Turbine Controls Seminar

TECHNICAL THERMODYNAMIC

SELECTED FOUNDAMENTALS RELATED TO STEAM TURBINE CONTROLS

Pero Skoric - 2018

First & Second Law Of Thermodynamic

The First Law Of Thermodynamic is about Conservation of Energy.

It says : Energy NEVER **disappears** however**, it** can be **transformed** into some other form as, heat to work, etc.

E + Q + W = Constant [J/kg]

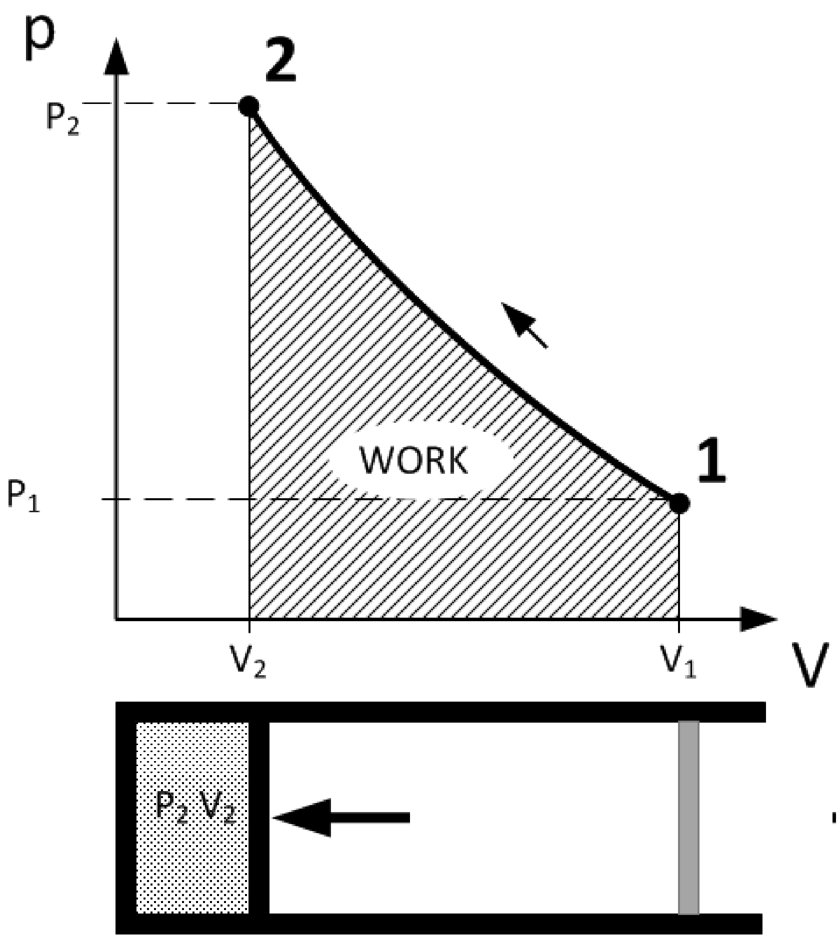
The Second Law Of Thermodynamic is the philosophy of technical thermodynamic. Introduces Entropy s [J/K/kg] as a property of matter.

It says: In order to extract out any work by a cyclic process some heat needs to be exchanged both to the process and out of it. It also says many other things as, heat can only go $t_2<t_1$, …

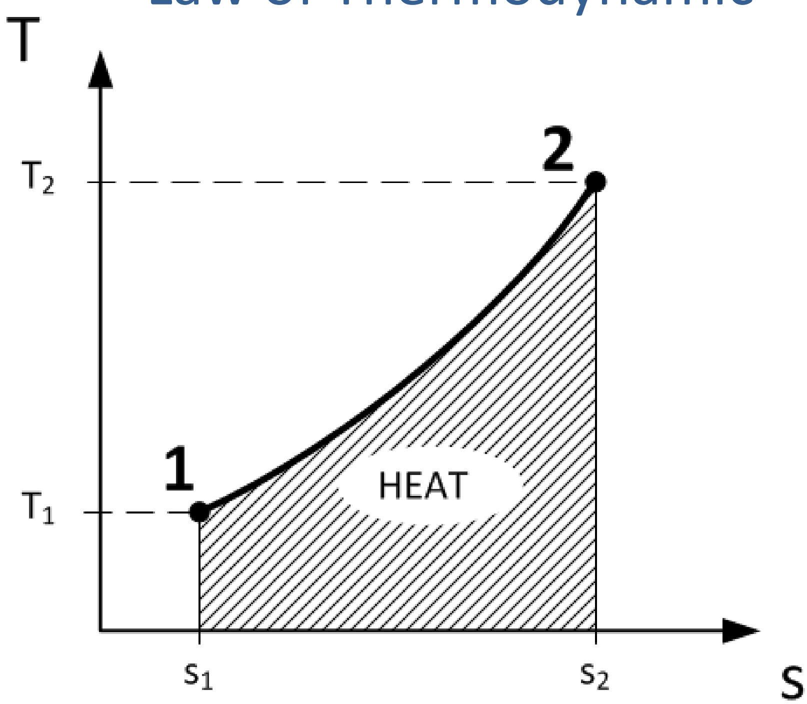
Q = T * Δs [J/kg]

