Ethylene oxide

HIGHLIGHTS

Processes and technology status – The basic materials for ethylene oxide (EO) production are high-purity grade oxygen and ethylene. The general process has different parts which are the reaction system (oxidation), reagents restoration, absorption system, CO_2 removal section, and EO purification system (Figure 1) [1], [2], [3].

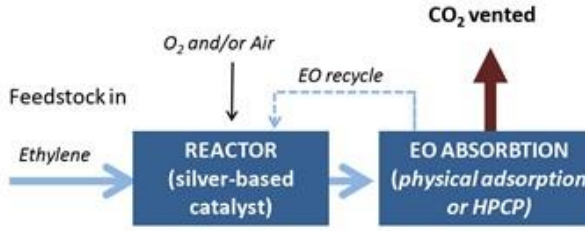

Figure 1. EO production flow sheet by direct oxidation route [4]

Cost - The whole working value (uncooked supplies, utilities, fastened prices and depreciation prices) estimated to supply EO was about €$_{2015}$577.2 [1] per ton of EO within the fourth quarter of 2015. The evaluation was primarily based on a plant constructed within the U.S. with capability to supply 550,000 metric tons per 12 months of EO [1].

Potential and barriers – The high ethylene costs and the low selectivity of the oxidation process exerts partial recycling of the reaction products. However, the side reactions lead to the 20-25% of ethylene lost in general [5], [6]. On the other hand, the emitted process base CO_2 has high purity which makes it a suitable candidate for implementation of carbon capture technology at first industrial approaches [4].

Production and consumption in Belgium – Ethylene oxide (EO) production lines in Belgium are BASF and Ineos plants located in Antwerp with capacity of 500,000 ton/year and 420,000 ton/year respectively at 2013 [7]. These two plants have announced to extend their production resulting in the whole EO production capacity of Belgium to more than 1,320,000 tons per year [8], [9], [10], [11].

Process overview - Ethylene oxide (EO) manufacturing was primarily based on the chlorohydrin course. However, this process is no longer considered to be installed due to emerging of the direct oxidation pass

[1] The values are converted from $ to € based on 1 €$_{2015}$ = 1,11 $$_{2015}$ [14]

Provided by Talieh Rajabloo
talieh.rajabloo@uhasselt.be

which costs 3-4 times less than the chlorohydrin process and is more environmental friendly process [1], [6].

The selectivity of the EO formation through direct oxidation technology is around 81%, while the ethylene conversion to EO is around 10%. Since the reactions are exothermic, water is used as a cooling medium on the shell side of the reactor and is later used to produce large quantities of low-pressure steam [3]. Figure 2 depicts the typical direct oxidation of EO in which pure oxygen is used as the oxidizing agent [1].

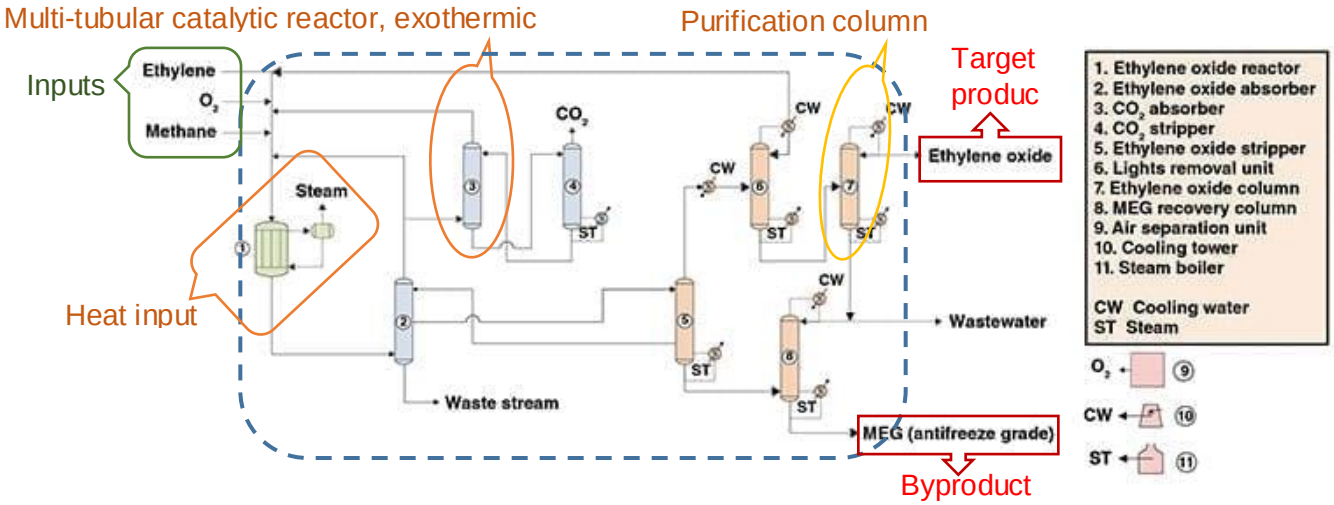

Figure 2. Flow sheet of ethylene oxide production via direct oxidation of ethylene [1]

Reaction and process main parameters

- $C_2H_4 + 0.5\ O_2 \rightarrow CH_2O.CH_2O$
- Catalyst is silver oxide on alumina
- Ethylene to air ratio: 3 – 10 %
- Side reaction products: CO_2, H_2O
- Operating temperature and pressure: 250 – 300°C and 120 – 300 psi
- Suppressing agent for side reactions: Ethylene dichloride
- Reaction is exothermic [6]

Investment and production costs - Ethylene makes up for approximately 68% of the total cost of the EO process [5]. Therefore, it is important to optimize the selectivity towards EO and thus reduce the consumption of ethylene [6].

