Energetic processes and equipment (BMEGEENBGEB)

Basics

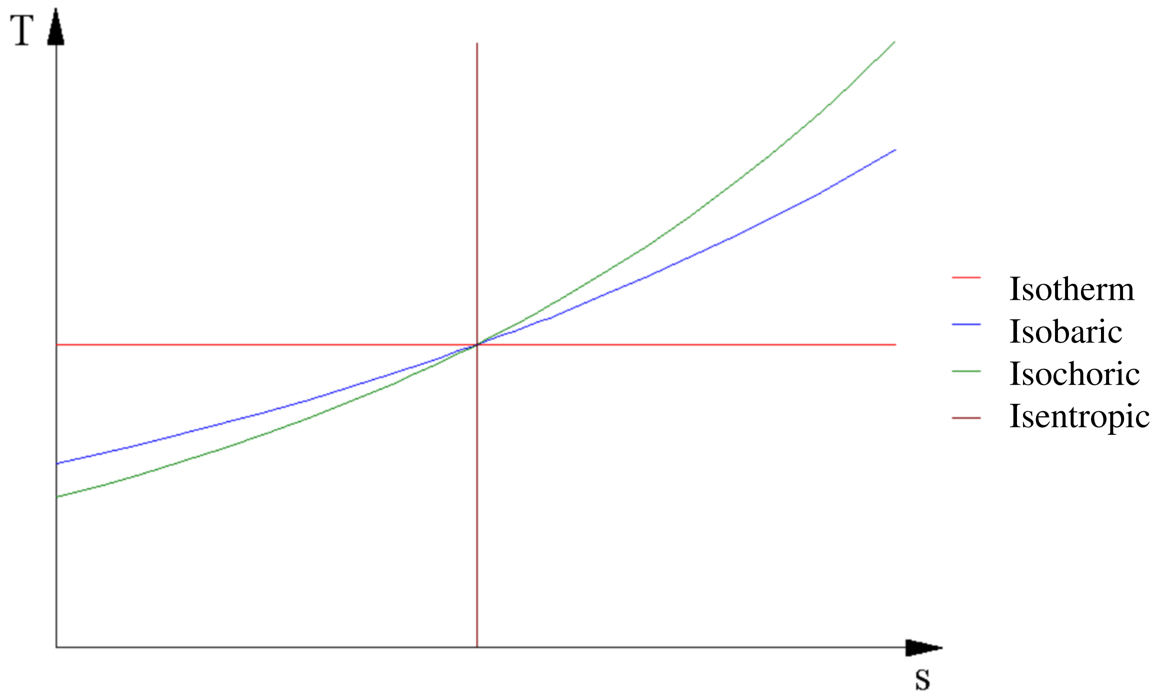
2023

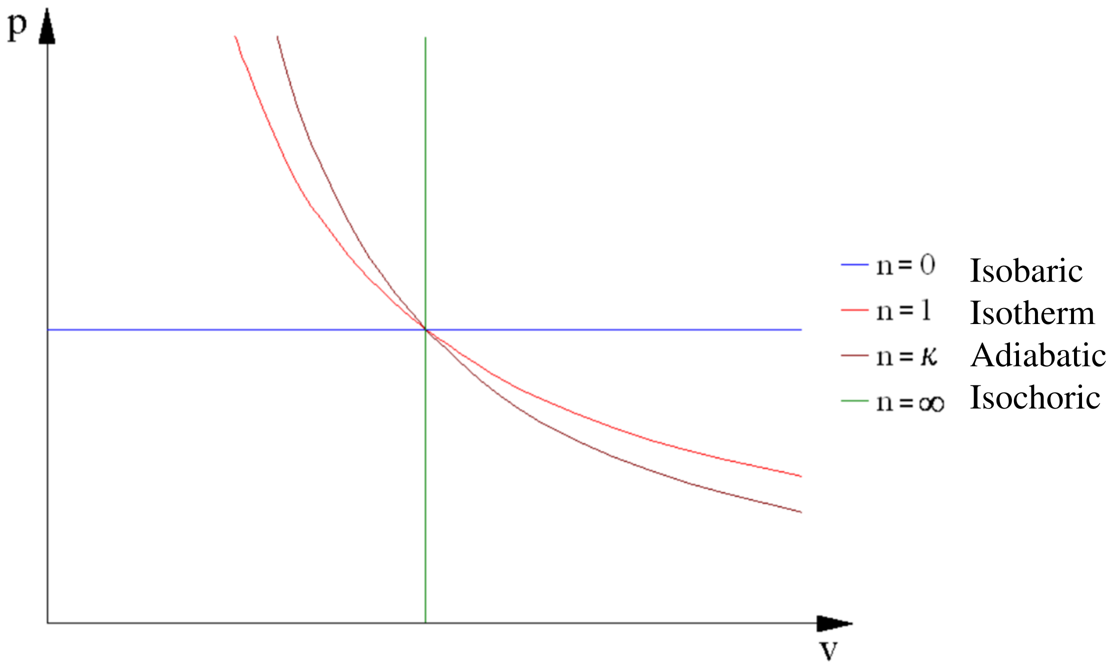
Educ. week	Date	Topics	Pres.	Note	Tests
1	2023.09.04	Repeat, main cycles, Lab safety for all groups	门éfalvay		
2	2023.09.11	Solar Cells	Mayer		
3	2023.09.18	Fuel cells	Lévai		
4	2023.09.25	Combustion	Cséfalvay/ Lezsovits		
5	2023.10.02	Combustion	Lezsovits		TEST
6	2023.10.09	Cooling	Maiyaleh		
7	2023.10.16	Cooling	Maiyaleh		
8	2023.10.23			Day off	
9	2023.10.30	Gas Turbines	Sztankó		TEST
10	2023.11.06	Steam Turbines	Sztankó		
11	2023.11.13	Gas engine	Bereczky		
12	2023.11.20	ICE	Bereczky		
13	2023.11.27	ICE	Bereczky		
14	2023.12.04	supp.TEST	Bereczky		TEST + supp. 1.+ 2.

All information will be on the Moodle homepage of the topic

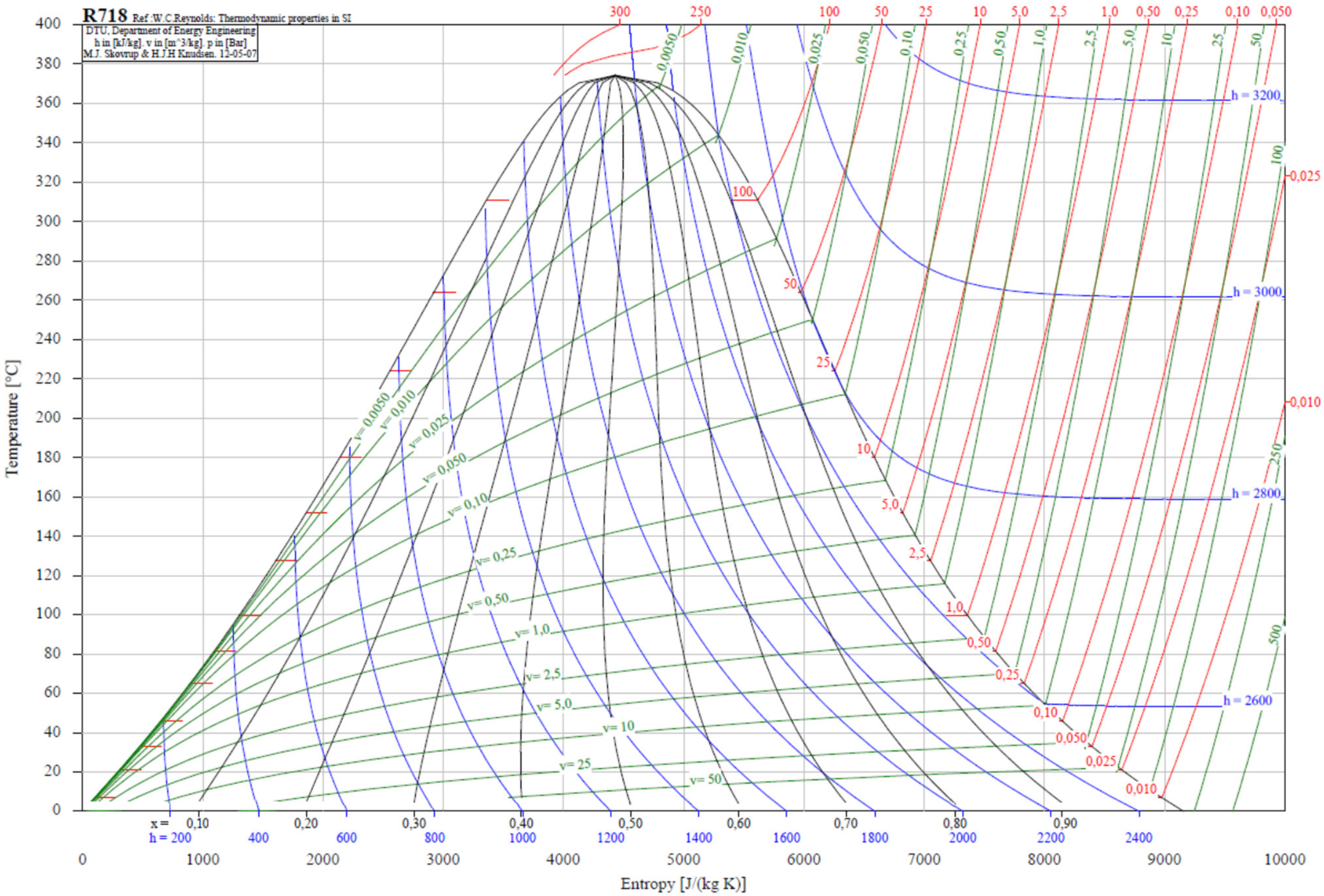
Tuesdays 12:15-14:00										
Educ. week	Date	Solar Cell	Flame propagation	Fuel cell	Stationer boiler test	High Temperature Measurement	Gas Turbine	Stirling	Cooling system	Supp. Labs.
1	~~2023.09.05~~									
2	~~2023.09.12~~	Sport day							Day off	
3	~~2023.09.19~~									
4	2023.09.26	A	B	C	D					
5	2023.10.03	D	A	B	C					
6	2023.10.10	C	D	A	B					
7	2023.10.17	B	C	D	A					
8	2023.10.24					A	B	C	D	
9	2023.10.31					D	A	B	C	
10	2023.11.07					C	D	A	B	
11	2023.11.14					B	C	D	A	
12	2023.11.21									
13	2023.11.28									all groups
14	2023.12.05									
	Loc.	**K4**	**K1**	**K10**	**F6**	**K3**	**K1**	**F6**	**K2**	**-**
	Lecturer and lab supervisor	D. Markovics	H. Sadah	E. Lévai	M. Chabrecsek	R. Kardos	K. Lukács	D. Csemány	R. Shaheen	