P-V & T-s diagrams

P-V is the most basic Thermodynamic Diagram

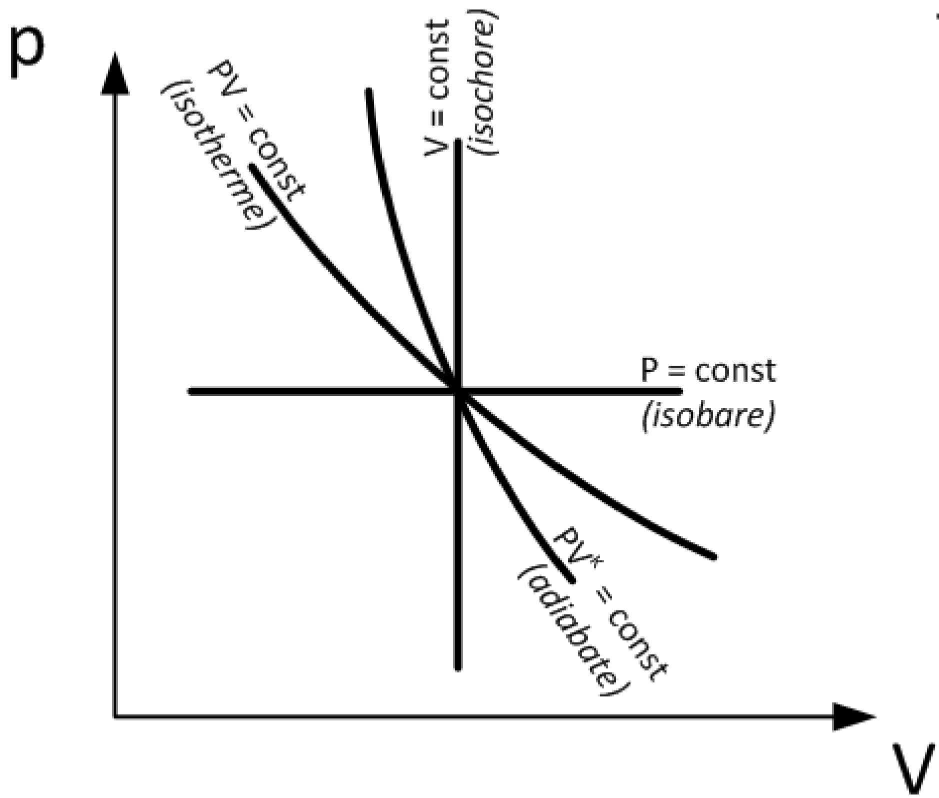


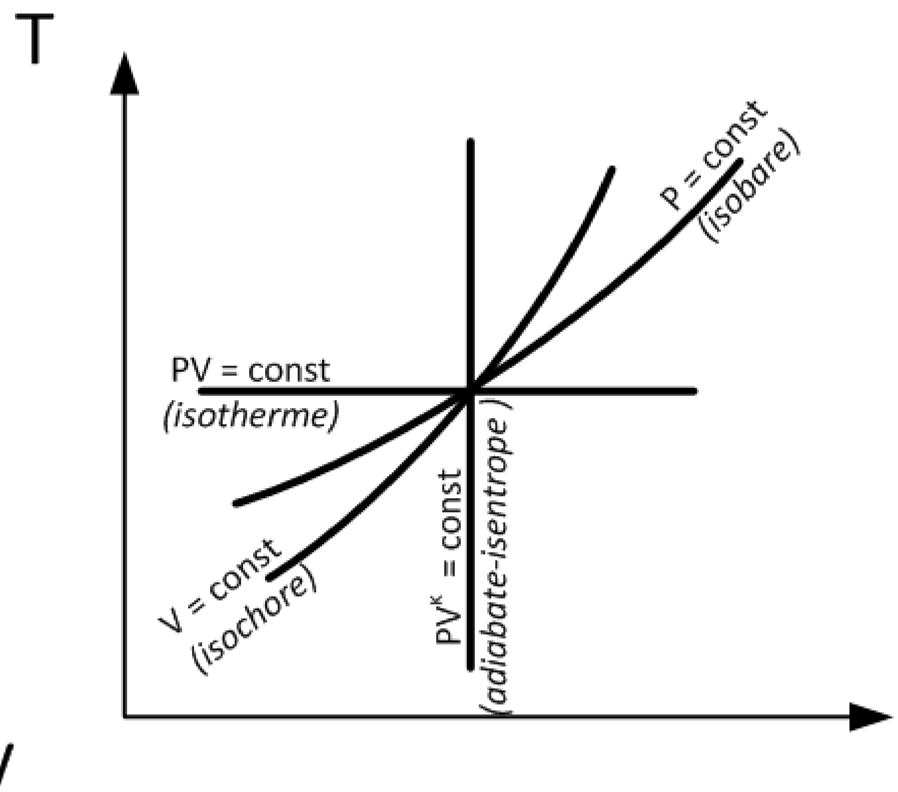
T-s is coming from Second Law of Thermodynamic



