Formeln Thermodynamik

Umrechnungen:

$1\,Pa \;=\; 1\,N/m^2 \;=\; 10^{-5}\,\text{bar}$

$1\,\text{bar} = 0{,}1\,MPa = 10^5\,Pa = 0{,}1\,N/mm^2 = 100000\,N/m^2 = 10^5\,N/m^2 = 10^5\,Nm/m^3 = 10^5\,J/m^3$

$T_{Kelvin} \;=\; T_{°C} + 273{,}15$ $\qquad 1\text{L} = 10^{-3}\,m^3$

$1\,Nm \;=\; 1\,J \;=\; 1\,Ws$

$\epsilon\, bei\; Kälte/Wärmeanlagen\; ist\; \epsilon = \dfrac{Nutzeffekt\; Energie(z.b.\, Kälteleistung)}{Zugeführte\; Energie}$

$R_{i\,Luft} = 287\,\dfrac{J}{kgK}$

$c_{p\,Luft} = 1{,}006\,\dfrac{kJ}{kgK}$

$\kappa_{Luft} = 1{,}402$

$\kappa_{Luft} = \dfrac{c_p}{c_v}$

Allgemeine Gleichungen:

Allgemeine Zustandsgleichung der Gase:

für 1 kg Gas: $p \cdot v \;=\; R_i \cdot T$

für m kg Gas: $p \cdot V \;=\; m \cdot R_i \cdot T$

$R_i \;=\; c_p - c_v$

Wichtige Formeln der Leistung: $P \;=\; p \cdot m \;\rightarrow\; p \;=\; \dfrac{P}{m} \;\rightarrow\; w = \dfrac{P}{\dot{m}}$

Allgemeine Raumänderungsarbeit: $W_r \;=\; \int_{v_1}^{v_2} p \cdot dV \quad \dfrac{N}{m^2} \cdot m^3 \;= Nm$

Allgemeine technische Arbeit: $W_t \;=\; -\int_1^2 V \cdot dp \quad Nm$

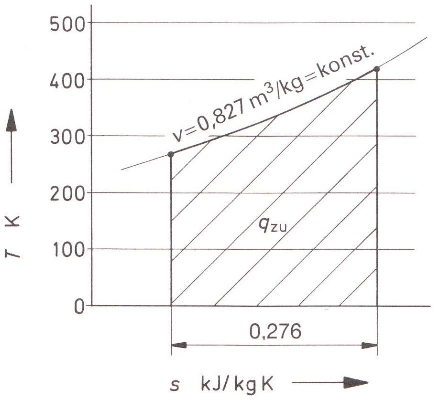
$w_t \;=\; h_1 - h_2$

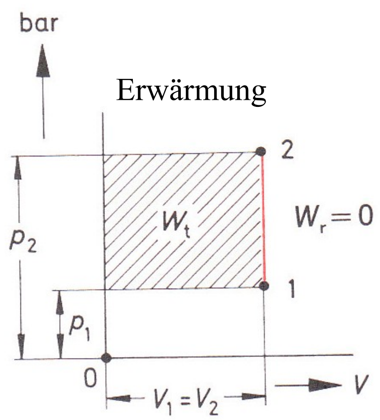
Enthalpie: $h \;=\; c_p \cdot (T_2 - T_1)$

$h_1 - h_2 \;=\; \int_{T_1}^{T_2} c_p \cdot dT$

Zustandsänderungen:

isochor:





$\Delta V \;=\; 0$

$\dfrac{p_1}{P_2} \;=\; \dfrac{T_1}{T_2}$

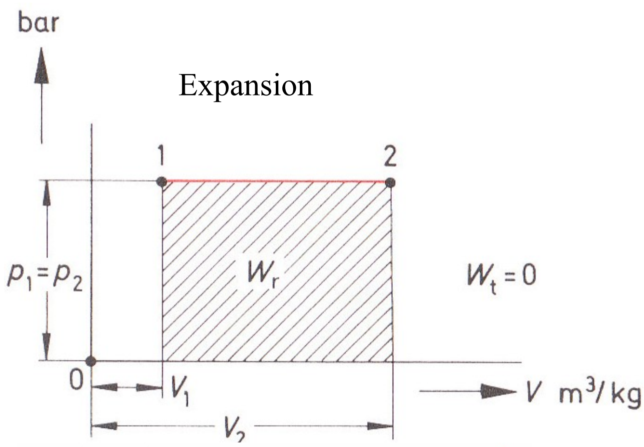
$w_r \;=\; 0$

$w_t \;=\; v \cdot (p_1 - p_2) \quad Nm/kg$

$s_2 - s_1 \;=\; c_v \cdot \ln(p_2/p_1)$

$s_2 - s_1 \;=\; c_v \cdot \ln(T_2/T_1)$

isobar:

