Vapor Power Cycles

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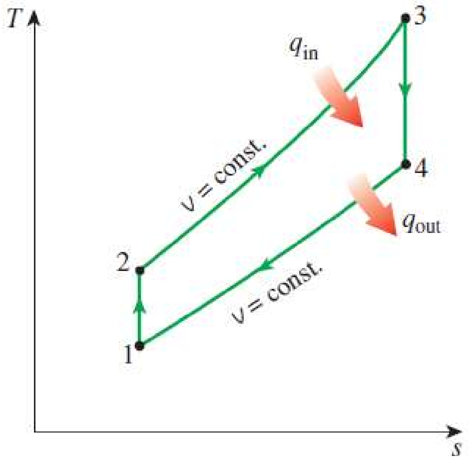
Previously: Otto-, Diesel-, Brayton- & Stirling-Cycles

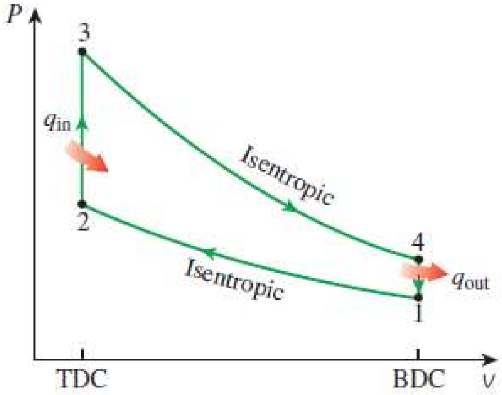


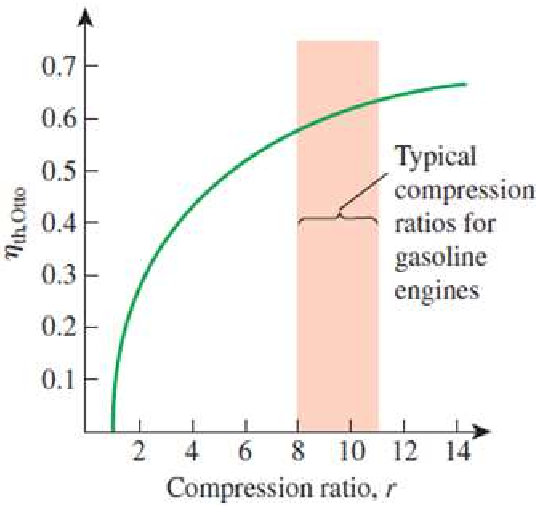
$$q_{in} - w_{b,out} = u_3 - u_2 \rightarrow q_{in} = P_2(v_3 - v_2) + (u_3 - u_2)$$
$$= h_3 - h_2 = c_p(T_3 - T_2)$$

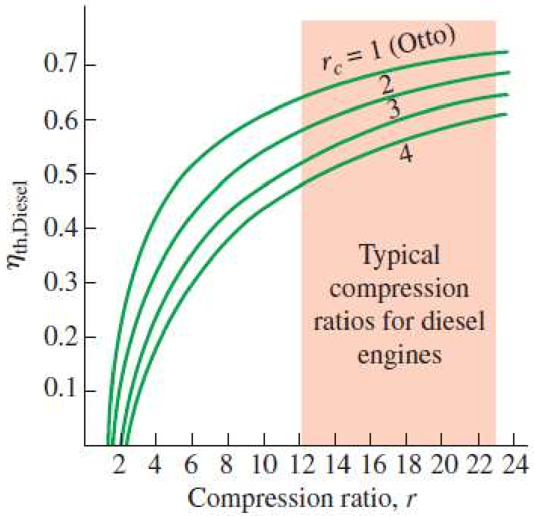
$$\eta_{th,Otto} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{T_1(T_4/T_1 - 1)}{T_2(T_3/T_2 - 1)}$$

