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OPTIMIZATION OF ETHYLENE PLANT FRACTIONATION PROCESS

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Abstract: Research and Study of Ethylene Plant Fractionation Process
Key Words: Ethylene; Fractionation Process; Ethyle Acetate;

I. INTRODUCTION

Ethylene is among the most essential petrochemical intermediates and is a feedstock for numerous items. End products made with ethylene include food product packaging, movie, playthings, food containers, bottles, pipes, antifreeze, rugs, insulation, housewares, and so on. Chemicals that aremade from ethylene in order to generate these end products are polyethylene, ethylene dichloride, ethylene oxide, ethylbenzene, and vinyl acetate,simply to name a few. In this paper we will study the optimization of Etylene Plant fraction Process. The real time improvement of Ethyle Acetate using simulation.

II. REAL TIME OPTIMIZATION OF ETHYL ACETATE USING SIMULATION MODELING

Ethyl acetate is produced from ethylene and steam which initially produces ethanol and in reactive distillation; acetic acid is added to obtain ethyl acetate in the top (FP) and left over acid (ACIDW) in the bottom. R.T.O is applied for the final column (RCOL-3) where initially obtained ethyl acetate is further purified, Figure 1 represents the process flow diagram.

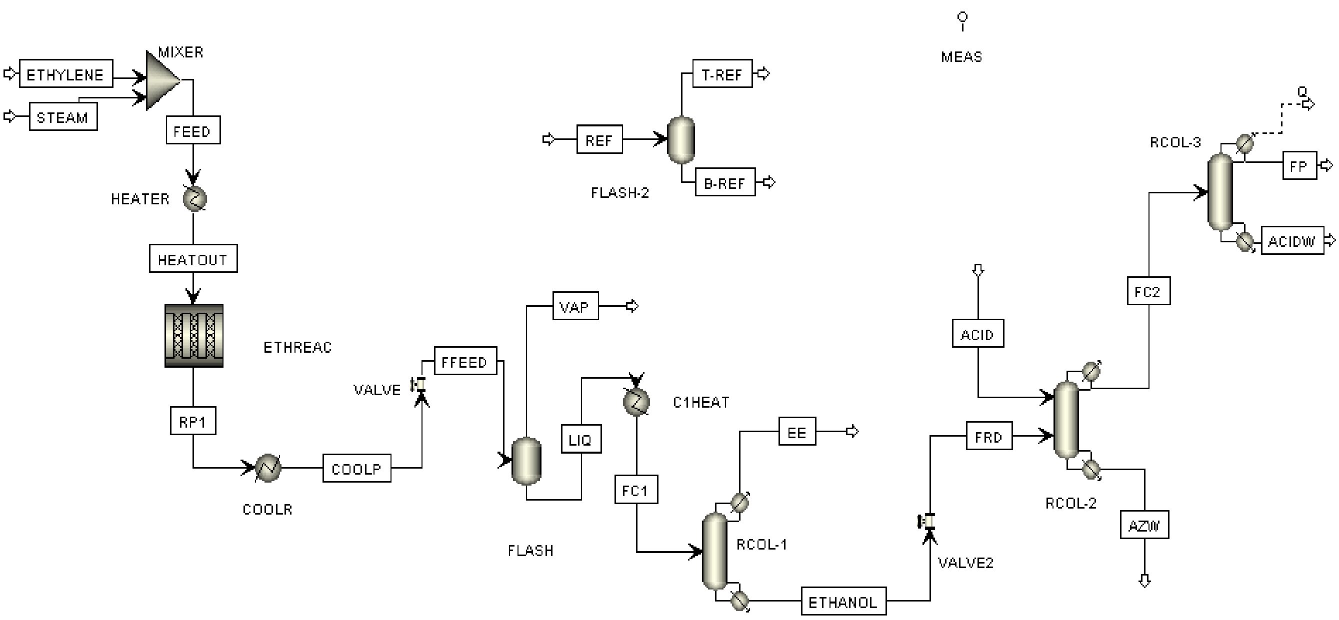

Fig 1. Process Flow Diagram

Level – I:

1. **Three or more Unit Operations:**
   - ETHREAC (PFR) FLASH
   - FLASH2 RCOL-1
   - RCOL-2 RCOL-3
2. **Five or more Non-zero Components:**
   - Ethylene in Feed with (along with Ethane) Ethanol
   - Acetic Acid Ethyl Acetate Water
3. **Design Specification:**
   - DS-1: TO adjust the flow of propylene in FLASH2 to match the RCOL-3 condenser duty.
4. **Calculator defining Objective function:**
   - Calculator, C-1 is defined to find the total profit obtained from the products.
5. **Five or Measurements defined:**

Index	Tag	Value	Open variable	Enabled
1	FI001	2800	ETHYLENE.BLK.MASS	YES
2	AI001	0.3	RCOL-3.BLK.REFL_RATIO_MASS	YES
3	FI002	8100	RCOL-3.BLK.DISTILLATE_MASS	YES
4	AI002	0.002	RCOL-3.FP.STR.ACID	YES
5	FI003	0.85	RCOL-3.BLK.D:F_MASS	YES
6	FI004	250	RCOL-3.BLK.BOTTOMS_MASS	YES
7	AI004	0.00	RCOL-3.ACIDW.STR.ETHYLACE	YES
8	FI005	17000	REF.BLK.MASS	YES

6. **EO Variables additional sheet with Query:**
   AN EO variables sheet is created along with measurement block variables (MEAS).

Level – II:

1. **HXFlux block linked to Open Variable:**
   The design spec in order to fix the outlet temperature flash block to calculate propylene stream inlet pressure, runs for that particular time and vanishes at the very next run, unable to identify the error, so I did not use HxFlux Block.
2. **EO Input form with four or more entries:**

Variable/Alias Type	Enabled	Value	Lower bound	Upper bound	Bound
RCOL-3.FP.STR.ETHYLACE	YES	0.565	0.3	0.7	HARD
RCOL-3.ACIDW.STR.ACID	YES	0.515	0.2	0.55	HARD

3. **Three or more active Spec Groups (including measurement and parameter estimation spec swaps):**

Group	Status Enabled	Variables
COMP	YES	Var=RCOL-3.BLK.D:F_MOLE, User Spec=Calc; Var=RCOL-.BLK.REFL_RATIO_MOLE, User Spec=Calc; Var=RCOL...
MSPEC	YES	Var=RCOL-3.FP.STR.ACID,User Spec=Calc;Var=MEAS.BLK.AI002_PLANT, User Spec=Const; Var=MEAS.BLK.A...
PSPEC	YES	Var=MEAS.BLK.FI001_OFFSET, User Spec=Param; Var=MEAS.BLK.AI001_OFFSET, User Spec=Param; Var=MEAS....

4. **Objective Function defined:**
   Objective function is defined to optimize the profit from the products.
5. **One or more measurement specification swaps:**
   Measurement specification swap is done to optimize the acid rate in the top and ethyl acetate rate in the bottom of the column (RCOL-3).
6. **One or more Parameter Specification swaps:**
   Parameter estimation specification swap is done between column's (RCOL-3) Murphree efficiency and Distillate to feed ratio mole. The optimized objective function value before parameter estimation specification swap between Murphree efficiency and Distillate to feed ratio mole = 1205 $/HR. And the objective function value = 1310 $/HR after doing specification swap The profit excludes heat duties and involves only product costs.

III. CONCLUSION AND RESEARCH FINDINGS

1. Use Dynamic Simulation to minimize Flare emissions during Ethylene Plant shut down.

Abstract: There are large amount of emissions from flare during startup, shutdown and upset of an ethylene plant. Literature survey shows a shutdown procedure of a 300 kt ethylene emits about 150 ton of hydrocarbon through flare. Based on the 98% combustion efficiency that EPA recommended, it emits 1.2 ton of carbon monoxide, 0.22 ton of nitrogen oxides (NOx) and 3.4 ton of volatile organic compounds (VOCs).

Since flare emissions happen within a short time, they will cause big impact on ambient air quality. In this paper, dynamic simulation was used for shutdown procedure of an ethylene plant. Rigorous dynamic models were built, which included charge gas compressor (CGC), chilling train, demethanizer, deethanizer, depropanizer, hydrogenation reactor, ethylene splitter, propylene splitter, debutanizer and depentanizer. The shutdown procedure included many stages, and each stage had one or more dynamic models. Through dynamic simulation, a new shutdown procedure was proposed, which would decrease flare emissions by 50%. The new procedure was accepted by the ethylene plant and will be used for their next shutdown.