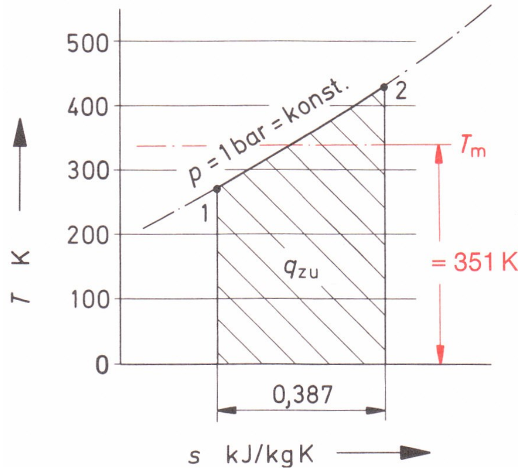


$$\Delta p = 0$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

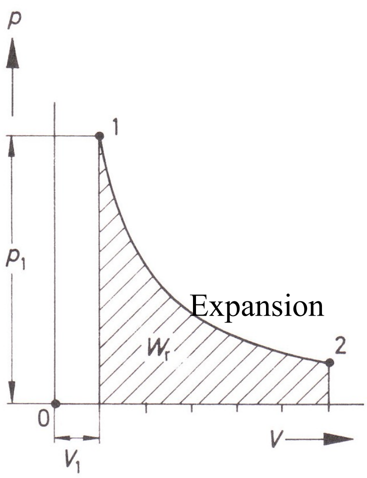
$$w_r = p \cdot (v_2 - v_1) \quad Nm/kg$$

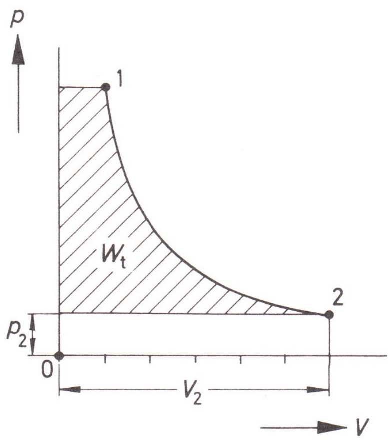
$$w_t = 0$$



$$s_2 - s_1 = c_p \cdot \ln(T_2 / T_1)$$

isotherm:





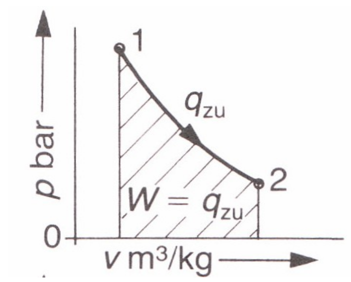
$$\frac{p_1}{p_2} = \frac{v_2}{v_1}$$

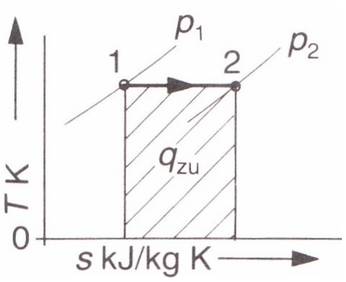
$$w_t = w_r = R_i \cdot T_1 \cdot \ln(v_1 / v_2)$$

$$= R_i \cdot T_1 \cdot \ln(p_2 / p_1)$$

$$w_t = w_r = p_1 \cdot v_1 \cdot \ln(p_2 / p_1)$$

$$w_t = w_r = q$$

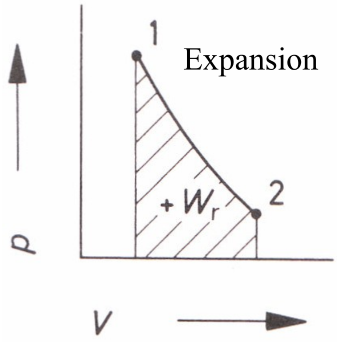


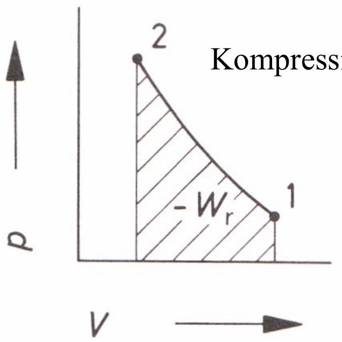


$$s_2 - s_1 = R_i \cdot \ln(p_2 / p_1)$$

← 1-2: ísotherme Expansion

adiabate (isentrope):





