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A Pre-Designed Study of The Ethylene Dichloride Plant from Ethylene and Chlorine with 40,000 tons/year Capacity

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Abstract

Ethylene dichloride (EDC) or 1,2 dichloroethane ($C_2H_4Cl_2$) is used in industry as a raw material for vinyl chloride monomers (VCM) and intermediates in polyvinyl chloride (PVC) production. Besides, the EDC is also used in TEL components, which are mixed in an anti-knock mixture; solvents for oils, waxes, and coating removers (coat cleaners); and raw materials for diamine ethylene, perchlorate ethylene, carbon tetrachloride, and trichloroethylene. The EDC needs in the world have increased since 1985 with the increasing demand for vinyl chloride and polyvinyl chloride. Based on the Indonesian Central Bureau of Statistics data until the end of 2005, Indonesia exports EDC from producing countries such as the USA, Japan, and European countries. Therefore, to meet the lack of domestic EDC requirements, the establishment of the EDC plant was considered. Ethylene dichloride can be produced from ethylene and chlorine. Ethylene can be obtained from Candra Asri Plant in Cilegon and chlorine obtained from Sulfindo Adi Venture Plant. Based on domestic and foreign EDC requirements consideration, existing plant capacity, availability of raw materials, and range capacity for EDC plants is between 9,000-46,000 (Faith and Keyes, 1957). It is the design of this EDC plant with a size of 40,000 tons/year. Based on a review of low operating conditions (temperature and pressure) and the factory presence previously made, the Ethylene dichloride (EDC) plant is classified as low risk. Economic evaluation calculations result in the show: 1) Percentage of Return of Investments (ROI) before tax of 35; 2) Pay Out Time (POT) before tax is 2.24 years; 3) Break-Even Point (BEP) is 41.35%; 4) Shut Down Point (SDP) of 21.7%; 5) Discounted Cash Flow (DCF) of 25.56%. The bank's interest rate in 2018 was 8%, so the DCF was more significant than the bank's loan interest rate. This results based on Aries and Newton's (1955) economics criteria, which concluded that the EDC plant establishment is low-risk. Furthermore, the Ethylene dichloride (EDC) plant of ethylene and chlorine with a 40,000 ton/year production capacity is feasible.

Keywords: *Economics considerations, EDC plant, ethylene, chlorine*

1. Introduction

The increasing of the total population has an impact on the increasing needs, including manufacturing materials supported [1]-[3]. Ethylene dichloride (EDC) is a vital ingredient in supporting manufacturing materials fulfillment such as vinyl chloride monomer (VCM) raw material, intermediate in polyvinyl chloride (PVC) production [4], used in TEL components which are mixed in anti-knock mixtures, solvents for oils, candles, and coating remover, and raw materials for ethylenediamine, perchlorate ethylene, carbon tetrachloride, and trichloroethylene.

The world's need for EDC has increased since 1985. This increase is in line with the increasing demand for vinyl chloride and polyvinyl chloride [5], [6]. In 1985, EDC

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production in the USA was 7x106 tons, in Europe 8x106 tons, and Japan 2.5x106 tons. Until the end of 2005, Indonesia was still importing EDC from countries in the world even though Indonesia had already established an EDC plant that is *Asahimas Subentra* Chemical Company, located in Cilegon with a capacity of 29,900 tons/year. To meet the needs of EDC in Indonesia, in 2005, Indonesia still imported EDC of 3,926,568 tons from various countries in the world. World EDC needs since 1975 increased 5% per year; therefore, it is estimated that in 18 years, the EDC needs will be 137,771,329 tons.

The construction of the EDC plant will be very profitable because it reduces dependence on imports, even if domestic needs are met, Indonesia can export it. Raw materials supply must also be strictly considered to ensure plant continuity, and ethylene raw materials can be obtained from *Candra Asri* Cilegon Company with 522,000 ton/year production capacity. The chlorine raw material can be obtained from *Sulfindo Adi Usaha* Company with 100,000 ton/year production capacity. Faith and Keyes (1957) suggested that the EDC plant's ability ranged from 9,000 to 46,000 tons/year [7].

