4.3 PFD Part 1

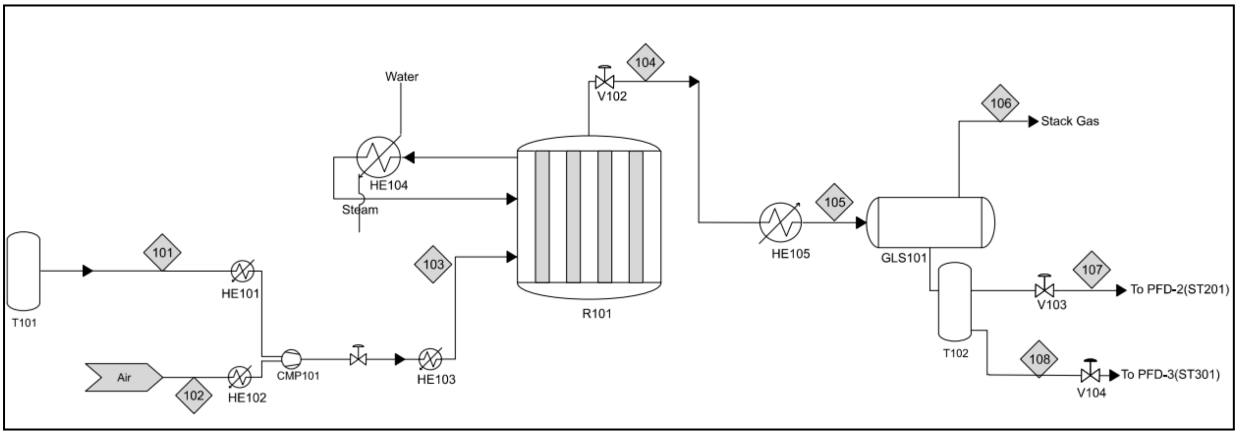

Fig 4.3.1: PFD Part 1

Stream Number	**101**	**102**	**103**	**104**	**106**	**107**	**108**
Phase	Vapour	Vapour	Vapour	Vapour	Vapour	Liquid	Liquid
Pressure(bar)	1	1	20	20	35	35	35
Temperature(°C)	30	30	180	200	0	0	0
Mass Flow: Ethylene (tonnes per hour)	18.44	0.00	18.44	0.00	0.00	0.00	0.00
Mass Flow: EO (tonnes per hour)	0.00	0.00	0.00	25.76	0.00	14.16	11.60
Mass Flow: Water (tonnes per hour)	0.00	0.00	0.00	2.63	0.00	0.00	2.63
Mass Flow: O2 (tonnes per hour)	0.00	18.03	18.03	1.64	1.64	0.00	0.00
Mass Flow N2: (tonnes per hour)	0.00	63.10	63.10	63.10	63.10	0.00	0.00
Mass Flow: CO2 (tonnes per hour)	0.00	0.00	0.00	6.44	6.44	0.00	0.00
Total Mass Flow Rate (tonnes per hour)	18.44	81.13	99.57	99.57	71.18	14.16	14.23
Total Molar Flow Rate(kmoles/hr)	658.51	2816.98	3475.50	3182.82	2451.14	321.77	409.91

