various steam pressure and temperature

define some units $kN := 10^3 \cdot N$ $kPa := 10^3 \cdot Pa$ $MPa := 10^6 Pa$ $kJ := 10^3 \cdot J$ $bar := 0.1MPa$

We have seen the calculation of a Rankine steam cycle in rankine_class_example.mcd Repeating these calculations for various combinations of boiler pressure and temperature allows us to investigate pressure and temperature on ideal thermal efficiency. the calculations are done in the area by doing a matrix of combinations:

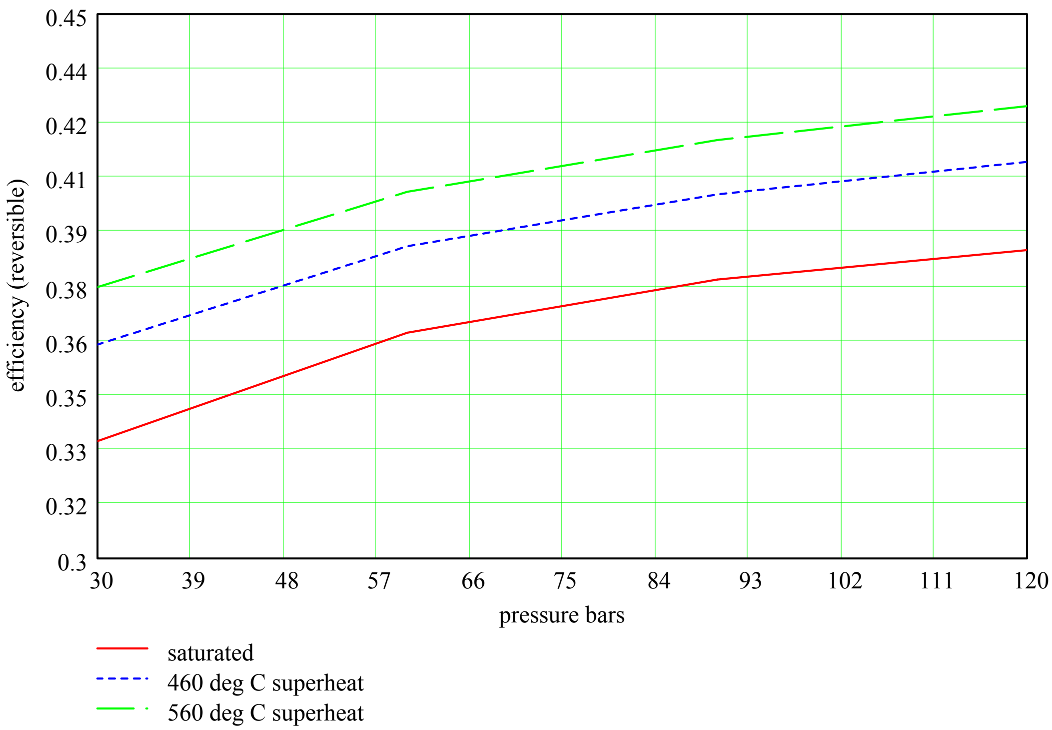
$$p_2 := \begin{pmatrix} 30 \\ 60 \\ 90 \\ 120 \end{pmatrix} bar \qquad T_{sat} := \begin{pmatrix} 233.90 \\ 275.64 \\ 303.4 \\ 324.75 \end{pmatrix} \qquad T_3 := \begin{pmatrix} T_{sat} \\ 460 \\ 540 \end{pmatrix}$$

since T_{sat} varies with pressure this was accomplished in a 4 x 3 array of temperatures

$$\begin{pmatrix} T_{sat} & 460 & 560 \end{pmatrix}$$

$$TT_3 := \begin{pmatrix} 233.90 & 460 & 560 \\ 275.64 & 460 & 560 \\ 303.4 & 460 & 560 \\ 324.75 & 460 & 560 \end{pmatrix} \begin{pmatrix} 30 \\ 60 \\ 90 \\ 120 \end{pmatrix} bar$$

▶ efficiency calculations



This plot shows the ideal efficiency at various combinations of pressure and temperature.

