DETAILED MATERIAL BALANCE

Basis : 200 TPD of Acrylic Acid .
(Plant works continuously for 24 hours a day)

$CH_2{=}CHCH_3 + O_2 \rightarrow CH_2 = CHCHO + H_2O$
acrolein

$CH_2{=}CHCHO + ½\ O_2 \rightarrow CH_2{=}CHCOOH$
acrylic acid

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

1 kmol of C_3H_6 → 1 kmol of AA
42 kg/hr of C_3H_6 → 72 kg/hr of AA

C_3H_6 required to produce 200 TPD of AA
= 200 x (42/72) = 116.67 TPD of C_3H_6

At a yield of 78%
kmol of C_3H_6 required = 116.67 / 0.78 = 149.57 TPD
= 148.38 kmol/hr

Oxygen required :
1 kmol of C_3H_6 requires → 3/2 kmol of O_2
Hence O_2 required = 3/2 x 148.38 kmol/ hr
= 222.57 kmol/ hr

REACTOR I

Oxidation of Propylene to Acrolein .
(From Literature)
$CH_2{=}CHCH_3 + O_2 \rightarrow CH_2 = CHCHO + H_2O$
acrolein

Catalyst composition : Ni. Fe. Zn. Bi. or Zn + Co (Fe promotion)
Contact time = 3.6 sec

Average temperature = 355˚ C
Feed Composition : C_3H_6 : Air : Steam :: 1 : 7.75 : 3.75
Overall conversion of C_3H_6 = 100%
Conversion to acrolein = 70%
Conversion to AA = 11%

C_3H_6 fed = 148.38 kmol/hr
Steam fed = 556.42 kmol/hr
Air fed = 148.38 x 7.75 = 1149.94 kmol/hr
O_2 entering = 241.48 kmol/hr
N_2 in = N_2 out = 908.45 kmol/ hr
O_2 used in the reactor = 148.38 kmol/hr
O_2 left unreacted = 93.1 kmol/hr
Acrolein produced = 148.38 x 0.7 = 103.866 kmol/hr
AA produced = 148.0.11 = 16.32 kmol/hr
Steam produced = 103.866 kmol/hr
Side products produced (CO_2 + Acetic acid)=48.38 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)

CH_2=CHCHO + ½ O_2 → CH_2=CHCOOH
acrylic acid

Catalyst composition : Mo_{12} $V_{1.9}$ $Al_{1.0}$ $Cu_{2.2}$ (support - Al sponge)
Contact time : 1 - 3 sec
Average temperature - 300˚C
Acrolein conversion - 100%
Yield of AA - 97.5%

Feed:
O_2 = 93.1 kmol/hr
N_2 = 908.45 kmol/hr
Steam = 660.286 kmol/hr
Acrolein = 103.866 kmol/hr
Acylic acid = 16.32 kmol/hr
Acetic acid = 14.096 kmol/hr
CO_2 = 14.096 kmol/hr

AA formed in reactor II = 101.26 kmol/hr
By products formed = 2.5966 kmol/hr
O_2 reacted = 51.352 kmol/hr
O_2 unreacted = 41.167 kmol/hr
N_2 in = N_2 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_2 produced = 15.3942kmol/hr

ABSORBER:

Feed entering at the bottom of the absorber.

Acrylic acid = 117.58 kmol/hr
Acetic acid = 15.38 kmol/hr
CO_2 = 15.38 kmol/hr
O_2 = 41.167kmol/hr
N_2 = 908.47 kmol/hr
Steam = 660.286 kmol/hr

From literature:
Acrylic acid and acetic acid is absorbed using water as solvent.
Gases CO_2 , O_2 , N_2 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_2 = 15.38 kmol/hr
N_2 = 908.4 kmol/hr
O_2 = 41.167 kmol/hr
AA = 1.1758 kmol/hr
Acetic acid = 0.1539kmol/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 x 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