Based on the description above and various considerations regarding the EDC amount needs at home and abroad, existing plant capacity, raw materials, and capacity range are based on literature studies. The determination of EDC plant capacity in EDC plant pre-designed from ethylene and chlorine is 40,000 tons/year.

2. Literature Review

Ethylene dichloride (EDC) or 1,2 dichloroethane with the chemical formula $C_2H_4Cl_2$ is a colorless liquid that smells like pleasant chloroform, tastes sweet, and dissolves in alcohol, chloroform, ether, acid, or chemical solution that is reactive, and the most solvent general [8]. The process used in the plant design direct chlorination in the gas phase [9] - [11]. This method's selection is based on the consideration that the process takes place in low conditions (low pressure and temperature), and raw materials are easily obtained. They do not need to add other equipment [12], [13]. Ethylene dichloride (EDC) from ethylene and chlorine by direct chlorination according to the following reaction [14], [15]:

$$C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2 \quad \text{.................................} \quad (1)$$

This reaction is exothermic and can be carried out well in both gas and liquid phases. Following operating conditions consideration and reaction ease of raw materials, this reaction uses the gas phase reaction, with the reaction that occurs is as follows (With a yield of 98%) [16]:

$$CH_2{=}CH_2 + Cl_2 \rightarrow ClCH_2CH_2Cl \quad \text{...} \quad (2)$$

Chlorine gas is inflated through an ethylene dibromide (EDB) tank. The steam mixture is directed to the chlorination tower, where the temperature is maintained at 400^oC-500^oC. The chlorine meets ethylene gas flow and reacts in one reactor, then the reaction results at temperatures above 850^0C are put into a partial condenser and separated into a separator. Ethylene dibromide (EDB) is thawed and returned to the process. Ethylene dichloride (EDC) gas is fed to the fractionation column to get the desired and purer product [7], [17].

The essential intermediate material produced by addition is ethylene dichloride, $ClCH_2CH_2Cl$ [18]. The first derivative of ethylene dichloride is vinyl chloride monomer (VCM), which is used to produce polyvinyl chloride (PVC), resins, and chlorinated hydrocarbons [19]. In the past, VCM was produced from acetylene by EDC purification with chlorine or oxychlorination processes. Variations are mostly under catalyst and reaction conditions [20].

In the chlorine purification process, EDC is produced in the liquid or vapor phase of chlor and ethylene with metallic chloride or ethylene dibromide as catalysts at 400^oC-1400^oC and 0.1 - 0.5 MPa (14.7 – 72.5 Psi) [21]. In general, the uses of EDC are as

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follows; a) used for manufacturing vinyl chloride monomers and manufacturing synthetic fibers; b) used in the manufacture of Tetra Ethyl Lead (TEL), an additive used to increase the quality of anti-knock and gasoline; c) used in soap, fungicide, and pharmaceutical factories; d) as a solvent and refrigerant, used in paint and varnish factories; e) as a raw material for making vinylidene chloride which is an intermediate material for making films/coatings.

3. Results and Discussion

In EDC making process from ethylene and chlorine, a process description that occurs is explained. Chlorine gas (1.5 atm, 30^oC) from *Sulfindo Adi Usaha* is channeled through a pipe, then heated from 30^oC to 35^oC with a heater (HE-02) until the pressure becomes 1.4 atm. The chlorine fed into a mixing tank (T-02). In this tank, chlorine mixed with ethylene dibromide from EDB tank (T-01) and recycle flow from Distillation Tower (MD) until the chlorine gas coming out of the mixing tank (T-02) will contain ethylene dibromide vapor. This gas mixture along with ethylene gas (1.5 atm, 30^oC) is channeled through a pipeline from the *Candra Asri* Olefin Center Cilegon factory, where the temperature has been heated from 30 to 40^oC in the heater (HE-01) until the pressure becomes 1.4 atm then fed into the Single Tube (R) Pipe Flow Reactor. In the reactor, the chlorination reaction occurs as follows:

$$C_2H_{4\,(g)} + Cl_{2\,(g)} \rightarrow C_2H_4Cl_{2\,(g)} + Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The reactions that occur in the reactor are exothermic and non-isothermal adiabatic. The reaction results that come out of the reactor are fed into a partial condenser (CD-P). The gas comes out results partial condenser is purged all into the UPL after the temperature is reduced from 93.5^oC to 45^oC with Cooler (CL-04). The liquid results under partial condenser flowed to the Cooler (CL-01) to lower the temperature from 93.5^oC to 87.6^oC, where at that temperature, the material is in a saturated liquid condition.

The results under a partial condenser have been cooled to 87.6^oC then fed into Distillation Tower (MD), which has a sieve tray (perforated plate) type column. The top yield containing ethylene dichloride compounds, and a little water is condensed in a condenser (CD). The condenser results then fed into the accumulator (AC) to maintain continuity and stability between the reflux flow that enters the MD again and product flow. The product is then reduced in temperature from 83.8^oC to 45^oC using Cooler (CL-04) and stored in a tank (T-03). The bottom product MD, which mostly contains ethylene dibromide catalyst, is evaporated in the Reboiler (RB) to be refluxed. The liquid product partially recycled to the mixing tank and partly purged towards the UPL, which was previously reduced from 132^oC to 45^oC with Cooler (CL-03), and the pressure drops from 1.2 to 1 atm. Qualitative and quantitative flow diagrams are presented to illustrate the overall process description.

3.1 Qualitative Flow Chart

Qualitative Flowchart is a block arrangement that illustrates ethylene dichloride making the process from ethylene and chlorine. Each flow is equipped with data-flowing materials. Each block represents specific devices that are equipped with operating condition data (P and T), as presented in Figure 1.

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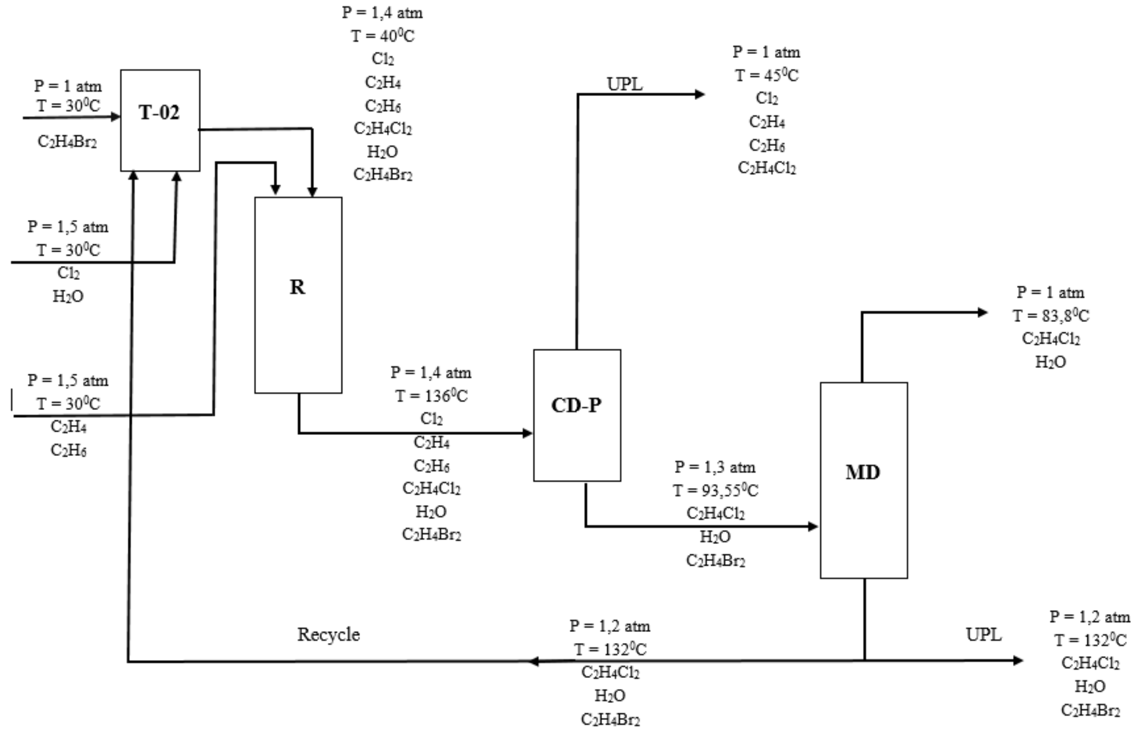

