RECAP

$$de = dq - dw = dq - P\,dv$$

dw: BY FLUID

IDEAL GAS: $de = c_v(T)\,dT$

$$c_v = c_v(\text{SPECIES}, T)$$

IDEAL GAS LAW: $P = \rho R T$

e IS WELL-SUITED FOR NO-THROUGH-FLOW SYSTEMS

FOR SYSTEMS W/ $\underbrace{\text{MOVING BOUNDARIES}}_{\text{E.G., ICE ENGINE}}$

OR $\underbrace{\text{THROUGH-FLOW}}_{\text{E.G. TURBINE / COMPRESSOR}}$

A BETTER SUITED VARIABLE IS ENTHALPY

$$h \equiv e + Pv = e + \frac{P}{\rho}$$

$$dh = de + v\,dP + P\,dv$$

$$dq - \cancel{P\,dv} + v\,dP + \cancel{P\,dv}$$

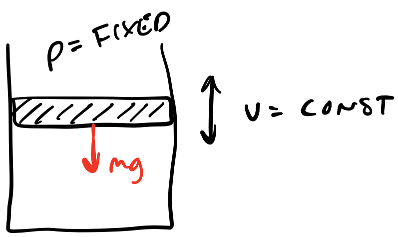
$$\rightarrow dh = dq + v\,dP$$

PROCESS OF INTEREST: CONSTANT PRESSURE

$\rightarrow dP = 0$

$\rightarrow dh = dq$

EX.



$$\underbrace{\left(\frac{\partial h}{\partial T}\right)_P}_{\equiv c_p} = \left(\frac{\partial q}{\partial T}\right)_P$$

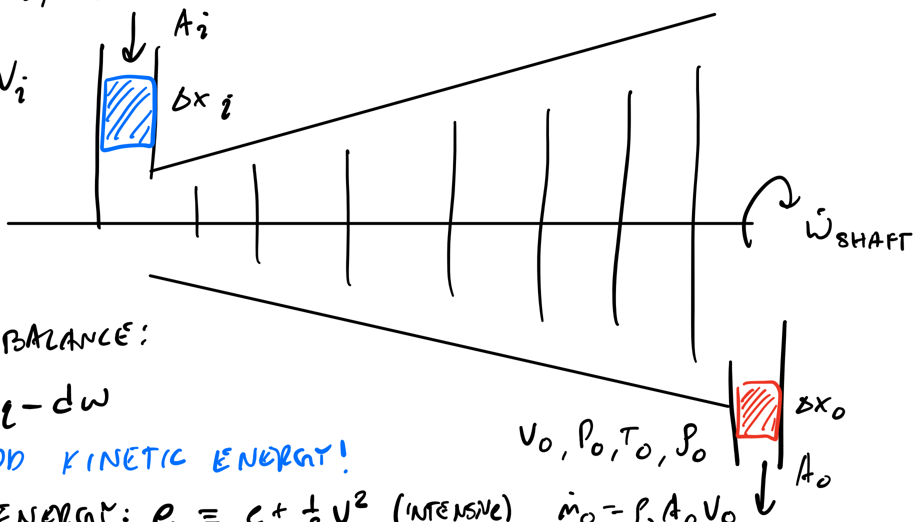
FOR IDEAL GAS:

$$h = e + Pv = e + RT$$

$$dh = de + RdT = C_v dT + RdT = (C_v + R)\,dT$$

$$\rightarrow \underbrace{\left(\frac{\partial h}{\partial T}\right)_P}_{C_p} = C_v + R \qquad \text{OR} \qquad \bar{C}_p = \bar{C}_v + \bar{R}$$

$$C_p = C_v + R$$



ENERGY BALANCE:

$$de = dq - dw$$

MUST ADD KINETIC ENERGY!