Neptun 1,2,6	**group**
A0C	A
A91	A
BKT	A
BRR	A
CZO	A
EF2	A
FZE	B
GL8	B
HHP	B
HOP	B
H3I	B
ID5	C
N1T	C
PKU	C
P0T	C
RFI	C
S7B	D
TYP	D
UZL	D
W0E	D
ZU7	D



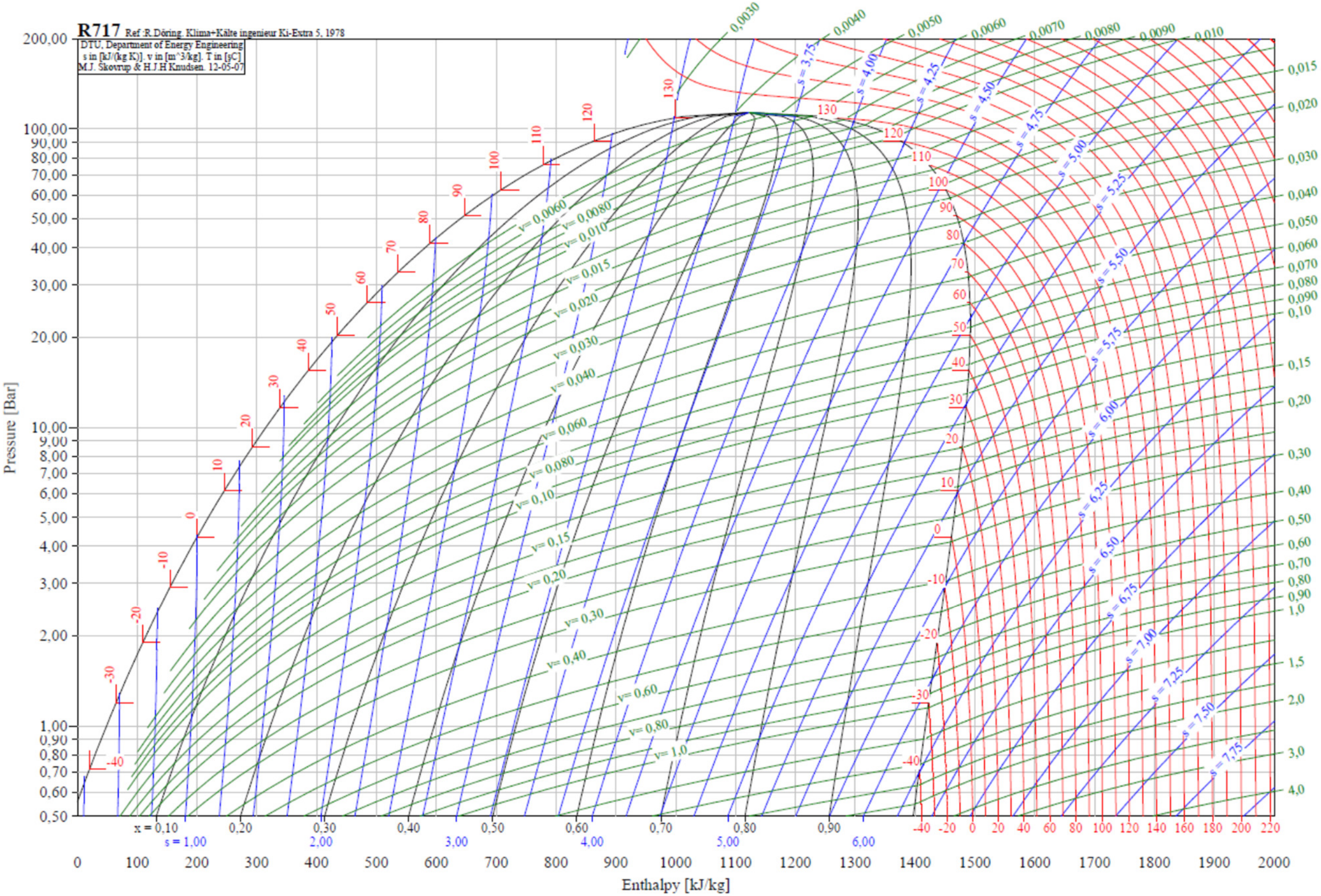


Source: Guide to seminars of Heat Engines (A. Kun-Balog)



T-S diagram of H_2O

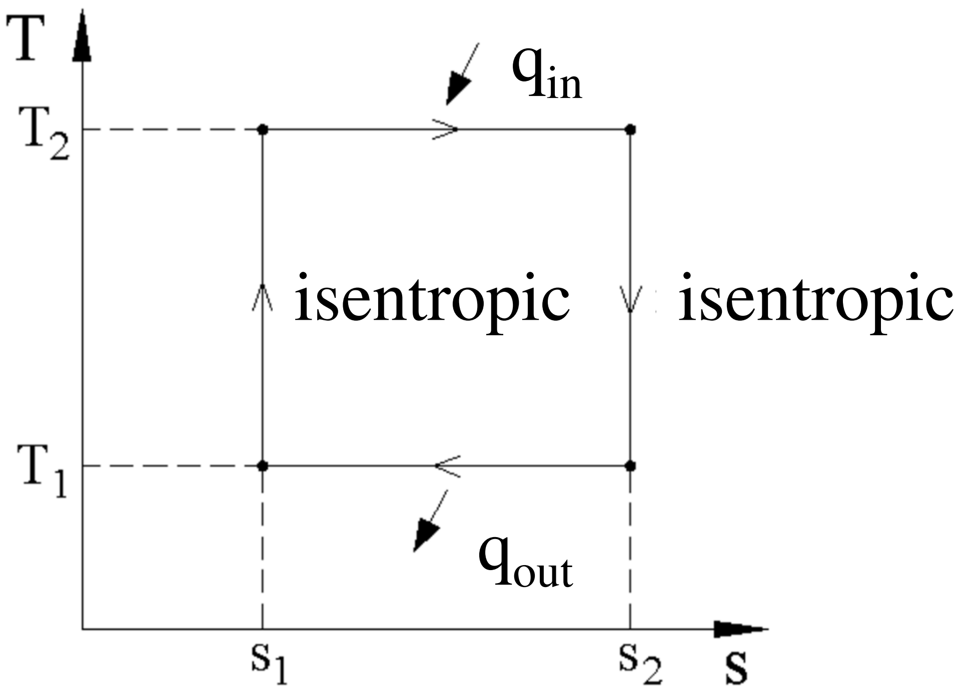
Source: Guide to seminars of Heat Engines (A. Kun-Balog)



