

## MATERIAL BALANCE

The two reactions taking place in this process are given below.



### **Molecular Weights:**

<b>Component</b>	<b>Molecular weights</b>
Ethylene	28
Oxygen	32
Ethylene oxide (EO)	44
Carbon dioxide	44
Water	18
Nitrogen	28

**Total ethylene oxide to be produced = 100 TPD.**

= 100000 Kgs/ day.

= **4166.67 Kgs/ hr.**

## **Basis: 1 Hour of operation**

### **REACTOR:**

Total weight of ethylene oxide is to be produced = 4166.67 Kgs.

Assuming 2% of the EO produced is lost during the production.

Total EO to be produced = 4250 Kgs/ hr. = 96.59 Kg moles/ hr.

Assuming a conversion of 50% of ethylene fed and in that 25 % of the ethylene is converted into ethylene oxide.

Ethylene to be supplied =  $96.59 / 0.25 = 386.36$  Kg moles/ hr.

$$= 386.36 \times 28 = \mathbf{10818.1 \text{ Kgs/ hr}}$$

### **Air to Ethylene ratio is 10:1**

Air supplied (95 Mole % oxygen and rest is assumed to be nitrogen)

$$= 10818.1 \times 10 = \mathbf{108181 \text{ Kgs/ hr}}$$

Molecular weight of the air supplied =  $(0.95 \times 32 + 0.05 \times 28) = 31.8$

Air supplied =  $108181 / 31.8 = 3401.92$  Kg moles/ hr

Ethylene converted to ethylene oxide =  $386.36 \times 0.25 = 96.59$  Kg moles/ hr.

$$= \mathbf{2704.52 \text{ kgs/ hr.}}$$

EO produced = 96.59 Kg moles/ hr = 4250 kgs/ hr.

Ethylene converted into water and carbon dioxide = 96.59 Kg moles / hr

$$= \mathbf{2704.52 \text{ Kgs/ hr.}}$$

$$\begin{aligned}\text{Carbon dioxide produced} &= 96.59 \times 2 = 193.18 \text{ Kg moles/ hr} \\ &= \mathbf{8500 \text{ Kgs/ hr.}}\end{aligned}$$

$$\begin{aligned}\text{Water produced} &= 96.59 \times 2 = 193.18 \text{ Kg moles/ hr.} \\ &= \mathbf{3477.24 \text{ Kgs/ hr.}}\end{aligned}$$

$$\begin{aligned}\text{Ethylene unreacted} &= 10818.1 - (2704.52 \times 2) = \mathbf{5409.06 \text{ Kgs/hr}} \\ &= 193.18 \text{ Kg moles / hr}\end{aligned}$$

Oxygen required for both the reactions.

$$\text{Oxygen entering} = 103148.37 \text{ Kgs/ hr} = 3231.824 \text{ Kg moles/ hr.}$$

$$\text{Nitrogen entering} = 5032.63 \text{ Kgs/ hr} = 179.73 \text{ Kg moles/ hr.}$$

$$\begin{aligned}\text{Oxygen needed for the production of EO} &= 96.59 / 2 = 48.295 \text{ Kg moles/ hr.} \\ &= \mathbf{1545.44 \text{ Kgs/ hr.}}\end{aligned}$$

$$\begin{aligned}\text{Oxygen needed for water and carbon dioxide} &= 96.59 \times 3 \\ &= 289.77 \text{ Kg moles/hr} \\ &= \mathbf{9272.64 \text{ Kgs/ hr.}}\end{aligned}$$

$$\begin{aligned}\text{Oxygen unreacted} &= 103148.37 - (1545.44 + 9272.64) = 92330.29 \text{ Kgs/ hr} \\ &= \mathbf{2885.32 \text{ Kg moles/hr.}}\end{aligned}$$