A cost analysis at 2010 at a U.S. Gulf Coast location is carried out based upon a 320,000 t/yr plant and released the estimated costs

Provided by Talieh Rajabloo
talieh.rajabloo@uhasselt.be

for EO production plant[2] which includes capital investment of about €$_{2010}$433.85 million, the product value: about €$_{2010}$0.945/kg , production cost: €$_{2010}$0.75/kg [12]

Energy requirements - The warmth from the exothermic reaction during partial oxidation of ethylene, generates steam on the reactor shell, and is used for heating functions all through the method. Therefore, except the possible start-up requirements, no fuel burning is required.

Carbon capture and storage (CCS) in EO production - Overall, processes with high purity CO_2 emissions such as EO production process are interesting as first sources for CO_2 capture [13]. The stoichiometry of the process suggests it is produced at a ratio of 6/2 EO to CO_2, which means that CO_2 generation is about a third of total ethylene oxide production [4].

Summary Table

Table3. Summary Table: Key EO Data and Figures

Technical Performance	**Oxidation**	**Separation of final products**
Energy input	The recovered heat from reactor	Chilly water for separation section
Output	-	-
EO production in Belgium	**2013**	**2022***
Overall production rate (t/yr)	920,000	≥ 1,320,000
Costs		
The whole working value** (€$_{2015}$/ton of ethylene oxide) [1]	577.2	
Materials (For air based production) [6]	**(t/t$_{EO}$)**	
Ethylene	0.92	
Oxygen	0.9	
Steam	0.1	
Water	180	
Methane	Inert gas to provide stability and manage flammable limits	

[2] The original reported costs were in $\$_{2010}$ and are converted into €$_{2010}$ based on the mean exchange rate: 1 €$_{2010}$ = 1.33 $\$_{2010}$ [14]

Provided by Talieh Rajabloo
talieh.rajabloo@uhasselt.be

***** Ineos will invest at its Zwijndrecht site in Antwerp, Belgium to upgrade (EO) production which includes modernizing EO storage and distribution facilities beside debottlenecking and increasing EO production. This can increase the amount of production reported for 2022.

****** The whole working value includes uncooked supplies, utilities, fastened prices and depreciation prices.

References

1. Technology Profile: Ethylene oxide production from ethylene - Chemical Engineering - Coding Societies. Accessed June 30, 2020. https://codingsocieties.com/technology-profile-ethylene-oxide-production-from-ethylene-chemical-engineering/
2. Bernardo P, Clarizia G. Integrated membrane operations in the ethylene oxide production. *Clean Technol Environ Policy*. 2012;14(3):475-485. doi:10.1007/s10098-011-0434-5
3. Janet Huang; Daniel Resendez GT. Reactor Design: Accessed June 30, 2020. http://www.owlnet.rice.edu/~ceng403/gr1599/finalreport3.html
4. Zakkour P, Cook G. CCS Roadmap for Industry : High-Purity CO_2 Sources. *Carbon Counts*. 2010;(September):1-62. doi:10.13140/RG.2.1.3717.8722
5. Peschel A, Karst F, Freund H, Sundmacher K. Analysis and optimal design of an ethylene oxide reactor. *Chem Eng Sci*. 2011;66(24):6453-6469. doi:10.1016/j.ces.2011.08.054
6. Perzon H. A Simulation Model of a reactor for Ethylene Oxide production. Published online 2015.
7. Chemical Profile: Europe ethylene oxide | ICIS. Accessed August 11, 2020. https://www.icis.com/explore/resources/news/2013/04/13/9658385/chemical-profile-europe-ethylene-oxide/
8. BASF advances capacity expansion at Antwerp complex | Market Report Company - analytics, Prices, polyethylene, polypropylene, polyvinylchloride, polystyrene, Russia, Ukraine, Europe, Asia, reports. Accessed August 11, 2020. http://www.mrcplast.com/news-news_open-361005.html
9. €500Mln Base chemistry investment (2019) by BASF in Belgium. Accessed August 11, 2020. https://chemicalparks.eu/investments/base-chemistry-721
10. Ineos Oxide invests €200 Million in Europe | CHEManager. Accessed August 11, 2020. https://www.chemanager-online.com/en/news-opinions/headlines/ineos-oxide-invests-200-million-europe
11. Ineos Expands EO - Everchem Specialty Chemicals. Published 2018. Accessed August 12, 2020. https://everchem.com/ineos-expands-eo/
12. Ethylene Oxide Production by Nippon Shokubai Process – Chemical production and investment cost. Accessed July 7, 2020. https://ihsmarkit.com/products/chemical-technology-pep-reviews-ethylene-oxide-production-2010.html
13. van Dael M. *Market Study Report*. Vol December.; 2018.
14. Euro to U.S. dollar exchange rate 1999-2018 | Statista. Accessed August 10, 2020. https://www.statista.com/statistics/412794/euro-to-u-s-dollar-annual-average-exchange-rate/

Provided by Talieh Rajabloo
talieh.rajabloo@uhasselt.be