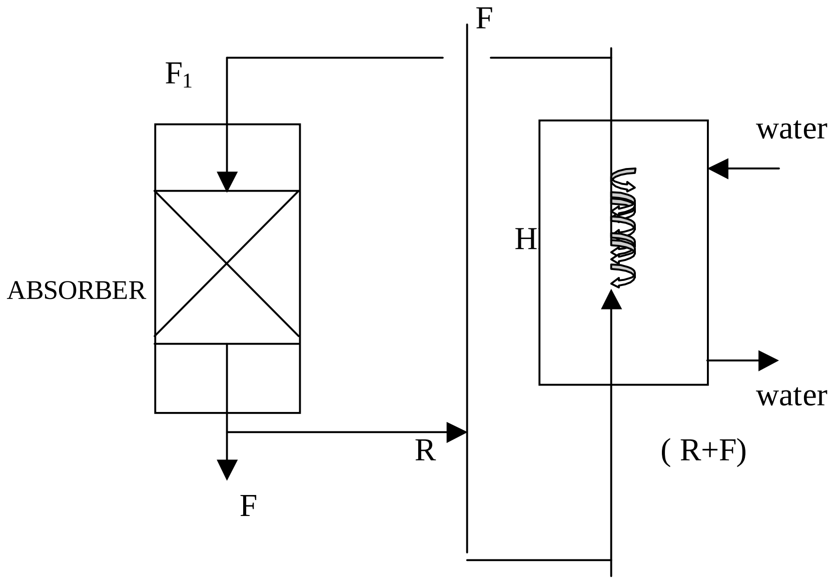
6. HEAT BALANCE

1. SHELL AND TUBE HEAT EXCHANGER

Since all the reactions in absorber and even formation of aq.ammonia, which is sent to absorber are exothermic reaction the heat of reaction should be removed off from absorber section, to maintain it at a low temperature of 20^0c. This task is achieved by installing a shell and tube heat exchanger to the stream that is being sent to the absorber section a part of bottoms of absorber is recycled to achieve the good conversion.

Determination of temperature of inlet and outlet stream to the heat exchanger.



Basis: 1 hour operation.

Let (NH_4OH) stream from tank = F kg

Let R kg be recycle stream to HE

Assuming R be 50% of F_1

$\therefore\ R = 0.50\,[R + F]$

$0.5R = 0.5F$ $(\therefore F_1 = R+F)$

$\therefore$

Hence, recycle R = F = 7176.5 kg

Let ‘X’ be mass fraction of NH_4OH in recycle stream to HE (2) consider 15% conversion in absorption tower.

$$X = \frac{(F + RX) \times (1 - 0.15)}{F + R}$$

$$X = \frac{(1+X) \times 0.85}{2}$$

$$X = 1/\ 1.35 = 0.74$$

$$\boxed{X = 0.\ 74}$$

The total mass of stream fed back to the absorber tower,

$$F_1 = \frac{R\,X + F}{35} + \frac{(1 - X)F}{96}$$

$$= \frac{(FX + F)}{35} + \frac{(1 - X)F}{96}$$

$$= F\frac{(1 + X)}{35} + \frac{F(1-X)}{96}$$

$$= \frac{7176.5(1+0.74)}{35} + \frac{7176.5\,(1 - 0.74)}{96}$$

$$= \underline{376.2 \times 10^3 \text{ g mol}} \quad = 14353 \text{ kg/hr}$$

Stream sent to the heat exchanges is 376.2 x 10^3 g mol or14353 kg/hr. In reality it is mixture of Ag. Ammonia and ammonium carbonate but concentration of ammonium carbonate is too small that the entire stream can be considered as containing of only Aq. Ammonia.