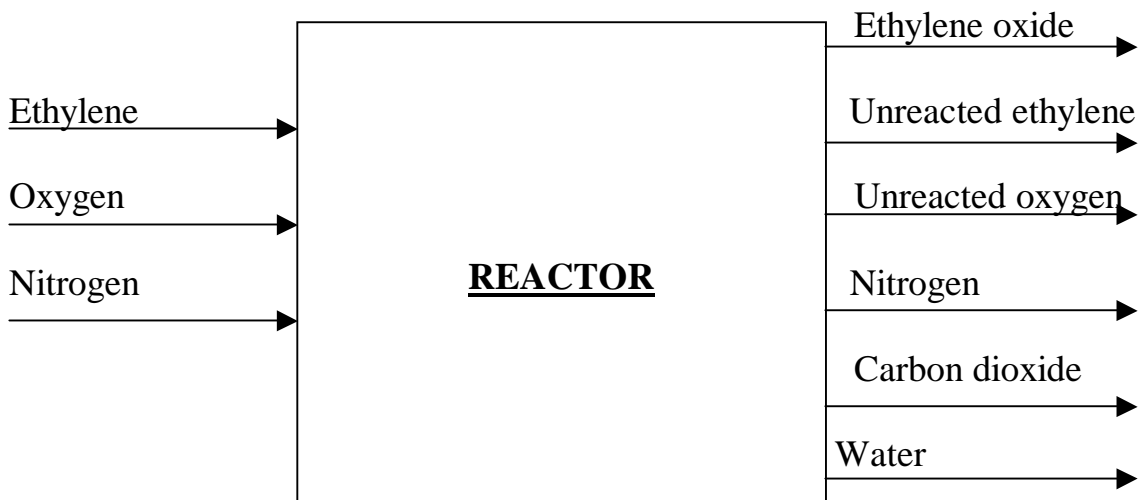
$$\text{Nitrogen leaving the reactor} = 5032.63 \text{ Kgs/ hr.}$$

**INPUT TO THE REACTOR:**

Ethylene	= 10818.1 Kgs/ hr
Oxygen	= 103148.37 Kgs/ hr
Nitrogen	= 5032.63 Kgs/ hr
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<b>Total</b>	<b>= 118999 Kgs/ hr</b>

**OUTPUT FORM THE REACTOR:**

Ethylene oxide	= 4250 Kg/ hr
Ethylene unreacted	= 5409.06 Kgs /hr
Oxygen unreacted	= 92330.29 Kgs/ hr
Nitrogen	= 5032.63 Kgs/ hr
Carbon dioxide	= 8500 Kgs/ hr
Water	= 3477.24 Kgs/ hr
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<b>Total</b>	<b>= 118999 Kgs/ hr</b>



## **WATER ABSORBER:**

The solubility of EO in water is infinity. So the amount of water required for the absorption of EO is the equal amount of water.

Water used for absorption =  $4250 \times 1.10 = 4675 \text{ Kgs/hr}$

(10 % of extra water is used to scrub all the EO produced.)

Total EO scrubbed = **4250 Kg/ hr**

### **Solubility data:**

<b>Component</b>	<b>Solubility (Kgs/ Kgs of water)</b>
Nitrogen	$1.3462 \times 10^{-5}$
Carbon dioxide	$1.379 \times 10^{-3}$
Oxygen	$2.87 \times 10^{-5}$
Ethylene	$1.482 \times 10^{-2}$

During the absorption EO in water oxygen, nitrogen, carbon dioxide and ethylene is also absorbed in smaller quantities.

Nitrogen absorbed =  $4675 \times 1.3462 \times 10^{-5} = 0.0629 \text{ Kgs/ hr}$

Carbon dioxide absorbed =  $4675 \times 1.379 \times 10^{-3} = 6.4 \text{ Kgs/ hr}$

Ethylene absorbed =  $4675 \times 1.482 \times 10^{-2} = 69.2835 \text{ Kgs/ hr}$