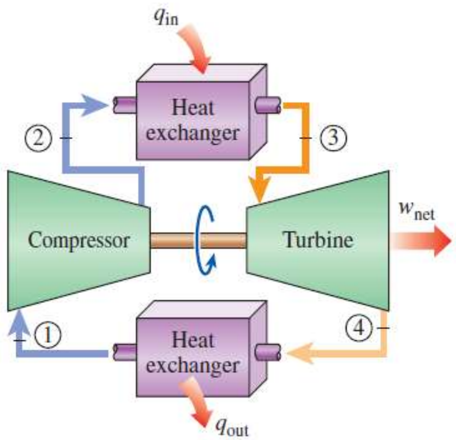
Isoentropic gas results for 1→2 & 3→ 4

$$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}}$$









Compression ratio & autoignition/engine knock

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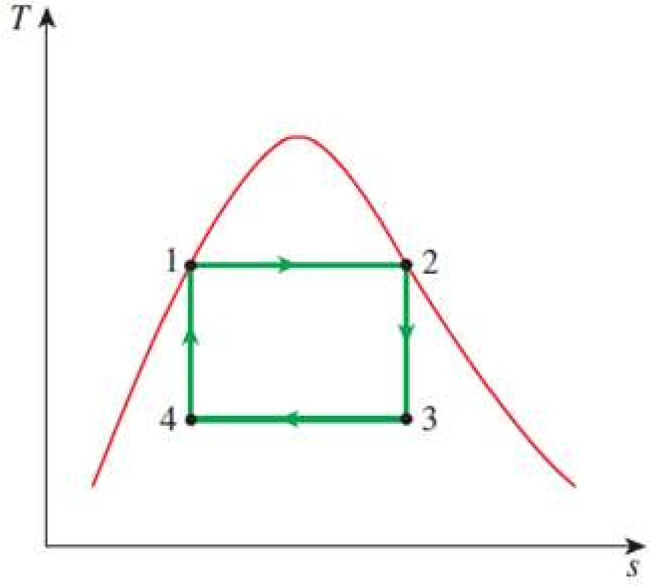
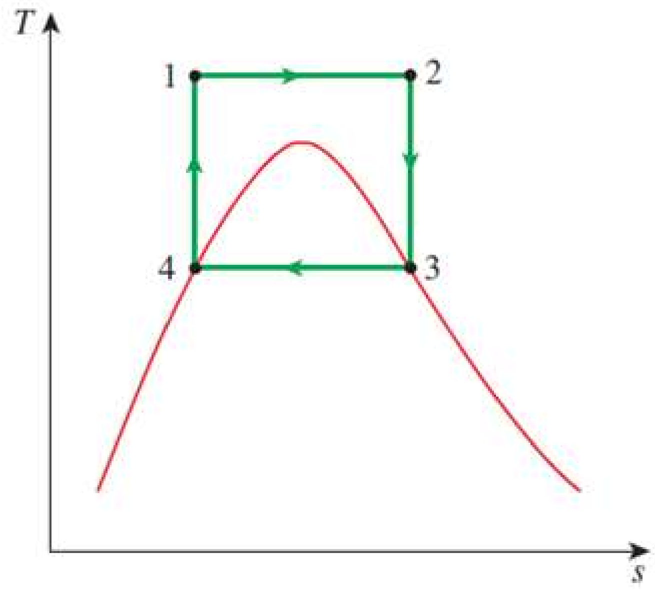
Limitation of Carnot Vapor Cycle



1-2 isothermal heat addition in a boiler
2-3 isentropic expansion in a turbine
3-4 isothermal heat rejection in a condenser
4-1 isentropic compression in a compressor