logp-h diagram of Ammonia

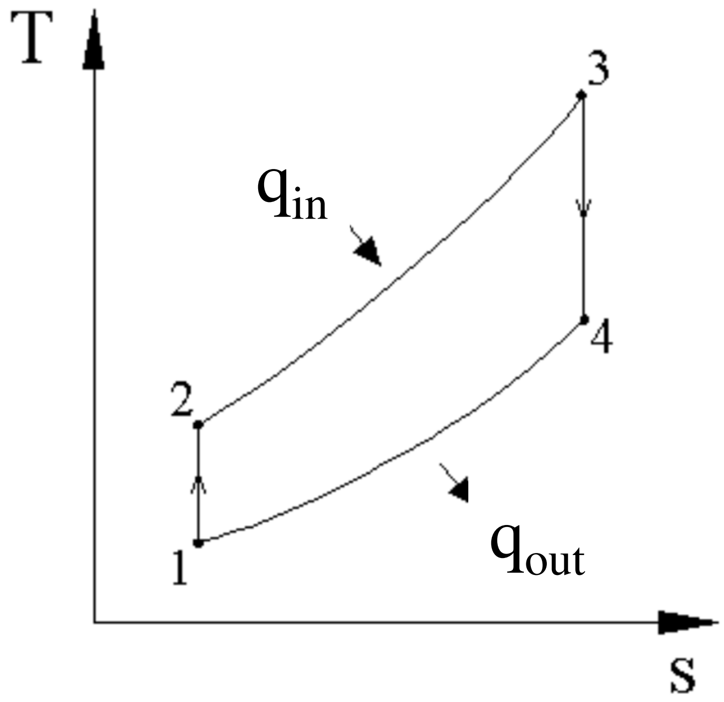
Source: Guide to seminars of Heat Engines (A. Kun-Balog)

$$\eta_t = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{T_1 \cdot (s_2 - s_1)}{T_2 \cdot (s_2 - s_1)} = 1 - \frac{T_1}{T_2}$$



Carnot cycle

Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)

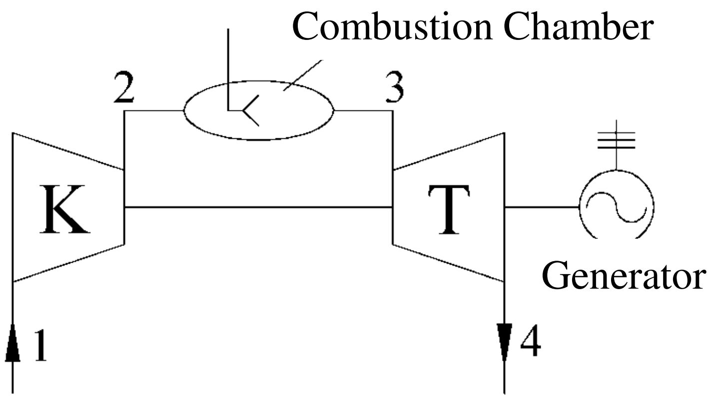


$$\eta_t = 1 - \frac{1}{\pi^{\frac{\kappa-1}{\kappa}}}$$

Brayton-Joule cycle

Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)

Theoretical Gas Turbine



$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\kappa - 1}{\kappa}}$$

$$\frac{p_2}{p_1} = \pi$$

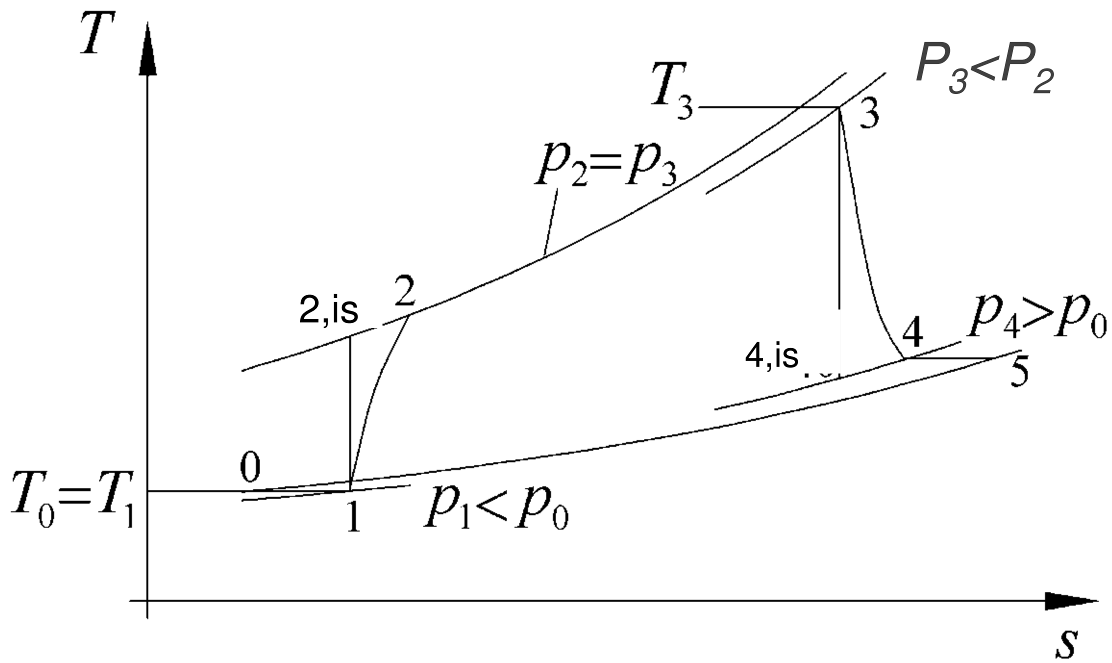
$$P_C = \dot{m} \cdot \Delta h_{1-2} = \dot{m} \cdot c_{p,air} \cdot (T_2 - T_1) = \dot{m} \cdot c_{p,air} \cdot T_1 \cdot \left(\frac{T_2}{T_1} - 1\right) = \dot{m} \cdot c_{p,air} \cdot T_1 \cdot \left(\pi^{\frac{\kappa_{air} - 1}{\kappa_{air}}} - 1\right)$$

$$\dot{Q}_{in} = \dot{m} \cdot \Delta h_{3-2} = \dot{m} \cdot c_{p,exh} \cdot (T_3 - T_2)$$

$$P_T = \dot{m} \cdot \Delta h_{3-4} = \dot{m} \cdot c_{p,exh} \cdot (T_3 - T_4) = \dot{m} \cdot c_{p,exh} \cdot T_3 \cdot \left(1 - \frac{1}{\frac{T_3}{T_4}}\right) = \dot{m} \cdot c_{p,exh} \cdot T_3 \cdot \left(1 - \frac{1}{\delta^{\frac{\kappa_{exh} - 1}{\kappa_{exh}}}}\right)$$

Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)

Real Gas Turbine



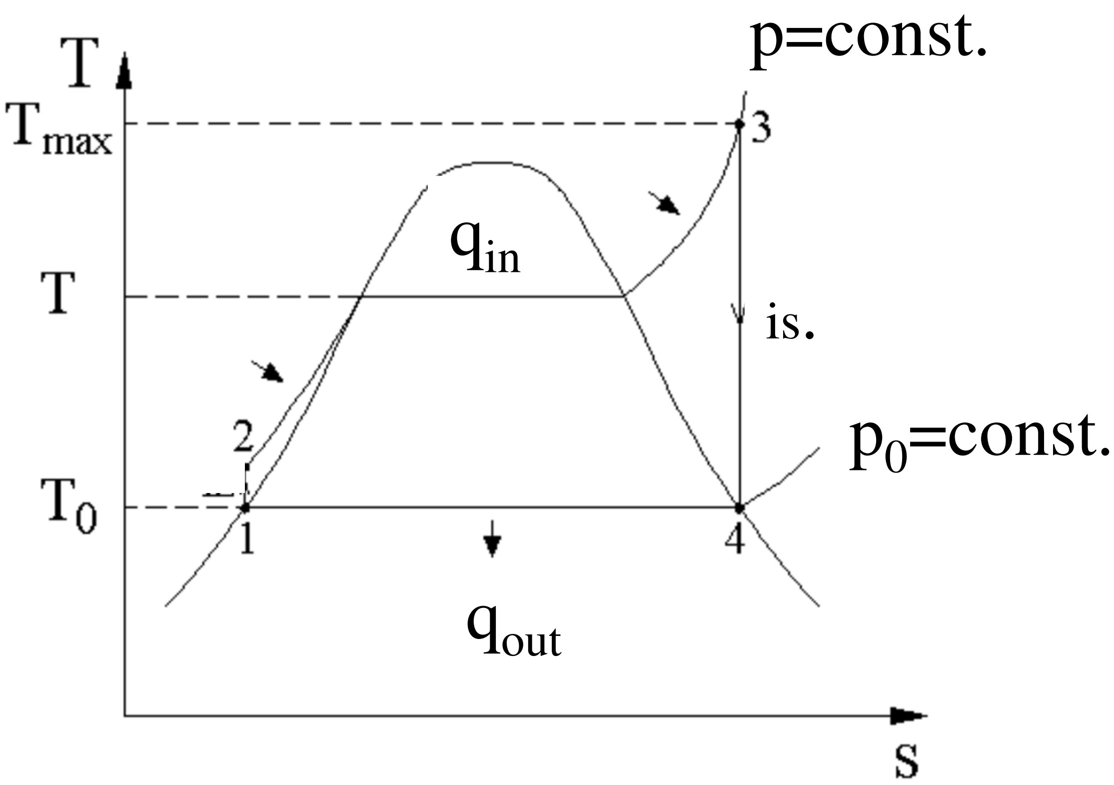
$$\delta = \frac{p_3}{p_4} = \prod \sigma_i \cdot \pi$$