Oxygen absorbed =  $4675 \times 2.87 \times 10^{-5} = 0.134 \text{ Kgs/ hr}$

Recycled and Purged streams calculation

Ethylene recycled =  $5409.06 - 69.284 = 5340 \text{ Kgs/ hr}$

Oxygen recycled=  $92330.29 - 0.134 = 92330.156 \text{ Kgs/ hr}$

Carbon dioxide purged =  $8500 - 6.4 = 8493.6 \text{ Kgs/ hr}$

Nitrogen purged =  $5032.63 - 0.0629 \text{ Kgs/ hr} = 5032.56 \text{ Kgs/ hr}$

**INPUT TO THE ABSORBER:**

Ethylene oxide =  $4250 \text{ Kg/ hr}$

Ethylene unreacted =  $5409.06 \text{ Kgs /hr}$

Oxygen unreacted =  $92330.29 \text{ Kgs/ hr}$

Nitrogen =  $5032.63 \text{ Kgs/ hr}$

Carbon dioxide =  $8500 \text{ Kgs/ hr}$

Water =  $3477.24 \text{ Kgs/ hr}$

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**Total = 118999 Kgs/ hr**

Water used for absorption =  $4675 \text{ Kgs/ hr.}$

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**Total = 123674 Kgs/hr**

**RECYCLE AND PURGE STREAM FORM THE ABSORBER:**

Ethylene =  $5340 \text{ Kgs/ hr}$

Oxygen =  $92330.156 \text{ Kgs/hr}$

Carbon dioxide =  $8493.6 \text{ Kgs/ hr}$

Nitrogen =  $5032.56 \text{ Kgs/hr}$

EO =  $21.2 \text{ Kgs/ hr}$

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**Total = 111217.5 Kgs/ hr**

### OUTPUT FROM THE ABSORBER:

EO = 4228.8 Kgs/ hr

Oxygen = 0.134 Kgs/ hr

Nitrogen = 0.0629 Kgs/ hr

Carbon dioxide = 6.4 Kgs/ hr

Water = 8152.24 Kgs/ hr

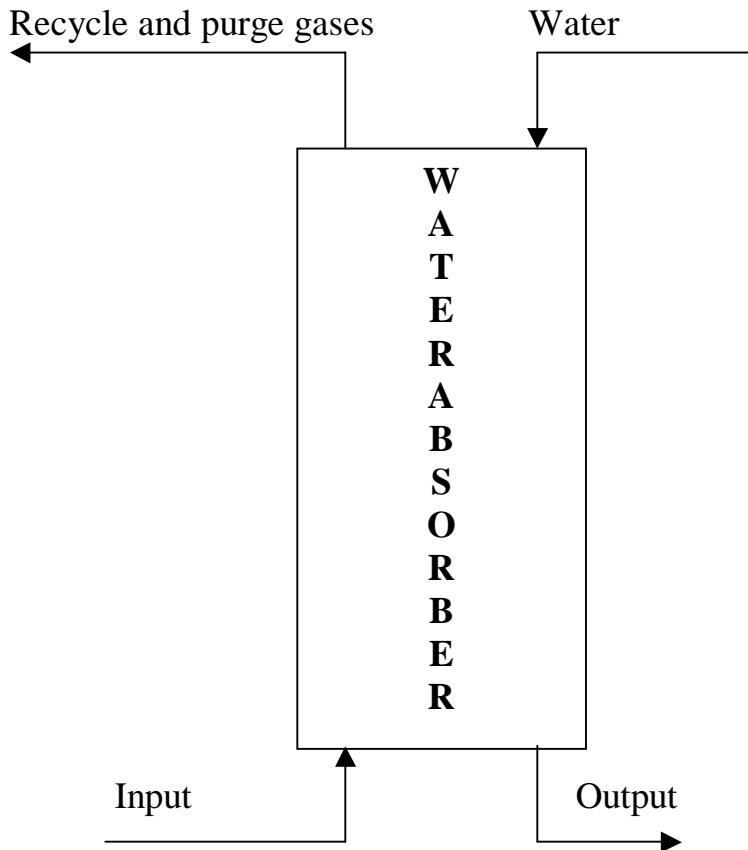
Ethylene = 69.2835 Kgs/ hr

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**Total = 12456.92 Kgs/ hr**

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**Total = 123674Kgs/ hr**



**DESORBER:** The amount of used for absorbing the ethylene oxide in the absorber is desorbed in the desorber and recycled. 0.5% of the produced ethylene oxide is also lost with the water.