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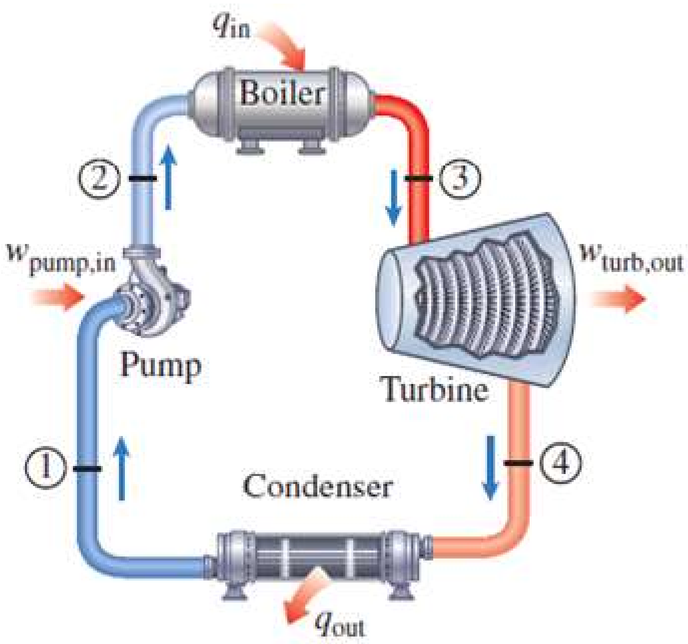
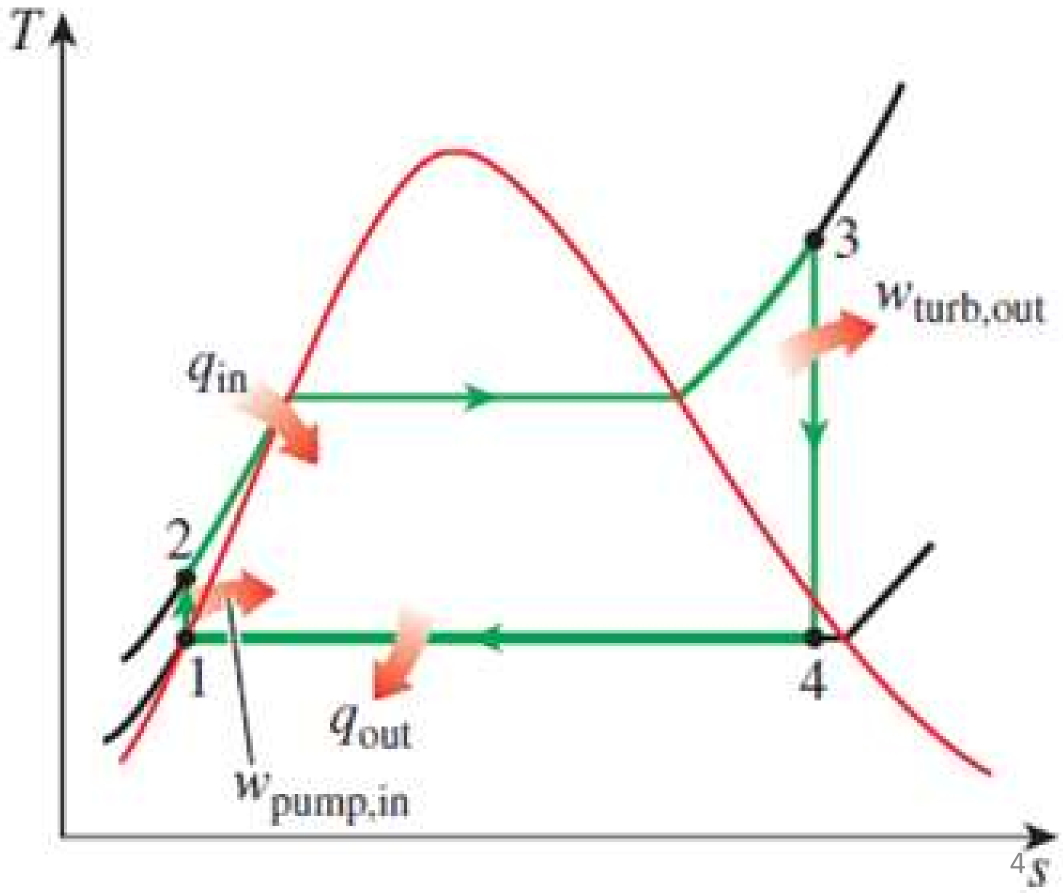
Motivations & Operations of Rankine Cycle



1-2 Isentropic compression in a pump
2-3 Constant pressure heat addition in a boiler
3-4 Isentropic expansion in a turbine
4-1 Constant pressure heat rejection in a condenser



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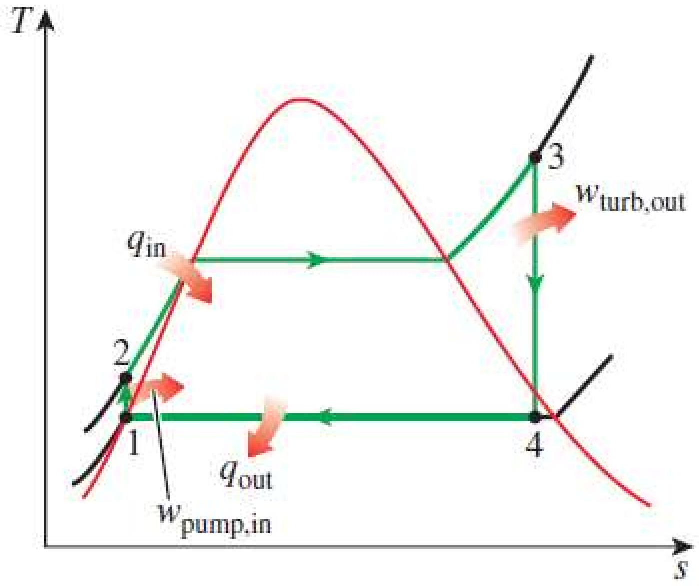
Analysis of Rankine Cycle