$$P_C = \dot{m}_{air} \cdot \left(h_2 - h_1\right) = \dot{m}_{air} \cdot c_{p\,air} \cdot \left(T_2 - T_1\right) = \dot{m}_{air} \cdot c_{p\,air} \cdot T_1 \cdot \left(\pi^{\frac{\kappa_{air}-1}{\kappa_{air}}} - 1\right) \cdot \frac{1}{\eta_{adC}}$$

$$P_T = \dot{m}_{exh} \cdot \left(h_3 - h_4\right) = \dot{m}_{exh} \cdot c_{p\,exh} \cdot \left(T_3 - T_4\right) = \dot{m}_{exh} \cdot c_{p\,exh} \cdot T_3 \cdot \left(1 - \frac{1}{\delta^{\frac{\kappa_{exh}-1}{\kappa_{exh}}}}\right) \cdot \eta_{adT}$$

$$\eta_{ad,C} = \frac{T_{2,0} - T_1}{T_2 - T_1} \qquad \eta_{adT} = \frac{T_3 - T_4}{T_3 - T_{4,0}}$$

Source: Guide to seminars of Heat Engines (A. Kun-Balog)



$$\eta_t = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{h_4 - h_1}{h_3 - h_2}$$

Clausius – Rankine cycle

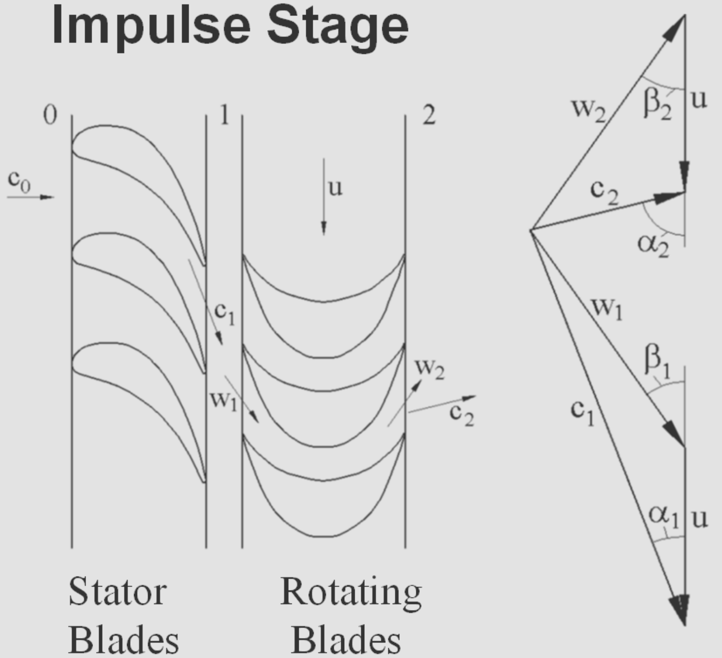
Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)

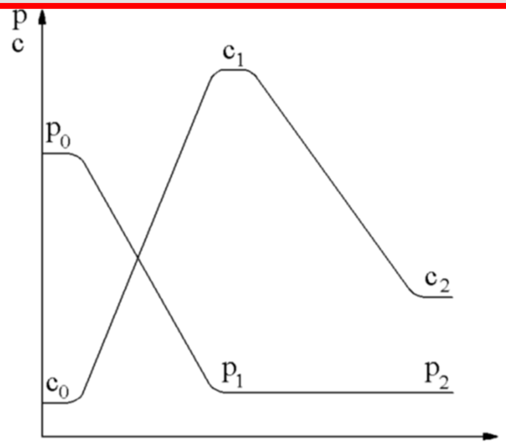
Steam Turbines

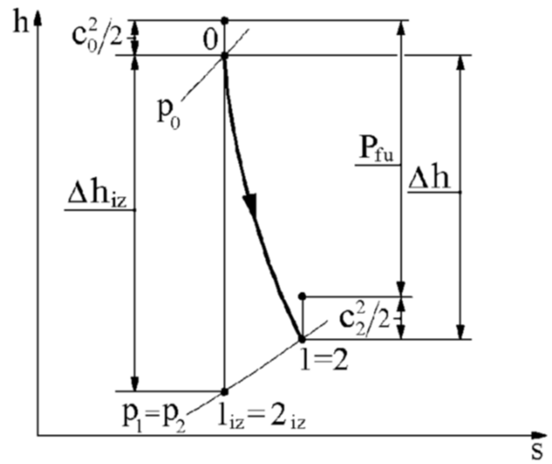
$$P_u = F_u \cdot u = \dot{m} \cdot u \cdot \left(\overrightarrow{c_{1u}} - \overrightarrow{c_{2u}} \right) = \dot{m} \cdot u \cdot \left(\left| w_{1u} \right| + \left| w_{2u} \right| \right)$$

