Manufacturing of para toluene sulfonic acid engineering essay

In the Final year of Bachelor of Chemical Engineering from S. S. Jondhale College of Engineering, I undertook the Project to design and develop a plant for the manufacturing of Para Toluene Sulfonic acid with 1 tonne per day of production capacity, as the part of partial fulfilment of engineering degree. The main objective of this project report is to improve understanding and implementation of various technical skills developed during engineering studies, to develop the skills to undertake the research work, analysis of the financial and economic factors to be considered while developing the project in the real world scenario. The project also aims to understand the importance of team work, communication, and the impact of the time constraint on the project.

The technical aspects included in the project are selection of the manufacturing process, developing process flow diagram, mass balance, energy balance, chemical and mechanical designing of the process equipments, calculating the required utilities, site selection, cost estimation and calculating financial feasibility of project.

C. E. 1. 2. 2: Organisational Structure

CE1. 2. 3: Project Responsibilities

At the beginning of the project with mutual consent I was selected as the Project leader. I had the responsibility to communicate with college authorities regarding the process of the project. Other project responsibilities were divided between the group members. I was assigned the task of literature review to find the possible process for the manufacturing of Para Toluene sulfonic acid and to select the process which is appropriate for this project with proper justifications and develop the process flow diagram. I was

also entrusted for the mechanical and chemical design of main reactor and to conduct mass and energy balance on it. I have to carry out the profitability analysis and cost analysis. To gather import export data, market research, site selection and mass and energy balance on other process equipments was the duty of other team members.

C. E. 1. 3: Personal Engineering Activity

C. E. 1. 3. 1: Product Details

PTSA is an organic compound, highly corrosive in nature. It causes burns and is extremely harmful if inhaled. It is extremely destructive to the upper respiratory tract, eyes as well as the skin. It is stable under normal conditions of use; PTSA in flake form is ivory colored, crystalline and a hygroscopic in nature. It dissociates almost completely in aqueous solution and water. It is highly acidic and the acid strength is comparable to that of sulfuric acid.

Molecular Formula: C7H8SO3

Molecular weight: 172. 20

Melting point: 380 C (anhydrous)

1060 C (monohydrate)

Boiling point: 1850 C at 0. 1mmHg

Vapor pressure: 14 mmHg at 200 C.

Flash point : 410 C.

Density : 1. 07

Solubility : Water – very soluble (67/100ml)

CAS No : 104-15-4

ITC code : 290410. 09

PTSA is used as catalyst for acid-catalyst reaction such as polymerization, alkylations, esterification, trans-esterification, hydrolysis, etherification, actualization and dehydration. PTSA is used in the manufacture of phthalic acid esters, polyvinyl acetate, alkyd resins, epoxy resins. PTSA is used for varieties of organic syntheses such as manufacture of p-cresol, dyestuffs, tanning agents and pesticides, its alkyl esters are good alkylation agents.

C. E. 1. 3. 2: Selection of Manufacturing Process

I conducted research by using chemical engineering journals and engineering books available in the university and information available on internet to find the methods that can be used for the manufacturing of PTSA. I found three methods that can be used which are listed below,

Batch sulphonation of toluene.

Continuous partial pressure sulphonation.

Manufacturing of PTSA using SO3.

Selection of appropriate manufacturing method is very crucial for the success of the project in terms of financial gain as well as the acceptance by

the regulatory authorities and socio-environmental perspective. The factors which I took in consideration while selecting the manufacturing process are:

Cost of raw materials and its availability

Cost of equipments and utilities required

Production cost and the revenues

Revenue from the sales of by products

Environmental impact of the process

Process variables like temperature, pressure etc.

Overall yield of the reaction, product purity and the by-products formed

After the due consideration of all the process, I selected Manufacturing of PTSA using SO3 as the process to be employed for this project with detailed justifications. This method has the highest yield percentage of 97. 1% as which is very high as compare to other methods. Low yield of by-products such as MTSA and OTSA eliminates the requirement of very complex process required for the separation from the main product. The reaction rate is high which decrease the time duration and small size of reactor is required which reduces the cost of production. Less amount of use of Sulphuric acid also reduces cost of neutralisation. The process is environment friendly with very less amount of emissions.

