Optimization of Ethylene Oxide Absorber

Gas Absorbers are extensively used in the Chemical Process Industry (CPI) to separate components through absorption by contact with a liquid in which one of the components is soluble. The solute is transferred between the gas and liquid phases. This paper discusses the application of process simulation to optimize Ethylene Oxide (EO) Absorber operations while improving energy efficiency at the Ethylene Oxide and Ethylene Glycol (EOEG) plant of Reliance Industries Limited (Figure 1).

Ethylene Oxide is produced by silver-catalyzed, vapor-phase partial oxidation of ethylene by molecular oxygen. The ethylene oxide content in the hot gaseous reactor effluent is quite low. It is recovered from the effluent gas by absorbing with lean absorbent, producing a very dilute EO solution (rich absorbent). This rich absorbent is stripped in an EO Stripper to produce an EO rich stream.

Figure 1. Ethylene Oxide and Ethylene Glycol (EOEG) Plant at Reliance Dahej

The EO Absorber was modeled using the Aspen Plus process simulator (from Aspen Technology Inc.). This paper presents the steps followed in developing the simulation model, starting with the selection of property methods, input of tray details, and finally tuning the model to match operating data. Sensitivity analysis was performed to understand the effect of certain variables, such as Lean Absorbent temperature and flow, without compromising the top and bottom product specifications. It was concluded from the simulation study that it is possible to reduce the Lean Absorbent flow by 8% without compromising product quality. This recommendation was implemented in the operating plant through a stepwise reduction of the Lean Absorbent flow to the EO Absorber. There was also a corresponding reduction in pumping energy of 39 kW and steam to EO stripper reboiler of around 1000 kg/hour of Low Pressure Steam (3.0 barg). This translates into significant energy savings, resulting in annual economic benefits of INR 9.5 million (USD 200,000) without any capital investment.

Beyond energy savings, the same simulation model was also utilized to evaluate the potential for flooding at increased throughput in the column. The tray ratings were done by specifying the existing geometry of the trays, and the flooding tendency was then evaluated for both the current operating conditions and for the reduced absorbing liquid flow case.

Need for Energy Reduction

After raw materials, energy is the next largest expense in most chemical processes. Energy reduction in chemical processes is therefore necessary to sustain cost effective production and manage capacity in an ever changing market place. It can maximize plant profitability.

Process

In the EOEG Plant, ethylene undergoes vapor phase oxidation over a silver-base catalyst in the presence of oxygen to form ethylene oxide (EO). EO is recovered from the reactor effluent cycle gas in an EO Absorber and is further processed to

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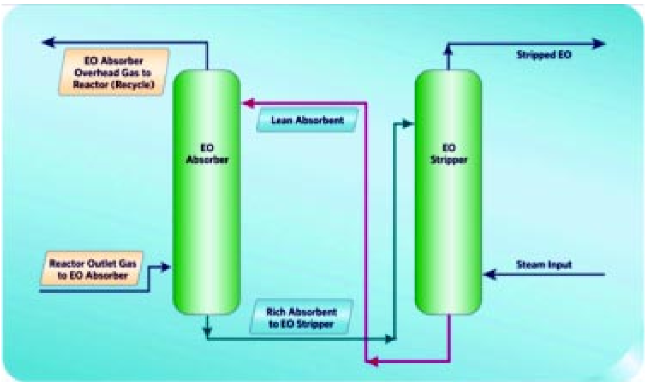

Figure 2. Ethylene Oxide Absorber and Stripper Process

produce pure EO and mono Ethylene Glycol (EG). See Figure 2.

The purpose of the EO Absorber is to separate EO from the Cycle Gas. The cooled Cycle Gas enters the EO Absorber from the bottom and is contacted counter-currently with Lean Absorbent from the top, which absorbs the ethylene oxide. The Rich Absorbent with ethylene oxide from the bottom of EO Absorber then flows to the EO Stripper for recovery of EO. The concentration of EO in the Absorber top recycle gas product is maintained by adjusting the lean absorbent flow. It is important to maintain this concentration below a certain high limit to avoid process problems downstream.

Simulation Study

The main objective of the simulation modeling study was to evaluate the energy reduction potential in the EO Absorber without any capital investment, and to check the EO Absorber column performance for operating at higher loads (throughput).