$$\eta_u = \frac{P_u}{\Delta h_{iz} + \frac{c_0^2}{2} - \frac{c_2^2}{2}}$$

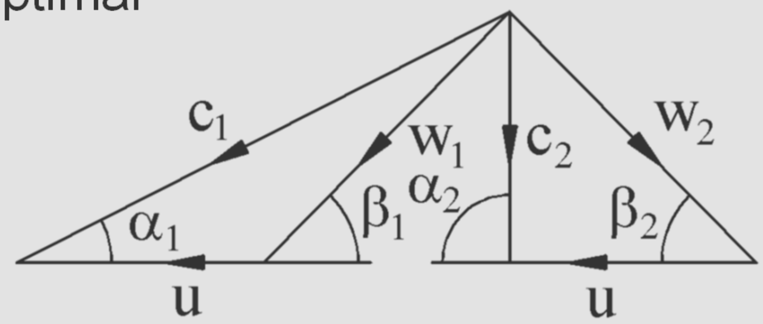
Impulse Stage







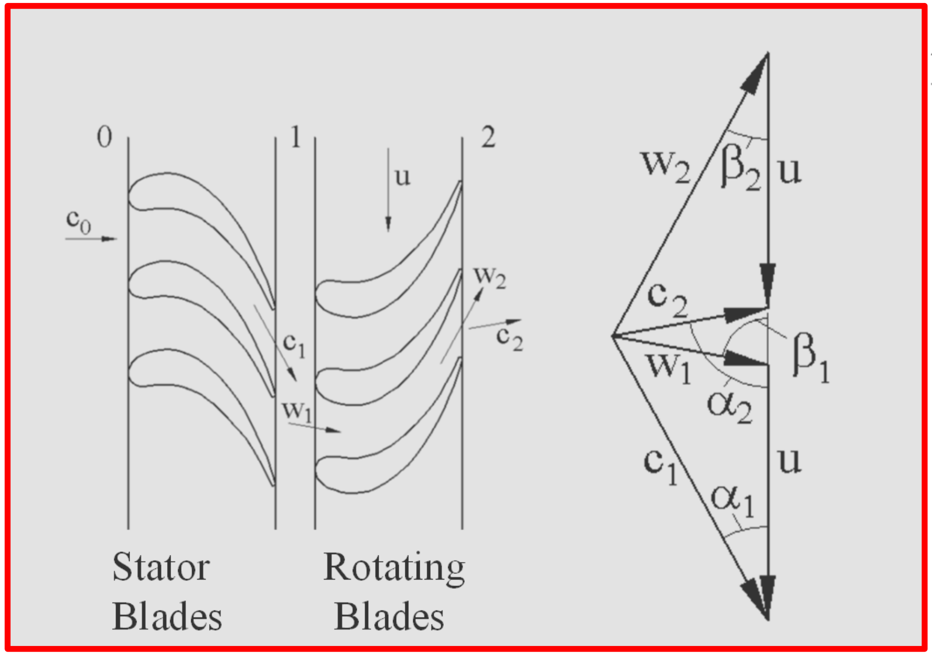
Theoretical Optimal

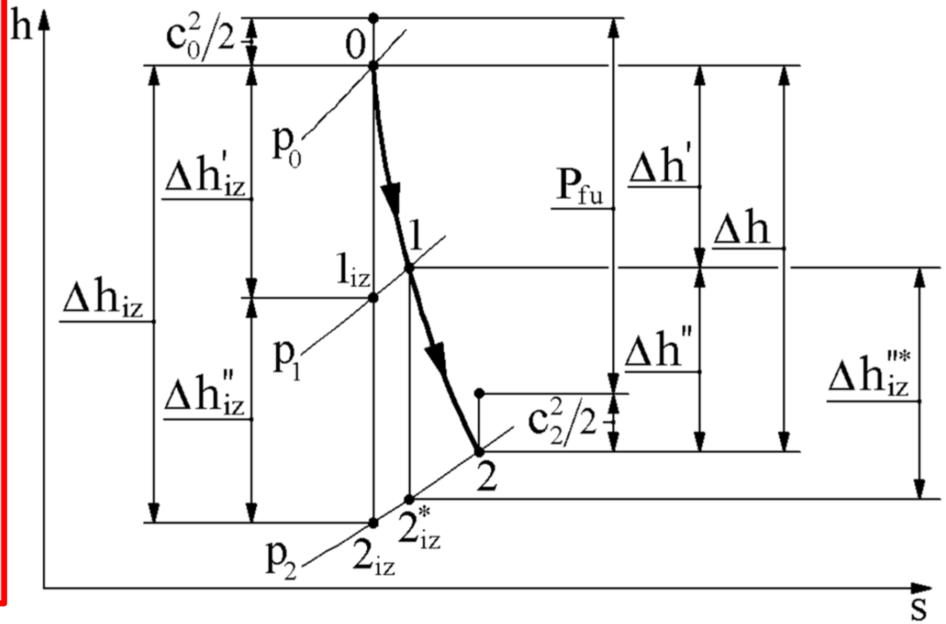


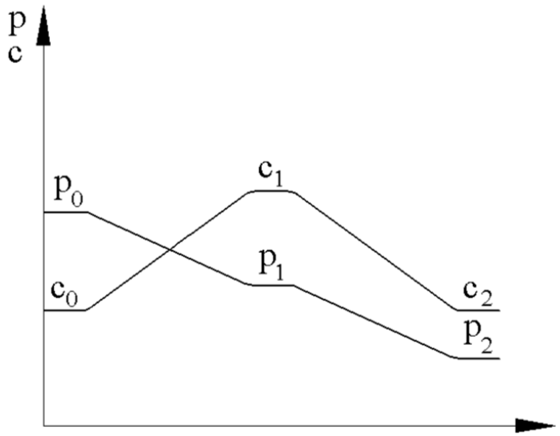
Source: Guide to seminars of Heat Engines (A. Kun-Balog)

Reaction Stage

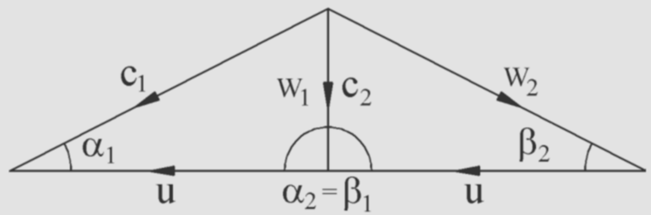
$$r = \frac{\Delta h''}{\Delta h' + \Delta h''}$$





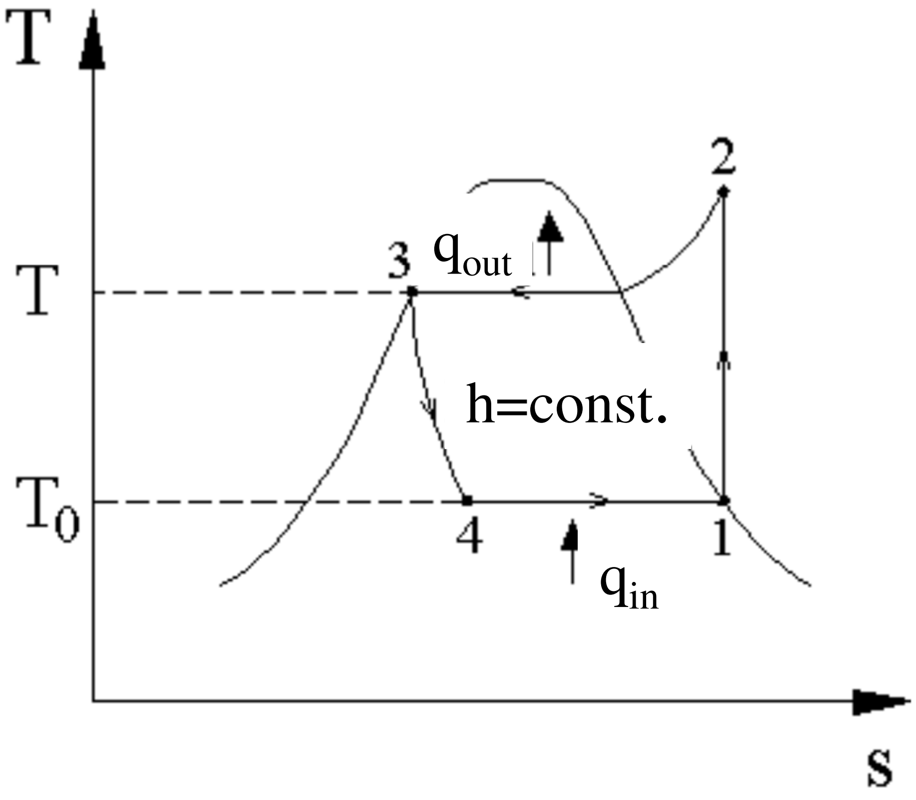


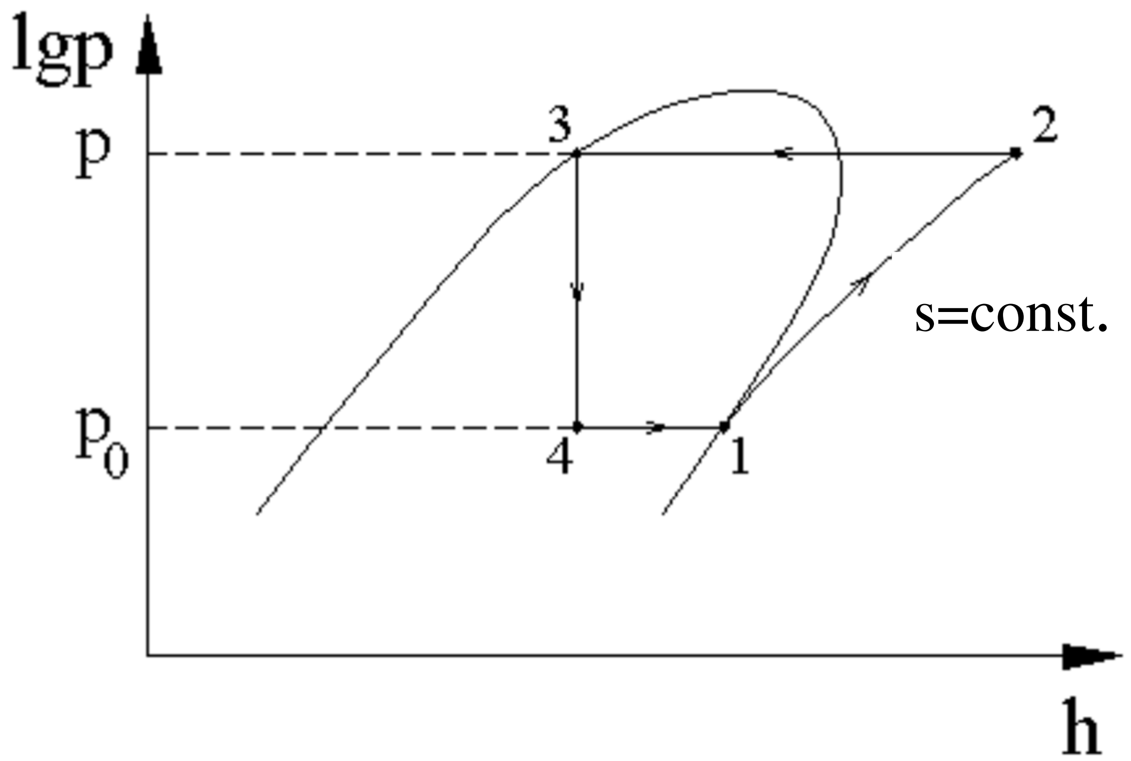
Theoretical Optimal



Source: Guide to seminars of Heat Engines (A. Kun-Balog)