Table 4.3.1: Stream Table of PFD Part 1

4.4 PFD Part 2

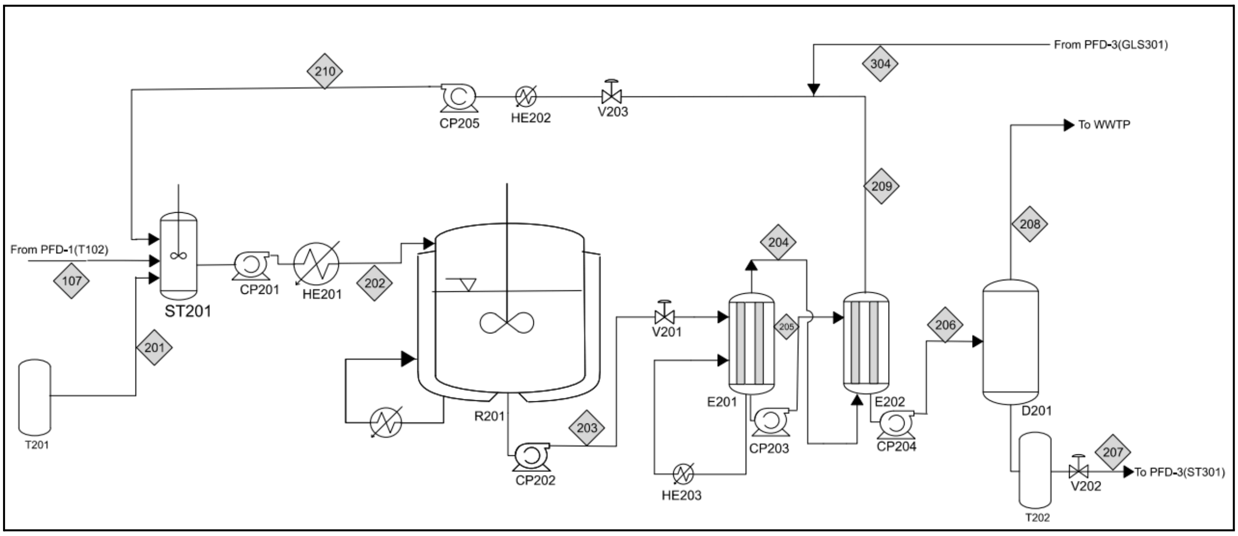

Fig 4.4.1: PFD Part 2

Stream Number	**107**	**201**	**202**	**203**	**206**	**207**	**208**	**209**	**210**
Phase	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Vapour	Vapour	Liquid
Pressure(bar)	35	35	35	35	20	20	20	20	35
Temperature(°C)	0	140	140	190	200	220	220	200	140
Mass Flow: MEG (tonnes per hour)	0.00	0.00	0.00	15.71	15.71	15.71	0.00	0.00	0.00
Mass Flow: DEG (tonnes per hour)	0.00	0.00	0.00	2.72	2.72	2.72	0.00	0.00	0.00
Mass Flow: TEG (tonnes per hour)	0.00	0.00	0.00	0.85	0.85	0.85	0.00	0.00	0.00
Mass Flow: EO (tonnes per hour)	14.16	0.00	15.06	0.90	0.00	0.00	0.00	0.90	0.90
Mass Flow: Water (tonnes per hour)	0.00	39.02	61.62	56.49	33.89	0.00	33.89	22.60	22.60
Total Mass Flow Rate (tonnes per hour)	14.16	39.02	76.68	76.68	53.18	19.28	33.89	23.50	23.50
Total Molar Flow Rate(kmoles/hr)	322	2168	3765	3444	2168	285	1883	1276	1276

