Energetic processes and equipment (BMEGEENBGEB)

Basics

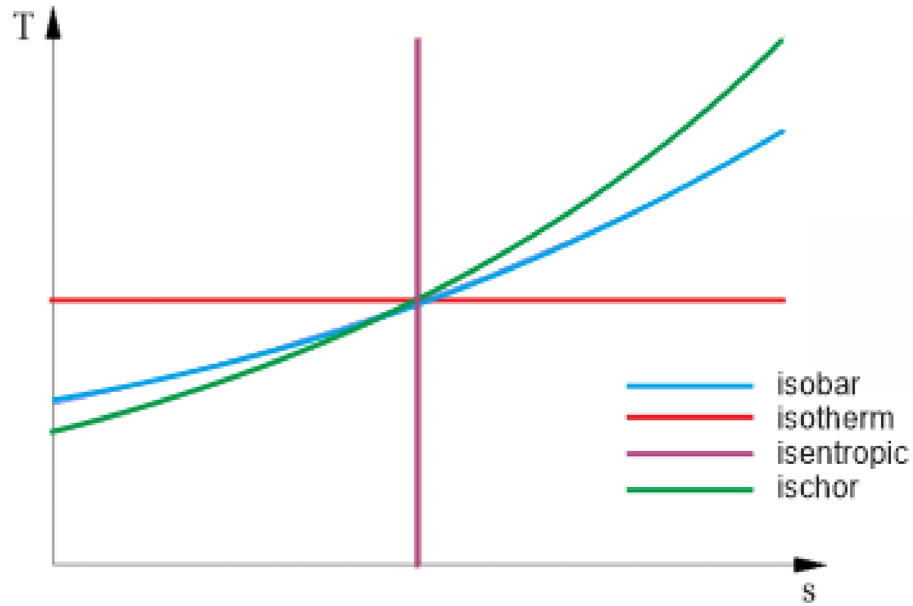
2024

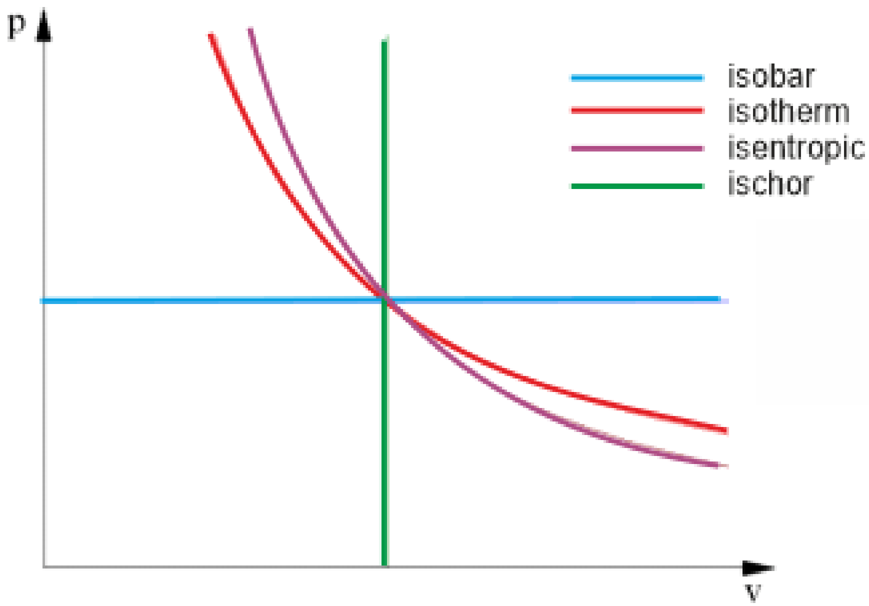
Educ. week	Date	Topics	Pres.	Note	Tests
1	2024.09.02	Repeat, main cycles, Lab safety for all groups	Cséfalvay		
2	2024.09.09	Solar Cells	Mayer		
3	2024.09.16	Fuel cells	Lévai		
4	2024.09.23	Combustion	Lezsovits		TEST-1 13:15-14:00
5	2024.09.30	Combustion	Cséfalvay/ Lezsovits		
6	2024.10.07	Cooling	Maiyaleh		
7	2024.10.14	Cooling	Maiyaleh		
8	2024.10.21	Cooling	Maiyaleh		
9	2024.10.28	Gas Turbines	Sztankó		TEST-2
10	2024.11.04	Steam Turbines	Sztankó		
11	2024.11.11	ICE	Bereczky		
12	2024.11.18	ICE	Bereczky		
13	2024.11.25	Gas engine	Bereczky		
14	2024.12.02	supp.TEST	Bereczky		TEST-3 + supp. 1.+ 2.