Figure 1. Qualitative flow chart

Based on the qualitative diagram in Figure 1, it can be seen that there are four main tools used, which is Mixing Tank (T-02), Reactor (R), Partial Condenser (CD-P), and Distillation Tower (MD). Tank 02 aims to mix the EDB catalyst with chlorine. This tank is the upright type with a thrower with 2.41m diameter, 9.65m height, and 0.3375in head height. The amount provided is two pieces. The material for this tool is stainless steel SA 167 type 316, volume 47.79 m^3, with a volumetric speed of gas entering the tank is 955.68 m^3/hour. Tank 02 operates at a temperature of 40^{o}C and 1.4atm pressure with 3 minutes of residence time.

The reactor is intended as a place for the reaction to form ethylene dichloride from ethylene and chlorine with the help of an ethylene dibromide (EDB) catalyst. This type of reactor is Single Tube Pipe Flow Reactor, with 1m diameter, 3.5m height, 2.75m^3 volume, 0.3125in head thickness, 6.0544in head height, and 0.25in shell thickness. The construction material used is stainless steel SA 283 grade C. The reaction phase is a gas with an operating condition of inlet temperature of 40^{o}C, the inlet pressure of 1.4atm, the outlet temperature of 136^{o}C, and outlet pressure of 1.3 atm. The number of reactors is one piece.

Partial Condense (CD-P) functions to inflate some reactor products. This device type is the Shell and Tube Heat Exchanger, which has a heat transfer area of 8,818.0463ft^2 with a heat load of 2.10 x 108Btu/hour. The tube side (cooling water) has an 0.75in outside diameter, 12ft length, the number of tubes is 3,745 tubes, BWG 16, the pressure drop is 2,0023Psi, the inlet temperature is 55^{o}C, and the outlet temperature is 30^{o}C. The side shell (top of the distillation tower product) has a 20in inside diameter, 0.0046 Psi pressure drop, 90.7^{o}C shell exit temperature, and 136^{o}C shell entry temperature.

Distillation Tower (MD) functions to separate the catalyst and purify the product. This MD type is Sieve Tray, with SA 283 grade C stainless steel construction material. Total tower height is 32.63m with a tower base diameter of 1.4m and spire diameter 0.3m. Shell thickness of 0.1735in, the head thickness of 0.25in, and head height of 5.88in. The number of the tray is 59, the feed location is on the 31st plate, and the tray spacing is 0.45m. MD operating conditions are at the peak with 1atm pressure and 83.8^{o}C

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temperature, a feed with 1.1atm pressure and 87.9°C temperature, and under 1.2atm pressure and 132°C temperature.

3.2 Quantitative Flow Chart

Quantitative Flow Diagram is a block arrangement that illustrates the ethylene dichloride was making the process from ethylene and chlorine in which each stream is equipped with materials data flowing along with its flow rate (in kg/hour), as in Figure 2.

