

## ENERGY BALANCE

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### Chlorinator

Assumption is made that the fresh benzene and chlorine to the chlorinator are stored at a temperature of 30 °C. The reaction temperature is 40 °C.

The inlet gases are to be heated to the reaction temperature. Thus the heat

$$\Delta H = \sum_i n_i \int_{303}^{313} C_{p_i} dT = 13012.1 \text{ kcal/hr}$$

required for this process is

Where

$\Delta H$  is the heat required.

$C_p$  is the specific heat of component

Specific heat of benzene = 1.7514 kJ/kg K

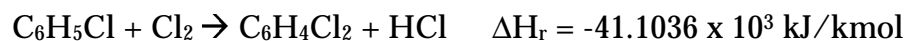
Specific heat of chlorine = 8.28 + 0.00058T

This heat may be supplied by condensing at atmospheric pressure.

$$m_s = \frac{\Delta H}{\lambda_s} = 24.1 \text{ kg/hr}$$

Amount of steam required for producing this much of heat is

Where  $\lambda_s$  is the latent heat of vaporization of steam = 2256.9 kJ/kg



Thus the heat liberated within the reactor is

$$\Delta H = \Sigma n \Delta H = 413.22 \times 10^3 \text{ kJ/hr}$$

The reactor is assumed to function under isothermal conditions. Hence cooling water must be provided via jackets to keep the reactor at the constant temperature of 40 °C.

Cooling water flow rate is found out by

$$m_w = \frac{\Delta H}{C_{pw} \Delta T} = 4942.8 \text{ kg/hr}$$

The gases from the chlorinator go out at the temperature of 40 °C.

Neutralizer



Net heat produced in the neutralizer is  $\Delta H = -171.313 \times 10^3 \text{ kJ/hr}$

This heat produced is utilized to increase the temperature of the outlet stream.

$$\Delta H = \sum_i n_i \int_{313}^T C_{pi} dT = 171.313 \times 10^3 \text{ kcal/hr}$$

By a process of trial and error we find that the outlet temperature is 345 K.

### **Benzene Column**

Assumption is made that no heat losses occur in the column. For such a column the heat balance may be written as

$$Fh_f + Q_w = Dh_D + Wh_w + Q_c$$

F is feed flow rate

D is the distillate flow rate

W is the underflow flow rate.

h indicates the enthalpy of the respective stream

$Q_w$  and  $Q_c$  are the reboiler and condenser heat loads.

$$h = \sum x C_p (T - T_r)$$

$T_r$  is reference temperature taken as 0 K

$$h_f = 555.4 \text{ kJ/kg}$$

$$h_d = 615.33 \text{ kJ/kg}$$

$$h_w = 538 \text{ kJ/kg}$$

The condenser heat load may be calculated as

$$Q_C = \sum m \lambda$$

$\lambda$  is the latent heat of vaporization the values for benzene and chlorobenzene are 393.3 kJ/kg and 331.1 kJ/kg respectively.

hence  $Q_C$  is obtained as  $7.9588 \times 10^3$  kJ/hr

Substituting the values obtained we get

$$Q_W = 3.2192 \times 10^6 \text{ kJ/hr} = 894.22 \text{ kW}$$

### **Chlorobenzene Column**

Assumption is made that there are no heat losses. Hence the previous equation holds.

$$F h_f + Q_w = D h_D + W h_w + Q_c$$

The values for the enthalpies of various streams are

$$h_f = 505.7 \text{ kJ/kg}$$

$$h_d = 508 \text{ kJ/kg}$$

$$h_w = 497.3 \text{ kJ/kg}$$

The condenser heat load is calculated as

$$Q_C = \sum m \lambda$$

$$\text{Thus } Q_C = 1.3226 \times 10^6 \text{ kJ/hr} = 367.4 \text{ kW}$$

$$\text{Hence } Q_W = 2.8017 \times 10^3 \text{ kJ/hr} = 778.25 \text{ kW}$$