▶ data for saturation curve

this plot for

select_pressure :=

- 30
- **60**
- 90
- 120

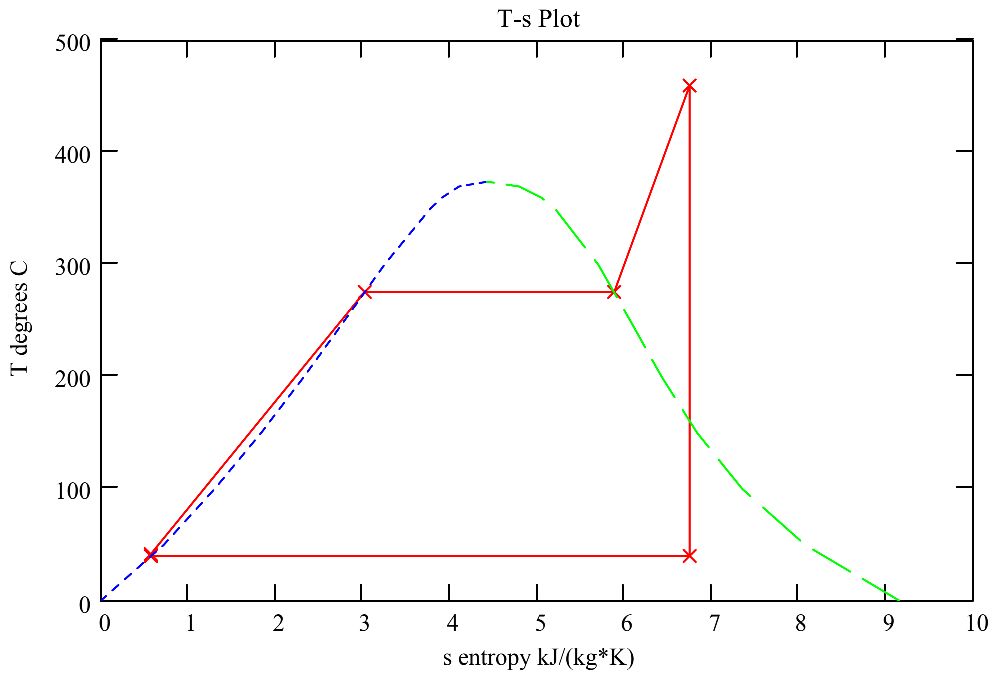
select_temperature :=

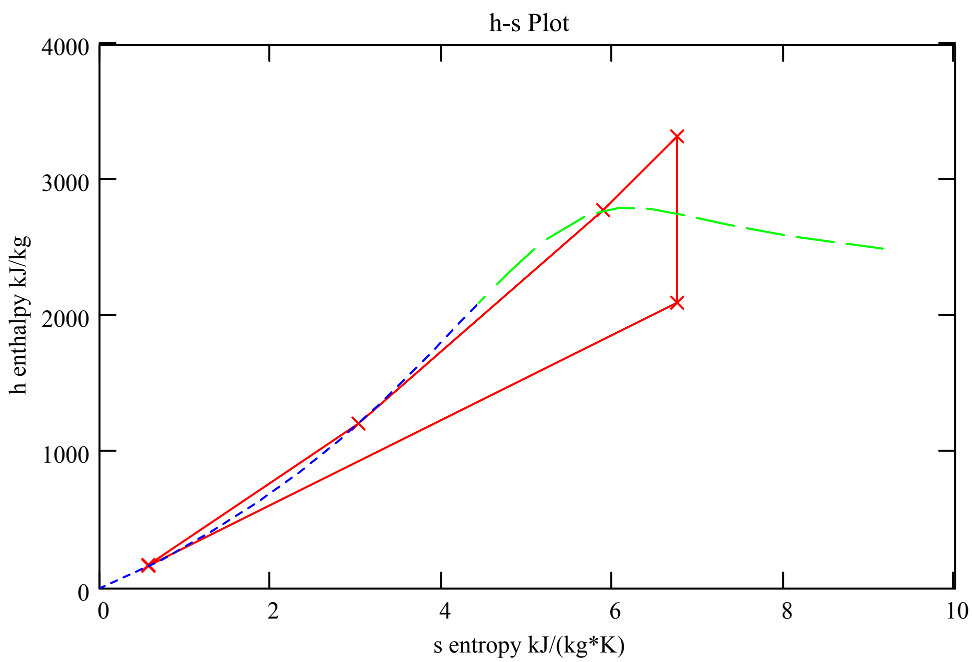
- saturated
- **superheat to 460 deg C**
- superheat to 560 deg C