Heat liberated

$2NH_4OH + CO_2 \longrightarrow (NH_4)_2 CO_3 + H_2O \quad \Delta H_R = -22$ kcal/ g.mol

In terms of NH_4OH $\quad \Delta H_R = 22/2$

$= 11$ Kcal/gmol of NH_4OH

$\therefore$ Total heat liberated $Q = F_1 \times \Delta H_R \times 0.15$

$Q = 376.2 \times 10^3 \times 11 \times 10^3 \times 0.15$

$Q = 0.620 \times 10^9$ cal

Or $Q = 2.60 \times 10^9$ 5

This amount of Q is to be revered in heat exchanges

$\therefore F_1 = F_1 \times C_p \times (T - T_r)$

$\underline{T_r = 20^0c}$

Cp of NH_4OH = 90 J /g.mo°c [3]

$\therefore 2.60 \times 10^9 = 376.1 \times 10^3 \times 90 [T - 20]$

$\therefore \boxed{T = 96.81 \simeq 97\,^0c}$

or $\boxed{T = 97\,^0c}$

2. REACTOR SECTION

The reaction taking place in the reactor is,

$$(NH_4)_2\,CO_3 + CaSO_4 \longrightarrow (NH_4)_2SO_4 + CaCO_3 \;\; + 3.9 \text{ k cal/ g. mol }^{o}C$$

96 % of conversion is assumed. The reaction is exothermic, but reactor temperature has to be maintained at room temperature. The heat produced is removed by installing cooling coils in the reactor.

Heat generated in the reactor $Q = F \text{ x} \Delta H_R \text{ x}$ % conversion.

$$= 9842/\ 96 \text{ x } 3.9 \times 10^3 \text{ x } 0.96$$

$$= 383.\ 84 \text{ KJ}$$

the outlet stream contains ammonium sulphate , ammonium carbonate and calcium carbonate.

In the exit stream

Amount of ammonium sulphate = 10517/ 132= 79. 67 g.mol

Amount of calcium carbonate = 9700/ 100= 97 g.mol

Amount of ammonium carbonate = 843.5/ 96 = 8.78 g. mol

Specific value of ammonium sulphate = 1.63 KJ / Kg ^{o}C = 215.1 J / g.mol

Specific value of calcium carbonate = 1.20 KJ / Kg ^{o}C =120.5 J / g.mol

Specific value of ammonium carbonate = 3.10 KJ / Kg ^{o}C = 298.5 J / g.mol

Rise in temperature

The total heat in the reactor exit stream Q,

$$Q = 383.84 \times 10^3 = [79.69x\ 215.1 + 97\ x\ 120.5 + 8.\ 78\ x\ 298]\ x\ (\ T - 30)$$

$\therefore \quad T = 42\ ^oC$

Hence cooling water requirement = m = $(383.\ 84\times 10^3)/\ (4.184x\ (\ 42- 30))$

= <u>1.835kg/ hour</u>

DECOMPOSER SECTION.

In decomposer, the un-reacted ammonium carbonate from reactor outlet stream will be decomposed off into ammonia, carbon dioxide and water. The decomposition reaction is:

$$(NH_4)_2\,CO_3 \longrightarrow 2\,NH_3 + CO_2 + H_2O$$

$\Delta H_R = +311$ kcal/ kg of $(NH_4)_2\,CO_3$

Or 1300 KJ /kg of $(NH_4)_2\,CO_3$

The reaction is endothermic in nature i.e. the decomposition of ammonium carbonate requires heat of decomposition. This can be achieved by supplying steam into through stem coil inside the decomposer. this decomposition of ammonium carbonate is achieved above 109°C.

Heat required by decomposer Qd:

Q_d = heat require stream to decomposition temperature + heat required for decomposition reaction

$Q_d = (m_{as} c_{p1+} m_{water} c_{p2} {}_{+} m_{ac} c_p) (109- 30)$

Q_d = [109417x 1.63 + 657.7 x 4.184 + 843.5 x 3.10] (109- 30) = 843.5 x 1300

Q_d = 2861 KJ

Steam requirement.

It is assumed that saturated steam is supplied and the exhaust stream would be of saturated liquid

Amount of steam required for decomposition of ammonium carbonate, m_h

$m_{h =}$ 2861/ 1.80 (100- 0)= 15.69 kg / hour

4. KRYSTAL EVAPORATIOR.

In this section evaporative crystllisation takes place.

Amount of water to be evaporated = 345 kg.

Assuming the steam side is at higher pressure, i.e. 2 atmospheres.

Amount of heat required for evaporation = m λ_1

= 345 x 2256.9 (λ_1 = 2256.9 KJ/ kg)

= 778.63 x 10^3 KJ/ kg

At 2 atmospheric pressure latent heat of stem λ_2 = 2198.18 KJ/ kg

Amount of steam required= 778.63 x 10^3 / (2198.18)

= 354.18 kg / Hr