Nomenclature

AR: Annual revenue
B_1, B_2: Constants
C_1, C_2, C_3: Constants
C_{BM}: Bare module equipment cost
cw: Cooling water
CEPCI: Chemical Engineering Plant Cost Index
C_{GE}: Cost of general expense
C_{GR}: Grassroots cost
C_{OL}: Cost of operating labor
C_p^o: Purchase cost for base condition
COM: Cost of manufacturing (without depreciation)
COM_d: Cost of manufacturing (with depreciation)
C_{RM}: Cost of raw materials
CS: Carbon steel
C_{TM}: Total module cost
C_{UT}: Cost of utilities
C_{WT}: Cost of waste treatment
D: Diameter
DEG: Di-ethylene glycol
EO: Ethylene oxide
F_{BM}: Bare module cost factor
FCI: Fixed capital investment
F_M: Material of construction factor
F_p: Pressure factor
F_q: Tower factor
hps: High pressure steam
K_1, K_2, K_3: Constants
L: Length
MEG: Mono-ethylene glycol
N: Numbers of tray
N_{OL}: number of operators per shift
N_{NP}: number of processing operations
P: Pressure
SS: Stainless steel
SF: stream factor
ROI: Return on investment
V: volume

Executive Summary

The production of mono-ethylene glycol (MEG) is extensively studied in chemical industry as it lends itself to a wide array of applications. For this reason, it is necessary to optimize the design of such chemical plant and assess its viability. The purpose for this project was to simulate a catalytic thermal hydration of ethylene oxide (EO) to produce mono-ethylene glycol. The challenge faced in simulating this process was obtaining a 5000 kg/hr production rate of MEO with a 99 wt% purity while maintaining a 90% selectivity toward MEG and a H_2O/EO ratio of 22. This was addressed by prepping (1) the feed stream (H_2O and EO) to the reactor favorable operating conditions, (2) separating the desired (MEG) product from its byproduct (DEG) using a two-stage distillation system, (3) recycling water to the reactor during the separation, and (4) bringing the product stream to atmospheric conditions. The project was simplified in that the only side-product oligomer considered in the reaction was di-ethylene glycol. The next step in the project would be to simulate a nearly pure and selective MEG production plant while accounting for other oligomer byproducts.

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Process set-up

Feed preparation

The two feed streams had to be modified to get to the conditions necessary for the reactor. It was decided to pump the streams first and then heat them before mixing them and sending the mixed stream to the reactor. The reason for pumping the streams first was that if the temperature was raised first then vapour would be present. With vapour present it would be necessary to use expanders which are usually more expensive than pumps [8]. The operating conditions for the pumps can be seen below in table

Table 4: Pumps used for feed preparation

Pumps	**P-101**	**P-102**
Flow (kg/h)	36070	4009
Fluid density (kg/m^3)	1007	885.2
Power (kW)	18.81	2.046
Type		
Efficiency	75%	75%

To bring the streams to the temperature needed for the reactor a heat exchanger with high pressure steam was used. The steam is at a temperature of 280°C and the condenses to provide the heat. The flow rates of steam were 12020 and 1866 kg/h of steam for E-101 and E-102 respectively.

Reactor

The reactor conditions were provided as seen in table 1. The temperature was 150°C and the pressure was 1.5Mbar. There were two reactions which occurred, the main reaction as well as one side reaction.

$$C_2H_4O + H_2O \rightarrow HO - CH_2CH_2 - OH$$

$$C_2H_4O + \ HO - CH_2CH_2 - OH \rightarrow HO - CH_2CH_2OCH_2CH_2 - OH$$

Operating Costs

Operating cost for the process were summarized as follow:

Table 6: Operating cost summary breakdown

Operating labour cost	900000	
MEG production (tonne / h)	5.003	
3 operators per shift	15	operators
Operator salary ($/year)	60000	
Working hours per year (h/y)	8736	
Cost of labour ($/h)	900000	

The fixed capital investment was obtained from the Grass root cost (March 2017)

Table 7: Fixed capital investment

FCI	1288655

Water was recycled in this process and there was not any waste water treatment. Next, the cost of utilities along with material costs were calculated and the result were summarized as follow:

Table 8: Cost of utilities and materials

Cost of utilities	5.3E+07
Total cooling water mass fowrate (kg/h)	32410.9
Total high pressure steam mass fowrate (kg/h)	1.66E+06
Cooling water price ($)	14.8
High pressure steam price ($)	29.97
Total cooling water cost ($)	4E+07
Total high pressure steam cost	1.4E+07
Total utility cost ($)	5.3E+07

Cost of raw materials	5.6E+07
H_2O mass flowrate (kg/h)	36066.2
EO mass flowrate (kg/h)	4008.91
H_2O price	-
EO price ($/kg)	1.687
H_2O raw material cost	-
EO raw material cost	5.6E+07

From there, the cost of manufacturing was calculated. The cost of manufacturing (March 2017) was found to be $132, 285 681.6 with a revue of $ 673 051 70.83 and an annual profit of $ 69, 688 186.26: