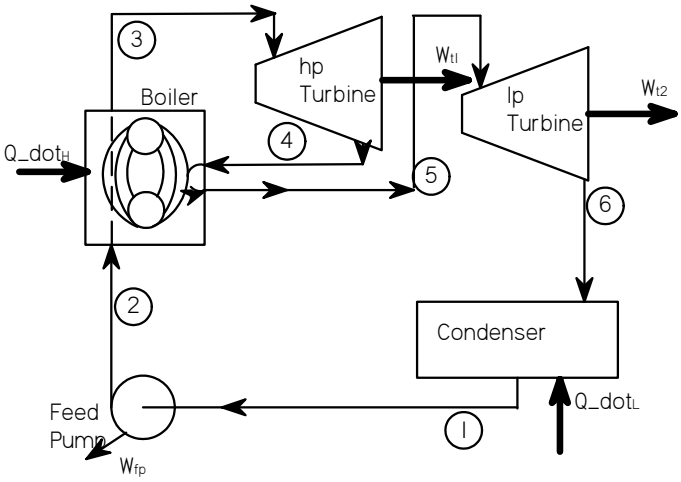
Rankine cycle at various steam pressure and temperature with reheating

this note calculates plot of η vs steam plant pressure with fixed condenser pressure (Temperature) and max temperature with reheating to saturation 460 deg C and 560 deg C. steam is extracted at 400kPa from hp turbine for reheating to boiler outlet temperature.



1 - vacuum; saturated liquid T=40 C

2 - sub cooled liquid at boiler pressure P=3, 6, 9, 12 MPa

3 - saturated vapor, superheated vapor T=460 C, T=560 C, p = p_2

4 - extraction steam; superheated vapor @ 400 kPa or ... vapor + liquid @ saturation temperature and pressure tbd

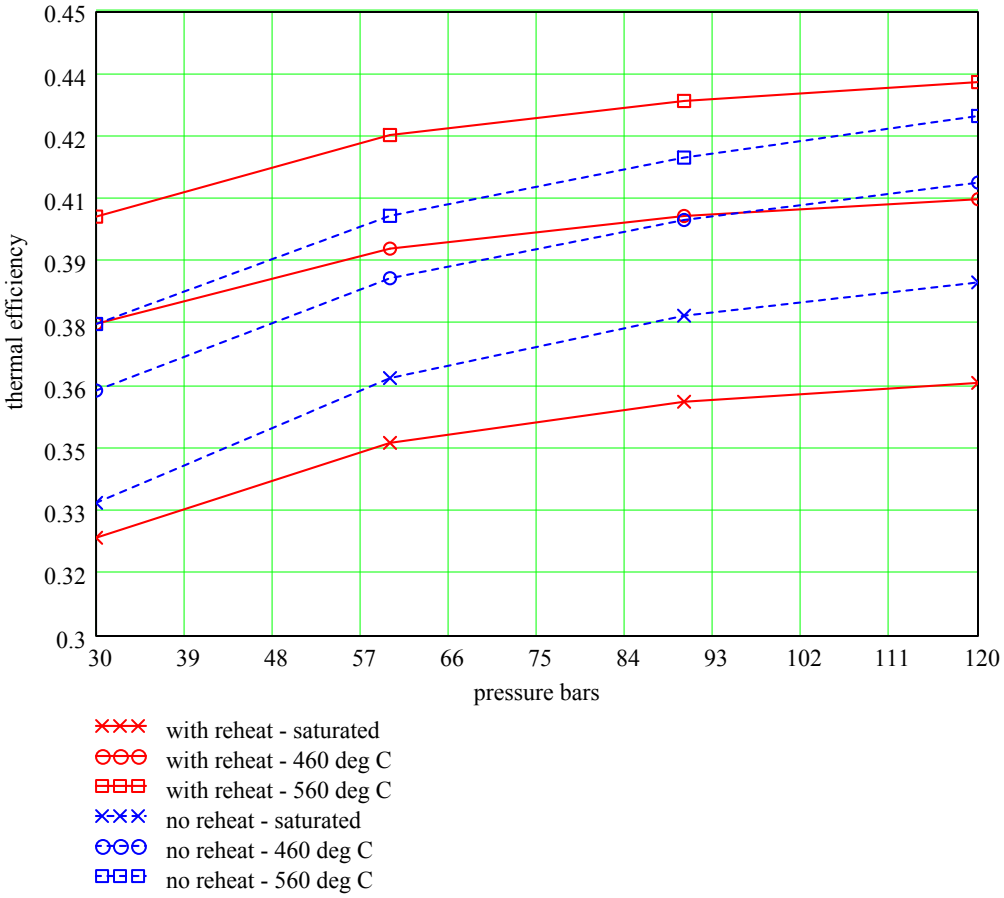
5 - superheated vapor @ saturation temperasature for p_2, T=460 C, T=560 C, p = p_4 = 400 kPa

6 - vapor + liquid @ saturation temperature (40 C) and pressure or ...superheated vapor @ saturation pressure for 40 C; tbd

the results are shown below
in the details of calculation for state 4 - extraction steam; superheated vapor @ 400 kPa or ... vapor + liquid @ saturation temperature and pressure tbd - it can be seen that combinations of
p=3 MPa, T = 460 C
p=3 MPa, T = 560 C and ....
p=6 MPa, T = 460 C
result in superheated vapor extraction (x_6 calculated >1) while the other combinations result in $x_6 < 1$

also ... state 6 - lp turbine exhaust - is superheated vapor @ saturation pressure for 40 C when boiler temperature is 560 C
The approach will be as the regenerative example; calculate x; if > 1 use super heat interpolation for results.

▶ calculations



N.B. efficiency ***decreases*** at saturation reheat, and at 460 C reheat at 12 MPa. This is observable when looking at the T - s plot below for saturation temperature. The effect is noticeable at all pressures, but most significant at 12 MPa. Recall the entropy average temperature concept and observe that the temperature where heat is being added is lowered.

The benefit from reheat is the exhaust moisture in the turbine output (in the latter stages of the single turbine)

quality out of hp turbine

$$x_4 = \begin{pmatrix} 0.8615 & 1.0427 & 1.0989 \\ 0.8034 & 0.972 & 1.0315 \\ 0.7619 & 0.9267 & 0.9899 \\ 0.7258 & 0.8913 & 0.9586 \end{pmatrix}$$

quality out of lp turbine

$$x_6 = \begin{pmatrix} 0.8773 & 0.9767 & 1.0124 \\ 0.8985 & 0.9767 & 1.0124 \\ 0.9117 & 0.9767 & 1.0124 \\ 0.9214 & 0.9767 & 1.0124 \end{pmatrix}$$

quality out of pressure temperature file

$$x = \begin{pmatrix} 0.731 & 0.851 & 0.889 \\ 0.692 & 0.804 & 0.844 \\ 0.664 & 0.774 & 0.816 \\ 0.64 & 0.75 & 0.795 \end{pmatrix}$$

N.B. values of x > 1 are bogus and actual x = 1, i.e. steam is superheated vapor

▶ 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 $p2_{ip} = 12\,MPa$ iT := select_temperature − 1 $TT3_{ip,iT} = 324.75$

data for T s and H s plots