All information will be on the Moodle homepage of the topic

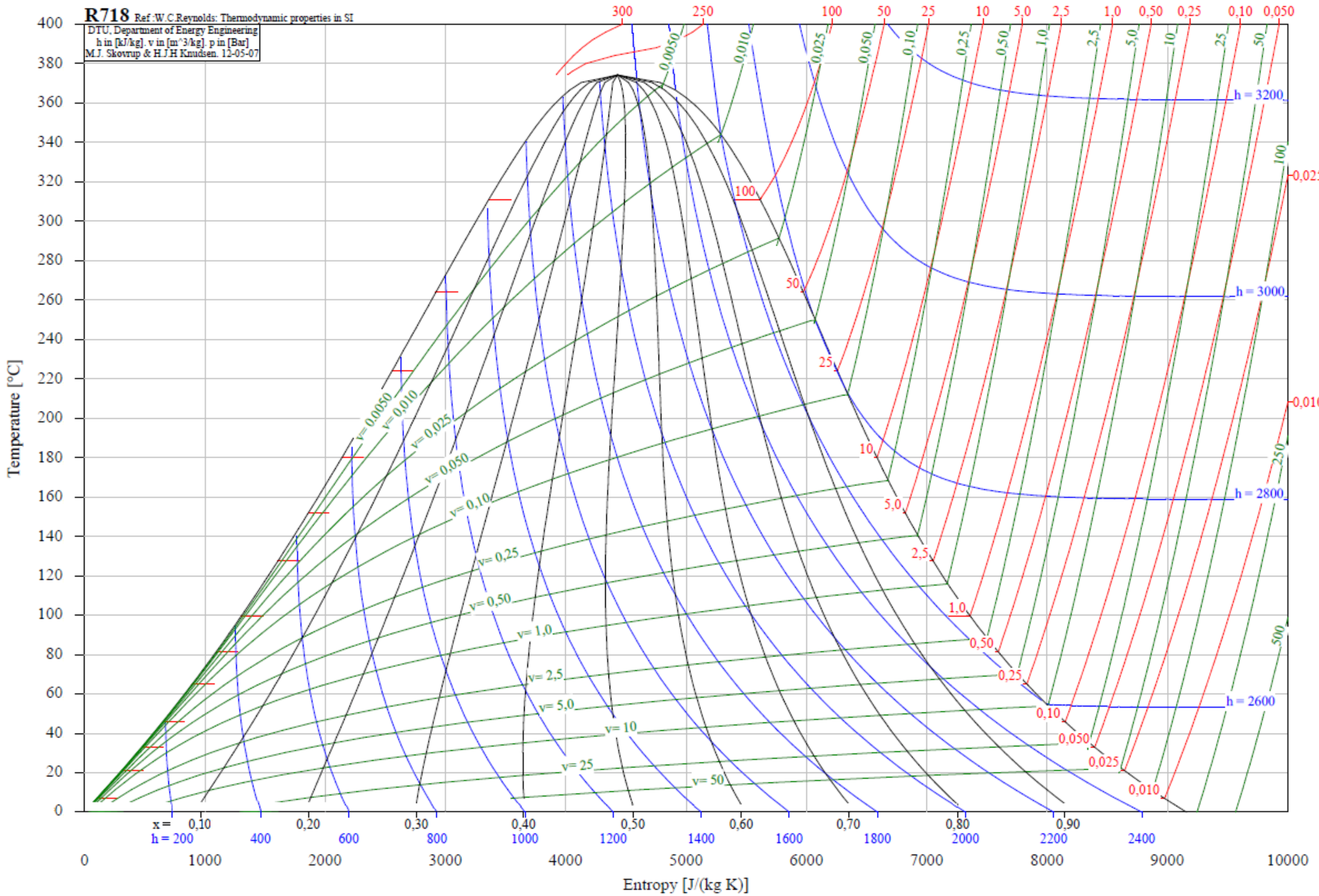
Tuesdays 12:15-14:00											
Educ. week	Date	Stationer boiler test,	Solar Cell	Flame propagation	Fuel cell	Cooling system	Gas Turbine	Heat radiation	High Temperature Measurement	Supp. Labs.	Room
1	2024.09.03										
2	2024.09.10										
3	~~2024.09.17~~	Sport day							Day off		
4	2024.09.24	occupational health and safety	12:15: A-C	13:15: D-F							
5	2024.10.01	A	B	C	D	E	F				
6	2024.10.08		A	B	C	D	E	F			
7	2024.10.15			A	B	C	D	E	F		
8	2024.10.22	F			A	B	C	D	E		
9	2024.10.29	E	F			A	B	C	D		
10	2024.11.05	D	E	F			A	B	C		
11	2024.11.12	C	D	E	F			A	B		
12	2024.11.19										
13	2024.11.26									all groups	
14	2024.12.03										
	Loc.	**F6**	**K4**	**K1**	**K10**	**K2**	**K1**	**F6**	**K3**	**-**	
	Lecturer and lab supervisor	Qais Al-Madanat	Bálint Békési	H. Sadah	E. Lévai	R. Shaheen	K. Lukács	E. Cséfalvay Á.Bereczky	Mark Kovacs		

Thermodynamic state changes



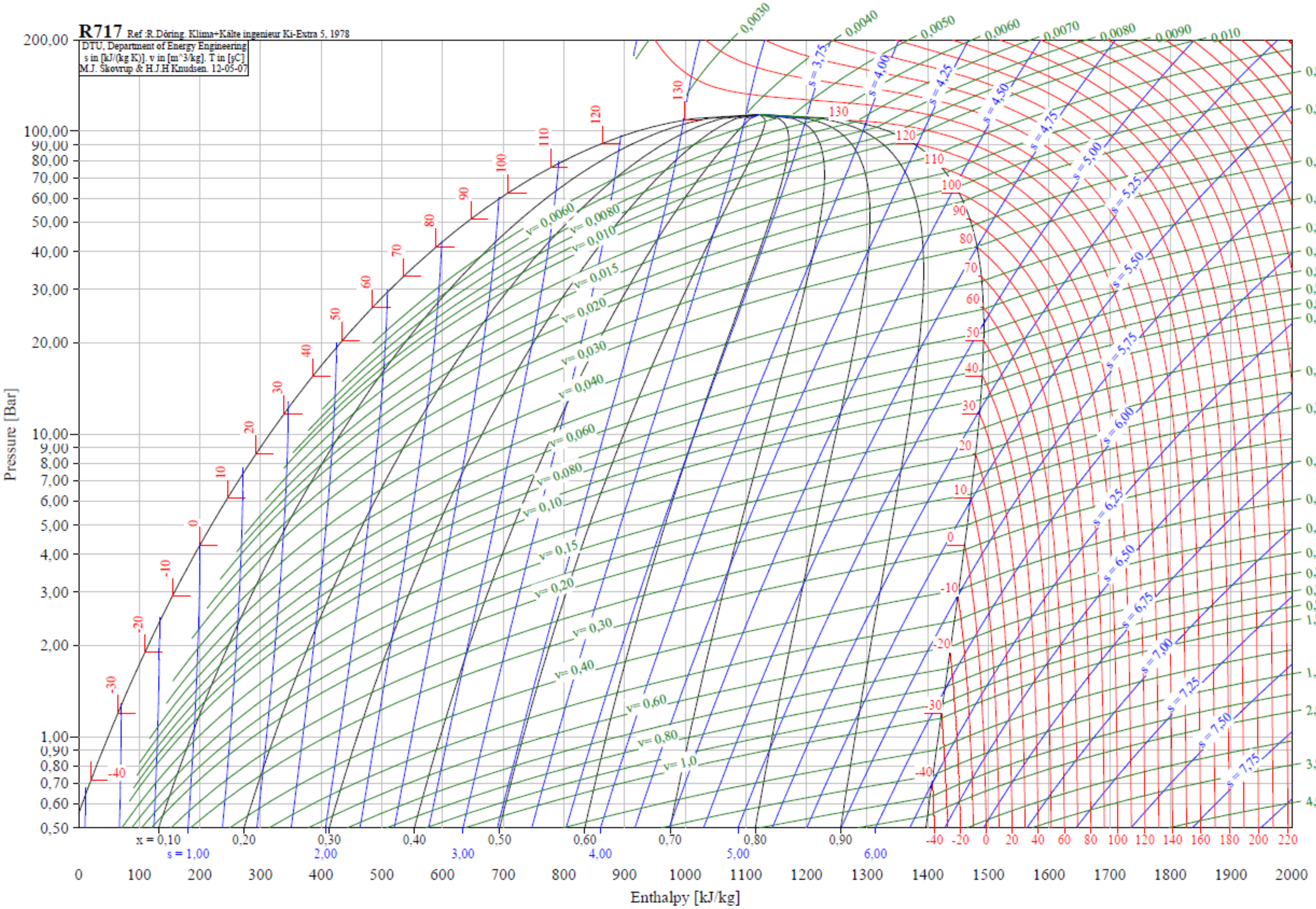


Source: Guide to seminars of Heat Engines (A. Kun-Balog)



