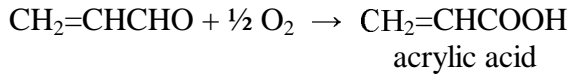
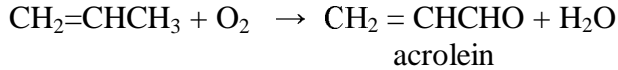


DETAILED MATERIAL BALANCE

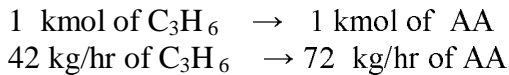
Basis : 200 TPD of Acrylic Acid .

(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



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

At a yield of 78%

$$\text{kmol of C}_3\text{H}_6 \text{ required} = 116.67 / 0.78 = 149.57 \text{ TPD}$$
$$= 148.38 \text{ kmol/hr}$$

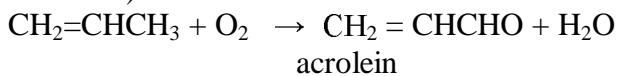
Oxygen required :

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

REACTOR I

Oxidation of Propylene to Acrolein .

(From Literature)



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

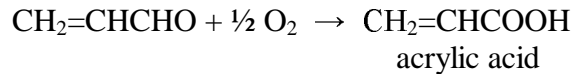
Contact time = 3.6 sec

Average temperature = 355° C
 Feed Composition : C₃H₆ : Air : Steam :: 1 : 7.75 : 3.75
 Overall conversion of C₃H₆ = 100%
 Conversion to acrolein = 70%
 Conversion to AA = 11%

C₃H₆ fed = 148.38 kmol/hr
 Steam fed = 556.42 kmol/hr
 Air fed = 148.38 x 7.75 = 1149.94 kmol/hr
 O₂ entering = 241.48 kmol/hr
 N₂ in = N₂ out = 908.45 kmol/hr
 O₂ used in the reactor = 148.38 kmol/hr
 O₂ left unreacted = 93.1 kmol/hr
 Acrolein produced = 148.38 x 0.7 = 103.866 kmol/hr
 AA produced = 148.011 = 16.32 kmol/hr
 Steam produced = 103.866 kmol/hr
 Side products produced (CO₂ + Acetic acid) = 48.38 x 0.19 = 28.192
 (in equal quantities) kmol/hr
 Total steam leaving the reactor = 660.286 kmol/hr

REACTOR II

Oxidation of Acrolein to Acrylic acid (From literature)



Catalyst composition : Mo₁₂ V_{1.9} Al_{1.0} Cu_{2.2} (support - Al sponge)
 Contact time : 1 - 3 sec
 Average temperature - 300°C
 Acrolein conversion - 100%
 Yield of AA - 97.5%

Feed:

O₂ = 93.1 kmol/hr
 N₂ = 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
 CO₂ = 14.096 kmol/hr

AA formed in reactor II = 101.26 kmol/hr
 By products formed = 2.5966 kmol/hr
 O₂ reacted = 51.352 kmol/hr
 O₂ unreacted = 41.167 kmol/hr
 N₂ in = N₂ 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 CO₂ 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
CO₂ = 15.38 kmol/hr
O₂ = 41.167 kmol/hr
N₂ = 908.47 kmol/hr
Steam = 660.286 kmol/hr

From literature:

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

Gases CO₂, O₂, N₂ 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 :

CO₂ = 15.38 kmol/hr
N₂ = 908.4 kmol/hr
O₂ = 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

with Solvent with high solubility for acrylic acid and acetic acid , and low solubility 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