Characteristic Thermodynamic Processes in P-V & T-s Diagrams

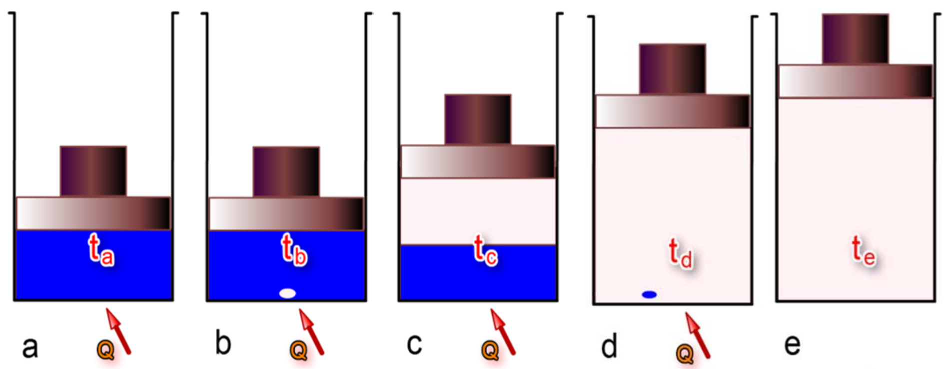
Isobare (p=const), isochore(V=const), isotherme(pV= const), adijabate(pV^{κ}= Const & Q=0) ~ isethrope (pV^{κ}= Const & Q=0 & s=const)





Steam(1)

Evaporation process



a) p; t_a
b) p; $t_b > t_a$
c) p; $t_c = t_b$
d) p; $t_d = t_c$
e) p; $t_e > t_d$

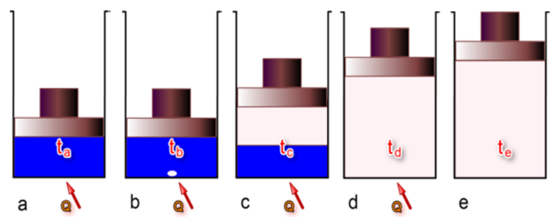
b, c, d – saturation region

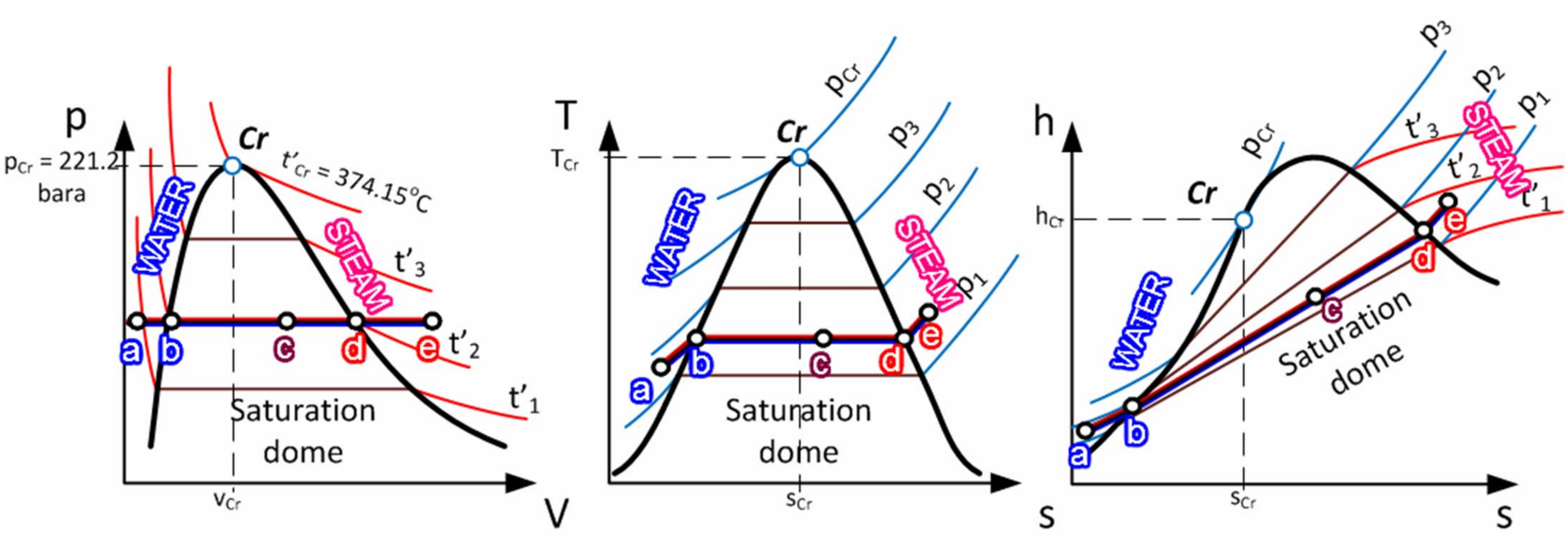
$t_b = t_c = t_d = t'$ (saturation temperature)

