GAS IDEALI

EQUAZIONI DI STATO

$u = u(s, v)$ ⟶ $u = u(T, v)$

$h = h(s, P)$ ⟶ $h = h(T, P)$

$s = s(u, v)$ ⟶ $s = s(T, v)$

GRANDEZZE DI INTERESSE — PROPRIETÀ DEL SISTEMA/MATERIA MISURABILI

CALORE SPECIFICO $\left[\frac{J}{kg\,K}\right]$

CALORE NECESSARIO PER INCREMENTARE DI 1K LA TEMP. DI 1Kg DI SOSTANZA

- A V COST:

$$C_v = \left.\frac{\delta Q_{(TIR)}}{dT}\right|_{V=COST}$$

- A P COST

$$C_p = \left.\frac{\delta Q_{(TIR)}}{dT}\right|_{P=COST}$$

⟹ NEI GAS IDEALI

$$C_v = \frac{R}{2}(\text{gdl TRASLAZIONALI}) + \frac{R}{2}(\text{ROTOTRASLAZIONALI})$$

$C_p - C_v = R$ RELAZIONE DI MAYER $C_p > C_v$

MOLECOLA:

- MONOATOMICA 3gdl TRASL. $C_v = \frac{3}{2}R$ $C_p = \frac{5}{2}R$
- BIATOMICA 3gdl TRASL, 2gdl ROT $C_v = \frac{5}{2}R$ $C_p = \frac{7}{2}R$

- POLI-ATOMICA: 3 gdl TRASL, 3 gdl ROT $\quad C_v = 3R \quad C_p = 4R$

Eq. DI STATO

$$\boxed{Pv = RT}$$

$$R\left[\frac{J}{kg\,K}\right] = \frac{R^*}{M_m} = \frac{8314}{M_m} \frac{\left[\frac{J}{kmol\,K}\right]}{\left[\frac{kg}{kmol}\right]}$$

$$du = C_v dT$$

$$dh = C_p dT$$

$$ds = \frac{C_p dT}{T} - \frac{R\,dP}{P}$$

$$ds = \frac{C_v dT}{T} + \frac{R\,dv}{v}$$

$$\int_0^1 \longrightarrow$$

$$u_1 - u_0 = C_v \cdot (T_1 - T_0)$$

$$h_1 - h_0 = C_p \cdot (T_1 - T_0)$$

$$s_1 - s_0 = C_p \cdot \ln\left(\frac{T_1}{T_0}\right) - R \cdot \ln\left(\frac{P_1}{P_0}\right)$$

$$s_1 - s_0 = C_v \cdot \ln\left(\frac{T_1}{T_0}\right) + R \cdot \ln\left(\frac{v_1}{v_0}\right)$$

$$\Delta H = \Delta U + l$$

TRASFORMAZIONI:

- POLITROPICA
- ISOCORA
- ISOTERMA
- ISOBARA
- ISOENTROPICA

1) POLITROPICA:

Hp:
- GAS IDEALE $Pv = RT$
- TIR
- CALORE SPEC. COSTANTE DURANTE LA TRASFORMAZIONE

$$C_x = \left(\frac{\delta q_{in}}{dT}\right)_x \left[\frac{J}{kg\,K}\right] = cost \qquad q = C_x \Delta T$$

