ENERGY BALANCE

EQUATIONS FOR SPECIFIC HEAT:

COMPONENT	EQUATION (Kcal/°K mol)	TEMP. RANGE (°K)
Cl_2	8.28 +0.00056T	273 – 2000
HCl	6.7+0.00084T	273 – 2000
N_2	6.5 + 0.001T	300 – 3000
O_2	$8.27 + 0.000258T - 187700/T^2$	300 - 5000

BASIS: 1 HOUR OF OPERATION

HEAT BALANCE IN REACTOR:

Heat of reaction at 450°C = - 192 Kcal/ kg of HCl reacted

$\therefore$ Total heat of reaction ΔH_r = - 192 x 1350.25 x 4.18

= - 1083656 kJ/hr

The feed enters into the reactor at temperature of 20°C.

$\therefore$ Heat input, Q_i = m C_p ΔT

=[(384.704/32 x 6.1592) + (17.71/28 x 6.79) + (1800.2/36.5 x 6.946) + (36.74/ 18 x 4.18)] x 4.18 x (20 – 0)

= 35356.635 kJ/hr.

Let **T** be the temperature of the product stream, which leaves the reactor.

$\therefore$ Heat output, Q_o = m C_p Δ T

= [(1313.216/71 x 8.24) + (88.78/32 x 7.089) + (450.045/36.5 x 7.013) + (17.71/ 28 x 6.87) + (369.71/18 x 8.456)] x 4.18 x (T – 273) + (369.7 x 2253.27)

$\therefore$ Q_o = [1844.04 x (T – 273)] + 833047.443

At steady state;

Input + Generation = Output

$\Rightarrow Q_i + \Delta H_r = Q_o$

$\Rightarrow 35356.635 + 1083456 = 1844.04 \text{ X } (T - 273) + 833047.44$

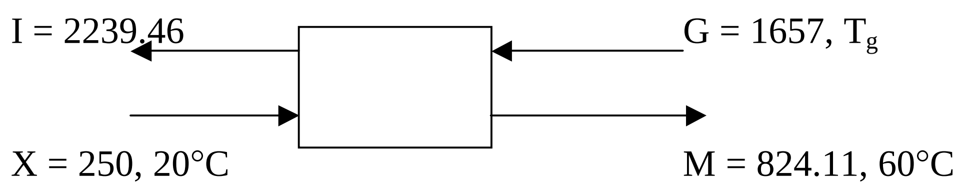
Solving the equation we get

$$T = 428.2 \text{ °K or } T = 155.2 \text{ °C}$$

HEAT BALANCE AROUND PRODUCT GAS COOLER:

Product from the converter leaves at 155.2 °C. This stream is then cooled to 110°C in a reverse flow heat exchanger and then fed at the bottom of the product gas cooler.

Substantially all the water present in the product gas condenses in the cooler. And hence the temperature of the streams M & Y are assumed to be 60°C.



Heat input:

$Q_i = m_i C_p (T - T_R)$

The reference temperature T_R= 0°C.

$Q_i = 2239.46 \times 0.6553 \times 110 = 161427$ kJ/hr

$Q_x = 250 \times 2.92 \times 20 = 14600$ kJ/hr

Heat output:

$Q_m = 824.11 \times 2.98 \times 60 = 147350.87$ kJ/hr

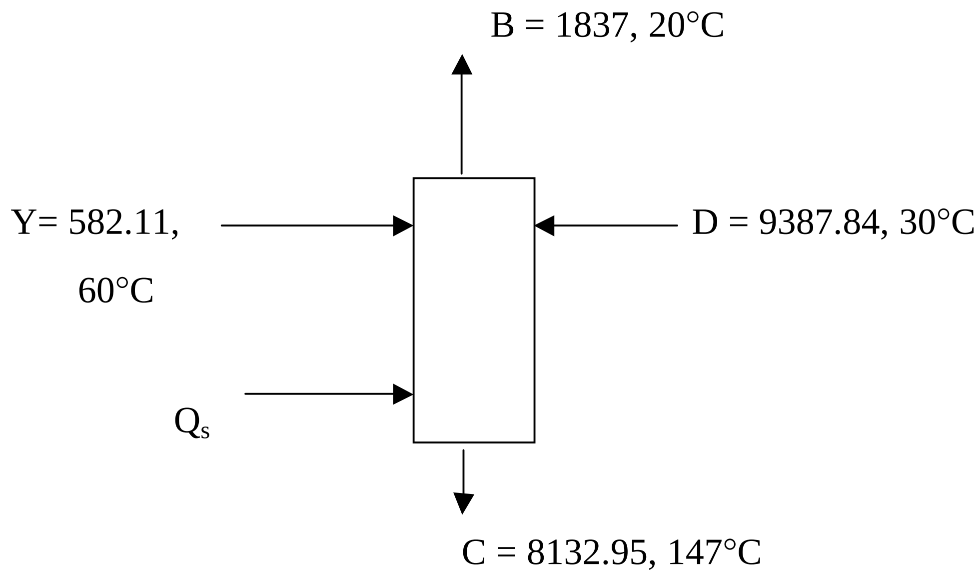
$Q_g = 1657 \times 0.567 \times T_g = 939.52\ T_g$

Heat input = Heat output

$\therefore$ 161427 + 14600 = 147350.87 + 939.52 T_g

$\Rightarrow T_g$ = 30°C

HEAT BALANCE AROUND EXPELLER:



The feed is fed to the expeller from HCl tank. This feed temperature is assumed to be 30 °C.

T_c = 147 °C

Heat input:

Q_Y = 852.11 x 2.94 x 60 = 102684.2 kJ/hr

Q_D = 9387.84 x 2.52 x 30 = 709872.8 kJ/hr

Heat output:

Q_B = 1837 x 0.497 x 20 = 18277.2 kJ/hr

Q_C = 8132.95 x 2.926 x 147 = 3298160.7 kJ/hr

Heat input = heat output

$\therefore Q_S$ + 102684.2 + 709872.8 = 18277.2 + 3498160.7

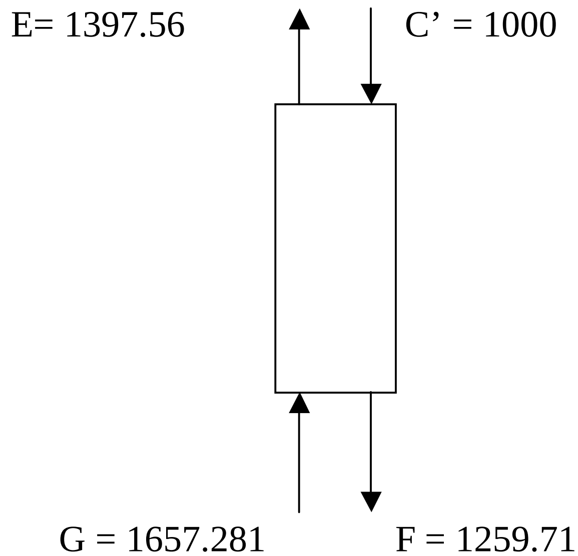
$\Rightarrow Q_S$ = 2703880.9 kJ/hr = 751078105 J/sec.

Assuming process steam is available at 5 atm.

$\lambda_{5\ atm}$ = 2109.687 kJ/kg.

∴ Steam flow rate m_s = 751078.03/ 2109687 = 0.356 kg/sec.

HEAT BALANCE AROUND ABSORBER:



Let Q_{AB} be the heat of absorption of HCl at 30°C.

∴ Q_{AB} = 420 kcal / kg HCl.

∴ HCl absorbed = 453.49 – 220 = 233.49 kg/hr.

∴ Total heat of absorption = 420 x 4.18 x 233.49

Q_{ab} = 409915.04 kJ/hr.

$Q_{ab} + Q + Q_G + Q_C = Q_E + Q_F$

Q_g = 939.52 x 30 = 28185.6 kJ/hr.

Q_c = 1000 x 0.7 x 4.18 x 30 = 87780 kJ/hr.

Q_F = 1259.56 x 2.94 x 30 = 111093.2 kJ/hr.

Q_E = 1397.56 x 0.54 x 30 = 22640.472 kJ/hr.

Substituting all the values in the above equation we get

Q = 392146.97 kJ/hr.