$t' = f(p)$

Steam(2)

Evaporation process in p-v & T-s & h - s (Mollier Chart)





MAIN HEAT ENGINES

In thermodynamics , **heat engine** is a system that converts heat or thermal energy and chemical energy into mechanical energy, which can then be used to do mechanical work. https://en.wikipedia.org/wiki/Heat_engine

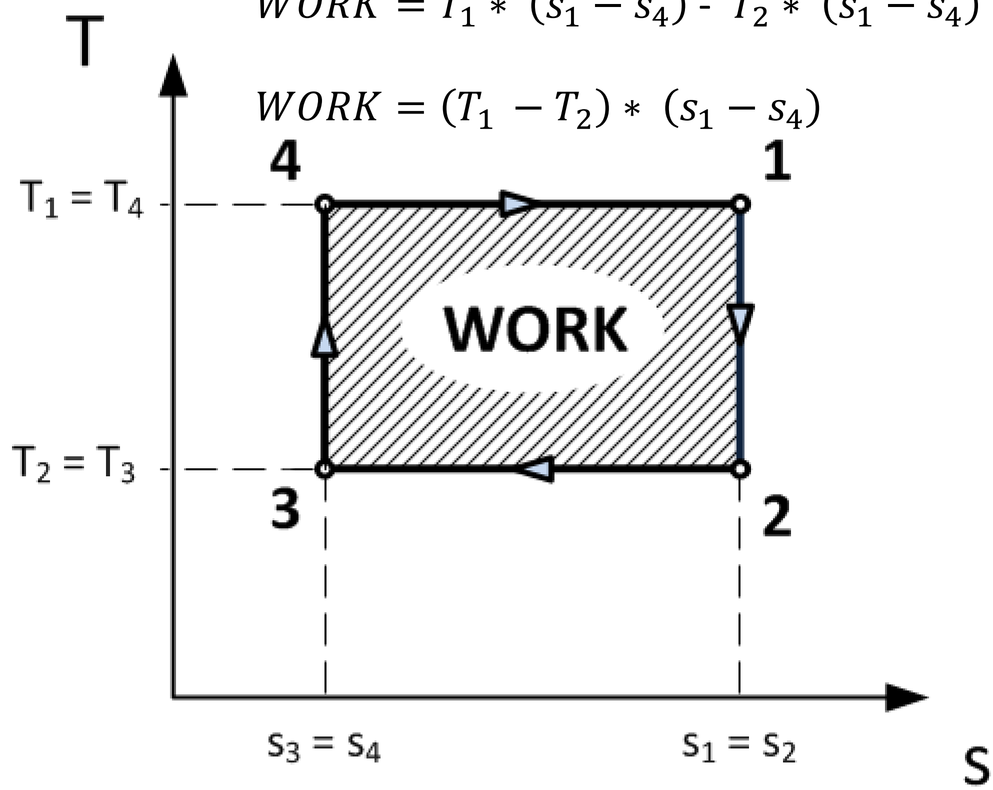
- **Carnot Engine** (https://en.wikipedia.org/wiki/Carnot_heat_engine)
  #1Engine. The most possible theoretical thermal efficiency.
- **Otto Engine**
  Petrol engines.
- **Diesel Engine**
  Diesel engines. Higher thermal efficiency than Otto .
- **Bryton Engine** (https://en.wikipedia.org/wiki/Brayton_cycle)
  Gas turbines. Also called Joule Engine.
- **Rankin Engine** (https://en.wikipedia.org/wiki/Rankine_cycle)
  Steam power plants. Utilizes steam evaporation process.

