Rubric for solving problems for properties of pure substances and boundary work in simple compressible systems

DEFINE the state of the system: require two (2) independent intensive properties from among:

T, P, v (or $\rho = 1/v$), u, h, x, where **v = V/m**,

Sat. mixture: T and P are NOT independent, use quality, x

$x = m_g/m_T = (v_{mix} - v_f)/v_{fg}$

SELECT the appropriate property relations determined by the material PROCESS PATH determines boundary work

IDEAL GAS: $T > T_{cr}$ and $P < P_{cr}$

$Pv = RT$ (absolute T and P)

$c_P = c_V + R$ (A-2)

$\Delta u = c_V \Delta T$

$\Delta h = c_P \Delta T$

Polytropic Process: $PV^n = C$, where C = constant

$P_1/P_2 = (V_2/V_1)^n$

$n = \ln(P_1/P_2)/\ln(V_2/V_1)$

n=1: isothermal ideal gas, $P_1/P_2 = (V_2/V_1)$

n=0: isobaric (P = C)

Boundary work in closed system $W_b = \int PdV$

Isobaric process: $W_b = P^*(V_2 - V_1)$

Isothermal process: $W_b = P_1V_1^*\ln(V_2/V_1)$

$= P_2V_2^*\ln(V_2/V_1) = mRT^*\ln(V_2/V_1)$

Poly tropic process:

$W_b = (P_2V_2 - P_1V_1)/(1-n)$ $n \neq 1$

Ideal gas + polytropic:

$W_b = mR^*(T_2 - T_1)/(1-n)$ $n \neq 1$

IDEAL LIQUID OR SOLID

(INCOMPRESSIBLE) $c_P \approx c_V$ (A-3)

ΔP small: $\Delta u = \Delta h = c_P \Delta T$

ΔT small (pump): $\Delta u \approx 0$, $\Delta h = v\Delta P$

Boundary work in closed system:

Usually 0 since $W_b = \int PdV$ and liquids & solids incompressible

NON-IDEAL: LIQUID-VAPOR MIXTURE, NON-IDEAL SUPERHEATED VAPOR

USE PROPERTY TABLES

H_2O (A-4 – A-6) and R-134a (A-11 – A-13)

Mixture: $T = T_{sat}$ given P. $P = P_{sat}$ given T

$0 < x < 1$

$v_f < v_{mix} < v_g$; $u_f < u_{mix} < u_g$; $h_f < h_{mix} < h_g$

Superheated: P and T are independent

$T > T_{sat}$ given P and $P < P_{sat}$ given T

Compressed liquid: P and T are independent

$T < T_{sat}$ given P and $P > P_{sat}$ given T

$v \approx v_f$; $u \approx u_f$; $h \approx h_f$ at system T

Critical state: $T = T_{cr}$ & $P = P_{cr}$ for substance

$v_f = v_g$; $u_f = u_g$; $h_f = h_g$

Boundary work in closed system, non-ideal

$W_b = \int PdV$

Isobaric: $W_b = P^*(V_2 - V_1) = P^*m^*(v_2 - v_1)$

Isothermal phase change, constant P ($0 \leq x \leq 1$)

$W_b = P^*(V_2 - V_1) = P^*m^*(v_2 - v_1)$

Isochoric: $W_b = 0$

All other, estimate area under P-v process line