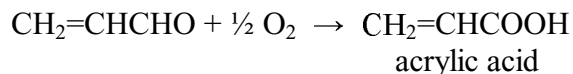
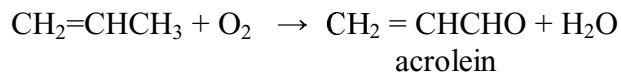


## DETAILED MATERIAL BALANCE

**Basis :** 200 TPD of Acrylic Acid .

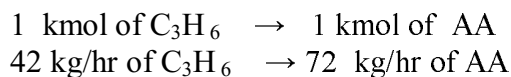
( Plant works continuously for 24 hours a day )



Compound	Molecular weight
----------	------------------

Propylene	42
Acrylic acid(AA)	72
Acetic acid	60
Acrolein	56
Oxygen	16
Carbon dioxide	44

### **Propylene required to produce 200 TPD of AA**



$$\begin{aligned} \text{C}_3\text{H}_6 \text{ required to produce 200 TPD of AA} \\ = 200 \times (42/72) = 116.67 \text{ TPD of C}_3\text{H}_6 \end{aligned}$$

$$\begin{aligned} \text{At a yield of 78\%} \\ \text{kmol of C}_3\text{H}_6 \text{ required} &= 116.67 / 0.78 = 149.57 \text{ TPD} \\ &= 148.38 \text{ kmol/hr} \end{aligned}$$

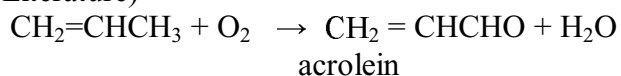
### **Oxygen required :**

$$\begin{aligned} 1 \text{ kmol of C}_3\text{H}_6 \text{ requires } &\rightarrow 3/2 \text{ kmol of O}_2 \\ \text{Hence O}_2 \text{ required} &= 3/2 \times 148.38 \text{ kmol/hr} \\ &= 222.57 \text{ kmol/hr} \end{aligned}$$

## **REACTOR I**

### **Oxidation of Propylene to Acrolein .**

(From Literature)



Catalyst composition : Ni. Fe. Zn. Bi. or Zn + Co (Fe promotion )

Contact time = 3.6 sec

Average temperature = 355° C

Feed Composition : C<sub>3</sub>H<sub>6</sub> : Air : Steam :: 1 : 7.75 : 3.75

Overall conversion of C<sub>3</sub>H<sub>6</sub> = 100%

Conversion to acrolein = 70%

Conversion to AA = 11%

C<sub>3</sub>H<sub>6</sub> fed = 148.38 kmol/hr

Steam fed = 556.42 kmol/hr

Air fed = 148.38 x 7.75 = 1149.94 kmol/hr

O<sub>2</sub> entering = 241.48 kmol/hr

N<sub>2</sub> in = N<sub>2</sub> out = 908.45 kmol/hr

O<sub>2</sub> used in the reactor = 148.38 kmol/hr

O<sub>2</sub> left unreacted = 93.1 kmol/hr

Acrolein produced = 148.38 x 0.7 = 103.866 kmol/hr

AA produced = 148.38 x 0.11 = 16.32 kmol/hr

Steam produced = 103.866 kmol/hr

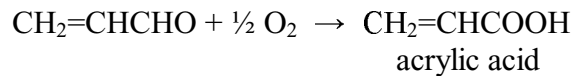
Side products produced (CO<sub>2</sub> + Acetic acid) = 148.38 x 0.19 = 28.192 kmol/hr  
( in equal quantities )

Total steam leaving the reactor = 660.286 kmol/hr

## REACTOR II

### Oxidation of Acrolein to Acrylic acid

(From literature)



Catalyst composition : Mo<sub>12</sub> V<sub>1.9</sub> Al<sub>1.0</sub> Cu<sub>2.2</sub> ( support - Al sponge)

Contact time : 1 - 3 sec

Average temperature - 300°C

Acrolein conversion - 100%

Yield of AA - 97.5%

Feed:

O<sub>2</sub> = 93.1 kmol/hr

N<sub>2</sub> = 908.45 kmol/hr

Steam = 660.286 kmol/hr

Acrolein = 103.866 kmol/hr

Acrylic acid = 16.32 kmol/hr

Acetic acid = 14.096 kmol/hr

CO<sub>2</sub> = 14.096 kmol/hr

AA formed in reactor II = 101.26 kmol/hr

By products formed = 2.5966 kmol/hr

O<sub>2</sub> reacted = 51.352 kmol/hr

O<sub>2</sub> unreacted = 41.167 kmol/hr

N<sub>2</sub> in = N<sub>2</sub> out = 908.45 kmol/hr

Total AA formed in 2 reactors =  $101.26 + 16.32 = 117.58$  kmol/hr

Total Acetic acid produced = 15.3942 kmol/hr

Total CO<sub>2</sub> produced = 15.3942 kmol/hr

**ABSORBER:**

Feed entering at the bottom of the absorber.