ip := select_pressure − 1 $\quad p2_{ip} = 6\ \text{MPa}$

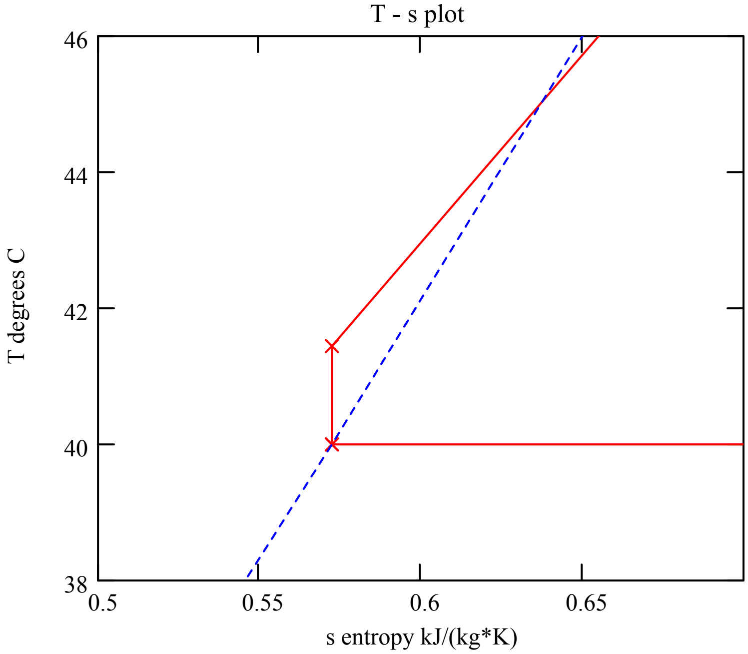
iT := select_temperature − 1 $\quad TT3_{ip,\,iT} = 460$

