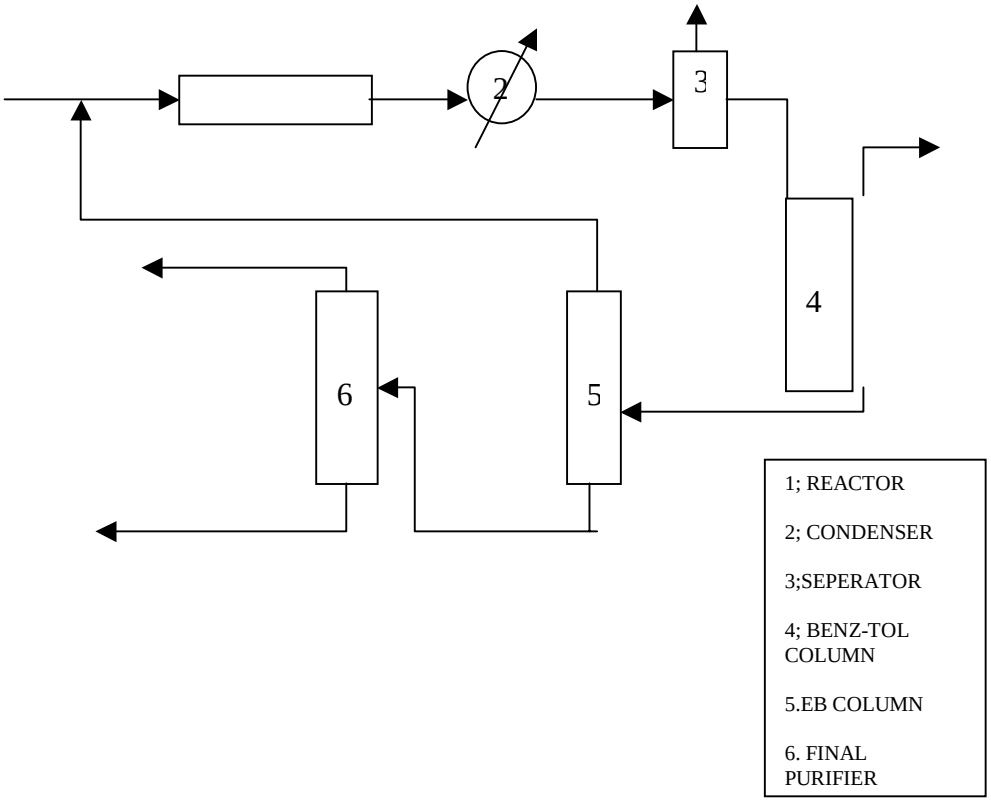
MATERIAL BALANCE

ASSUMPTION

- The solubility of the organic phase in water is negligible.
- Other than benzene and toluene the generation of any other impurities during reaction can be neglected.
- The selectivity of EB to styrene is 95%.[1]
- Conversion in the adiabatic reactor per pass is 65%.[1]
- Purity of styrene from the final distillation column is 99%.
- Separation of water from the system been done with 100% efficiency.
- Feed of EB given to the system is of 100% purity.



The above figure shows the simplified model of actual flow diagram. Since steam is added to the reaction system in order to supply the heat of reaction to the endothermic dehydrogenation and the assumption we made that, there the solubility of the organic phase in the aqueous phase is negligible and water been separated completely in the decanter so water will act as a inert in the material balance and can be neglected.

SPECIFICATIONS:

Selectivity to styrene conversion= 95%

Selectivity to toluene conversion=3%

Selectivity to benzene conversion=2%

Let us assume the wt fraction of ethyl benzene in the recycle stream= 50%

For the benzene-toluene column:

Distillate composition= 90% (benzene+toluene)

Residue composition=1% (benzene+toluene)

For the EB recycle column:

Distillate composition= 50% of EB

Residue composition= 5% of EB

For the final styrene purification column:

Distillate composition= 99% of styrene

Residue composition = 2.3% of styrene

BASIS: 100 kg of pure EB feed per hour.

Let, "R" is the recycle stream ratio to that of the pure feed. i.e. For 100 kg of pure EB feed recycle stream is 100*R kg.

Therefore, total ethyl benzene feed to the reactor = **(100 +100*R*0.5)** kg

Wt composition in the stream leaving the reactor;

Unreacted EB (W_0) = **0.35*(100 +100*R*0.5) kg**

Styrene (W_1) = **[100*R*0.5 + 0.65*(100 +100*R*0.5)*0.95*104/106] kg**

Benzene (W_2) = **0.65*(100 +100*R*0.5)*0.02*78/106 kg**

Toluene (W_3) = **0.65*(100 +100*R*0.5)*0.03*92/106 kg**

Therefore, the total feed (W)= [50*R + (1+ 0.5*R)* (98.23)] kg

Balance about the toluene-benzene column ;

X_D =0.9

X_W =0.01

X_F = (W_2 + W_3)/ W

Therefore the residue from the 1st column = **F(X_F-X_W)/(X_D – X_W)**

= (94.48+ 97.79*R) kg (= F^1)

and the distillate = **F(X_F-X_D)/(X_W – X_D)**

= **(5.95 + 1.314*R) kg**

assuming the rest 10% loss with the distillate from the 1st column contains only EB, the EB loss in the 1st column (**wl**)= **0.1*(5.95 + 1.314*R) kg**

=(0.6+ 0.13*R) kg

Similarly ,for the EB recycle column:

X_D =0.5

X_W =0.05

X_F = (W_0- wl)/ F^1

Hence the distillate calculated= (65.59+27.71*R) kg

Again, this stream is been recycle back to the reactor, so:

(65.59+27.71*R)= R

i.e., R= 0.91

Therefore, with the known recycle ratio all the stream can be recalculated

i.e., all the calculated values are given as below:

Pure styrene feed= 100 kg

Recycle stream = 91 kg

Residue from the benzene toluene column= 183.69 kg

Distillate from the benzene toluene column= 7.14 kg

Residue from the ethyl benzene recycle column= 91.83 kg

Distillate from the ethyl benzene recycle column = 91 kg

And, Distillate from the final purification column= 89 kg (since yield is 91%[1])

Residue from the final purification column = 2 kg

For a production of 300 TPD, assuming 24 working hr a day:

Hourly production rate = $(300 * 10^3)/24$ kg

= 12500 kg

From previous calculation,

For a yield of 89 kg styrene production per hour a feed of 100 kg of pure EB is required

Hence for a production of 12500 kg styrene per hr a feed of 14045 kg of pure EB is required.

BASIS: 1 hour operation

Balance around the reactor;

Feed = 14045 kg fresh EB feed

Recycle steam= 12781 kg

- EB in the recycle stream = 6390.5 kg
- Styrene in the recycle stream =6390.5

After conversion;

EB= 7152.42 kg

Styrene= 18771.33 kg

Toluene =345 .86 kg

Benzene= 195.49 kg

Since the from the reactor also contain about 0.3% of heavy end as impurity

The amount of heavy end product = 79.634 kg

Therefore the composition of the stream leaving the reactor :

Styrene= 70.71%

EB = 26.94%

Benzene= 0.75%

Toluene = 1.3%

Heavy ends = 0.3%

Benzene-toluene tower:

Distillate=313.17%

Residue =26231.53%

EB recycle tower:

Distillate=12882.6 kg (N.B. this value come more than that of the recycle stream because here include the heavy end impurities into consideration)

Residue= 13348.93 kg

Final purifier:

Distillate (product) = 12500 kg

Residue (heavy ends) =848.93 kg