Carnot Engine

$$WORK = Q_{in} - Q_{Out}$$

$$WORK = T_1 * (s_1 - s_4) - T_2 * (s_1 - s_4)$$

$$WORK = (T_1 - T_2) * (s_1 - s_4)$$

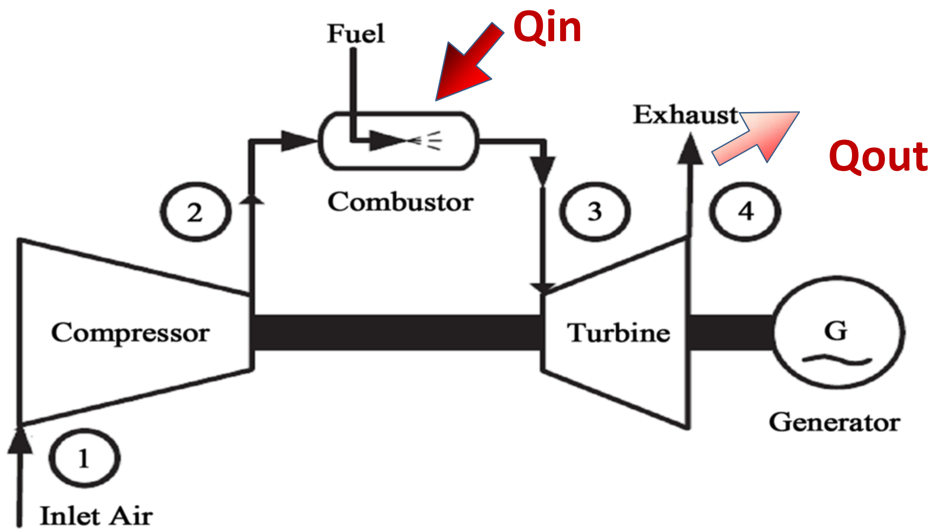


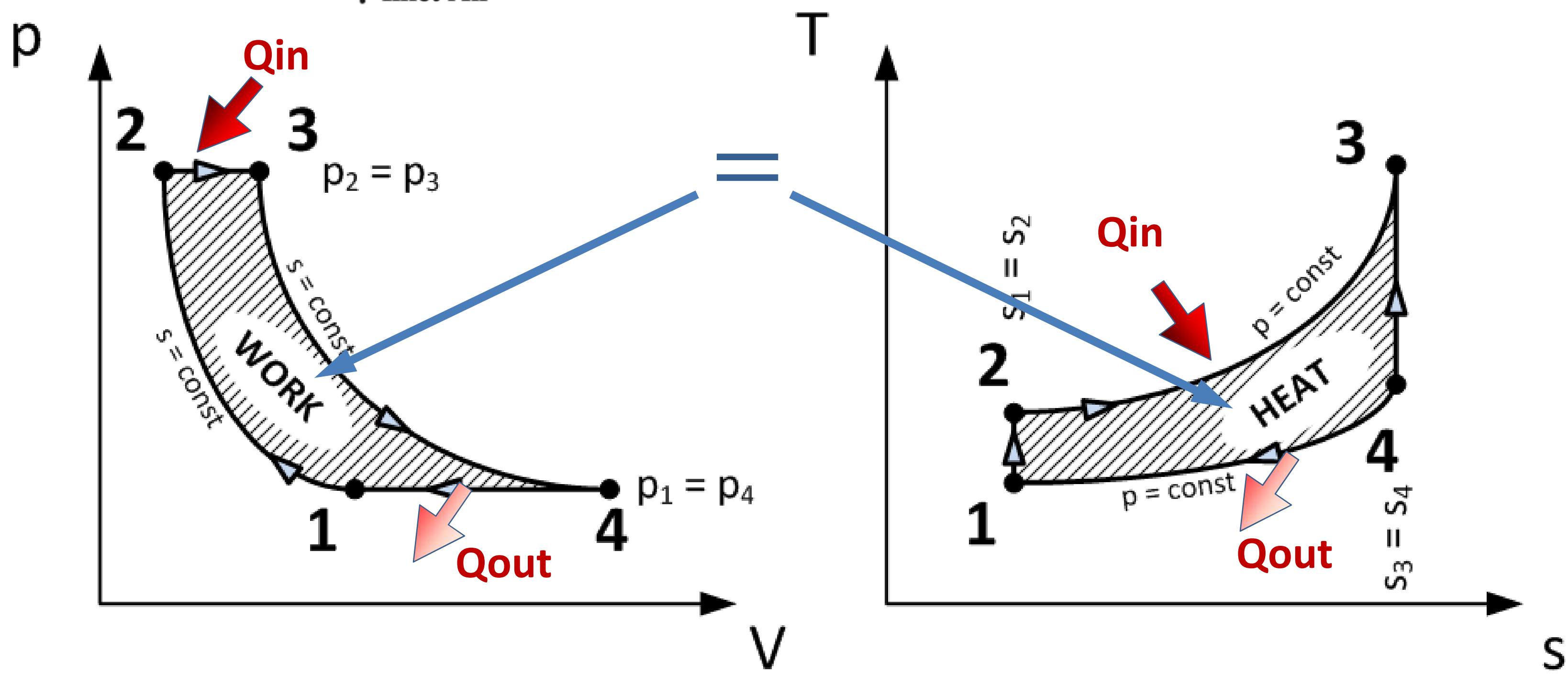