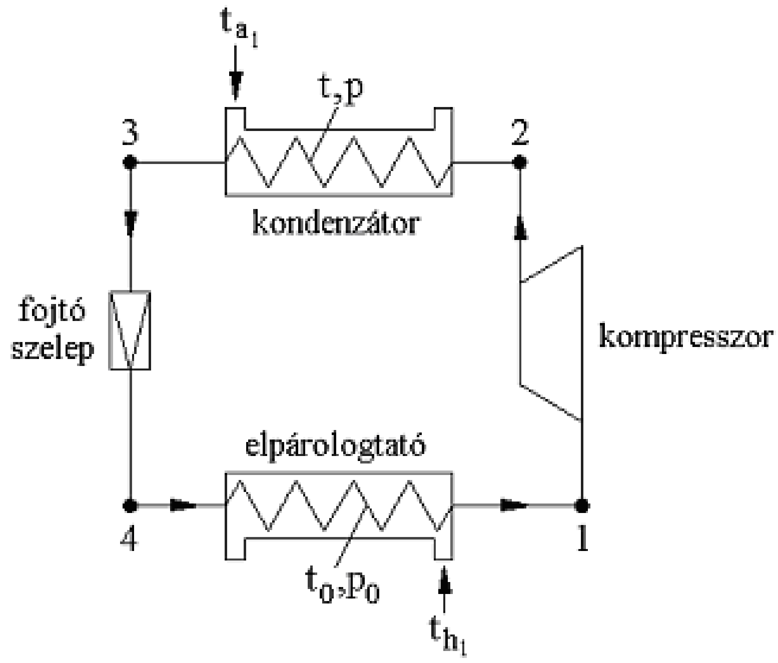
Theoretical Cooling cycle

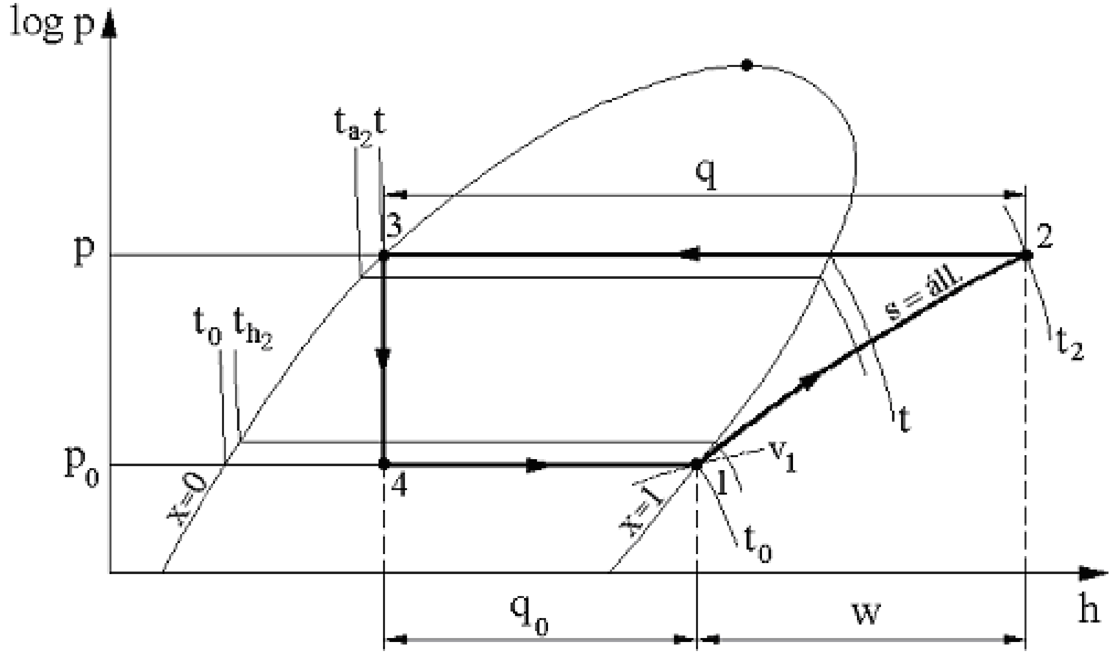


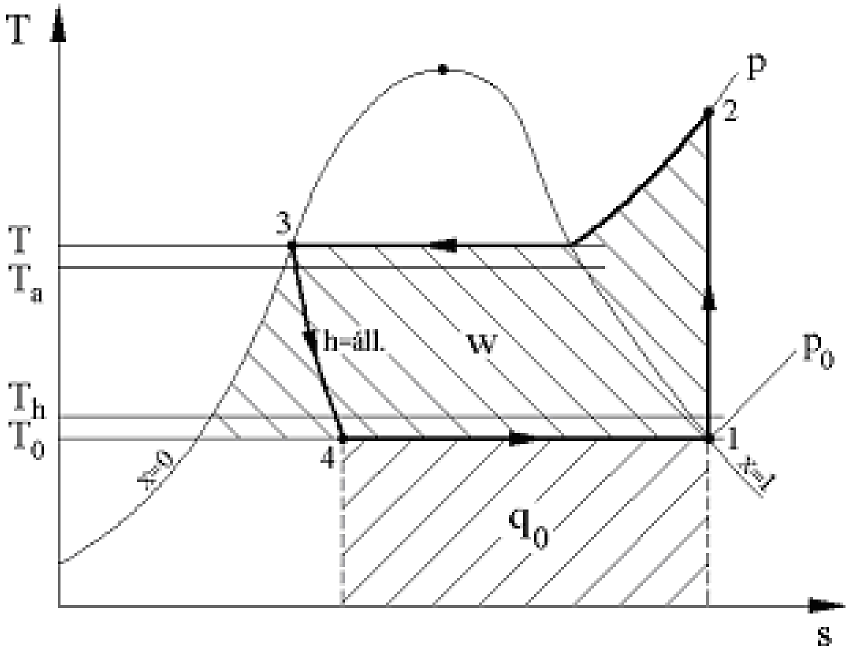


$$COP = \varepsilon = \frac{q_0}{w} = \frac{h_1 - h_4}{h_2 - h_1}$$

Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)







$$q_0 = h_1 - h_4 \quad \left[\frac{kJ}{kg}\right]$$

$$w = h_2 - h_1 \quad \left[\frac{kJ}{kg}\right]$$

$$q = h_2 - h_3 \quad \left[\frac{kJ}{kg}\right]$$

$$C.O.P. = \frac{q_0}{w}$$

A hűtőfolyamat teljesítménytényezője:

Excess air factor

Air–fuel equivalence ratio (λ)

Fuel–air equivalence ratio (ϕ)

$$C_8H_{18} + 12{,}5\ O_2 = 8\ CO_2 + 9\ H_2O$$

$$C_8H_{18} + 12{,}5\ (O_2 + 79/21 N_2) = 8\ CO_2 + 9\ H_2O + 12{,}5\ 79/21 N_2$$

$$114\ kg\ C_8H_{18} + 400\ kg\ O_2 + 1316{,}67\ kg\ N_2 = 352 kg CO_2 + 162 kg H_2O + 1316{,}67 kg N_2$$

$$\mathbf{1\ kg\ C_8H_{18} + 15{,}06\ kg\ air} = 3{,}09\ kg\ CO_2 + 1{,}42\ kg\ H_2O + 11{,}55\ kg\ N_2$$

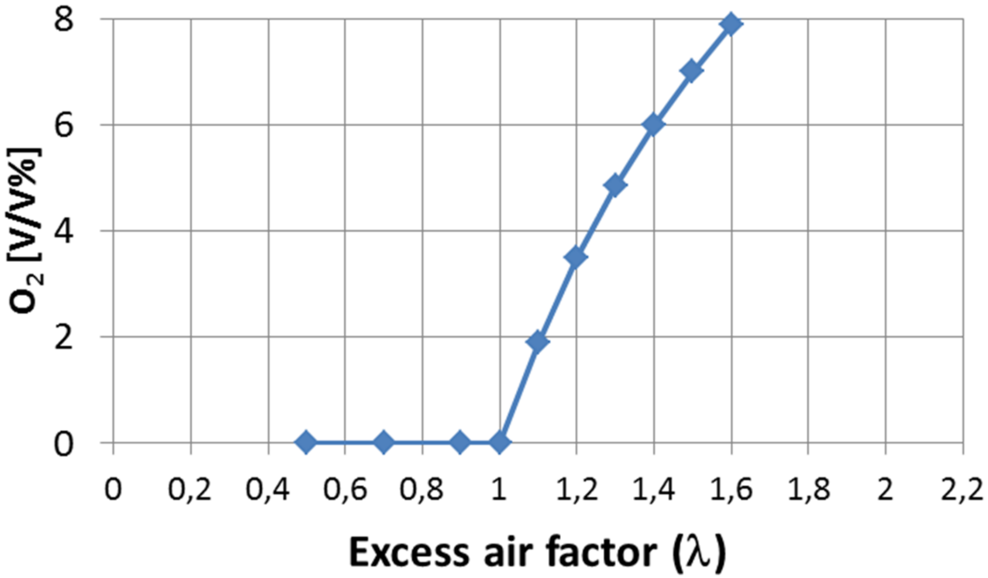
$$\lambda = m_{real}/m_{theoretical} = \mathbf{m_{real}/B^{*}\mu_{lo}}$$