T-S diagram of H_2O

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

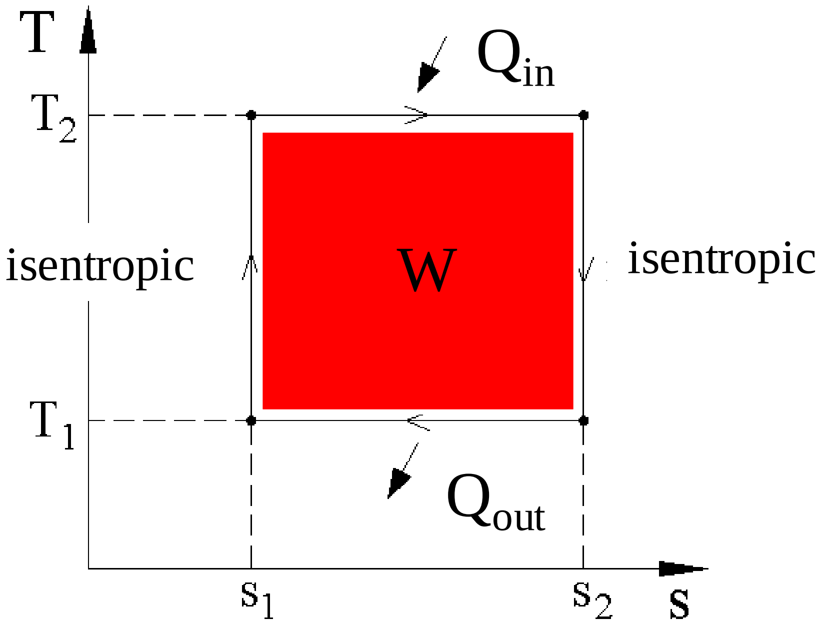


logp-h diagram of Ammonia

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

Carnot cycle

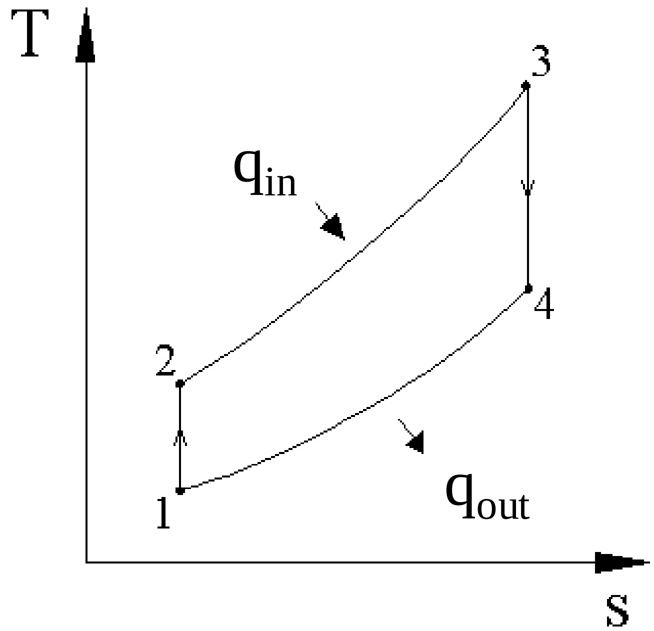
Q_{in} is the heat put into the system (heat energy entering the system),
Q_{out} is the heat taken from the system (heat energy leaving the system),
W is the work done by the system (energy exiting the system as work),



Entropy [J/kg K]

$$\eta_T = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}} = 1 - \frac{T_1(S_2 - S_1)}{T_2(S_2 - S_1)} = 1 - \frac{T_1}{T_2}$$

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

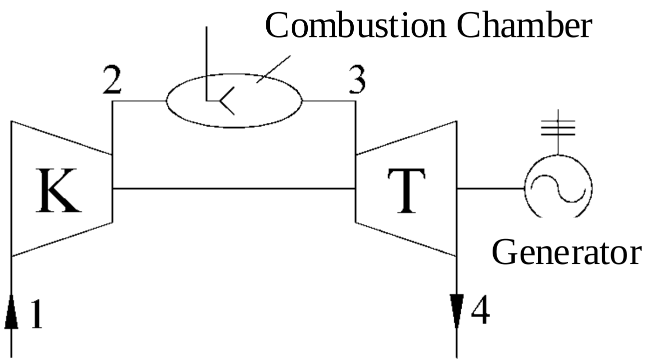


$$\eta_t = 1 - \frac{1}{\pi^{\frac{\kappa-1}{\kappa}}}$$

Brayton-Joule cycle

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

Theoretical Gas Turbine



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

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

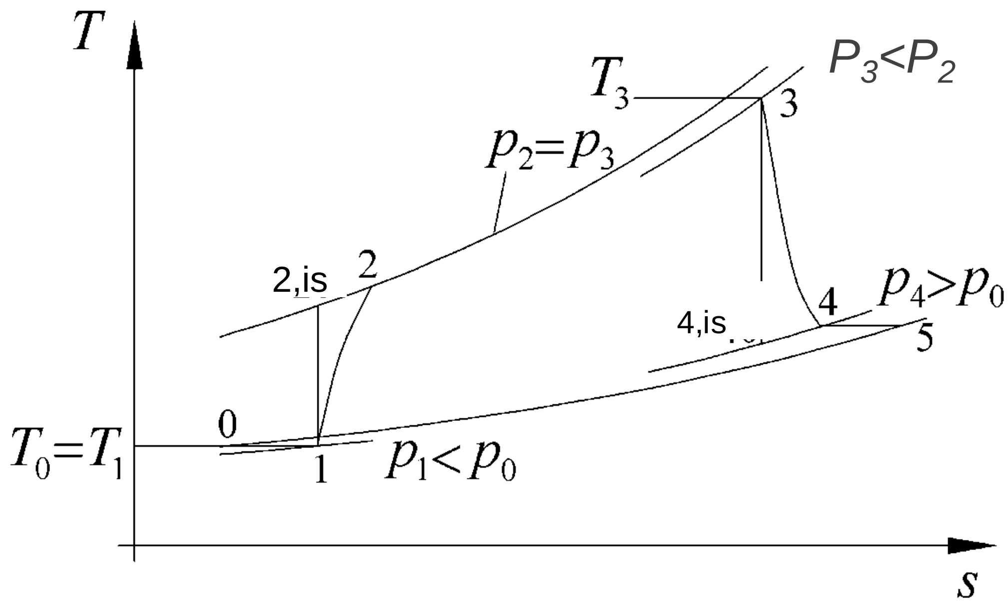
$$P_C = \dot{m} \cdot \Delta h_{1-2} = \dot{m} \cdot c_{p,air} \cdot (T_2 - T_1) = \dot{m} \cdot c_{p,air} \cdot T_1 \cdot \left(\frac{T_2}{T_1} - 1\right) = \dot{m} \cdot c_{p,air} \cdot T_1 \cdot \left(\pi^{\frac{\kappa_{air} - 1}{\kappa_{air}}} - 1\right)$$