Acrylic acid = 117.58 kmol/hr

Acetic acid = 15.38 kmol/hr

CO<sub>2</sub> = 15.38 kmol/hr

O<sub>2</sub> = 41.167 kmol/hr

N<sub>2</sub> = 908.47 kmol/hr

Steam = 660.286 kmol/hr

From literature:

Acrylic acid and acetic acid is absorbed using water as solvent.

Gases CO<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub> and small amount of steam leave the absorber at the top.

Assumptions :

90% of the steam entering gets condensed.

Solvent:

Water entering at the top = 488.6 kmol/hr

Off gases leaving at the top :

CO<sub>2</sub> = 15.38 kmol/hr

N<sub>2</sub> = 908.4 kmol/hr

O<sub>2</sub> = 41.167 kmol/hr

AA = 1.1758 kmol/hr

Acetic acid = 0.1539 kmol/hr

Product liquid leaving at the bottom of the absorber to recovery section:

Acrylic acid = 116.404 kmol/hr

Acetic acid = 15.236 kmol/hr

water = 1082.85 kmol/hr

Mol fraction of AA in the product stream =  $0.0958 = 9.58\%$

Weight fraction of AA in the product stream =  $0.2911 = 29.11\%$

**SOLVENT EXTRACTION COLUMN :**

Feed from the bottom of the absorber:

Acrylic acid = 116.404 kmol/hr  
Acetic acid = 15.236 kmol/hr  
water = 1082.85 kmol/hr

Solvent with high solubility for acrylic acid and acetic acid, and low solubility with water is used to extract AA acid from absorber stream.

Assumption: Solvent required for 99.5% extraction of AA is 500 kmol/hr.

Recycled stream from solvent recovery column and waste tower.

Acrylic acid = 0.53 kmol/hr  
Acetic acid = 0.08 kmol/hr  
Water = 129.94 kmol/hr

Total Acrylic acid in = 116.934 kmol/hr  
Total Acetic acid in = 15.316 kmol/hr  
Total water in = 1212.79 kmol/hr

Extract phase contains (to solvent recovery plant):

Acrylic acid =  $0.995 \times 116.404 = 115.83$  kmol/hr.  
Acetic acid = 15.16 kmol/hr  
Water = 21.657 kmol/hr  
Solvent = 488.5 kmol/hr

Raffinate phase contains (to waste tower):

Acrylic acid = 1.104 kmol/hr  
Acetic acid = 0.156 kmol/hr  
Water = 1191.13 kmol/hr  
Solvent = 11.5 kmol/hr

#### **SOLVENT RECOVERY COLUMN :**

Assumption: Complete recovery of solvent occurs.

Bottom product contains only acetic acid and acrylic acid.

Feed : Extract phase from the liquid-liquid extractor:

Acrylic acid = 115.83 kmol/hr.  
Acetic acid = 15.16 kmol/hr  
Water = 21.657 kmol/hr

Solvent = 488.5 kmol/hr

Upstream contains (recycled to extraction column) :

Solvent = 488.5 kmol/hr

Acrylic acid = 0.53 kmol/hr

Acetic acid = 0.08 kmol/hr

Water = 21.657 kmol/hr

Column bottoms contain ( to acid tower ) :

Acrylic acid = 115.3 kmol/hr

Acetic acid = 15.08 kmol/hr

#### **WASTE TOWER**

Assumption : Bottom product contains water and all acrylic acid , acetic acid entering the column.

Feed : Raffinate phase from the liquid-liquid extractor.

Acrylic acid = 1.104 kmol/hr

Acetic acid = 0.156 kmol/hr

Water = 1191.13 kmol/hr

Solvent = 11.5 kmol/ hr

Column bottom stream ( to waste water treatment plant)

Water = 1082.845 kmol/hr

Acetic acid = 0.156 kmol/hr

Acrylic acid = 1.104 kmol/hr

Column overhead stream ( recycled to extraction column)

Solvent = 11.5 kmol/hr

Water = 108.2 kmol/hr

#### **ACID TOWER ( Designed as a major equipment )**

Assumption : Top product is 95 wt. % acetic acid  
Bottom product is 99.5 wt.% acrylic acid.

Feed :

Acrylic acid = 115.3 kmol/hr

Acetic acid = 15.08 kmol/hr

Top product

Acetic acid = 14.883 kmol/hr

Acrylic acid = 0.14 kmol/hr

**Acetic acid produced = 21.67 TPD at 95 % purity**

Bottom product

Acrylic acid = 115.16 kmol/hr

Acetic acid = 0.197 kmol/hr

**Acrylic acid produced = 200 TPD at 99.5% purity**