$1/\lambda = \phi$ (equivalence ratio)

Stoichiometric air (to) fuel ratio

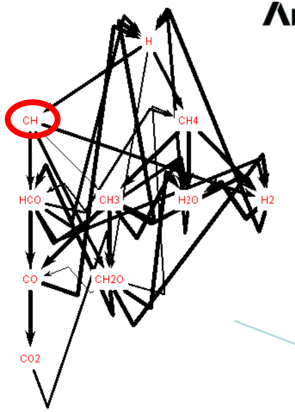
Excess air factor

$$\lambda = \frac{m_{air,real}}{m_{air,theoretical}} = \frac{\dot{m}_{air,real}}{\dot{m}_{air,theoretical}} = \frac{\dot{m}_{air,real}}{\dot{B}_{fuel} * L_0}$$

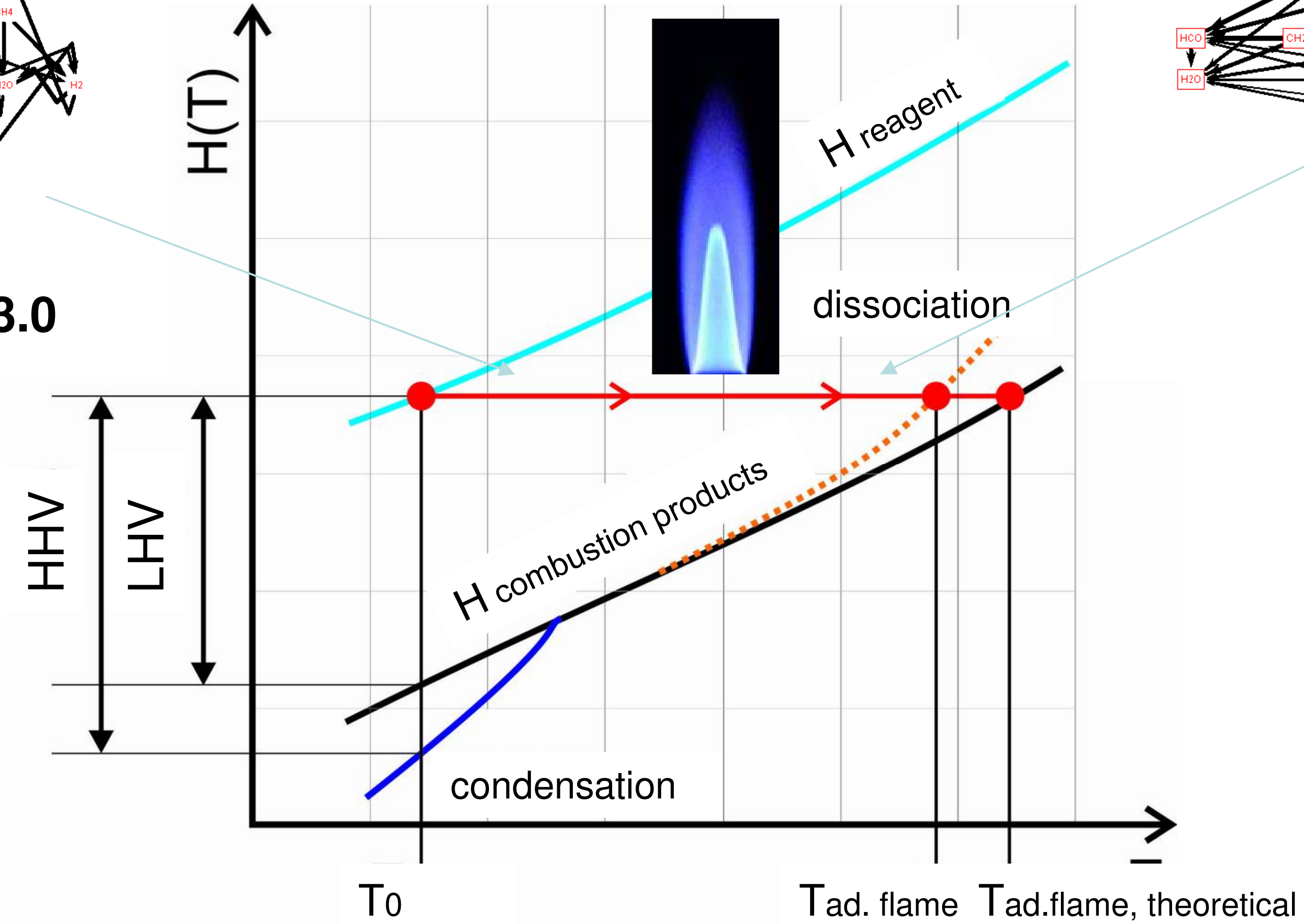


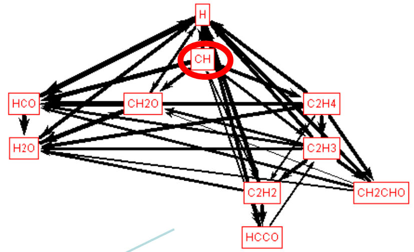
$$\lambda = 1 + \left[\frac{O_{2,meas.}}{21 - O_{2,meas.}} \right] \cdot \frac{V_0}{L_0} \approx \frac{21}{21 - O_{2,meas.}}$$

Excess air factor + LHV, HHV



GRI 3.0





GRI 3.0

Theoretical: CH_4, O_2, N_2 -> CO_2, N_2, H_2O

Real Combustion (reaction models like **GRI 3.0**)

(Adiabatic) Flame Temperature :

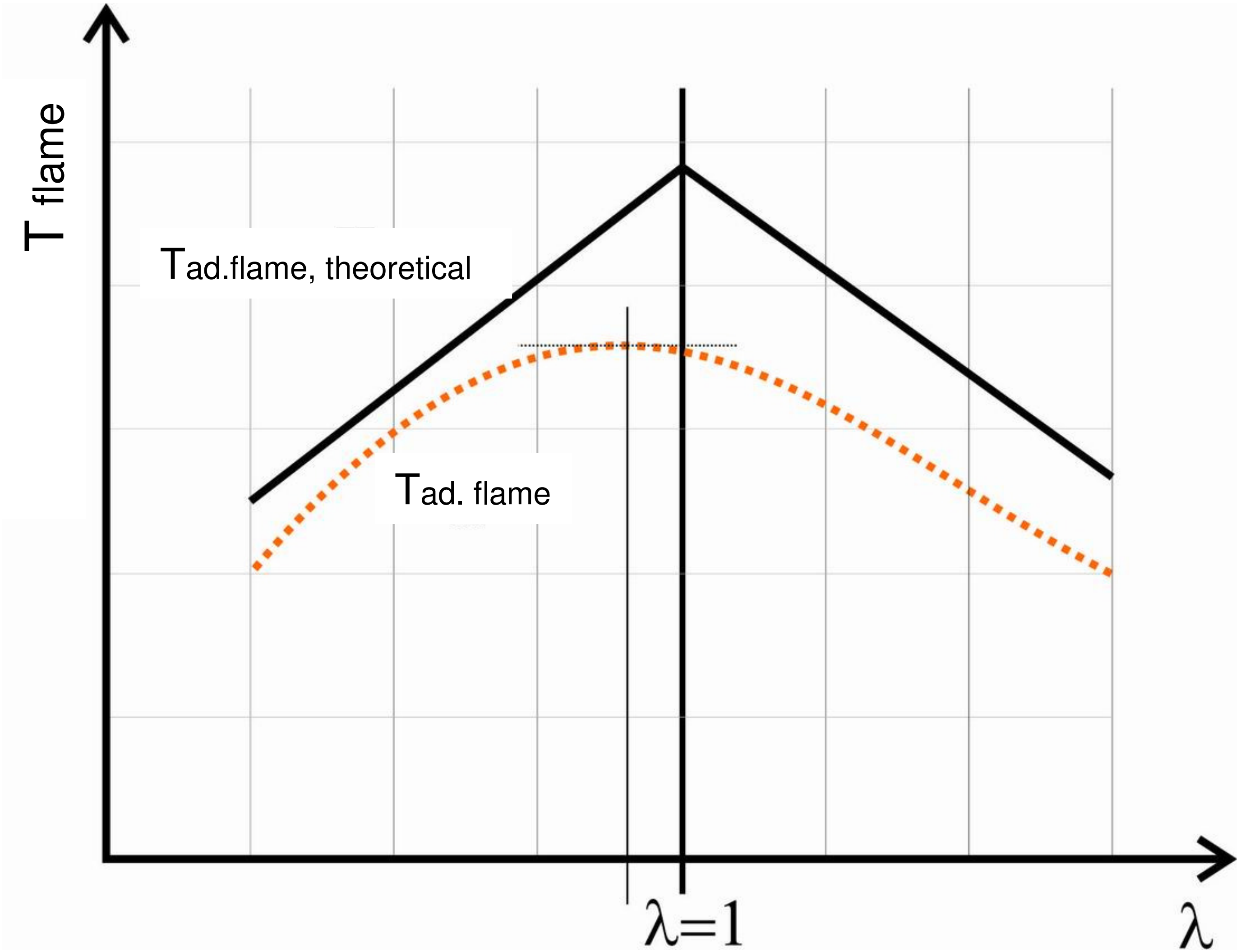
- Theoretical Flame Temperature:
  - Reactants: fuel, O2, N2
  - Combustion products : CO2, CO, H2O, N2