$$\text{Eff} = \frac{WORK}{Qin}$$

$$\text{Eff} = \frac{(T_1 - T_2) * (s_1 - s_4)}{T_1 * (s_1 - s_4)}$$

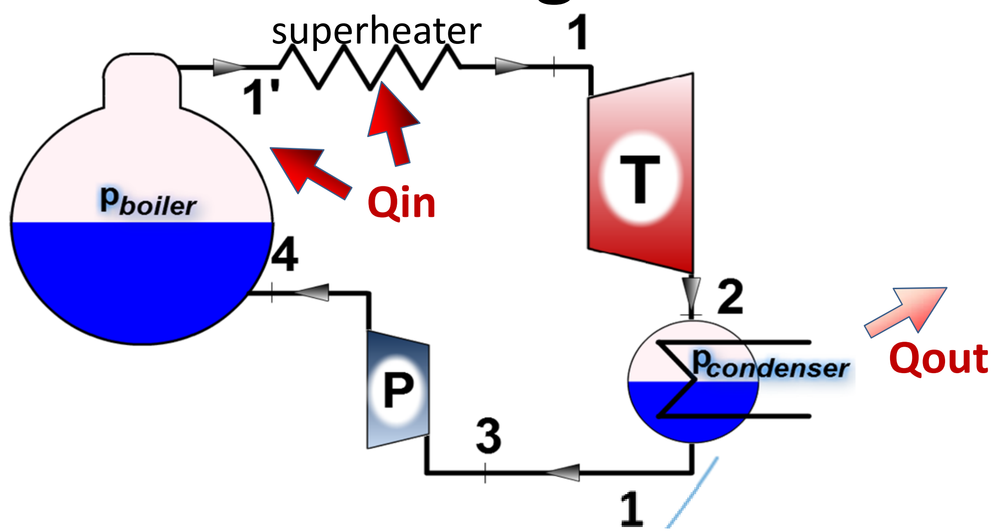
$$\text{Eff} = 1 - \frac{T_2}{T_1}$$

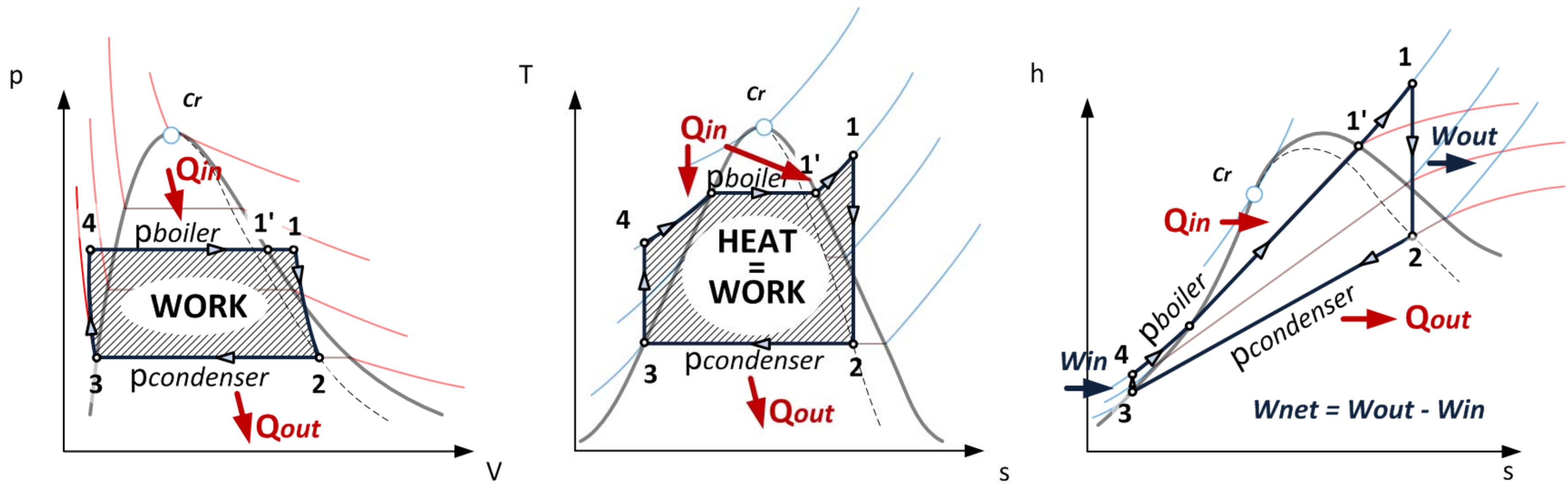