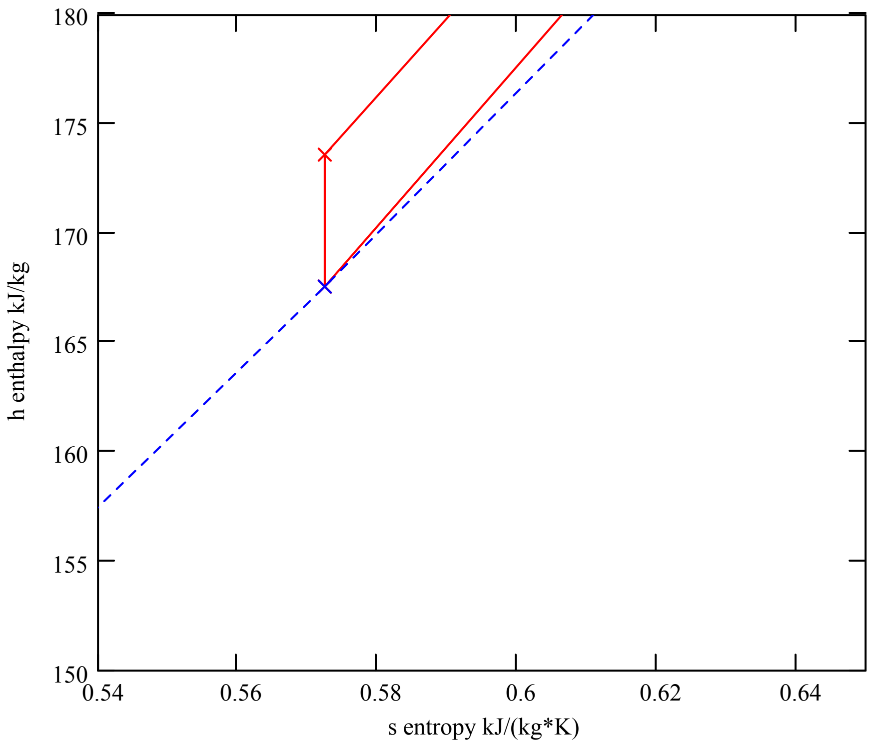
data for T s and H s plots





close up of points 1 and 2





enthalpy average temperature approach for efficiency

we defined the entropy average temperatures in class and showed that the thermal efficiency (ideal) could be calculated ...

$$\eta = 1 - \frac{T\_bar\_L}{T\_bar\_H}$$

using this approach let's calculate the thermal efficiency and compare with above

$$h_3 = \begin{pmatrix} 2804.2 & 3366.6 & 3591.7 \\ 2784.3 & 3326.1 & 3564.2 \\ 2742.1 & 3283.1 & 3535.7 \\ 2684.9 & 3237.2 & 3506.2 \end{pmatrix} \frac{kJ}{kg} \quad h_2 = \begin{pmatrix} 170.586 \\ 173.609 \\ 176.633 \\ 179.656 \end{pmatrix} K \frac{kJ}{kg \cdot K} \quad s_3 = \begin{pmatrix} 6.187 & 7.114 & 7.402 \\ 5.889 & 6.753 & 7.057 \\ 5.677 & 6.521 & 6.844 \\ 5.492 & 6.34 & 6.684 \end{pmatrix} \frac{kJ}{kg \cdot K} \quad s_2 = 0.572 \frac{kJ}{kg \cdot K}$$

$$i := 0 .. 3 \qquad j := 0 .. 2$$

calculate entropy average TH

$$Q_H = h_3 - h_2 \qquad Q_L = h_1 - h_4$$

or ... in indicial notation

$$Q_{H_{i,j}} = h_{3_{i,j}} - h_{2_i} \qquad Q_L = h_1 - h_4$$

entropy average high temperature ...

$$T\_bar\_H_{i,j} := \frac{h_{3_{i,j}} - h_{2_i}}{s_{3_{i,j}} - s_2} \qquad T\_bar\_H = \begin{pmatrix} 469.082 & 488.545 & 500.917 \\ 491.036 & 510.095 & 522.852 \\ 502.57 & 522.253 & 535.608 \\ 509.206 & 530.17 & 544.309 \end{pmatrix} K$$

entropy average low temperature ... is the constant condenser pressure - convert to K

$$T\_bar\_L := (T_1 + 273.15) \cdot K \qquad T_1 = 40$$

$$\eta_{i,j} := 1 - \frac{T\_bar\_L}{T\_bar\_H_{i,j}}$$

$$\begin{pmatrix} T_{sat} & 460 & 560 \end{pmatrix}$$

$$\eta = \begin{pmatrix} 0.332 & 0.359 & 0.375 \\ 0.362 & 0.386 & 0.401 \\ 0.377 & 0.4 & 0.415 \\ 0.385 & 0.409 & 0.425 \end{pmatrix} \quad \begin{pmatrix} 30 \\ 60 \\ 90 \\ 120 \end{pmatrix} bar$$

from above; identical !! as expected

$$\begin{pmatrix} T_{sat} & 460 & 560 \end{pmatrix}$$

$$\eta_{th} = \begin{pmatrix} 0.332 & 0.359 & 0.375 \\ 0.362 & 0.386 & 0.401 \\ 0.377 & 0.4 & 0.415 \\ 0.385 & 0.409 & 0.425 \end{pmatrix} \quad \begin{pmatrix} 30 \\ 60 \\ 90 \\ 120 \end{pmatrix} bar$$