Ex. A rigid, well-insulated tank is connected to two valves. One valve goes to a steam line that has steam at 1000 kPa & 600K and the other to a vacuum pump. Both valves are initially closed. Then the valve to the steam line is opened so that the steam enters the evacuated tank very slowly until the pressure in the tank equals the pressure in the steam line. Calculate the final temperature of the steam in the tank.

Steam line
- p = 1000 kPa
- T = 600K

System = tank
- System is U/S
- (Initially no mass but we have mass)
- Δ open.

Basis = 1 kg steam

Steam at 1000 kPa & 600K

\[ m_{in} \Delta T = m_{in} \Delta h_{in} - m_{ex} \Delta h_{ex} \]

\[ T = 327°C \]

\[ E_{f2} - E_{i1} = ΔU - ΔW - Δ(H + KE + PE) \]

1) No change in \( PE \) & \( KE \) given \( \rightarrow \) \( ΔE = ΔU \)
2) tank is rigid - no work \( \rightarrow \) \( W = 0 \)
3) since tank is well-insulated \( \rightarrow \) \( Q = 0 \)
4) \( ΔKE + ΔPE \) of the steam entering the system = 0
5) No steam exits the system \( \rightarrow \)\( H_{out} = 0 \)
6) A vacuum exists so the state = 0
\[ U_{f_2} - 0 = -(H_{f_{out}} - H_{in}) \]

\[
\min U_{f_2} = -m_{in}^\hat{A} \Rightarrow \hat{U}_{f_2} = \hat{H}_{in}
\]

Find \( \hat{A}_{in} \) at 1000 kPa & 600K then \( \hat{A}_{in} \) at 1000 kPa & with the \( \hat{U}_{f_2} \) find the state & find the temp. which is \( \hat{A}_{in} \) 7.

\[ \hat{A}_{in} = 3158.44 = \hat{U}_{f_2} \Rightarrow T = 764 \text{ K} \]

\[ 491 \text{ °C} \]

If there is more than one input & output stream for the system, you will find it becomes convenient to calculate the properties of each stream separately & sum up the respective inputs & outputs so

\[
\Delta E = E_{f_2} - E_{f_1} = \sum_{i=1}^{M} m_i (\hat{H}_i + kE_i + p\hat{E}_i) - \sum_{o=1}^{N} m_0 (\hat{H}_o + kE_o + p\hat{E}_o) + \Delta - W
\]

Example: You read that \( U_{f_2} - U_{f_1} = Q + W \) non-flow.

If you cannot find the notation listed in the book, would you agree that the \( Q \) represents the \( ES \) for an open, USS?

No, no flow terms present.
5.74 Find the power output of an insulated generator that uses 700 kg/h of steam at 10 atm and 500°C. The steam exits at 1 atm and is saturated.

\[ \Delta T = \text{2655.5°C} \]
\[ \Delta U = 2595 \]
\[ V = 0.213 \text{ m}^3/\text{kg} \]
\[ \overline{V} = 1.634 \]

Insulated \( q = 0 \) \( \Delta KE = \Delta PE = 0 \)

For hour \( 55 \) continuous process

\[ \Delta E = 0 = q - W - (\Delta H) m \]
\[ W = -(\Delta H) m = -(\Delta H_{h} - \Delta H_{i}) m \]
\[ = -(2655.5 - 2889.8) \frac{kJ}{kg} \cdot 700 \text{ kg/h} \]
\[ = 150820 \frac{kJ}{h} \cdot \frac{kw}{1kJ/s} \cdot \frac{h}{3600} = 41.88 \text{ kW} \]
CB for open SS systems

most of the industrial processes are OPEN SS

\[ \Delta E = 0 = Q - W - \Delta (H + KE + PE) \]

\[ Q - W = \Delta (H + KE + PE) \]

When \( \Delta P, \Delta KE \) are negligible? Energy terms in EB in most open processes are dominated by \( Q, W, \Delta H \).

1) PE change would require 1 kg to go up a distance of 100 m

2) KE change would require a velocity change from 0 to 45 m/s.

So \( Q - W = \Delta H \)

Ex: Milk (essentially water) is heated from 15°C to 25°C by hot water that goes from 70°C to 35°C as shown in Fig. What assumptions can you make to simplify GEB \& what is the flow rate of water in kg/mm per kg/mm of milk?