2. Study on the Integrated Chilling Train and Mixed Refrigerant System for an Ethylene Plant.

Abstract: Refrigeration is one of the most important and crucial process in chilling train of ethylene plants. There are different ways to provide refrigeration for the process. The latest trend is to use a mixed refrigerant system (MRS) which has at least three components for the refrigerationtask. An MRS provides a continuum of temperatures change with smaller temperature differences during the heat exchange process than the single or cascade refrigerant system. This leads to a lower energy loss in MRS and some other advantages than the traditional cascade refrigerant systems. On the other hand, chilling train in ethylene plants contains a series of multiple heat exchangers and flash drums to separate hydrogen and methane gas from cracked gas and to liquefy the C2 and heavier components. It handles process streams whose temperatures vary from 40 to -160 oC, which requires significantamount of cooling duty. Obviously, the chilling train and mixed refrigerant systems should be integrated for study in terms of energy saving and system operational performance improvement. The present work deals with combining chilling train and mixed refrigerant system for an ethylene plant. Both process models are developed by ASPEN Plus. Based on the rigorous simulation model, the conceptual optimal design and operational optimization for improving the integrated system has been conducted.

3. Dynamic Simulation of Demethanizer and Chilling Train System.

Abstract: The chilling train system is an important part of ethylene plant which is usually combined with demethanizer and a series of flash drums to separate hydrogen and methane from cracked gas, and recover the hydrogen and methane as different products through multi-stream heat transferwith refrigerants. The system of demethanizer and chilling train is the intermediate part of an ethylene plant whose performance can significantly affect the amount of flaring during start-up and thus energy consumption. However, most research efforts are focused on design and steady-state optimization aspects, the dynamic behavior of chilling train is rarely explored. In this study, several control strategies of demethanizer and chilling train system will be simulated and corresponding dynamic responses will be investigated in order to reduce time and flaring during start-up. General methodology includes the following steps: 1) In the first place, a steady-state model will be built using the sequential modular approach and plant design data; 2) the model will be further validated with normal steady state operating conditions obtained from the DCS (distributed control system) historian; 3) If the steady-state model is satisfied, it will be exported to the dynamic simulation environment. Three types of data will be needed in this transferring, including equipment dimensions, control strategies and P&ID (piping and instrument diagram) parameters, and the heat transfer option; 4) after the dynamic modeling is completed, it will be further validated to match some process upsets in DCS historian; 5) the control strategies will be tested in dynamic simulation to decrease start-up time and energy consumption. A case study is used for the demonstration.

4. Optimization and Thermodynamic Analysis of Mixed Refrigerant System for Ethylene Plants.

Abstract: Refrigeration is one of the most important and crucial system in chemical plants. A refrigeration system generally works by removing heat from low temperature streams throughvapor compression cycles at the expense of mechanical work. Since a refrigeration system can cool down a process stream below the ambient temperature, it is indispensable to cryogenic cooling and used for separation process in many chemical industries, such as large scale productions of ethylene, oxygen, nitrogen and liquefied natural gas (LNG). Usually refrigeration systems employ single component as refrigerant as long as it is thermodynamically desirable and operationally feasible. But a multi-component mixture can also be used as refrigerant, because a mixed refrigerant system provides a continuum of temperatures with smaller temperature differences even at the lower temperatures. This leads to a low energy loss in the system. Mixed refrigerant system has many inherent advantages than the traditional single component refrigerant system. In an ethylene plant, usually refrigeration is provided by cascading three single-component refrigeration systems. This process is not only expensive but also inefficient because cooling is not uniform throughout the process. The process streams in ethylene plant vary from 40 to -140 o C. For a single component refrigerant, it is impossible to provide constant refrigeration at a particular temperature. Mixed Refrigerant is used in order to improve refrigeration process by using four components as mixed refrigerant. The presented work deals with developing a mixed refrigerant system for an ethylene plant. The process is developed using a rigorous simulation model. Also, the process is optimized for its design and operation. The manipulated variables include compressor work and total consumption of the mixed refrigerants. This optimal model has several challenges. First, the minimum temperature difference in the heat exchangers is at least 2 o C. Second, the heat duties of all the heat exchangers in the process must satisfy specifications. Finally, the process is nonlinear so an efficient solution strategy is needed. The base case results are compared with optimized results based on the rigorous simulation and optimization methods. Process thermodynamic analysis is also conducted.

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