$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_e - h_i \qquad \text{(kJ/kg)}$$

Pump $(q = 0)$: $\quad w_{pump,in} = h_2 - h_1$

$$w_{pump,in} = v(P_2 - P_1)$$

$$h_1 = h_{f\,@\,P_1} \quad \text{and} \quad v \cong v_1 = v_{f\,@\,P_1}$$

Boiler $(w = 0)$: $\quad q_{in} = h_3 - h_2$

Turbine $(q = 0)$: $\quad w_{turb,out} = h_3 - h_4$

Condenser $(w = 0)$: $\quad q_{out} = h_4 - h_1$

$$w_{net} = q_{in} - q_{out} = w_{turb,out} - w_{pump,in}$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

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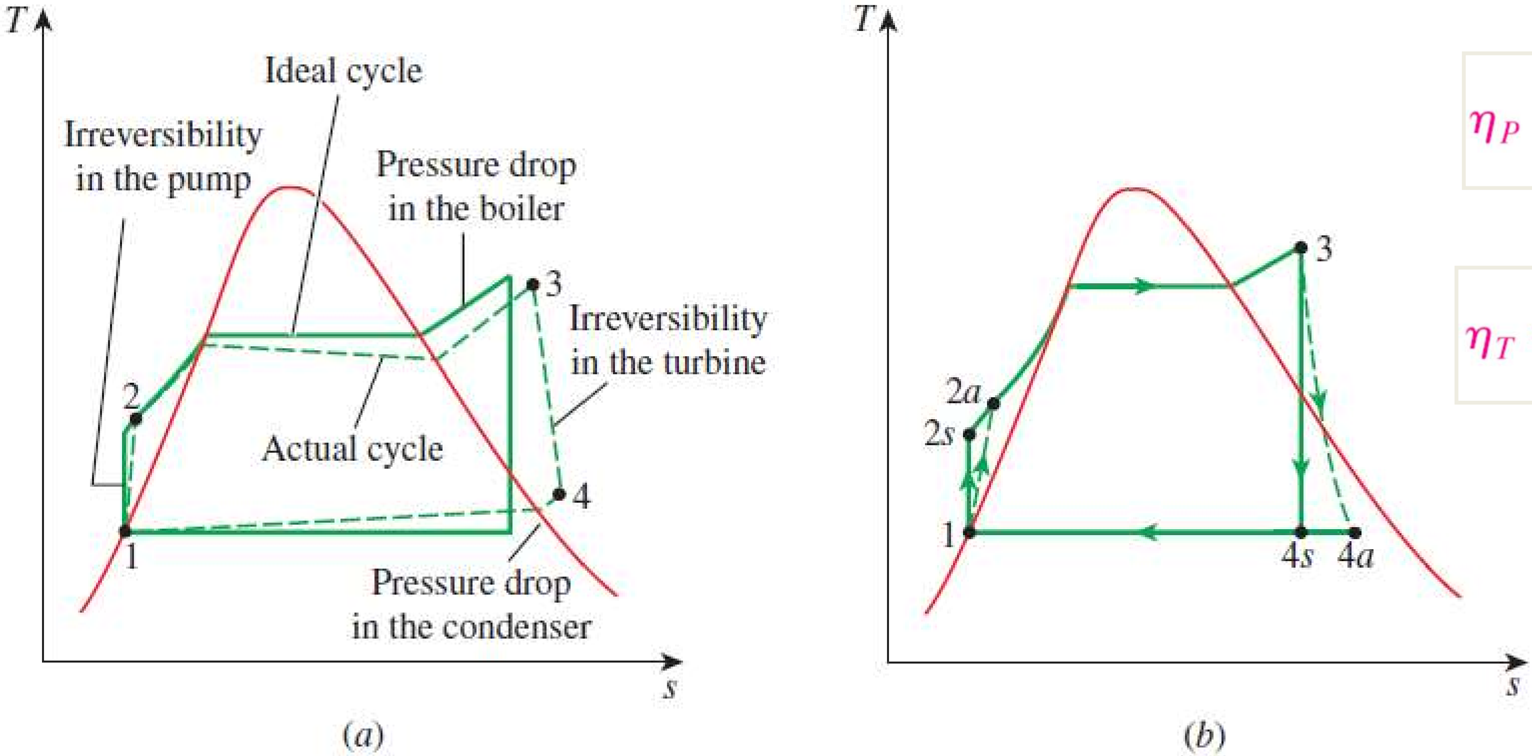
Real Vs. Ideal Rankine Cycle