[Diagram of water flow system: Hot water in at 70°C, milk in, water out at 35°C, milk out.]
system = milk + water in the tank

assumptions: 1) ΔKE & ΔPE are zero (if milk or water is selected as system - you cannot, but in order to simplify the sol'n I)
2) Q = 0 - think the system is isolated, water loses heat milk gains - so net heat is evolved outside the system.
3) W = 0 - our boundary, no work done

so

\[ ΔE = 0 = Φ - W = Δ(H + KE + PE) \]

\[ ΔH = 0 \]

\[ H_{out} - H_{in} = 0 \]

i.e.

\[ m_{milk}^\uparrow H_{milk}^\downarrow 25^\circ C + m H_{2}O^\downarrow 35^\circ C - \left( m_{milk}^\uparrow H_{milk}^\downarrow 1^\circ C + m H_{2}O^\downarrow 91^\circ C \right) \]

\[ H_{milk} = \int C_{p} \, dT \]

\[ m_{milk} \, ΔH + m H_{2}O \, ΔH = 0 \]

\[ m_{milk}(35 - 15) = -m H_{2}O (35 - 91) \]

\[ C_{p,milk} = C_{p,H_{2}O} + C_{p,milk}^\text{water vapor} + C_{p,fat} + W_{SNF} \, C_{p,SNF} \]

\[ = 0.87(4.18 \frac{kJ}{kg^\circ C}) + 0.03(0.674) + (0.837)(0.15) \]

\[ = 3.37 \frac{kJ}{kg^\circ C} \]

from steam table

\[ T^\circ C \quad ΔH \quad \frac{kJ}{kg} \]

| 15 | 62.01 |
| 25 | 103.86 |
| 35 | 146.69 |
| 50 | 293.15 |
\[ \Delta H_{\text{milk}}^{15 \to 25^\circ C} = 3.72 \frac{\text{kJ}}{\text{kg} \cdot ^\circ C} \times (25 - 15)^\circ C \]

\[ = 39.2 \text{ kJ/kg} \]

\[ - \Delta H_{\text{water}} = m (\Delta H_{35^\circ C} - \Delta H_{70^\circ C}) = (146.69 - 293.01) \text{kJ} \]

If instead of milk CP calculation, if we need to assume (since 87% H₂O) milk shows similar heat capacity with water:

\[ \Delta H_{\text{milk}} = 1 \text{ kg} \times (103.86 - 62.01) = 41.85 \text{ kJ} \]

\[ m_{\text{H}_2\text{O}} \Delta H_{\text{milk}} = - \left( \Delta H_{\text{water}} \right) m_{\text{H}_2\text{O}} \]

\[ m_{\text{H}_2\text{O}} = \frac{4.185 \text{ kJ}}{-146.32 \frac{\text{kJ}}{\text{kg}}} = 0.25 \text{ kg} \]

\[ m_{\text{H}_2\text{O}} = \frac{41.85 \text{ kJ}}{-146.32 \frac{\text{kJ}}{\text{kg}}} = 0.286 \text{ kg} \]

For each one kg milk we need 0.25 kg water.
5.68 One pound of steam at 130 psig & 600°F is expanded isothermally to 75 psig in a closed system. Thereafter it is cooled at constant volume to 60 psig. Finally it is compressed adiabatically back to its original state. For each of the three steps of the process, compute $\Delta U$, $\Delta H$, $\Delta W$.

**Closed system uses $\Delta E = \Delta U = Q - W$.**

1. $130 \text{ psig} \quad 600°F$ → $A$ → Work done → $75 \text{ psig} \quad 600°F$ → $B$ → $\Delta S = 0$

2. $\Delta U = - W \quad (\Delta T = 0) \rightarrow q = c$
3. $\Delta U = - \dot{Q} \quad (\text{lost}) \quad (\text{const. volume}) \rightarrow W = 0$
4. $\Delta U = - (-W) \quad (\text{adiabatic}) \rightarrow q = c$

$1) \dot{U}_1 = 12(12.5 \frac{84}{16}) \quad 2) \dot{U}_2 = 1215.95 \, \text{Btu/lb}$

$A \rightarrow \Delta U = 3.25 \, \text{Btu/lb} = - W$

$2) \dot{V} = 9.9635 \frac{165}{16} \Rightarrow \dot{V}_3 = 3.9655 \rightarrow \dot{U}_3 = 1191.66$

$e = \Delta U = 1191.66 - 1215.95 = -22.93 = q$
Ex: Water is pumped from a well in which the water level is a constant 20 ft below the ground level. The water is discharged into a level pipe that is 5 ft above the ground at a rate of 0.5 ft³/s. Assume that negligible heat transfer occurs from the water during its flow. Calculate the electric power required by the pump if it is 100% efficient & you can neglect friction in the pipe & the pump.