Brayton Engine





Rankine Engine





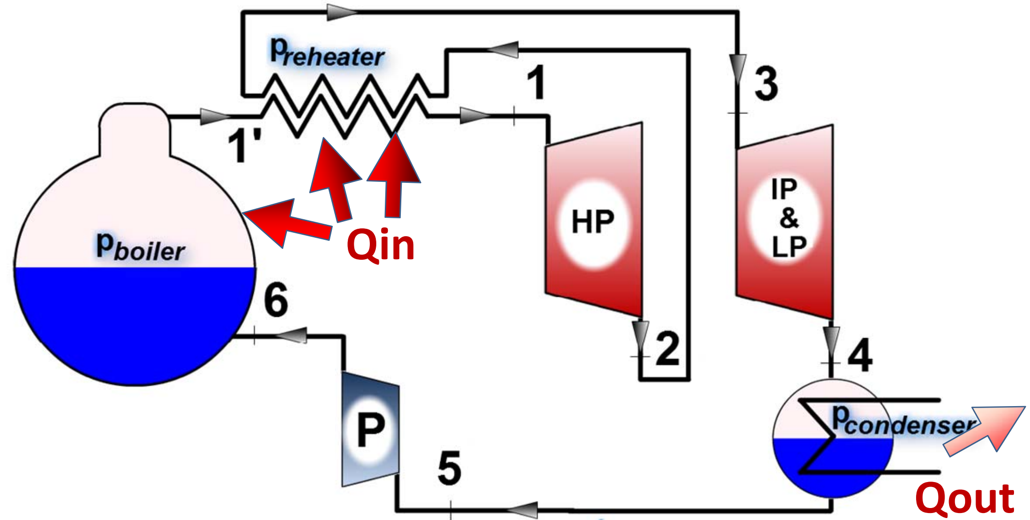
Rankine Engine – Steam Reheat

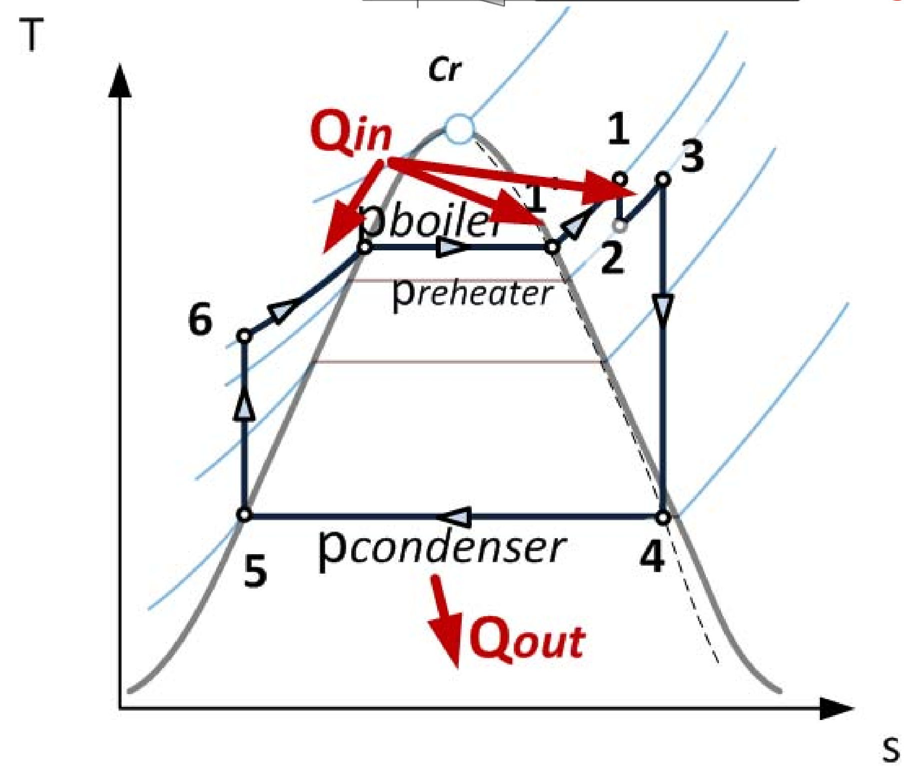
After passing through HP live steam goes back to boiler. Then goes to IP&LP.