1-2 Isentropic compression in a pump
2-3 Constant pressure heat addition in a boiler
3-4 Isentropic expansion in a turbine
4-1 Constant pressure heat rejection in a condenser



$$\eta_P = \frac{w_s}{w_a} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$\eta_T = \frac{w_a}{w_s} = \frac{h_3 - h_{4a}}{h_3 - h_{4s}}$$

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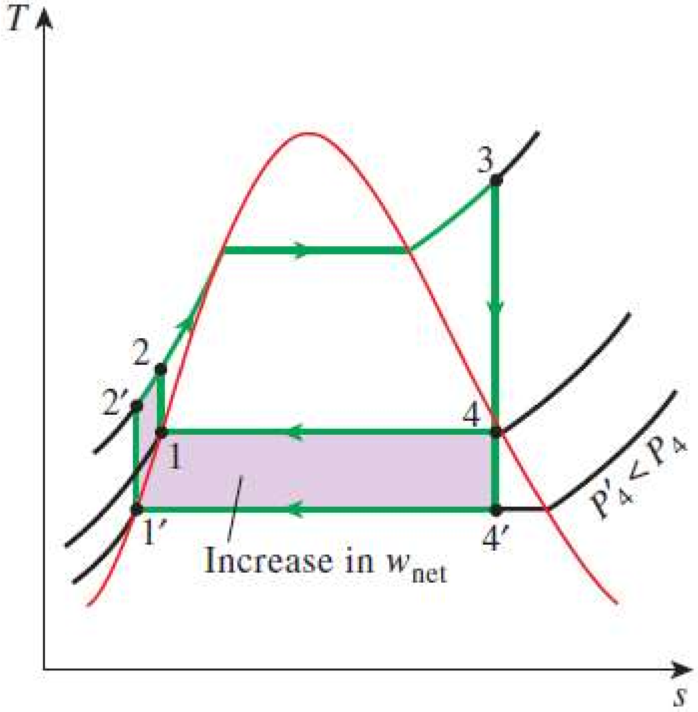
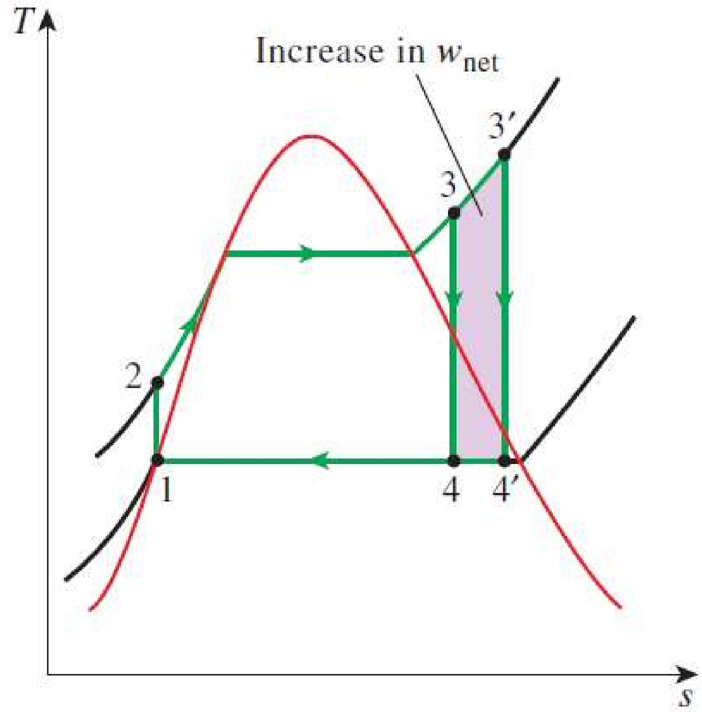
Increasing efficiency: T_h higher & T_l lower





