

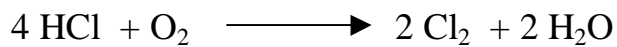
MATERIAL BALANCE

BALANCE AROUND REACTOR

Basis: 1 hour of operation

$$\begin{aligned}\text{Assume on stream time} &= 7500 \text{ hrs/ year} \\ \text{Chlorine production} &= (10000 \times 1000)/7500 \\ &= 1333.33 \text{ kg/ hr.} \\ &= 18.51 \text{ kmol/hr}\end{aligned}$$

From stoichiometry of the reaction:



$$\begin{aligned}\therefore \text{No. of moles of water produced} &= 18.51 \text{ kmol/ hr} \\ &= 333.33 \text{ kg/hr} \\ \therefore \text{Theoretical O}_2 \text{ required} &= 18.496/ 2 \\ &= 9.255 \text{ kmol/hr} = 296.16 \text{ kg/hr} \\ \therefore \text{Theoretical amount of HCl required} &= 18.51 \times 2 = 37.02 \text{ kmol/hr} \\ &= 1350.208 \text{ kg/hr}\end{aligned}$$

Assuming 75% conversion,

$$\begin{aligned}\text{Actual amount of HCl required} &= 1350.208/ 0.75 \\ &= 1800.25 \text{ kg/hr} \\ \text{Amount of water in 98\% HCl gas} &= 1800.25/0.98 - 1800.25 \\ &= 36.74 \text{ kg/hr}\end{aligned}$$

Since the feed contains 98% HCl and rest 2% water,

$$\begin{aligned}\therefore \text{Total flow rate of feed (HCl +Water)} &= 1800.25 + 36.74 \\ &= 1836.99 \text{ kg/hr}\end{aligned}$$

Assuming 30% excess oxygen,

$$\text{Actual amount of oxygen required} = 9.251 \times 1.3$$

$$= 12.026 \text{ kmol/ hr}$$

$$= 384.704 \text{ kg/hr}$$

Assuming 5% inert as nitrogen,

$$\text{Amount of nitrogen in oxygen} = 12.022/0.95 - 12.022$$

$$= 0.6327 \text{ kmol/ hr}$$

$$= 17.71 \text{ kg/hr}$$

∴ Actual molar ratio between HCl and O₂

$$\text{HCl} / \text{O}_2 = 49.322/ 12.655 = 3.897$$

$$\text{Unreacted HCl} = 1800.277 - 1350.208$$

$$= 450.045 \text{ kg /hr}$$

$$\text{Unreacted oxygen} = 9.251 \times 0.3$$

$$= 2.7744 \text{ kmol/hr}$$

$$= 88.78 \text{ kg/hr}$$

COMPONENT	MATERIAL IN (KG)	MATERIAL OUT (KG)
HCl	1800.27	450.045
O ₂	384.704	88.78
N ₂	17.71	17.71
H ₂ O	36.74	369.709
Cl ₂	-	1313.216
TOTAL	2239.461	2239.461

BALANCE AROUND PRODUCT GAS COOLER:

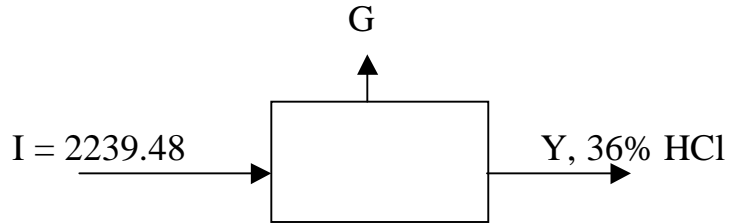
$\text{Cl}_2 = 1313.216 \text{ kg}$

$\text{HCl} = 450.045 \text{ kg}$

$\text{O}_2 = 88.78 \text{ kg}$

$\text{N}_2 = 17.71 \text{ kg}$

$\text{H}_2\text{O} = 369.709 \text{ kg}$



Overall balance

$$I = G + Y$$

HCl balance:

$$450.045 = \text{Amount of HCl in G} + 0.36 \times Y$$

Water Balance:

$$369.709 = Y \times (1 - 0.36 - 0.005)$$

$$\Rightarrow Y = 582.211 \text{ kg/hr}$$

$$\text{Amount of chlorine in Y} = 0.005 \times 582.211$$

$$= 2.911 \text{ kg/hr}$$

$$\text{Amount of HCl in G} = 450.045 - 0.36 \times 582.11$$

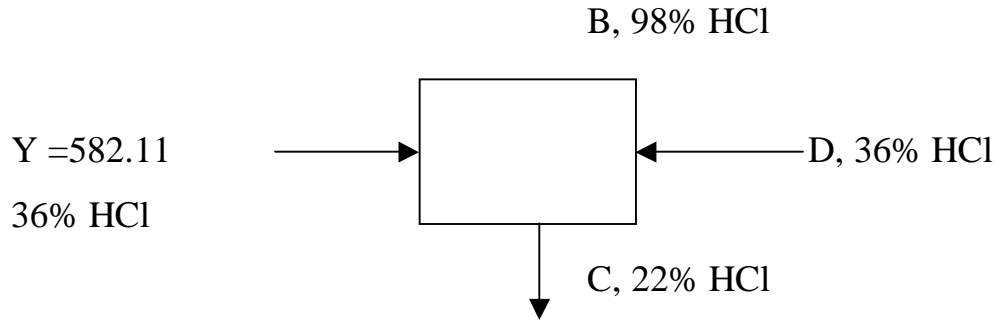
$$= 240.485 \text{ kg/hr}$$

$$\therefore G = I - Y = 2239.481 - 582.11 = 1657.281 \text{ kg/hr}$$

COMPONENT	MATERIAL IN I (kg)	MATERIAL OUT (kg)	
		G	Y
HCl	450.045	240.48	209.56
Cl_2	1313.216	1310.30	2.91
O_2	88.78	88.78	-
N_2	17.71	17.71	-
H_2O	369.709	-	369.709

BALANCE AROUND EXPELLER:





Overall balance: $Y + D = B + C$

98% of B = 1800.277 kg/hr

\Rightarrow Total amount of B = $1800.277 / 0.98$
 $= 1837.017$ kg/hr.

Now, $Y = 582.11$ kg/hr

\therefore The overall equation can be represented as

$$582.11 + D = 1837.017 + C \quad \longrightarrow (1)$$

HCl balance:

$$582.11 \times 0.36 + 0.36 D = 0.98 B + 0.22 C \quad \longrightarrow (2)$$

Solving 1 & 2 we get,

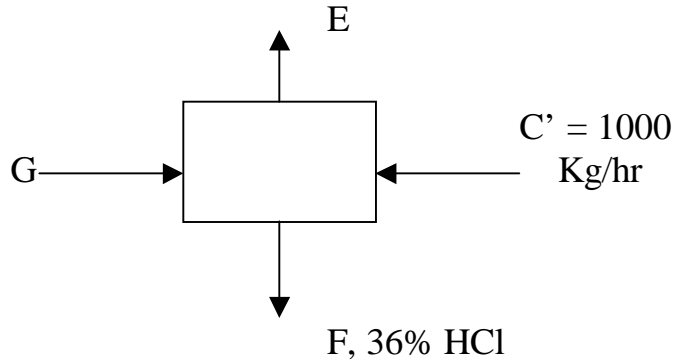
$$C = 8132.956 \text{ kg/hr}$$

$$D = 9387.8462 \text{ kg/hr}$$

COMPONENT	MATERIAL IN (kg)		MATERIAL OUT(kg)	
	Y	D	B	C
HCl	209.56	3379.62	1800	1789.25
Cl ₂	2.91	-	2.91	-
O ₂	-	-	-	-
N ₂	-	-	-	-
H ₂ O	396.64	6008.22	33.83	3643.706
TOTAL	9969.95		9969.95	

BALANCE AROUND ABSORBER:

$G = 1657.281 \text{ kg/hr}$
 $\text{HCl} = 240.4875$
 $\text{O}_2 = 88.78$
 $\text{N}_2 = 17.71$
 $\text{Cl}_2 = 1310.305$



Overall balance:

$$G + C = E + F$$

$$\Rightarrow E + F = 2657.28 \quad \longrightarrow \quad (1)$$

Assuming 0.5% HCl present in the stream E, the HCl balance is:

$$240.485 + 0.22 \times 1000 = 0.005 E + 0.36 F$$

$$\Rightarrow 0.005 E + 0.36 F = 460.485 \quad \longrightarrow \quad (2)$$

Solving equation 1 & 2 we get

$$E = 1397.56 \text{ kg/hr.}$$

$$F = 1259.71 \text{ kg/hr.}$$

COMPONENT	MATERIAL IN (kg)		MATERIAL OUT(kg)	
	G	C'	E	F
HCl	240.485	220.0	6.98	453.495
Cl ₂	1310.305	-	1284.08	26.225
O ₂	88.78	-	88.78	-
N ₂	17.71	-	17.71	-
H ₂ O	-	780.0	-	780.0
TOTAL	2657.28		2657.28	