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

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

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

Real Gas Turbine



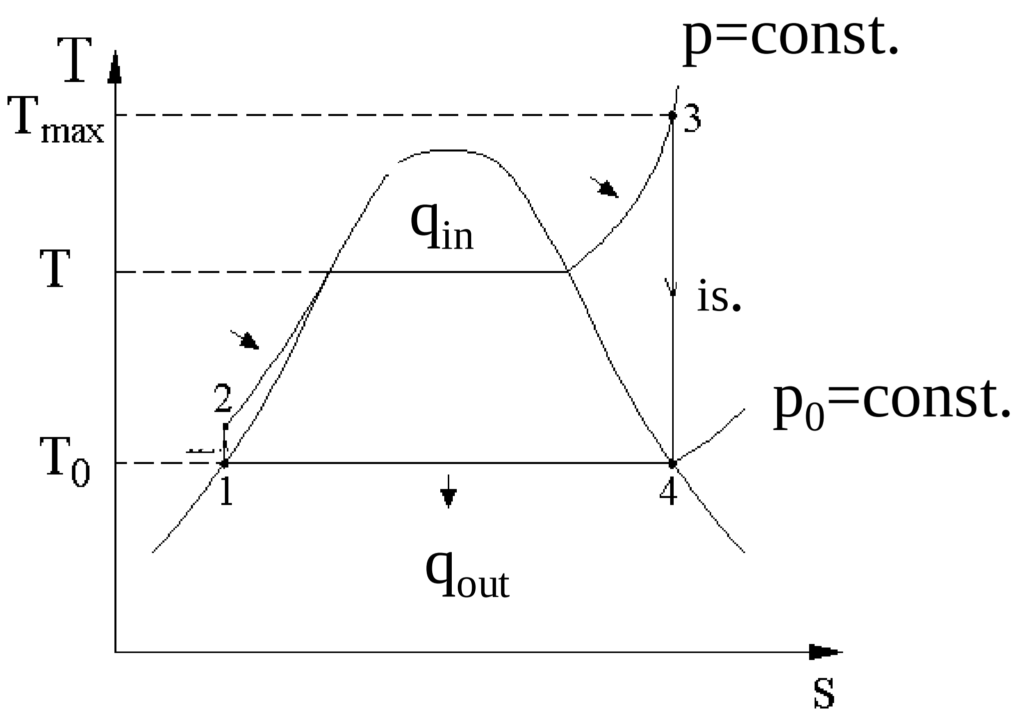
$$\delta = \frac{p_3}{p_4} = \prod \sigma_i \cdot \pi$$

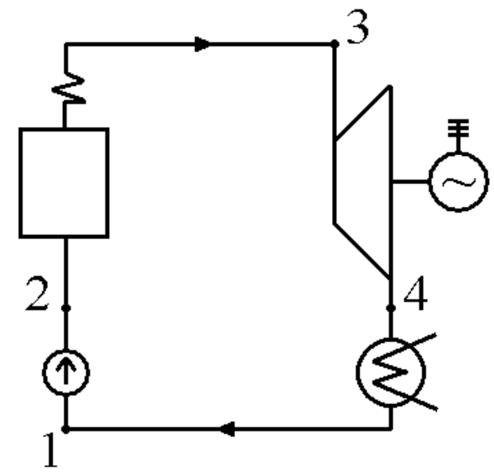
$$P_C = \dot{m}_{air} \cdot (h_2 - h_1) = \dot{m}_{air} \cdot c_{p\,air} \cdot (T_2 - T_1) = \dot{m}_{air} \cdot c_{p\,air} \cdot T_1 \cdot \left(\pi^{\frac{\kappa_{air}-1}{\kappa_{air}}} - 1 \right) \cdot \frac{1}{\eta_{adC}}$$

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

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

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



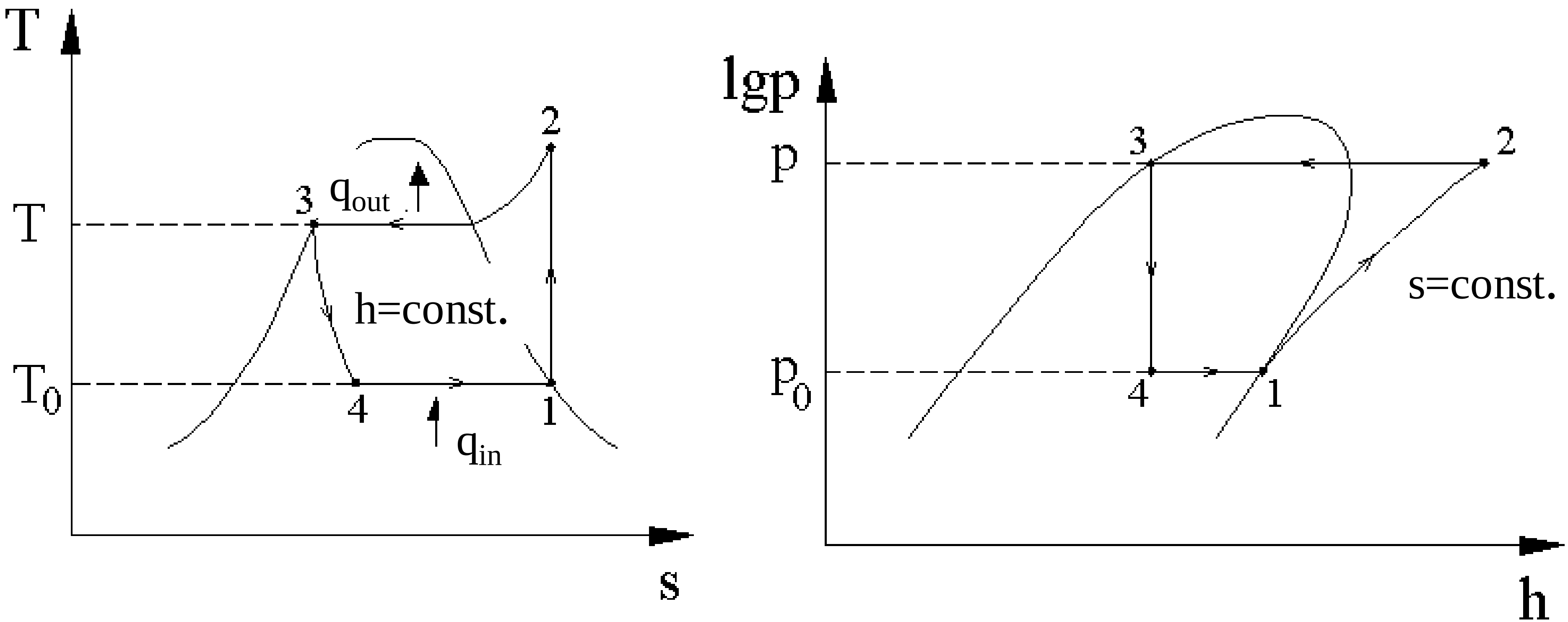


$$\eta_t = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{h_4 - h_1}{h_3 - h_2}$$