- Small increase in heat requirement
- Pressure should > sat. pr. of cooling medium
- Increased moisture

- Decreased moisture
- Material degradation at higher T

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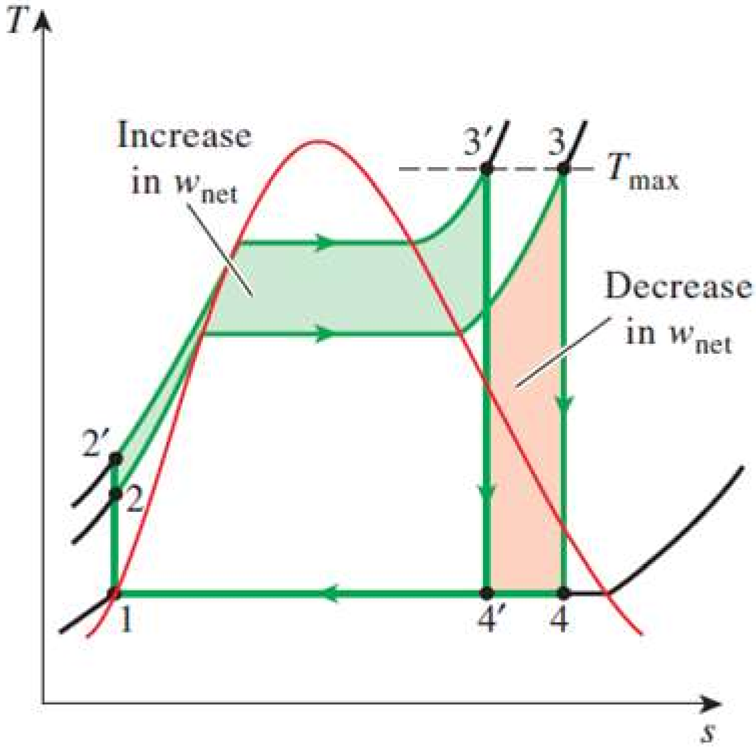
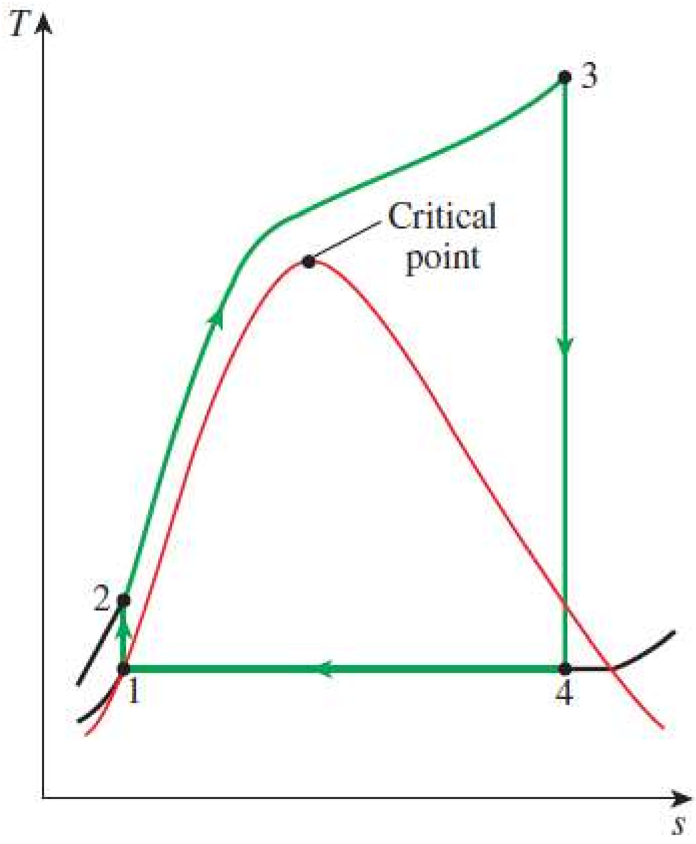
Increasing Boiler Pressure





- Increased moisture
- Reheat

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What's next?

- Refrigeration cycles