ENERGY BALANCE

Chlorinator

Assumption is made that the fresh benzene and chlorine to the chlorinator are stored at a temperature of 30 ^{0}C. The reaction temperature is 40 ^{0}C.

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

$$\Delta H = \sum_i n_i \int_{303}^{313} C_{pi} dT = 13012.1 \, {}^{kcal}\!/_{hr}$$

required for this process is

Where

ΔH 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.

$$m_s = \frac{\Delta H}{\lambda_s} = 24.1 \, {}^{kg}\!/_{hr}$$

Amount of steam required for producing this much of heat is

Where λ_s is the latent heat of vaporization of steam = 2256.9kJ/kg

$C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$ $\quad \Delta H_r$ = -8.5294 x 10^3 kJ/kmol

$C_6H_5Cl + Cl_2 \rightarrow C_6H_4Cl_2 + HCl$ $\quad \Delta H_r$ = -41.1036 x 10^3 kJ/kmol

Thus the heat liberated within the reactor is

$\Delta H = \Sigma n \Delta H$ = 413.22 x 10^3 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 ^{0}C.

Cooling water flow rate is found out by

$$m_w = \frac{\Delta H}{C_{pw}\Delta T} = 4942.8 \, {}^{kg}\!/_{hr}$$

The gases from the chlorinator go out at the temperature of 40 ^{0}C.

Neutralizer

$NaOH + HCl \rightarrow NaCl + H_2O$ $\quad \Delta H_r = 54.213 \times 10^3$ kJ/kmol

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

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

$$\Delta H = \sum_i n_i \int_{313}^{T} C_{pi}\, dT = 171.313x10^3 \, {}^{kcal}\!/_{hr}$$

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.

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

T_r is refernce temperature taken as 0 K

h_f = 555.4 kJ/kg

h_d = 615.33 kJ/kg

h_w = 538 kJ/kg

The condenser heat load may be calculated as

$Q_C = \Sigma m\lambda$

λ 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 7.9588×10^3 kJ/hr

Substituting the values obtained we get

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

Chlorobenzene Column

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

$Fh_f + Q_w = Dh_D + Wh_W + Q_c$

The values for the enthalpies of various streams are

h_f = 505.7 kJ/kg

h_d = 508 kJ/kg

h_w = 497.3 kJ/kg

The condenser heat load is calculated as

$Q_C = \Sigma m\lambda$

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

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