Clausius – Rankine cycle

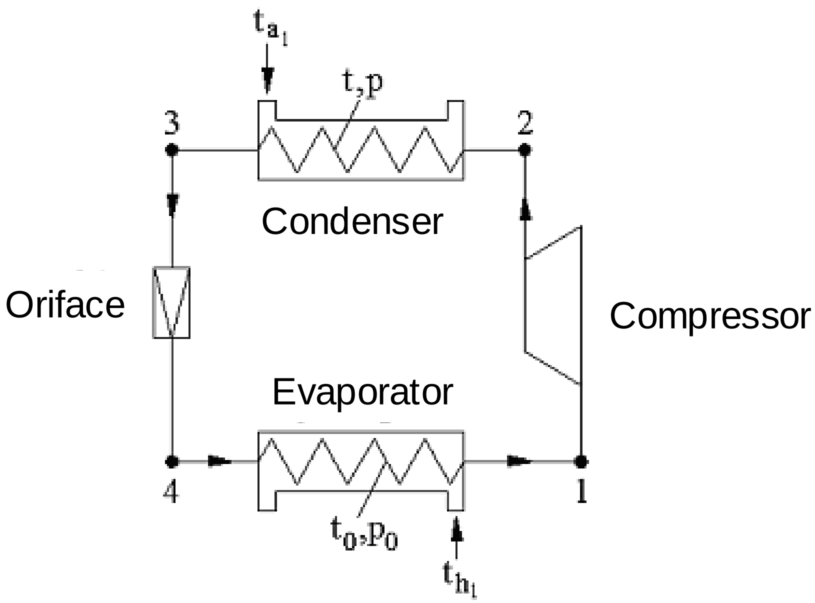
Source: Penninger- Maiyaleh: Heat Engines (in Hungarian)

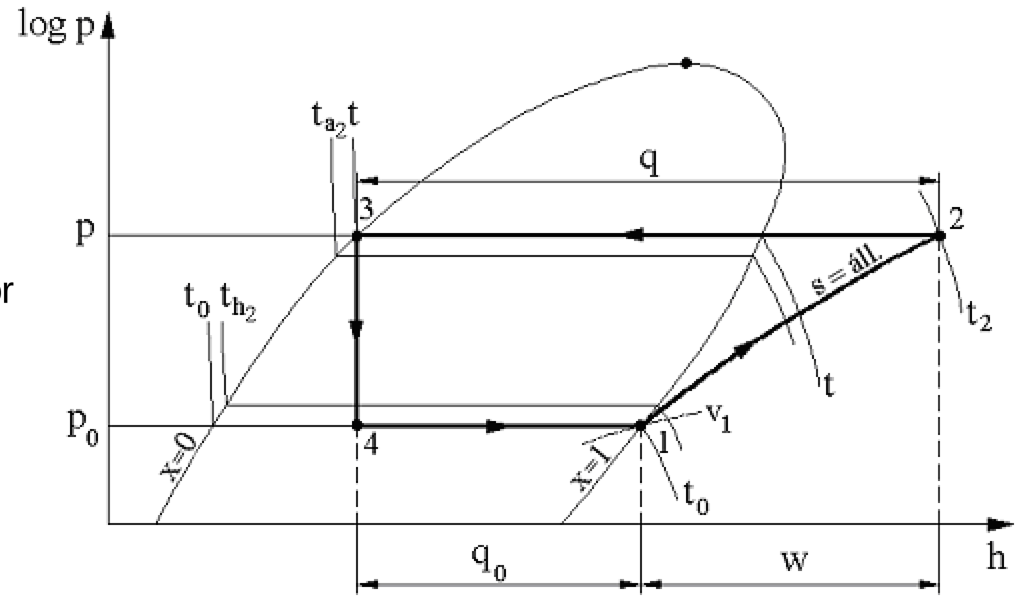
Theoretical Cooling cycle

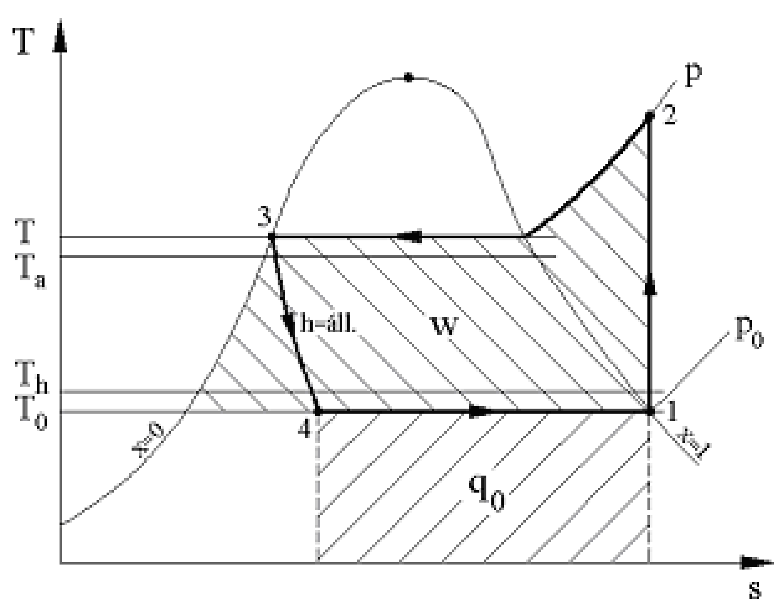


$$COP = \varepsilon = \frac{q_0}{w} = \frac{h_1 - h_4}{h_2 - h_1}$$

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







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

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

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

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

Excess air factor
Air–fuel equivalence ratio (λ)
Fuel–air equivalence ratio (ϕ)

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

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

$$114\ kg\ C_8H_{18} + 400\ kg\ O_2 + 1316{,}67\ kg\ N_2 = 352kgCO_2 + 162kgH_2O + 1316{,}67kgN_2$$

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

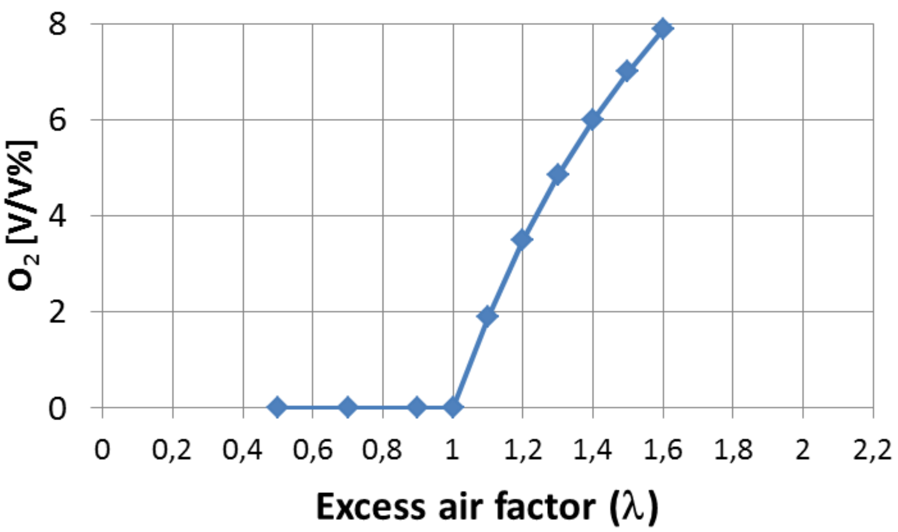
$$\lambda = m_{real}/m_{theoretical} = \mathbf{m_{real}/B^*\mu_{lo}}$$