Basis: 1 second

\[ Q = 0 \]

\[ \text{power} = ? \]

Flow rate = 0.5 ft³/s.

\[ \Delta KE \geq 0 \]

Open & SS system

\[ W = \Delta PE = mg (h_{out} - h_{in}) \]

\[ 0.5 \text{ ft}^3/\text{s} \times 62.4 \text{ lbm/ft}^3 = 31.2 \text{ lbm water/s} \]

\[ W = PE_{0-1} - PE_{m} = \frac{31.2 \text{ lbm H₂O}}{778.2 \text{ lbm-ft/ft}^3} \cdot \frac{32.2 \text{ ft} + 25 \text{ ft}}{s^2} \]

\[ \left( \frac{1.15}{32.2 \text{ ft} + 16 \text{ in}} \right) \left( \frac{1.055 \text{ kJ/kg}}{1 \text{ lbm-ft/ft}^3} \right) = 1.06 \text{ kW} \]

\[ Q - W - (\Delta H + \Delta KE + \Delta PE) \]

\[ Q - W - \Delta H - \Delta KE - \Delta PE = 0 \]
Water is being pumped from the bottom of a well 15 ft deep at the rate of 200 gal/h into a vented storage tank to maintain a level of water in a tank 165 ft above the ground. To prevent freezing in the winter, a small heater puts 25,000 Btu/h into the water during its transfer from the well to the storage tank. Heat is lost from the whole system at the constant rate of 25,000 Btu/h. What is the $T_2$ of the H2O as it enters the storage tank, assuming that the well water is at 35°F? A 2 hp pump is being used to pump the water. About 65% of the rated horsepower goes into the work of pumping & the rest is dissipated as heat to the atmosphere.

$$T_2 = ?$$
Basic 1 hr cp. 200 gal in & out = m = m, m
so ΔE = 0; Δx = 0 (u = v = 0)
0 = Q + W - Δ[\hat{A} + \hat{\rho} m]

ΔH = m ΔT = m \int_{T_1}^{T_2} c_p dT = m c_p (T_2 - 39 °F)

If c_p is constant

\[
\frac{200 \text{ gal}}{h} \times \frac{8.33 \text{ lb}}{\text{gal}} = 1666 \text{ lb/h}
\]

\[
Δp = m \hat{\rho} = m g \Delta h = 1666 \text{ lbm} \times \frac{32.2 \text{ ft}}{\text{s}^2} \times 18.2 \text{ ft} + \frac{1}{312 \text{ ft}^3} = 385.5 \text{ ft-lb}
\]

\[
\times \frac{16 \text{ m}}{270 \text{ ft + lb}} = 385.5 \text{ Btu}
\]

\[
Q = 3000 \text{ cc} \times 2500 \text{ cc} = 5000 \text{ Btu}
\]

\[
\dot{W} = 2 \text{ hp} \times 0.55 = \frac{33000 \text{ ft-lb}}{\text{min} \cdot \text{hp}} \times \frac{60 \text{ min}}{\text{h}} = 1800 \text{ ft-lb}
\]

\[
\Delta H = ? \quad 5000 + 2800 = \Delta U + 386
\]

\[
\Delta H = 4145 = m c_p \Delta T \Rightarrow \Delta T = 4.5 °C
\]

\[
\Delta H_y = 7.45 \quad T_f = 39.5 °F
\]
system: well inlet, piping, pump, & the outlet at the storage tank. Process is a steady state flow process

$$\Delta E = -\Delta \left[ (\hat{H} + \hat{P})m \right] + Q - W = 0$$

$$\Delta P = 0$$ since at the well & at the final point (tank) \( V_1 = V_2 = 0 \)

\( m_1 = m_2 = m \)

$$Q - W = \Delta \left[ (\hat{H} + \hat{P})m \right]$$

\( Q \) & \( \Delta P \) can be calculated & \( \Delta \hat{H} \) also from

$$\Delta H = m \Delta \hat{H} = m \int_{T_i}^{T_f} c_p dT = m c_p (T_f - T_i)$$

\( T_i = 35^\circ F \)

if \( c_p \) is constant then \( Q \)