**RECYCLE STRAEM FROM THE DESORBER:**

Water recycled	= 4675 Kgs/ hr
EO lost	= 21.14 Kgs/ hr
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<b>Total</b>	<b>= 4696.144 Kgs/ hr</b>

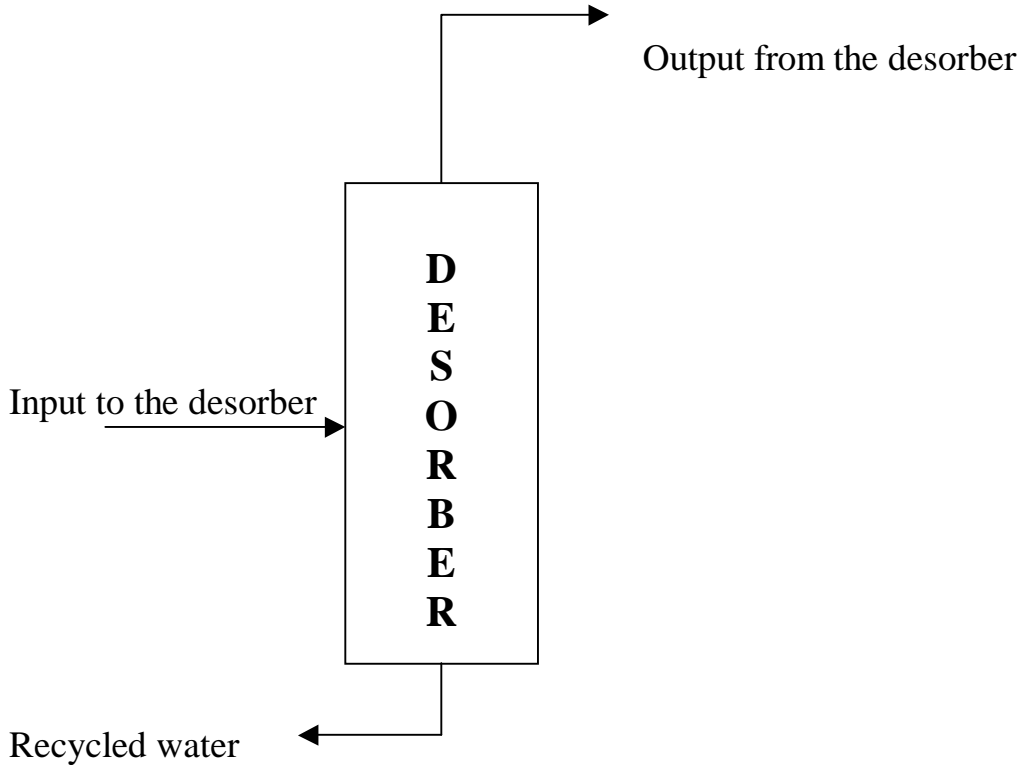
**INPUT TO THE DESORBER:**

EO	= 4228.8 Kgs/ hr
Oxygen	= 0.134 Kgs/ hr
Nitrogen	= 0.0629 Kgs/ hr
Carbon dioxide	= 6.4 Kgs/ hr
Water	= 8152.24 Kgs/ hr
Ethylene	= 69.2835 Kgs/ hr
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<b>Total</b>	<b>= 12456.92 Kgs/ hr</b>

**OUTPUT FROM THE DESORBER:**

EO	= 4206.8 Kgs/ hr
Oxygen	= 0.134 Kgs/ hr
Nitrogen	= 0.0629 Kgs/ hr

Carbon dioxide	= 6.4 Kgs/ hr
Water	= 3477.24 Kgs/ hr
Ethylene	= 69.2835 Kgs/ hr
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<b>Total</b>	<b>= 7760 Kgs/ hr</b>



**STEAM STRIPPER:**

Steam at a pressure of 1.5 bars is used for stripping the vent gases.