a) Eff = 1 - $\frac{T_2}{T_1}$

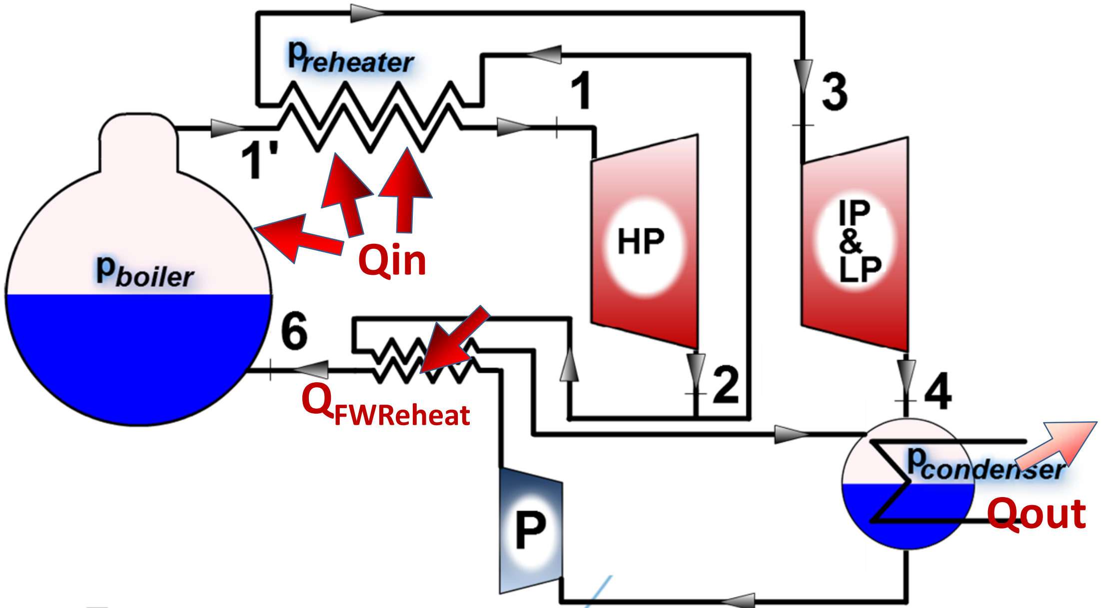
Max T_1 temperature is limited by material endurance. Steam reheat increases overall engine efficiency by increasing average T_1. Called Rankin Engine Carnotisation!;

b) **Reduces steam wetness at the back of the turbine. High wetness can cause serious erosion damages.**



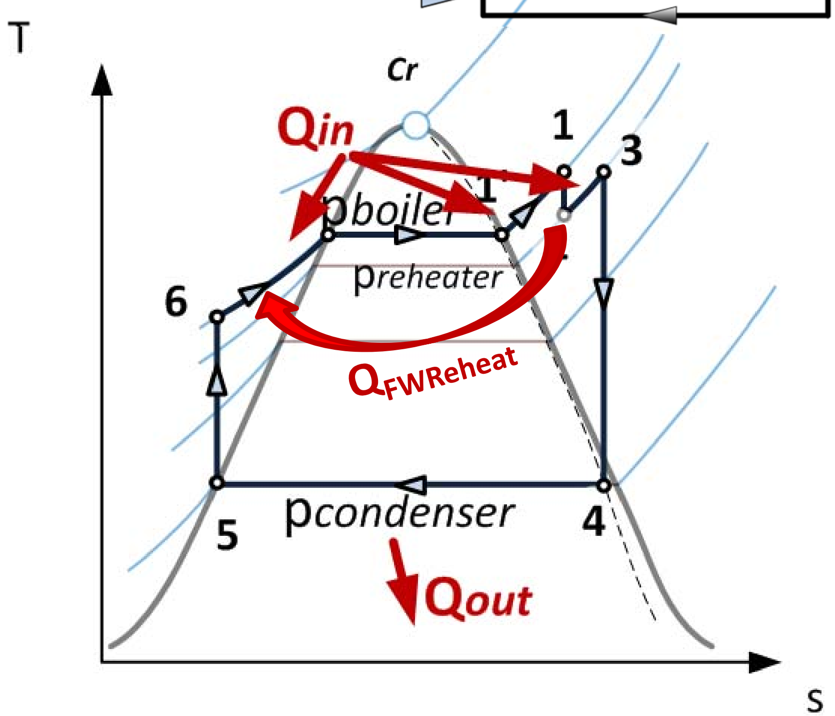


Rankin Engine – Feed Water Reheat



Part of the steam is redirected off from the turbine to heat up the feed water before it enters the boiler.

Increases overall engine efficiency by “saving” $Q_{FWReheat}$ back to the Engine.



By applying Steam and FW reheat Rankin Engine overall efficiency can go up to 45%. (theoretically)

DISCUSSION !