$$\Delta H = \frac{3314 \text{ Btu}}{16586 \text{ lb}} = 0.2$$

$$W = 415 \text{ Btu/ lb}$$

$$W = 415 \text{ Btu/ lb}$$

$$\Delta P = m \Delta \hat{P} = \frac{m g \Delta h}{s^2} = \frac{1666 \text{ lb}}{32.2 \text{ ft/lb}} \frac{180 \text{ ft}}{s^2} \frac{38.5 \text{ lb}}{s^2} = 385.5 \text{ Btu}$$

$$\Delta h = \frac{32000 - 25000}{5000 \text{ Btu}} = 1.4 \text{ Btu}$$

$$W = -2 \text{ hp} \times 0.55 \frac{180 \text{ Btu}}{1 \text{ hp} \times 60 \text{ min}} = -2830 \text{ Btu/lh}$$ (on the system)

$$\Delta H = \Delta W = \Delta H + \Delta P$$

$$5000 \text{ ft/cu ft} \Delta H = 38.6 \text{ Btu}$$
24.19 Energy released by fruit vegetables during cooling is called heat respiration. For potatoes the peak value is 35 mW/kg at 5°C. Suppose that in an insulated storage room 52 pallets each containing 24 boxes of potatoes are stacked. Each box corresponds to 2.1 kg of cardboard & 2.25 kg of potatoes.

The respective specific heat are 1.7 kJ/kg°C for cardboard & 3.05 kJ/kg°C for potatoes. If potatoes are cooled at the rate of 0.3°C/h, how much must be removed from the room in kW. Neglect effect of air in room.

Based on box then a room,\[ \Delta H = 2.1 \text{ kg} \times 1.7 \frac{\text{kJ}}{\text{kg}^\circ\text{C}} + 20 \text{ kg} \times 3.05 \frac{\text{kJ}}{\text{kg}^\circ\text{C}} \times 0.3 \frac{^\circ\text{C}}{\text{h}} \]

= 19.37 kJ/h \times 24 \text{ box} \times 52 \text{ pallet} = 24193.76 kJ/h

\[ 24193.76 \frac{\text{kJ}}{\text{h}} \times \frac{1}{3600} = 6.714 \text{ kW} \]

The lowest heat for one kg potato is 3.5 kJ/kg

\[ -6 \text{ kW} \times \frac{20 \text{ kg}}{\text{kg box}} \times \frac{24 \text{ box}}{\text{pallet}} \times \frac{52 \text{ pallet}}{\text{room}} = 0.8736 \text{ kW} \]

\[ Q = 6.7149 - 0.8736 = 5.84183 \text{ kW should be removed} \]
1. A gas cylinder contains N₂ at 700 kPa and 40°C. As a result of cooling at constant pressure the cylinder drops to 190 kPa and T = 55°C. How much work is done by the gas?

\[ W = \frac{(298 \times 3)(10 \times 1^1)}{(116.01)(10.73)^{1.2}} = 18.64 \text{ kJ} \]

1-2 \[ W = nRT \ln \frac{V_2}{V_1} = (1)(10.73)(18.64) \ln \frac{1}{10} = -460.53 \text{ kJ} \]

2-3 \[ \Delta V = 0 \Rightarrow W \]

3-4 \[ W = p (V_2 - V_1) = 80 \times 1^2 (10 - 1) \times 1^3 \times 1.14 \frac{82}{776.2} = 133.23 \text{ kJ} \]

Nitrogen gas goes through the ideal process, (Fig) calculate work done in kJ.
A water system is fed from very large tank, through so that the water level in tank is always constant. A pump delivers 3000 gal/min in a 12-in ID pipe to users 40 ft below the tank level. Rate of work delivered to the water is 1.52 hp. If exit velocity of water is 8.5 ft/s & water temperature in reservoir is the same as in exit water, estimate the heat loss per second from pipeline by water in transit.

ΔT = 0, Q = ?

Q = W = ΔH + ΔKE + ΔPE

ΔPE = V

ΔKE = \sqrt{\frac{2g}{5} \Delta \frac{1}{2} (8.5)^2 \frac{W}{s} \frac{1}{s}} = \frac{1}{52.2 \frac{1b}{1b \cdot s^2}} \frac{1}{778.2}

ΔKE = 416.9 \frac{1b}{5} \left(\frac{1}{2}\right) (8.5) \frac{1b}{s^2} = + 0.601 \frac{1b}{s}