Methodology Followed

1. Select property method and develop the simulation model
2. Validate property method and simulation model based on Process Flow Diagram (PFD) design data
3. Fine tune the simulation model based on current operating parameters
4. Model sensitivity analysis with respect to Lean Absorbent flow and temperature
5. Conduct plant trials to implement the modeling study recommendations
6. Analysis and conclusions, including benefits

Aspen Plus is the simulation software used for steady state simulation (Figure 3). For the purpose of this optimization study, the Radfrac rigorous column model was selected.

The SR-Polar Equation of State (EOS) was picked as the property prediction method. It was first validated by comparing the predicted model results with the actual PFD data provided by the licensor. It was further validated for the entire operating range

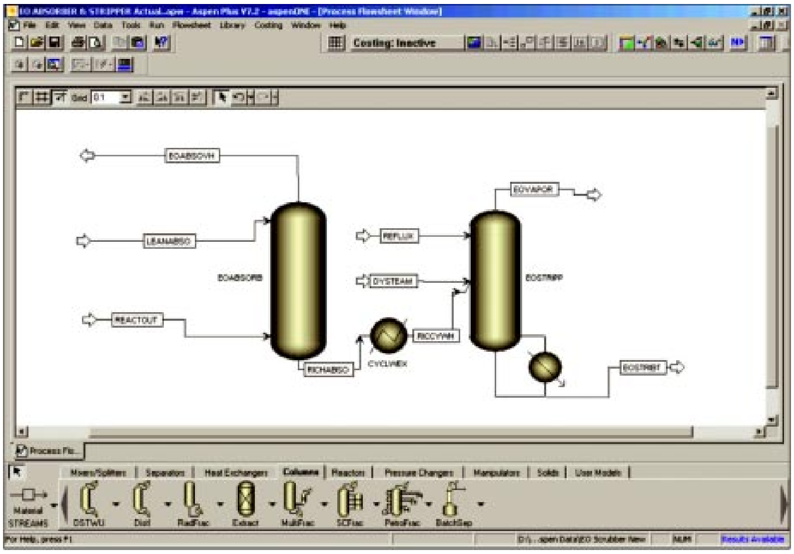

Figure 3. Aspen Plus V7.2 Simulation Model

of the project with operating data and proved to be the best method for this simulation model.

Initially the PFD data was used for feed composition, and the model predictions were compared to the stream compositions for the top and bottom products from the design case material balance. Later the actual feed compositions were taken from the online analyzer and the model predictions were again evaluated. The model was then fine-tuned by adjusting the Absorber Murphree tray efficiencies to match the following parameters with actual plant data:

- Temperature profile along the column
- Top and bottom products composition

Once the model was tuned it was used for sensitivity analyses with respect to:

- Change in Lean Absorbent flow
- Change in Lean Absorbent temperature

The objective of the sensitivity analyses was to gain insight to optimize operations without compromising the EO Absorber performance.

It was concluded from the simulation study and sensitivity analysis that it is possible to reduce the Lean Absorbent flow by 8% without compromising product quality (Table 1). This recommendation was implemented in a step-wise reduction of the Lean Absorbent flow in the operating plant, as described later.

Table 1. Effect on EO Absorption by Varying the Lean Absorbent Flow (at constant inlet Cycle Gas flow)

% Reduction in Lean Absorbent Flow versus Normal Operation	EO Mole Concentration in EO Absorber Overhead Gas (Simulated Values) (ppm)
- 5 %	3 ppm
- 10 %	3 ppm
- 15 %	4 ppm
- 18 %	4 ppm
- 20 %	5 ppm

The sensitivity analysis with respect to Lean Absorbent temperature was done to understand the impact of summer conditions, which essentially change cooling water supply temperature and can have an effect on the cooler in the Lean Absorbent circuit. Any change in lean absorbent temperature may impact absorption of pure EO from the cycle gas. This check was also necessary since the goal was to reduce lean absorbent flow, which could result in a change in lean absorbent temperature and thereby affect absorption. From the study (Table 2), it was concluded that a variation up to +2∞ C in lean absorbent temperature was insignificant in terms of absorber performance.