TOTAL ENERGY: $e_0 \equiv e + \frac{1}{2}V^2$ (INTENSIVE)

$$E_0 = m\left(e + \tfrac{1}{2}V^2\right) \text{ (EXTENSIVE)}$$

1st LAW REWRITES:

$$de_0 = dq - dw \qquad \text{OR} \qquad \Delta E_0 = \Delta Q - \Delta W$$

$$\Delta \equiv \text{OUT} - \text{IN}$$

IF ADIABATIC: $\Delta E_0 = \Delta \cancelto{0}{Q} - \Delta W$

FOR TURBINE, OVER TIME Δt

MASS IN = MASS OUT $= \dot{m}\Delta t$

STEADY STATE

$$\underbrace{\Delta W}_{\text{WORK}} = \underbrace{\dot{W}}_{\text{POWER}}\Delta t$$

MUST ACCOUNT FOR WORK PERFORMED:

- BY FLUID AT ENTRANCE
- ON FLUID AT EXIT
- BY FLUID ON BLADES

POWER $\dot{W} = \dot{W}_{INLET} + \dot{W}_{OUTLET} + \dot{W}_{SHAFT}$

WORK $W = (\quad '' \quad\quad '' \quad\quad '') \Delta t$

WITH: $\dot{W}_{INLET} \Delta t = \underbrace{P_i A_i}_{\text{FORCE}} \underbrace{(-\Delta x_i)}_{\text{DISPLACEMENT}}$ NEGATIVE SINCE VOLUME DECREASING

$\dot{W}_{OUTLET} \Delta t = P_o A_o \Delta x_o$

→ REASSEMBLE:

$$\dot{m} \Delta t \left(e_o + \frac{1}{2} V_o^2 - e_i - \frac{1}{2} V_i^2 \right) =$$
$$-\left(-P_i A_i \Delta x_i + P_o A_o \Delta x_o + \dot{W}_{SHAFT} \Delta t \right)$$

÷ THROUGH BY Δt:

$$\dot{m} \left(e_o + \frac{1}{2} V_o^2 - e_i - \frac{1}{2} V_i^2 \right) = -\Big(\underbrace{-P_i A_i \frac{\overbrace{\Delta x_i}^{V_i}}{\Delta t}}_{\dot{V}_i = \frac{\dot{m}}{\rho_i}} + \underbrace{P_o A_o \frac{\overbrace{\Delta x_o}^{V_o}}{\Delta t}}_{\dot{V}_o = \frac{\dot{m}}{\rho_o}} + \dot{W}_{SHAFT} \Big)$$

$$\rightarrow \quad \dot{m} \left[\underbrace{\left(e_o + \frac{P_o}{\rho_o} \right)}_{h_o} - \underbrace{\left(e_i + \frac{P_i}{\rho_i} \right)}_{h_i} + \frac{1}{2} V_o^2 + \frac{1}{2} V_i^2 \right] = -\dot{W}_{SHAFT}$$

$\Delta V^2 = \Delta(V^2)$

$$\dot{m} \left[\Delta h + \frac{1}{2} \Delta V^2 \right] = -\dot{W}_{SHAFT}$$

IF HEAT TRANSFER $\neq 0$

$$\dot{m} \left(\Delta h + \frac{1}{2} \Delta V^2 \right) = \dot{Q} - \Delta \dot{W}_{SHAFT}$$

→ $h_o \equiv h + \frac{1}{2} V^2$

ENTROPY

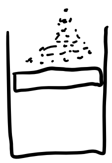
ANOTHER VARIABLE OF STATE

- MEASURES AMOUNT OF DISORDER WITHIN SYSTEM
- PREDICTS TOWARDS WHICH STATE A SYSTEM SPONTANEOUSLY TENDS

FOR A REVERSIBLE PROCESS $ds \equiv \frac{dq}{T} \underbrace{\geq 0}_{\text{2ND LAW OF THERMO}}$

REVERSIBLE PROCESS

- INFINITELY SLOW
- FRICTIONLESS
- DUE TO SMALL DISTURBANCES

 → INCREASE FORCE ON PISTON, 1 GRAIN AT A TIME