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

Stoichiometric air (to) fuel ratio

Excess air factor

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



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

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

$$\lambda = \frac{[CO_2] + \left[\frac{CO}{2}\right] + [O_2] + \left[\frac{NO}{2}\right] + \left(\left(\frac{H_{CV}}{4} \times \frac{3.5}{3.5 + \frac{[CO]}{[CO_2]}} \right) - \frac{O_{CV}}{2} \right) \times ([CO_2] + [CO])}{\left(1 + \frac{H_{CV}}{4} - \frac{O_{CV}}{2}\right) \times ([CO_2] + [CO] + (n \times [HC]))}$$

Where:

$[XX]$ = Gas Concentration in % Volume.

(You have to convert PPM HC to % HC by dividing it by 10,000)

H_{cv} = Atomic ratio of Hydrogen to Carbon in the fuel.

O_{cv} = Atomic ratio of Oxygen to Carbon in the fuel.

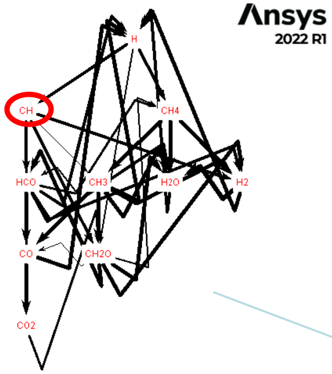
n = Number of carbon atoms in a molecule of the selected HC.

n = 6 for Hexane (Gasoline), 3 for Propane (LPG), 1 for Methane (CNG)

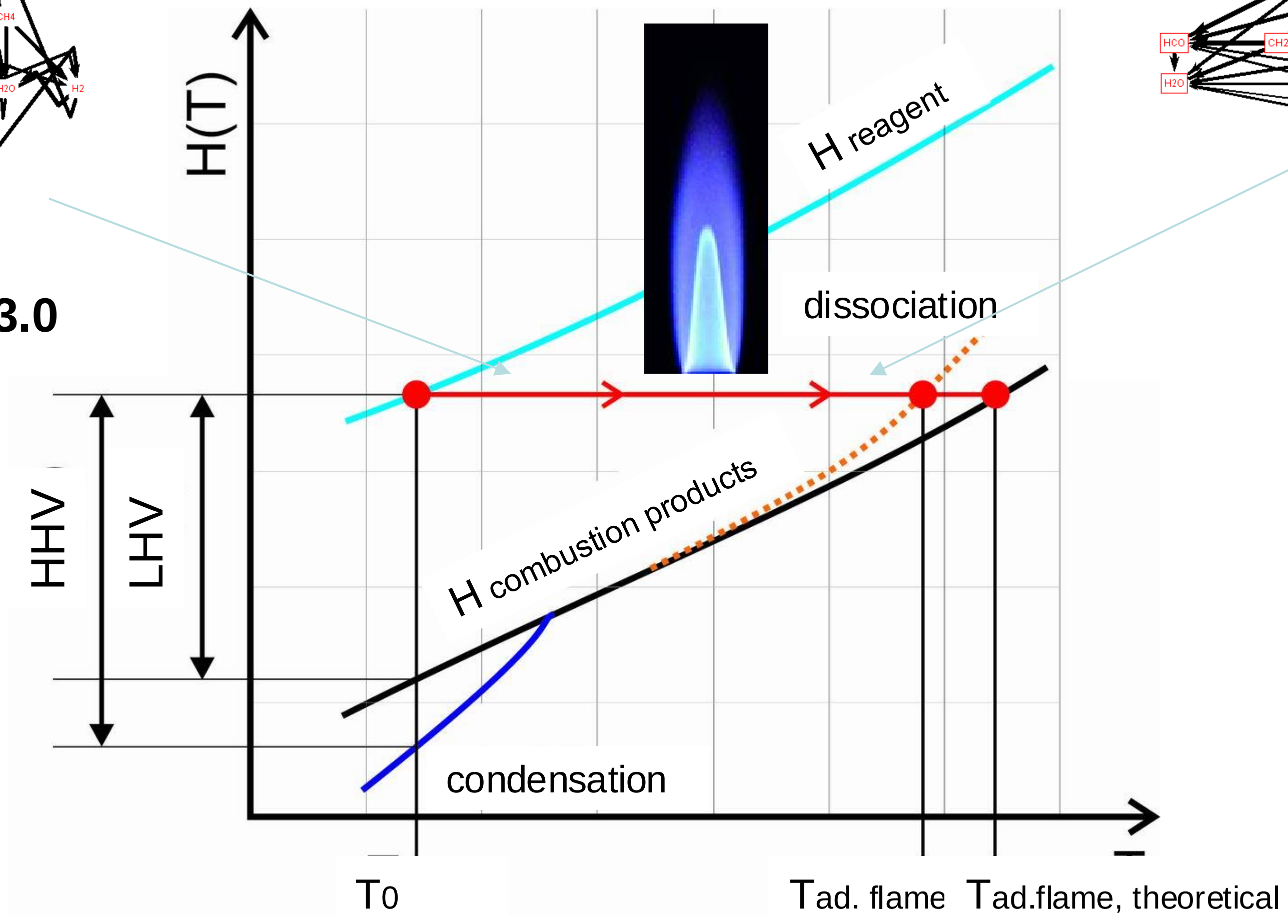
Sources:

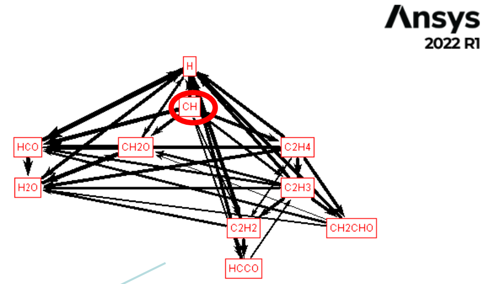
- Penninger- Maiyaleh: Heat Engines (in Hungarian)
- BRETTSCHNEIDER, v J. Calculation of the air ratio lambda of air fuel mixtures and its effect on measurement errors. Bosch Technische Berichte, 1979, 6.4.