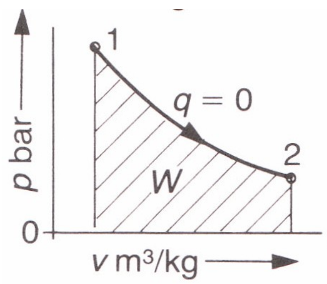
$$p_1 \cdot v_1^{\kappa} = p_2 \cdot v_2^{\kappa}$$

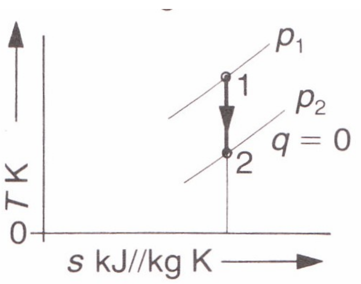
$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{\kappa-1}$$

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

$$\frac{v_2}{v_1} = \left(\frac{T_1}{T_2}\right)^{\frac{1}{\kappa-1}}$$

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





↑

1-2: adiabate Expansion

$$w_r = \frac{R_i}{\kappa-1} \cdot (T_1 - T_2)$$

$$w_r = \frac{R_i \cdot T_1}{\kappa-1} \cdot \left(1 - (p_2/p_1)^{\frac{\kappa-1}{\kappa}}\right)$$

für m kg Gas: $$w_r = \frac{1}{\kappa-1} \cdot (p_1 \cdot V_1 - p_2 \cdot V_2)$$

$$w_t = \kappa \cdot w_r$$

$$s_2 - s_1 = 0$$

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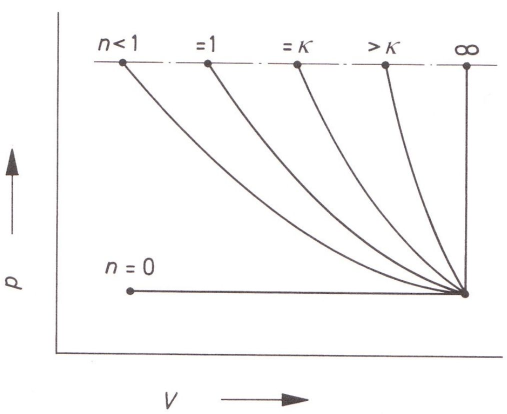
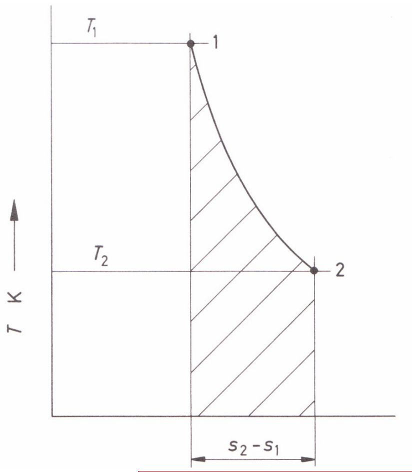
polytrope:





$$p_1 \cdot v_1^{n} = p_2 \cdot v_2^{n}$$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\frac{v_1}{v_2}\right)^{n-1}$$

$$\frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}}$$

$$\frac{p_1}{p_2} = \left(\frac{v_2}{v_1}\right)^{n}$$

$$s_2 - s_1 = c_v \cdot \ln \frac{T_2}{T_1} + R_i \cdot \ln \frac{v_2}{v_1}$$

$$= c_v \cdot \ln \frac{p_2}{p_1} + c_p \cdot \ln \frac{v_2}{v_1}$$

$$= c_p \cdot \ln \frac{T_2}{T_1} + R_i \cdot \ln \frac{p_2}{p_1}$$

$$= c_n \cdot \ln \frac{T_2}{T_1}$$

$$w_r = \left(\frac{R_i}{n-1}\right) \cdot (T_1 - T_2) = \frac{R_i \cdot T_1}{n-1} \cdot \left(1 - (p_2/p_1)^{\frac{n-1}{n}}\right)$$

$$= \left(\frac{1}{n-1}\right) \cdot (p_1 \cdot v_1 - p_2 \cdot v_2)$$

$$w_t = n \cdot w_r$$

$$q = c_v \cdot \left(\frac{n-\kappa}{n-1}\right) \cdot (T_2 - T_1)$$