Table 4.4.1: Stream Table of PFD Part 2

4.5 PFD Part 3

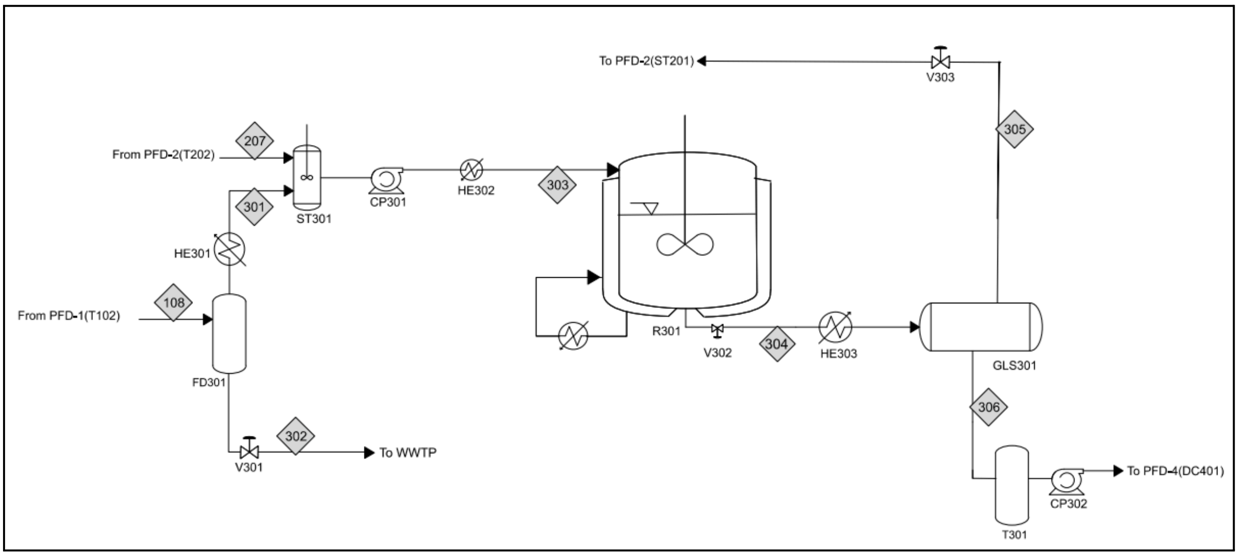

Fig 4.5.1: PFD Part 3

Stream Number	**108**	**207**	**301**	**302**	**303**	**304**	**305**	**306**
Phase	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Vapour	Liquid
Pressure(bar)	35	20	1	1	36	36	1	36
Temperature(°C)	0	220	0	25	198	200	25	197
Mass Flow: MEG (tonnes per hour)	0.00	15.71	0.00	0.00	15.71	3.14	0.00	3.14
Mass Flow: DEG (tonnes per hour)	0.00	2.72	0.00	0.00	2.72	18.84	0.00	18.84
Mass Flow: TEG (tonnes per hour)	0.00	0.85	0.00	0.00	0.85	6.94	0.00	6.94
Mass Flow: PEG (tonnes per hour)	0.00	0.00	0.00	0.00	0.00	1.97	0.00	1.97
Mass Flow: EO (tonnes per hour)	11.60	0.00	11.60	0.00	11.60	0.00	0.00	0.00
Mass Flow: Water (tonnes per hour)	2.63	0.00	0.00	2.63	0.00	0.00	0.00	0.00
Total Mass Flow Rate (tonnes per hour)	14.23	19.28	11.60	2.63	30.88	30.88	0.00	30.88
Total Molar Flow Rate(kmoles/hr)	410	285	264	146	548	285	0.00	285

Table 4.5.1: Stream Table of PFD Part 3

4.6 PFD Part 4

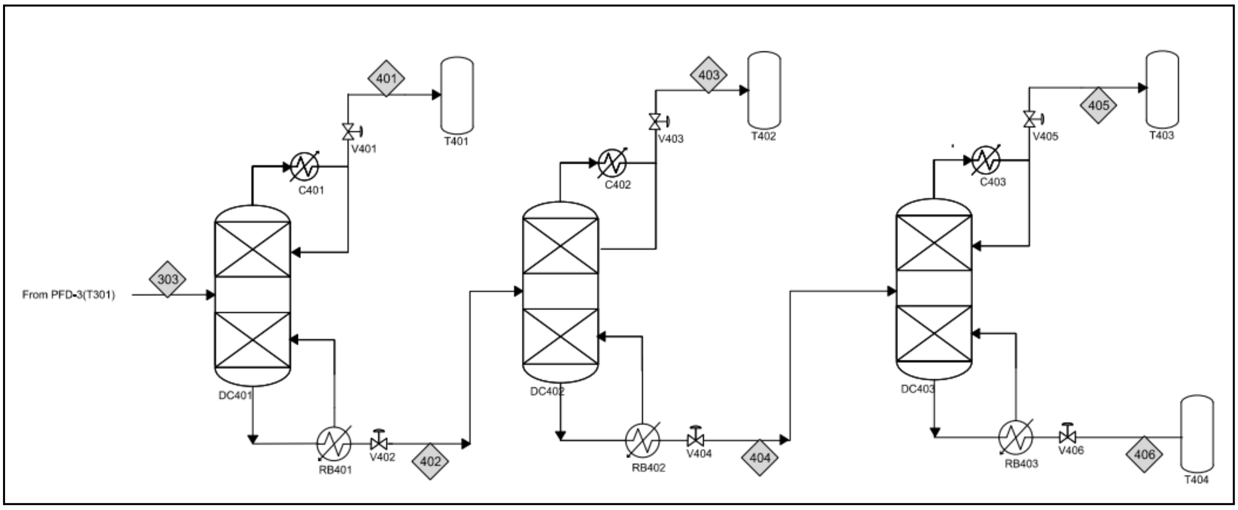

Fig 4.6.1: PFD Part 4

Stream Number	**306**	**401**	**402**	**403**	**404**	**405**	**406**
Phase	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Pressure(bar)	36	1	1	1	1	1	1
Temperature(°C)	197	195	258	245	296	286	327
Mass Flow: MEG (tonnes per hour)	3.14	3.14	0.00	0.00	0.00	0.00	0.00
Mass Flow: DEG (tonnes per hour)	18.84	0.09	18.75	18.75	0.00	0.00	0.00
Mass Flow: TEG (tonnes per hour)	6.94	0.00	6.94	0.01	6.93	6.93	0.00
Mass Flow: PEG (tonnes per hour)	1.97	0.00	1.97	0.00	1.97	0.00	1.97
Total Mass Flow Rate (tonnes per hour)	30.88	3.23	27.65	18.76	8.90	6.93	1.97
Total Molar Flow Rate(kmoles/hr)	285	51	234	177	56	46	10