ΔKE = 416.9 \frac{1b}{5} (401) \frac{1b}{s} = - 21.58 \frac{1b}{s}

W = 1.52 \frac{1b}{s} = 1.074 \frac{1b}{s}

Q = + W + ΔKE + ΔPE

\text{Area} = (6 \text{ in})^2 \frac{1 \text{ ft}^2}{144 \text{ in}^2} = 0.785 \text{ ft}^2

mass = 3000 \frac{\text{gal}}{\text{min}} \frac{0.1337 \text{ ft}^3}{\text{gal}} \frac{62.4 \text{ lb}}{\text{in}^3} \frac{60 \text{ sec}}{} = 4\text{ tons}

W = 1.52 \frac{1b}{s}

ΔKE = 416.9 \frac{1b}{5} \left(\frac{1}{2}\right) (8.5) \frac{1b}{s^2} = \frac{1}{52.2 \frac{1b}{1b \cdot s^2}} \frac{1}{778.2}

ΔPE = 416.9 \frac{1b}{5} (-401) \frac{1b}{s} = - 21.58 \frac{1b}{s}
d) In case sensible heat of the food milk is not used

\[ m = \frac{Q}{\Delta h_{fp}} = \frac{- (3.42) \cdot (4018.11) \cdot (76-4)}{-2200 \cdot 6300 \cdot \frac{J}{kg}} = 0.48 \text{ kg/s such a high steam is required.} \]

5.75 Water at 180°F is pumped at a rate of 100 ft³/h through a heat exchanger to reduce its T to 100°F. Find the rate at which heat is removed from the water in the heat exchanger.

\[ \begin{array}{c}
\text{TH} \rightarrow \text{HE} \rightarrow T = 100°F \\
T=180°F
\end{array} \]

Assume: SS no change in elevation (\( \Delta P = 0 \))

\[ \Delta h = -[h_f + h^g + h_e] m^1 + \theta - \theta_c \]

\[ d = (\Delta h - \Delta h_s) \Delta \theta \]

\[ \Delta h_s = 148 \text{ Btu/lb} \quad \Delta h = 67.11 \text{ Btu/lb} \]

\[ m = 62.4 \frac{15}{ft^3} \cdot \frac{100 \text{ ft}^3}{h} = 6240 \frac{15}{h} \]

\[ Q = (67.11 - 148) \frac{Btu}{lb} \cdot \frac{6240 \text{ lb}}{h} = -4.91 \times 10^5 \text{ Btu/h.} \]
Water at 180°F is pumped at a rate 100 ft³/hr through a HE to reduce 7 blocks. Find the rate at which 6 is removed from water in HE.

Assume SS, no change in elevation ($\Delta P E = 0$) and constant velocity ($\Delta KE = 0$). No work is done on or by the system.

\[ \Delta E = Q \Delta H + Q \Delta P + Q \Delta E \]

\[ Q = \Delta H \frac{m}{\rho} \]

\[ \Delta H_1 = 148 \text{ ft} \quad \Delta H_2 = 67.99 \text{ ft} \]

\[ m = 62.4 \text{ lbm} \quad 100 \text{ ft} \frac{\text{lbm}}{h} = 6240 \text{ lbm} \frac{1}{h}. \]

\[ Q = -4.93 \times 10^5 \frac{\text{ft}^3}{h} \]

\[ \Delta E = \Delta P = \Delta H = 0 \]

5.76 a) SS, flow $\Delta H = 0$ $\Delta KE = 0$ $\Delta PE = 0$

b) $\Delta KE = 0$ $Q = 0$ $\Delta P = 0$ $\Delta E = 0$

\[ \Delta H = W \]

c) $\Delta H = 0$
Ex: Air is being compressed from 100 kPa & 255 K (where it has an enthalpy of 483 kJ/kg) to 1000 kPa & 278K (where it has an enthalpy of 503 kJ/kg). The exit velocity of air from the compressor is 60 m/s. What is the power required (in kW) for the compressor if the load is 100 kg/h of air?

\[ \Delta H_1 = 483 \text{ kJ/kg} \]

\[ \Delta H_2 = 503 \text{ kJ/kg} \]

Assume initial velocity of air (entering 2) is zero.