$$\delta q_{in} + \delta l_{(in)} = du$$

P-v: $P_0 v_0^n = P_1 v_1^n$

T-P: $\frac{T_1}{T_0} = \left(\frac{P_1}{P_0}\right)^{\frac{n-1}{n}}$

T-v: $\frac{T_1}{T_0} = \left(\frac{v_0}{v_1}\right)^{n-1}$

$$n = \frac{C_x - C_p}{C_x - C_v} \qquad du = C_v dT$$

2) ISOBARA $P = cost$ SCAMBIATORE DI CALORE

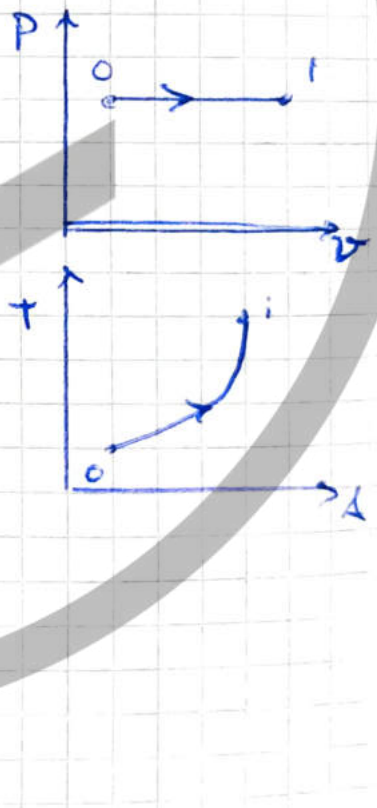
S. CHIUSO	S APERTO STAZIONARIO
BI°P.	BI°P
$q_{(in)} + l_{(in)} = \Delta u$	$q_{(in)} + l_{(in)} = \Delta h$
$q_{(in)} = (u_1 + Pv_1) - (u_0 + Pv_0) = \Delta h$	$q_{(in)} = \Delta h$
$l_{(in)} = -\int p\,dv = -P(v_1 - v_0)$	$l_{(in)} = v(P_{out} - P_{in}) \to 0$

I° P. (S. AP/CH) $\quad$ II° P. (S AP/CH)

$$q_{(in)} = \Delta h \qquad \int \frac{\delta q_{in}}{T} = \Delta s$$

→ GAS IDEALE

$$q_{in} = \Delta h \overset{GI}{=} c_p \cdot (T_1 - T_0)$$



↳ Politropica isobara

$$c_x = c_p \Rightarrow n = 0$$

$$\boxed{\frac{T_1}{T_0} = \frac{v_1}{v_0} \quad T\text{-}V}$$

↳ $\Delta s \overset{GI}{=} c_p \cdot \ln \frac{T_1}{T_0}$

$Q = \Delta H = M\Delta h = Mc_p(\Delta T)$

$\Delta U = M c_v(\Delta T)$

ISO-P + ADIAB ⇒ ISO-H

3) ISOCORA: $v = \text{cost}$

S. CHIUSO:

$q_{(in)} = \Delta u$

$l_{(in)} = -\int P\,dv = 0$

S. APERTO

$q_{(in)} = (h_{out} - vP_{out}) - (h_{in} - vP_{in}) = \Delta u$

$l_{(in)} = \int v\,dP = v(P_{out} - P_{in})$

I° P (S N/C)

$q_{(in)} = \Delta u$

II° P (S N/C)

$\int \frac{\delta q_{in}}{T} = \Delta s$

➜ **GAS IDEALE**

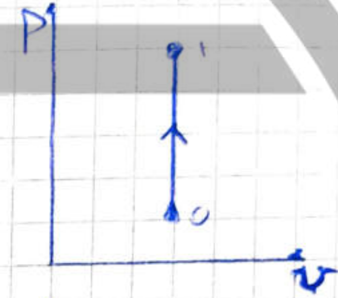
$q_{in} = \Delta u \overset{GI}{=} c_v \cdot (T_1 - T_0)$