C. E. 1. 3. 3: Description of Manufacturing Process

Toluene is introduced into the main reactor or the ageing tank at the temperature of 0 c. where the reaction between toluene and sulfur trioxide takes place. The mixture of SO3 and inert N2 is fed after separation of liquid reactant. The exothermic reaction takes place at 0 c which produces PTSA along with traces of O, M isomers of Toluene sulfonic acid. Small quantities of H2SO4 and DTS are also formed in the reactor. The cooling utility is required to carry out the reaction. The product stream goes to the gas separator where N2 is separated by mean of physical separation. The product stream is then mixed with cold water hence separates PTSA from product mix as PTSA is completely water soluble with the help of decanter. The PTSA is withdrawn from the overflow. The PTSA obtained is then feed to evaporator to remove the water content and the concentrated PTSA is sent to crystallizer where PTSA crystals are formed at 380C. The crystals thus formed are filtered, and dried in air drier to obtain the final product.

The remaining mix of the by-product removed from the bottom of decanter is fed to distillation column where toluene is separated and recycled back to the main reactor.

Following are the reactions that take place in the process:

C7H8 + SO3 —ïƒ C7H8SO3 + Ortho + Meta

(Toluene) (Sulphur trioxide) (PTSA 97. 91%)

2C7H8 + SO3 —ïƒ C7H7-SO2-C7H7 + H2O

(Di toluene sulphone 0. 1%)

C. E. 1. 3. 4: Process Flow Diagram

After the selection of the process was finalised, I prepared the process flow diagram (PFD) for the complete process as initially agreed. All the utilities and equipment required where considered while preparing the PFD which includes reactors, storage tanks, Heat exchangers, cooling utilities, decanter, separator, pumps, evaporator, distillation column, crystallizer and drier. I utilised knowledge gained while the studies of subjects such as chemical processes, process equipment design and drawing and other subjects learnt. I also took guidance from the respective professors and used engineering journal articles and books to overcome the difficulties.

CE1. 3. 5: Material and Energy Balance

After the completion of process development, I started to work on Material Balance and Energy Balance calculation for the main process reactor. All the other process and were considered by other group members. Calculations were carried out manually with the help of the knowledge gained from subjects mass transfer operations, chemical thermodynamics and heat transfer operations. All the results obtained are tabulated for each process which will be further used in the designing of the process equipments.

C. E. 1. 3. 6: Chemical and Mechanical Designing of Reactor

I designed the main reactor where toluene reacts with SO3 to form PTSA at 00 C, after all details of the material and energy balance were available. The chemical designing part of reactor included the determination of type of reactor i. e. CSTR or PFR, calculating the reaction kinetics and to evaluate

the volume of reactor and residence time. In the mechanical designed I faced the problem as the PTSA is highly corrosive so all the process equipments and piping should be made of stainless steel to avoid the contamination due to corrosion, and for the safety of the plant. But I need to keep the cost of construction up to optimum level for the financial viability of the project. So I designed the main reactor with the stainless steel type 316 and designed the external cooling system with mild steel as the construction material to keep the cost down. Mechanical design included stress of in the reactor, minimum thickness of reactor walls and other parameters.

C. E. 1. 3. 7: Cost Estimation and Profitability Analysis

I gathered all the work done by other team members to get the information about site selection, cost of equipments, steps to be taken to prevent the impact of project on environment, transportation cost for raw materials and final product, man power required and other utility requirements. I conducted the intense research from journal articles, books, company manual and company websites to get the most appropriate cost estimates and communicated with the companies where required. After all this research the fixed costs such as labour charges, land, equipments and variable cost such as raw materials, cost of utilities water, electricity required were calculated. On basis of this calculation I performed the feasibility analysis of the project using methods like net present value (NPV), payback period, and return on investment. The payback period for this project was found to be 20 months.

C. E. 1. 4: Summary

The project helped me to understand the difference between the theoretical knowledge and the gap between the implementing that knowledge in the real life scenario, and the skill required to be developed to fill that gap. It provided with the broader perspective of engineering challenges, the importance of time and constraints related to finance. It provided me with the opportunity to apply the fundamental of chemical engineering learnt in the course of more than 3 years. It helped me to enhance my communication and presentation skills when dealing with the team members, higher authorities and the companies. Over all I consider it to be successful completion of project as, I scored 90 marks in the Final submissions out of 100 marks and appreciation from our project supervisor.