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 :

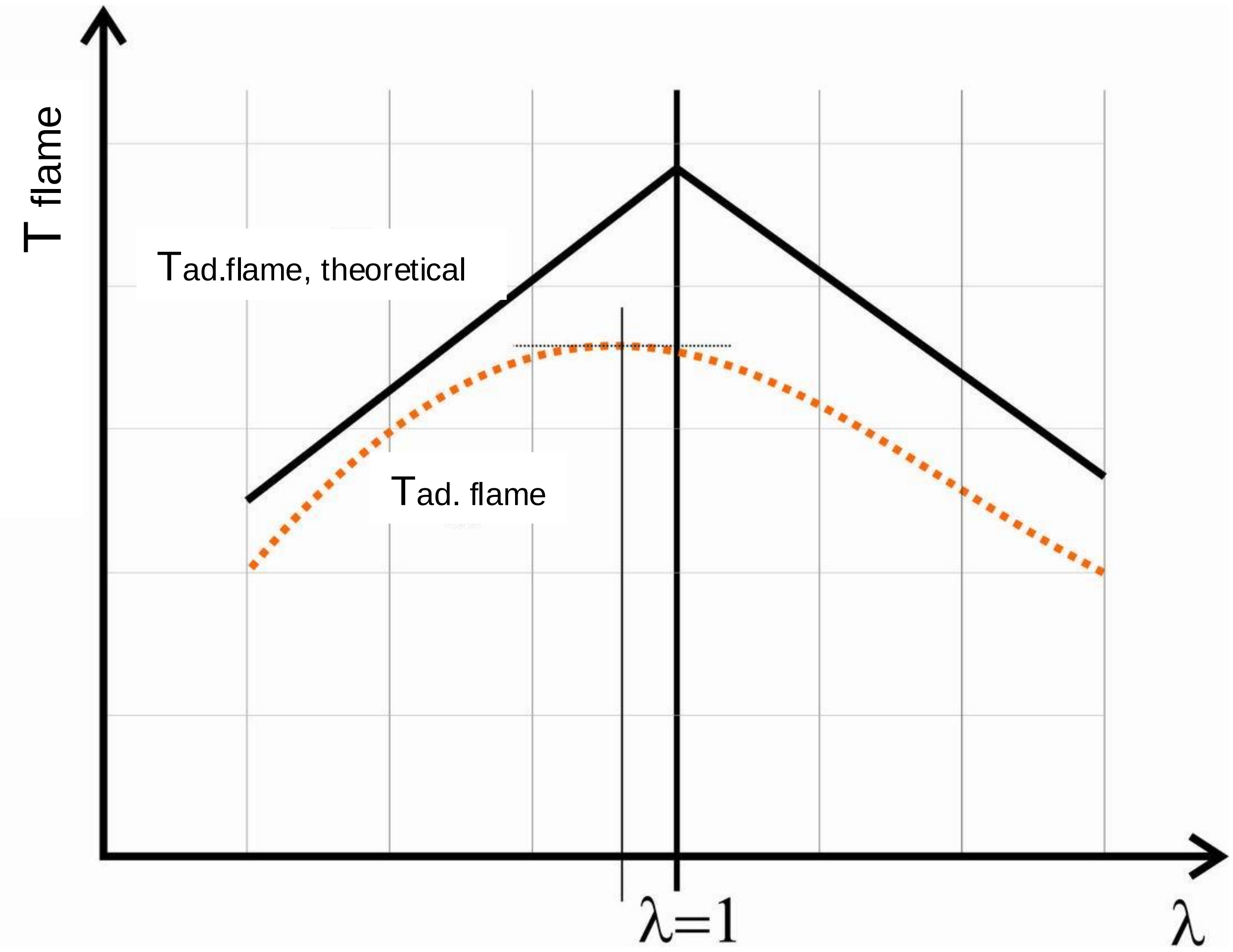
- Theoretical Flame Temperature:
  - Reactants: fuel, O_2, N_2
  - Combustion products : CO_2, CO, H_2O, N_2

- Real Combustion (with Dissociation)
  - Combustion products : CO_2, CO, H_2O, N_2, H, O, N, OH, CH, C_2, etc..

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

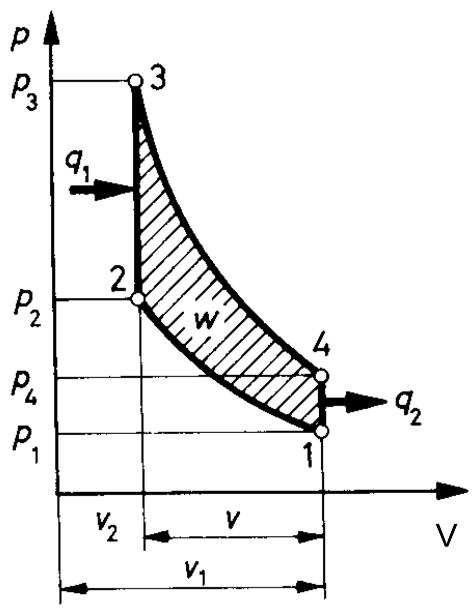
$$H_2 + \tfrac{1}{2}O_2 \Leftrightarrow H_2O \qquad CO + \tfrac{1}{2}O_2 \Leftrightarrow CO_2$$

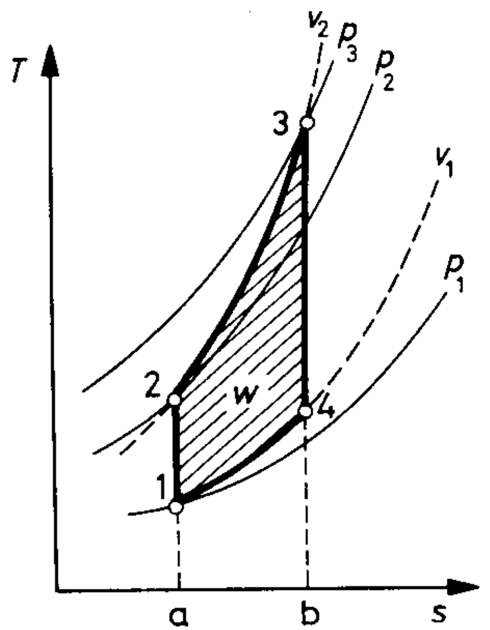
Real and Theoretical Flame Temperature



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

The ideal air standard Otto cycle:

