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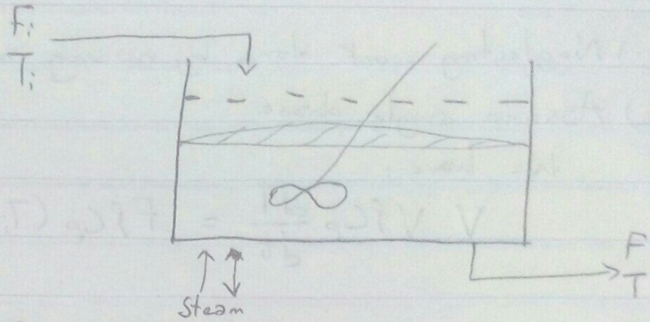
14/ENG01/002 – Chem. Engr.
CHE 531 Assignment I



$\rho = 1000 kg/m^3$

$C_p = 4.181 kJ/kg\,°C$

$f_i = 0.15 m^3/min$

$V = 3m^3$

$\lambda_s = 2258 kJ/kg$

Rate of heat transfer => $Q = \dot{m}_s \lambda_s$

Carrying out material balance

* Considering at constant density ρ

$$\frac{dV\rho}{dt} = f_i\rho - F\rho$$

* Constant tank hold up (volume) so $dV/dt = 0$

$$\therefore \quad F = f_i$$

Carrying out energy balance

Accumulation = IN − OUT + HEAT TRANSFERRED IN + WORK DONE

$$\frac{dT}{dt} = F\rho T_i - f\rho T + Q + W$$

Taking total work done on system

= Shaft work + Energy added to system + Energy performed on surroundings

We can write energy balance as:

$$\frac{dU}{dt} = F\rho\left(\bar{U}_i + \frac{P_i}{\rho_i}\right) - F\rho\left(\bar{U} + \frac{P}{\rho}\right) + Q + W_s$$

Recall $H = U + pV$

$$\frac{dH}{dt} - \frac{dpV}{dt} = F\rho\bar{H}_i - F\rho\bar{H} + Q + W_s$$

N.B: (i) $\frac{dpV}{dt} = V\frac{dp}{dt} + p\frac{dV}{dt}$ (ii) Constant volume

(iii) Since density is constant, mean pressure change is negligible

$$\frac{dH}{dt} = F\rho\bar{H}_i - F\rho\bar{H} + Q + W_s$$

(i) Neglecting work done by mixing impeller

(ii) Assume single phase

We have,

$$V\rho C_p \frac{dT}{dt} = F\rho C_p (T_i - T) + Q$$

$$\frac{dT}{dt} = \frac{F}{V}(T_i - T) + \frac{Q}{V\rho C_p}$$

We can rewrite as:

$$\frac{dT}{dt} = \frac{F}{V}(T_i - T) + \frac{\dot{m}_s \lambda_s}{V\rho C_p}$$

$$\frac{V}{F}\frac{dT}{dt} + T = T_i + \frac{\lambda_s}{F C_p \rho}\dot{m}_s$$

$$\frac{3m^3}{0.15\,m^3/min}\frac{dT}{dt} + T = T_i + \frac{2258\,kJ/kg}{0.15\frac{m^3}{min} \times 4.181\frac{kJ}{kg\,°C} \times 1000\frac{kg}{m^3}}\dot{m}_s$$

$$20\frac{dT'}{dt} + T' = T_i' + 3.6\dot{m}_s'$$

$$20(sT'(s) + T'(0)) + T'(s) = T_i'(s) + 3.6\dot{m}_s'(s)$$

$$20sT'(s) + T'(s) = T_i'(s) + 3.6\dot{m}_s'(s)$$

$$T'(s)(20s+1) = T_i'(s) + 3.6\dot{m}_s'(s)$$

$$T'(s) = T_i'(s)\left(\frac{1}{20s+1}\right) + \left(\frac{3.6}{20s+1}\right)\dot{m}_s'(s)$$