Table 2. Effect on EO Absorption by Varying the Lean Absorbent Temperature (at constant inlet Cycle Gas flow)

Temperature Increase of Lean Absorbent versus Normal Operation	EO Mole Concentration in EO Absorber Overhead Gas (Simulated Values) (ppm)
+ 1° C	3 ppm
+ 2° C	3 ppm
+ 3° C	3 ppm
+ 4° C	4 ppm
+ 5° C	4 ppm

Beyond energy savings, the same simulation model was also used to evaluate the potential for flooding at increased throughputs in the column. The column was operating at higher Lean Absorbent flow compared to the design values. The tray ratings were done by specifying the existing geometry of trays, and the flooding tendency was evaluated based on current operating conditions and after the reduction of Absorbent liquid flow. It was concluded from the simulation hydraulics study that the column was operating near the flooding limits and that reduction of Lean Absorbent cycle water flow will reduce tray flooding and increase the efficiency of the EO Absorber.

Optimized Operating Window

Based on the results of the simulation study, a trial plan was formulated for a step-wise reduction of Lean Absorbent flow with continuous monitoring of Absorber performance using the online analyzer and analytical methods for analysis. The following benefits were projected:

1. A reduction in Lean Absorbent flow to the EO Absorber will reduce the downstream load, leading to better performance of the EO stripping column and lower stream consumption for stripping EO from rich Absorbent.
2. A reduction in Lean Absorbent flow to the EO Absorber will reduce the load on the Lean Absorbent water cooler, leading to a lower Lean Absorbent supply temperature and improved EO absorption efficiency in the EO Absorber.
3. A reduction in Lean Absorbent flow to the EO Absorber will lower the pressure drop across the Absorber, thereby improving EO absorption efficiency in the EO Absorber.
4. This trial will also identify any system bottlenecks in terms of Lean Absorbent flow and temperature during high plant load operation.
5. The reduction in Lean Absorbent flow will also directly benefit energy consumption for pumping.

Plant Trial Plan

The Lean Absorbent flow to the Absorber was reduced in a series of six incremental steps over a six day period. After each reduction the unit was allowed to achieve stable performance and the key

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operating parameters and compositions were measured. The plant trial plan is described in Table 3.

Table 3. Plant Trial Plan to Reduce Lean Absorbent Flow

Lean Absorbent Flow Reduction Step	Days	Total Reduction in Lean Absorbent Flow to EO Absorber (%)
Step 1	Day 1	1.0%
Step 2	Day 2	1.0% (Total 2.0%)
Step 3	Day 3	1.5% (Total 3.5%)
Step 4	Day 4	1.5% (Total 5.0%)
Step 5	Day 5	1.5% (Total 6.5%)
Step 6	Day 6	1.5% (Total 8.0%)
Total Reduction in Lean Absorbent Flow = 8%		

Results

The plant trials validated the findings of the simulation study in all respects. The projected benefits described earlier were all achieved in actual operations. Specifically, the unit was able to achieve the desired 8% reduction in Lean Absorbent flow without compromising throughput, recovery or concentrations. The results are summarized in Table 4.

Table 4. Plant Performance after Implementing Study Recommendations

EO Absorber Performance after Implementing Study Recommendations				
	Lean Absorbent Flow (%)	Cycle Gas Flow	EO Content in EO Absorber Overhead Cycle Gas (ppm)	Lean Absorbent Pumping Energy (KW)
Reduction	8	None	73 ppm	39
Effect of EO Absorber Optimization on EO Stripper Operation				
	Rich Absorbent Feed Flow (%)		Steam Flow to EO Stripper Reboiler (MT/Hr)	
Reduction	8		1.00	

Conclusions

The simulation model predictions were highly accurate and very close to reality. The reduction in EO rich Absorbent flow proved to be even more beneficial in stripping EO - substantially reducing the amount of energy required to strip out EO in the EO Stripper Column. The EO recovery process was therefore successfully optimized. The EO Absorber Lean Absorbent flow was reduced by 8%, with a corresponding reduction of pumping energy of 39 kW and a 1000 kg/hr reduction of Low Pressure Steam (3.0 barg) in the EO stripper reboiler. These energy savings result in total economic benefits of INR 9.5 million (USD 200,000) per annum without any capital investment. This study strongly underscores the value of using process simulation technology to optimize operations and drive new levels of energy efficiency.

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