**INPUT TO THE STRIPPER:**

EO	= 4206.8 Kgs/ hr
Oxygen	= 0.134 Kgs/ hr
Nitrogen	= 0.0629 Kgs/ hr

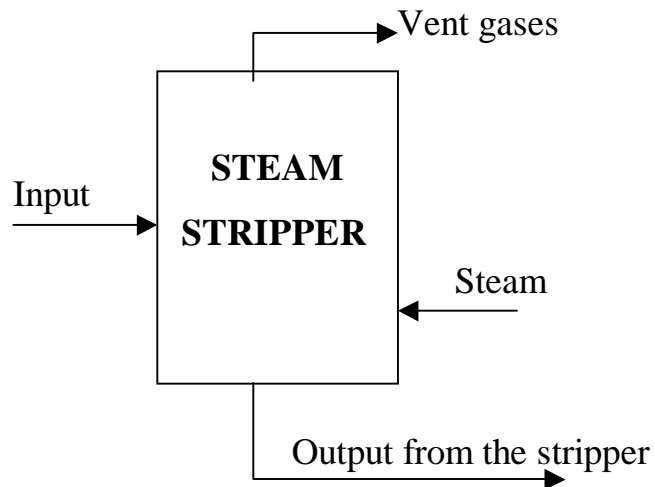
Carbon dioxide	= 6.4 Kgs/ hr
Water	= 3477.24 Kgs/ hr
Ethylene	= 69.2835 Kgs/ hr
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<b>Total</b>	<b>= 7760.776 Kgs/ hr</b>

**OUTPUT FROM THE STRIPPER:**

EO	= 4206.86 Kgs/ hr
Water	= 3477.24 Kgs/ hr
Ethylene	= 69.2835 Kgs/ hr
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<b>Total</b>	<b>= 7753.3835 Kgs/hr</b>

**VENT GASES:**

Carbon dioxide	= 6.4 Kgs/ hr
Nitrogen	= 0.0629 Kgs/ hr
Oxygen	= 0.134 Kgs/ hr
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<b>Total</b>	<b>= 6.5969 Kgs/ hr</b>



## REFINING STILL:

### INPUT TO THE REFINING STILL:

EO = 4206.86 Kgs/ hr

Water = 3477.24 Kgs/ hr

Ethylene = 69.2835 Kgs/ hr

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**Total = 7753.3835 Kgs/hr**

Input in Kg moles/ hr (F)= 290.71 Kg moles/ hr

$x_F$  = mole fraction for ethylene oxide in feed

$$= 95.133 / 290.17 = \mathbf{0.33}$$

Distillate = 4166.67 Kgs/ hr

$$= 4166.61 / (0.999 \times 44 + 0.001 \times 18)$$

$$(D) = \mathbf{94.65 \text{ Kg moles/ hr}}$$

$x_D$  = mole fraction of ethylene oxide in the distillate.(commercial grade

ethylene oxide)

$$= \mathbf{0.99}$$

$$F = D + W$$

$$290.71 = 94.65 + W$$

$$W = 196.06 \text{ Kg moles/ hr} = \mathbf{3586.77 \text{ Kgs/hr}}$$

$$F \cdot x_F = D \cdot x_D + W \cdot x_W$$

$x_w$  = mole fraction of ethylene oxide in the bottom stream

$$290.71 \times 0.33 = 94.65 \times 0.99 + 196.06 \times x_w$$

$$x_w = \mathbf{0.012}$$

Reflux ration calculation is given in the detailed design procedure of the process.

$$\text{Reflux ratio} = \mathbf{0.25}$$

$$L_0 / D = 0.25$$

$$L_0 = 0.25 \times 94.65$$

$$= 23.66 \text{ Kg moles/ hr}$$

$$= \mathbf{1040.42 \text{ Kgs/ hr}}$$

### **OUTPUT FROM THE REFINING STILL:**

$$\text{Ethylene oxide} \quad = 4166.67 \text{ Kgs/ hr}$$

$$\text{Water+ heavy ends} \quad = 3586.77 \text{ Kgs/ hr}$$

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$$\text{Total} \quad = 7753.3835 \text{ Kgs/hr}$$