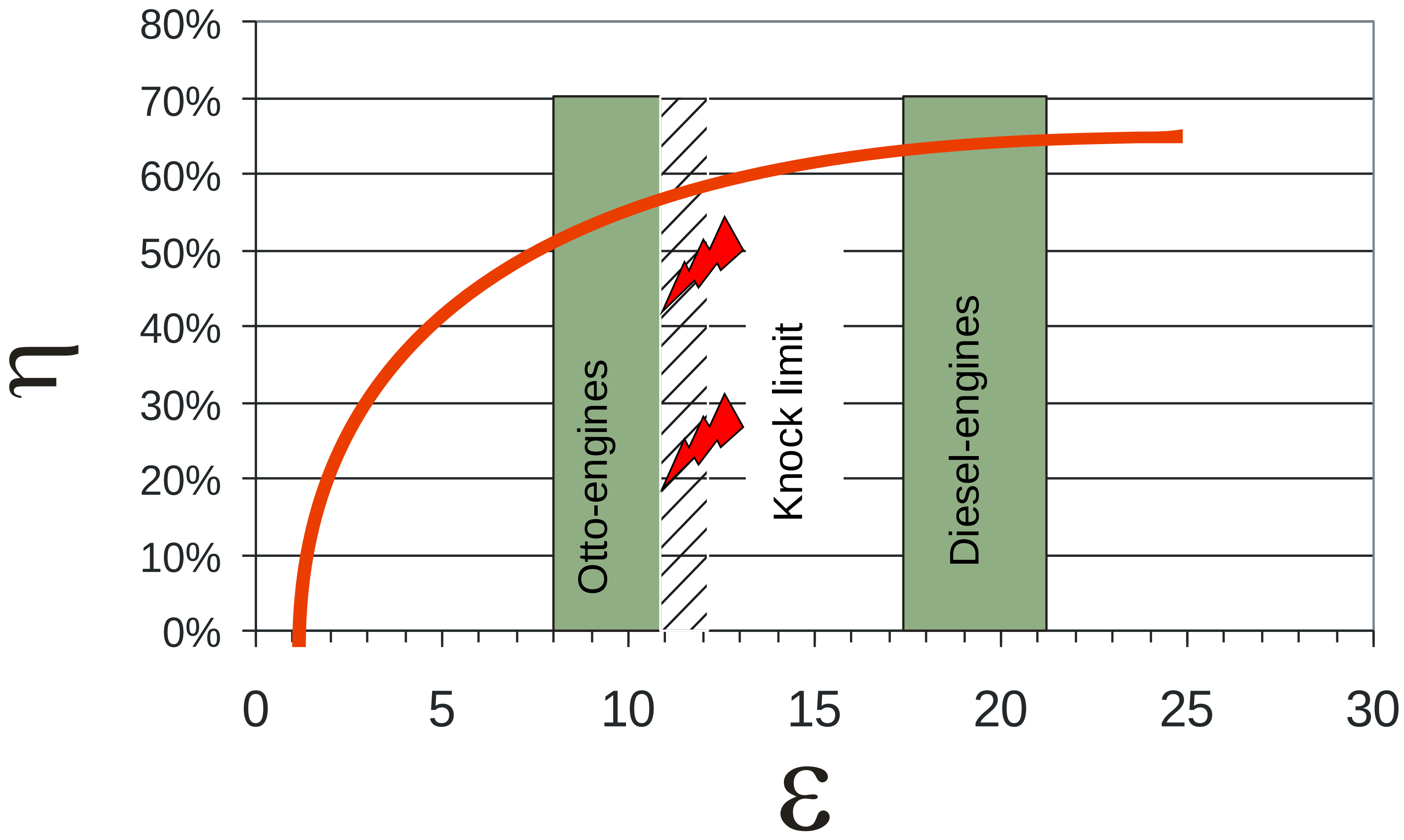




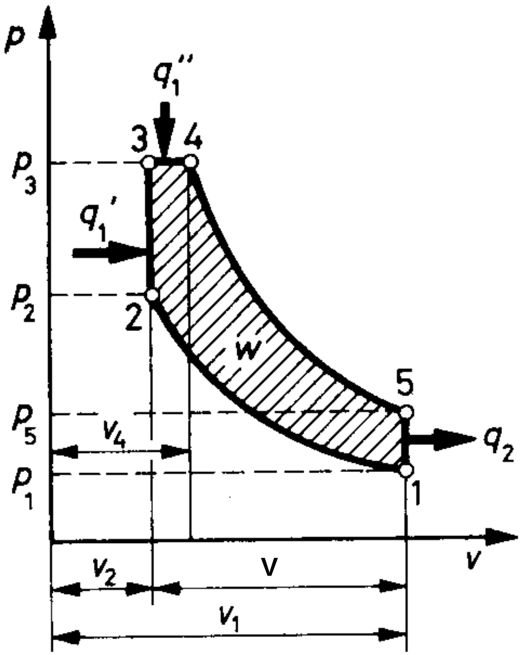
$$\varepsilon = \frac{V_1}{V_2}$$

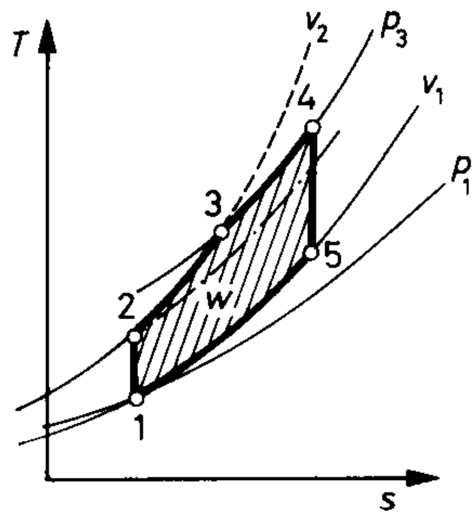
$$\eta = \frac{-\sum W}{Q_1} = \frac{\sum Q}{Q_1} = \frac{c_v(T_3 - T_2) - c_v(T_4 - T_1)}{c_v(T_3 - T_2)} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{1}{\varepsilon^{\kappa - 1}}$$

Efficiency in the function of the compression ratio



The Dual-combustion cycle





$$\eta = \frac{-\sum W}{Q_1} = \frac{\sum Q}{Q_1} = \frac{c_p(T_3 - T_2) + c_v(T_4 - T_3) - c_v(T_5 - T_1)}{c_p(T_3 - T_2) + c_v(T_4 - T_3)} = 1 - \frac{1}{\varepsilon^{\kappa-1}} \cdot \frac{\rho^{\kappa} \cdot \lambda - 1}{(\lambda - 1) + \kappa \cdot \lambda \cdot (\rho - 1)}$$

$$\rho = \frac{v_4}{v_3} \qquad \lambda = \frac{p_3}{p_2}$$

2020 End

Check questions

1. Present the Carnot cycle in T-s diagram, how to determine the thermodynamic efficiency of the cycle?
2. What equipment uses the Brayton-Joule cycle, how to determine the thermodynamic efficiency of the cycle?
3. What are the elements of the open Brayton-Joule cycle? Present the cycle in T-s diagram.
4. What are the losses of the real Gas Turbine cycle?
5. What equipment uses the Clausius - Rankine cycle? Present the elements and cycle in T-s diagram.
6. What are the elements of the Clausius - Rankine cycle?
7. ~~What is the degree of reaction? Present Reaction Stage in h-s diagram~~
8. ~~What is the degree of reaction in the impulse stage?~~
9. What does the COP mean? Present the cycle in lgp - h diagram.
10. What is Air–fuel equivalence ratio?
11. How to determine the COP for a chiller?
12. How to determine H-T diagram using the Tad?
13. How to determine H-T diagram using the HHV, LHV?
14. Which is the higher in the case of CO firing: HHV or LHV?

Real Adiabatic Flame Temperature