Table 4.6.1: Stream Table of PFD Part 4

4.7 Stream Descriptions

4.7.1 PFD Part 1

The total amount of ethylene oxide in stream 107 and 108 is 25.76 tonnes/hr. As we assume 100% conversion of ethylene, stack gas contains only nitrogen, carbon dioxide and unreacted oxygen. We have defined selectivity here as the amount of ethylene oxide formed to the amount of ethylene oxide + carbon dioxide. 80% selectivity means for every 10 moles of product formed, 8 moles will be ethylene oxide and 2 moles will be CO_2. We see that 1 mole of ethylene is required for formation of 1 mole of ethylene oxide and 0.5 moles of oxygen is consumed in this process, and 1 mole of ethylene is required for the formation of 2 moles of CO_2, consuming 3 moles of oxygen and producing 2 moles of water. For every 10 moles of ethylene oxide+carbon dioxide formed, 9 moles of ethylene is used, i.e for every 8 moles of ethylene oxide used, 9 moles of ethylene,and 8 moles of oxygen is required. Performing the back calculations for 25.76 tonnes/hr(585.45 moles/hr) of ethylene oxide, we require 658.51 moles/hr(18.44 tonnes/hr) of ethylene, and 585.45 moles/hr(18.73 tonnes/hr) oxygen is required. We take 10% excess air for complete conversion, hence performing all the balances, we conclude that: Carbon dioxide and water produced will be 146.34 moles/hr each, i.e 6.43 tonnes/hr and 2.63 tonnes/hr respectively. The unreacted oxygen will be 1.64 tonnes/hr.

4.7.2 PFD Part 2

The stream 203 contains the 19.28 tonnes/hr mixture of the glycols. The stream 209 contains unreacted ethylene oxide along with water. We have assumed that 40% of the excess water is evaporated in the multi effect evaporator, the rest 60% is evaporated in the dehydrator. We know that the conversion in the reactor R201 is 94%, with the selectivity of glycols as 89% MEG, 9% DEG, and 2% TEG.The ethylene oxide to water taken in the stream 202 is 1:10, as per the patents[1] available. Performing back calculations based on this data We obtain the flow rates of ethylene oxide as 15.06 tonnes/hr, and water as 61.62 tonnes/hr in the stream 202. The unreacted ethylene oxide which is about 6%(i.e 0.9 tonnes/hr approximately) of the input, and the water evaporated in the multi effect evaporator(22.6 tonnes/hr approximately) is recycled back in the tank ST201. As we assumed that no ethylene oxide is left in reactor R301, the stream 304 does not contain any ethylene oxide. The water evaporated in the streams 209 and 208 are 22.6 and 33.89 tonnes/hr respectively. The total mass of components in stream 202 is 76.68 tonnes/hr which matches with the mass flow rate of stream 203. Water consumed in the reactor is 5.13 tonnes/hr, and 33.89 tonnes/hr water is removed from the dehydrator, hence 39.02 tonnes/hr is the mass flow rate of water in stream 201. 0.9 tonnes/hr of ethylene oxide is recycled from stream 210, hence additional 14.16 tonnes/hr of ethylene oxide is required from T102 in stream 107.

4.7.3 PFD Part 3

As we have no specific data for the reaction in R303 we are assuming all the ethylene oxide is consumed, so that we can create a model for our mass balance. So the composition of stream 304 is the same as stream 306. As discussed earlier the conversion of MEG in R303 is 80% so, stream 303 contains 15.71 tonnes/hr MEG, 2.72 tonnes/hr of DEG, and 0.85 tonnes/hr of TEG, i.e a total of 19.28 tonnes/hr of glycol mixture. The amount of Ethylene oxide required in stream 301 and 303, supplied from FD101 can be calculated using the selectivity of the reaction. For each mole of DEG formed 1 mole of ethylene oxide is consumed, for each mole of TEG formed 2 mole of ethylene oxide is consumed, and consecutively 3 moles for PEG. Thus the molar flow rate of ethylene oxide required is 263.57 moles/hr, i.e. 11.6 tonnes/hr. The total sum of glycols and ethylene oxide is 30.88 tonnes/hr, which matches with the total mass flow rate of PFD-4

4.7.4 PFD Part 4

As mentioned earlier, we will be using the back calculation method for performing mass balance. The DEG production required is 18.76 tonnes/hr.According to the patent[12], the purity of MEG obtained from column 1 is 97.36%, DEG is 99.96% in column 2, and 99.99% TEG in column 3. The total amount of DEG present will be the sum of DEG obtained from column 2 and the DEG present as impurity with MEG obtained in column 1. By using 80% conversion of MEG in reactor R301, having selectivity 0.75, 0.2, and 0.05 for DEG, TEG, and PEG respectively, we obtain the amount of other glycols as 3.14 tonnes/hr of MEG, 6.94 tonnes/hr of TEG, and 1.97 tonnes/hr of PEG. The total amount of glycols entering the distillation column is 30.88 tonnes/hr.