Open system, flow process, steady-state

So \( \Delta E = 0 \)

\[ \dot{Q} = 0 \]

\[ m_1 = m_2 = m \]

\[ V_1 = 0 \]

\[ \Delta (\rho m) = 0 \]

\[ \Delta W = \Delta [\dot{H} + \dot{K} + \dot{P}] m = \Delta E = 0 \]

\[ -W = \Delta (\dot{H} + \dot{K}) m = \Delta H + \Delta K \]

\[ \Delta H = (503 - 483) \frac{\text{kJ}}{\text{kg}} \cdot 100 \text{ kg} = 2000 \text{ kJ} \]

\[ \Delta K = \frac{1}{2} (V_2^2 - V_1^2) m = \frac{1}{2} \cdot 100 \text{ kg} \cdot \left(\frac{60 \text{ m/s}^2}{\text{s}^2} \cdot \frac{1 \text{ kJ}}{1000 \text{ kg} \cdot \text{s}^2} \right) \]

\[ = 180 \text{ kJ} \]

Power = work/time

\[ \text{kW} = \frac{2180 \text{ kJ}}{1 \text{ h}} \]

\[ \frac{1 \text{kW}}{1 \text{ h}} = 1 \text{kW} \]
A closed vessel having a volume of 100 ft\(^3\) is filled with saturated steam at 265 psig. At some later time, the pressure has been fallen to 100 psig due to heat losses from the tank. Assuming that the contents of the tank at 100 psig are in ef. stat., how much heat was lost from the tank?

\[
\Delta U = 1117.3 \text{ Btu/ft}^3
\]

\[
\Delta U_g = 1.7547 \text{ ft}^3/\text{lb}
\]

\[
T = 406 \text{ F}
\]

\[
\Delta U_g = 1106.46 \text{ Btu/lb}
\]

\[
\Delta U_L = 298.5 \text{ Btu/ft}^3
\]

\[
\hat{v} = 1.7547 \text{ ft}^3/\text{lb}
\]

\[
\hat{v} = (1-x) 0.0177 + x (4.484) \]

\[
x = 0.39
\]

\[
\Delta U_{\text{final}} = 0.39 (1106.5) + 0.61 (298.5) = 613.3 \text{ Btu/ft}^3
\]

\[
\Delta U = (613.3 - 1117.3) \frac{\text{Btu}}{\text{ft}^3} \frac{100 \text{ ft}^3}{1 \text{ lb}} \frac{1 \text{ lb}}{1.7547 \text{ ft}^3} = 2822.28 \text{ Btu}
\]
5.64 A large piston does 12500 ft-lbf of work in compressing 3 ft³ of air to 25 psia. 5 lbs of water in jacket surrounding the piston increased in T by 2.3°F during the process. What was the change in internal energy of air? Closed & USS

\[
\begin{align*}
\Delta T_{\text{H}_2\text{O}} &= 2.3^\circ \text{F} \\
3 \text{ ft}^3 \text{ air} \\
C_v &= 0.44 \ \frac{\text{Btu}}{\text{lbm \circ F}} \\
Q - W &= \Delta U
\end{align*}
\]

\[
P_j = 25 \ \text{psia}
\]

\[
\Delta \text{lost system} = \Delta \text{gained H}_2\text{O} \\
= m \cdot C_v \cdot \Delta T = 5 \text{lb} \cdot (0.44 \ \frac{\text{Btu}}{\text{lbm \circ F}}) \cdot (2.3^\circ \text{F})
\]

\[
Q = -5.11 \ \text{Btu}
\]

\[
W = -12500 \ \text{ft-lbf} \cdot \frac{18 \text{ Btu}}{778 \text{ ft-lbf}} = -16.06 \ \text{Btu}
\]

\[
-5.11 - (-12500/778) = 10.95 \ \text{Btu} = \Delta U
\]
24.8 (5.60)

10 lb of steam is placed in a tank at 300 psia & 480°F. After cooling the tank to 30 psia, some of steam condenses. How much cooling was required & what was final T in tank?

Base: 1 lb steam 83°F initial stat

Steam → 10 lb → Liquid & Vapor

\[ \Delta L = 1150 \text{ Btu/lb} \]

\[ V = 1.716 \text{ ft}^3/\text{lb} \]

Final stat: how much condensing is not given

System is closed & constant

\[ Q = W = \Delta E \rightarrow Q = \Delta U \]

We have 10 lb steam with V = 17.16 ft³

Assume final state, all volume occupied with vapor so max. volume can be reached as 13.756 ft³/lb so

\[ \frac{13.16 \text{ ft}^3/\text{lb}}{13.75 \text{ ft}^3/\text{lb}} = 1.247 \text{ lb steam} \]

We can have so rest will liquid 8.75 lb liquid

Then \[ \Delta U = 10 \left[ \frac{6.728 (1218.8) + 1.280 (1088)}{10} \right] - \frac{1173.3}{10} \]

\[ = 8432 \text{ Btu} \]

20 psia

450°F = 1163 → 1173.3

500°F = 1181

40 psia

450°F = 1162

500°F = 1180 → 1172.8