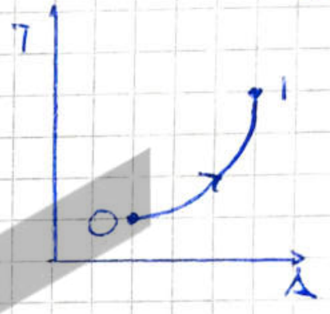
↳ Polit. isocora

$c_x = c_v \Rightarrow n = \infty$

$\boxed{\frac{P_1}{P_0} = \frac{T_1}{T_0} \quad T-P}$

↳ $\Delta s \overset{GI}{=} c_v \cdot \ln\left(\frac{T_1}{T_0}\right)$





4) ISOENTROPICA $s = cost$ — TURBINA, COMPRESSORE

S. CHIUSO	S. APERTO
BI°P	BI°P
$q(in) + l(in) = \Delta u$	$q(in) + l(in) = \Delta h$

$$\boxed{q(in) = 0 \quad \text{ADIABATICA ISOENTROPICA}}$$

S. CHIUSO	S. APERTO
$l(in) \left(= -\int P\,dv\right) = \Delta u$	$l(in) \left(= \int v\,dP\right) = \Delta h$
I°P S.C.	I°P S.A
$l_{in} = \Delta u$	$l(in) = \Delta h$

GAS IDEALE

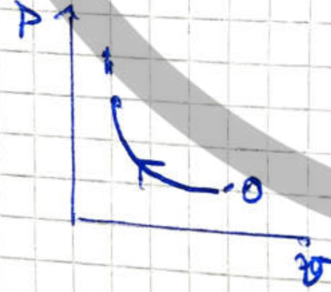
$$q_{in} = 0 \overset{GI}{=} \int C_x\,dT$$

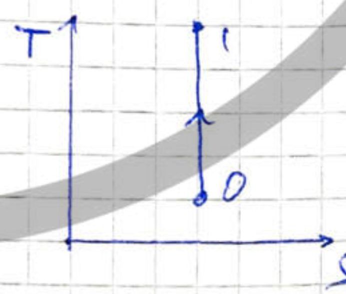
↳ POL. ISOENTROPICA

$$C_x = 0 \Rightarrow n = \frac{C_p}{C_v} = \gamma$$

$$\frac{T_1}{T_0} = \left(\frac{P_1}{P_0}\right)^{\frac{\gamma-1}{\gamma}} \qquad \frac{T_1}{T_0} = \left(\frac{v_0}{v_1}\right)^{\gamma-1} \qquad \frac{P_1}{P_0} = \left(\frac{v_0}{v_1}\right)^{\gamma}$$

T-P   T-V   P-V





ESPANSIONE:
$P\downarrow \Rightarrow T\downarrow \Rightarrow L^-(out) \Rightarrow \Delta h^-$

COMPRESSIONE
$P\uparrow \Rightarrow T\uparrow \Rightarrow L^+(in) \Rightarrow \Delta h^+$

$$\Delta s = 0 \overset{GI}{=} C_v \ln\frac{T_1}{T_0} + R\ln\frac{v_1}{v_0} \overset{GI}{=} C_p\ln\left(\frac{T_1}{T_0}\right) - R\ln\left(\frac{P_1}{P_0}\right)$$

5) ISOTERMA ($T = cost$)

S CHIUSO

BI°P

$q_{(in)} + l_{(in)} = \Delta u$

$q_{(in)} + l_{(in)} = 0$

$\Delta u = \int c_v \, \underbrace{dT}_{\to 0}$

S APERTO

BI°P

$q_{(in)} + l_{(in)} = \Delta h$

$q_{(in)} + l_{(in)} = 0$

$\Delta h = c_p \, dt = 0$

I°P (S A/C)

$q_{(in)} = -l_{(in)}$

II°P (S A/C)

$\int \frac{\delta q_{in}}{T} = \Delta s \xrightarrow[T\,cost]{} \frac{\delta q_{in}}{T} = \Delta s$

→ GAS IDEALE

$$q_{(in)} = \int T \, ds = - T R \ln\left(\frac{P_1}{P_0}\right)$$

↳ POLIT. ISOTERMA

$C_x = \infty \qquad n = 1$

$$\boxed{\frac{P_0}{P_1} = \frac{v_1}{v_0}} \quad P\text{-}v$$

↳ $\Delta s = R \ln\left(\frac{v_1}{v_0}\right) = -R \ln\left(\frac{P_1}{P_0}\right)$