- Real Combustion (with Dissociation)
  - Combustion products : CO2, CO, H2O, N2, H, O, N, OH, CH, C2, etc..

$$\tfrac{1}{2}O_2 \Leftrightarrow O \qquad \tfrac{1}{2}\mathrm{H}_2 \Leftrightarrow \mathrm{H} \qquad \tfrac{1}{2}N_2 \Leftrightarrow N \qquad \tfrac{1}{2}H_2 + \tfrac{1}{2}O_2 \Leftrightarrow OH$$

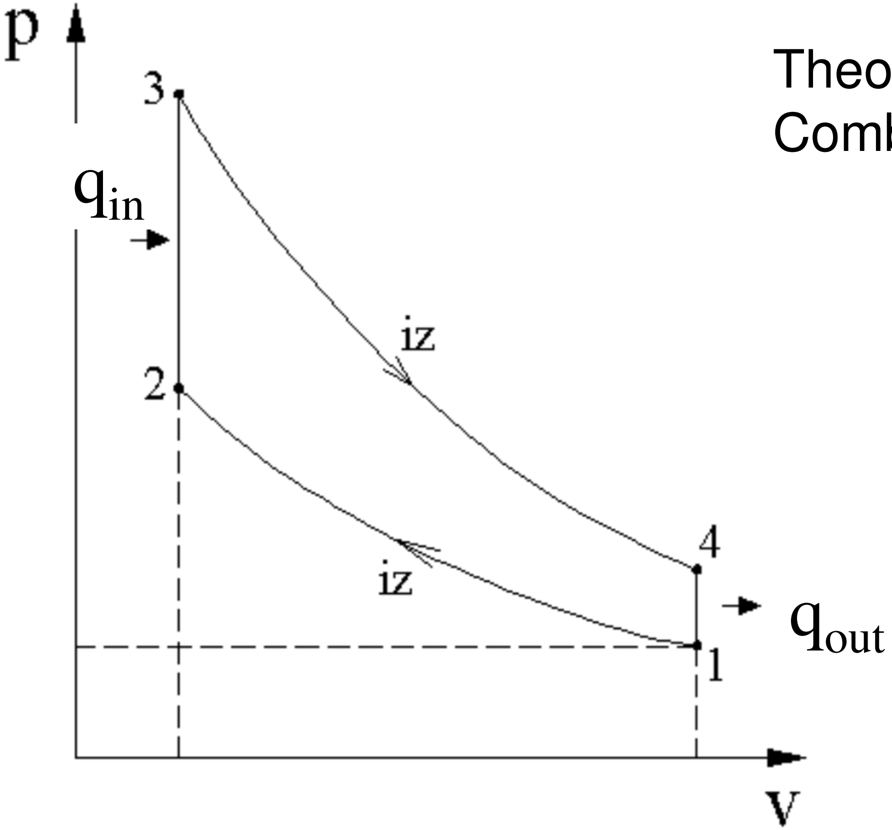
$$H_2 + \tfrac{1}{2}O_2 \Leftrightarrow H_2O \qquad CO + \tfrac{1}{2}O_2 \Leftrightarrow CO_2$$

Real and Theoretical Flame Temperature

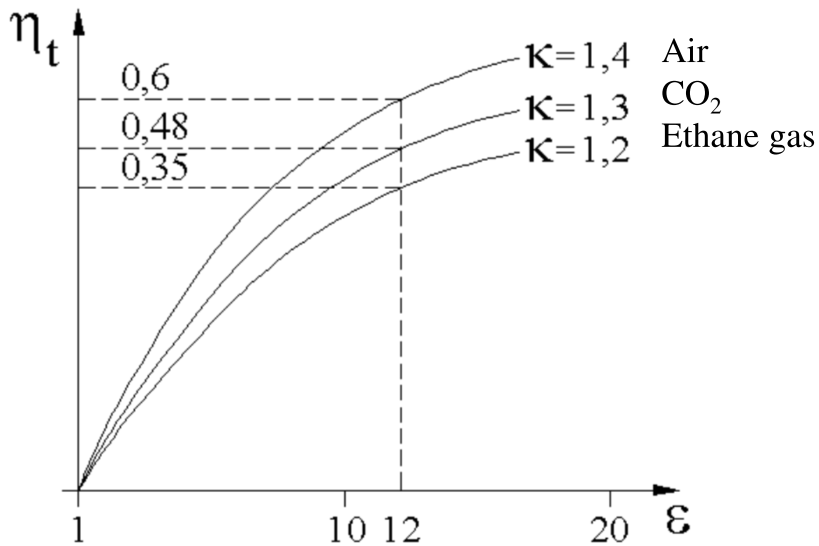


$$\sum_j b_j \int_{298}^{T_{ad,}} c_{p,b_j}(T)dT = \sum_i a_i \int_{298}^{T_{begining}} c_{p,a_i}(T)dT$$

Theoretical -Spark Ignition- Internal Combustion Engine cycle

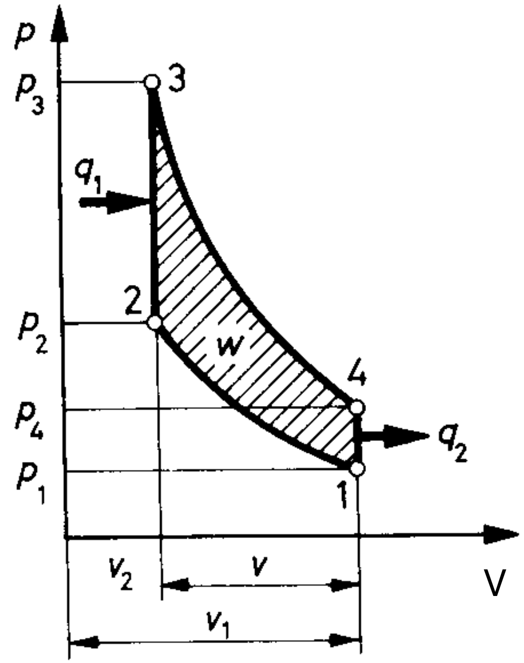


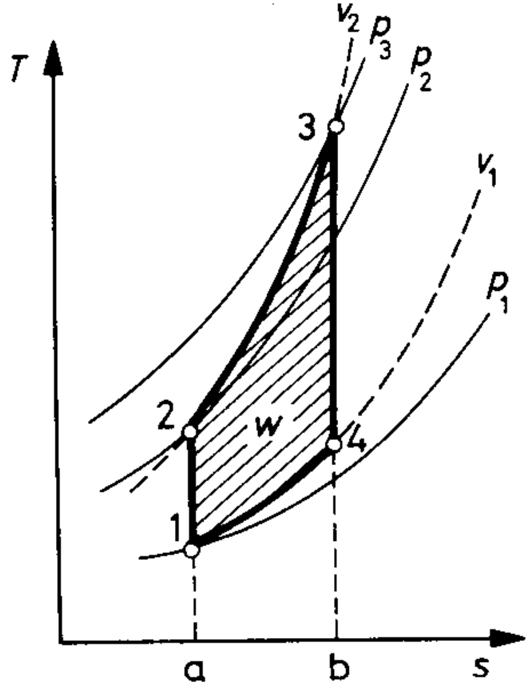
$$\eta_t = 1 - \frac{1}{\varepsilon^{\kappa - 1}}$$



Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)

The ideal air standard Otto cycle:





$$\varepsilon = \frac{V_1}{V_2}$$

$$\eta = \frac{-\sum W}{Q_1} = \frac{\sum Q}{Q_1} = \frac{c_v(T_3 - T_2) - c_v(T_4 - T_1)}{c_v(T_3 - T_2)} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{1}{\varepsilon^{\kappa - 1}}$$

2020 End

Check questions

1. What equipment does use the Brayton-Joule cycle?
2. What are the elements of the open Brayton-Joule cycle?
3. What are the losses of the real Gas Turbine cycle?
4. What equipment does use the Clausius - Rankine cycle?
5. What are the elements of the Clausius - Rankine cycle?
6. What is the degree of reaction?
7. What is the degree of reaction in the impulse stage?
8. What does the COP mean?
9. How to determine the COP for a chiller?
10. How to determine H-T diagram using the Tad?
11. How to determine H-T diagram using the HHV, LHV?
12. Which is the higher in the case of CO firing HHV or LHV?