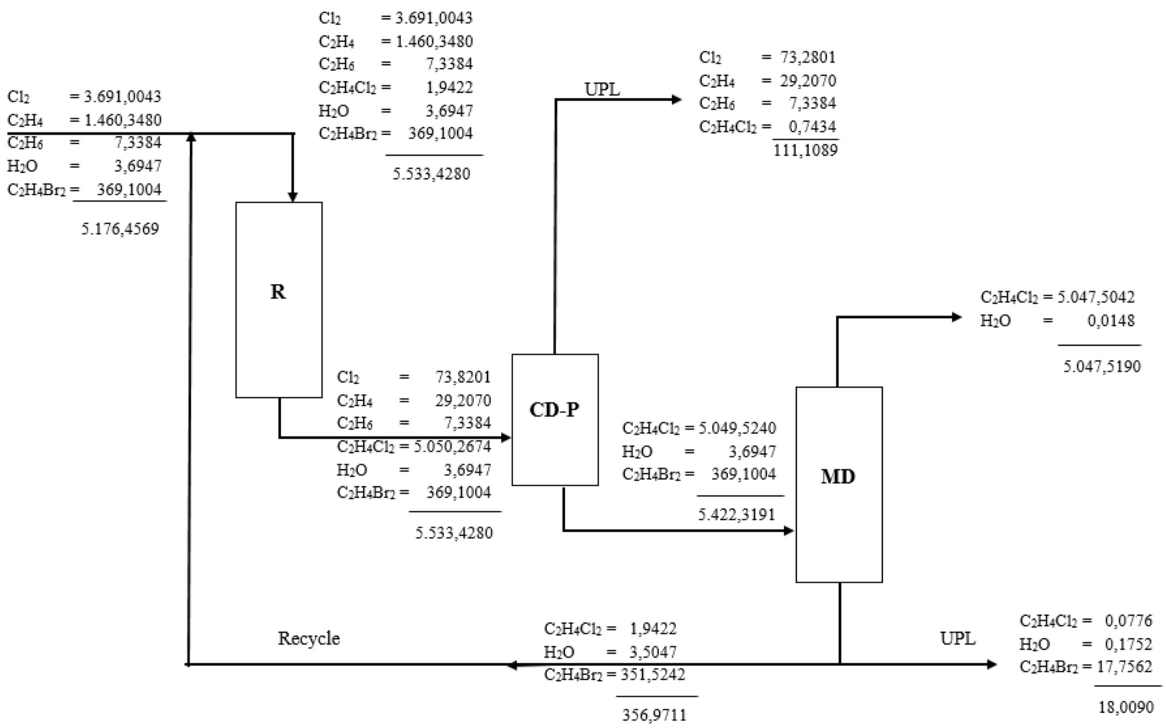

Figure 2. Quantitative Flow Chart

The quantitative diagram, as in Figure 1, shows inputs and outputs the number of each tool in kg/hour. The main products seen in MD are ethylene chloride ($C_2H_4Cl_2$) with a total of 5047.50042 kg/hour and water (H_2O) of 0.0148 kg/hour.

In addition to the process summarized description in qualitative and quantitative diagrams, it is also necessary to pay attention to the utility. Utilities are an essential part of a factory whose existence must always be present. This unit serves to provide process support materials at the ethylene dichloride plant. The plant's utilities include water, steam, compressed air, electricity, and fuel.

The water used in this plant is sourced from the Cibanten river, which is the closest river to the plant to be established, which is in Cilegon, Banten. The water used must through the water treatment process to remove the contents that will interfere with the reaction process. The water used to meet the needs cooling media (cooling water), boiler feed water (boiler feed water), process water (absorbent water), water for hydrants, and water for offices and households. The water treatment units are divided into three, which are Water Pumping Units, Process Water and Industrial Water Treatment Units, and Drinking Water Treatment Units. Steam used as a heating medium to meet heating needs of process equipment, such as a re-boiler of 4,369,1319 kg/hour, and can be used to heat water in a deaerator. As a steam generator boiler is used, which operates at 9atm pressure (132.3 psi) and 208°C temperature,

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compressed air in the ethylene dichloride plant is used as a driving instrument for control the plant. The need for compressed air is 500 kg/hour under 4atm conditions and 30^{o}C. Environmental air at 30^{o}C temperature with 70% humidity is pressed by a compressor equipped with an air filter to filter out the dust and compress it to obtain 4atm pressure. Next passed to the silica tank to remove the water content. Dry air has been removed has a moisture content collected in a compressed air tank. Electricity used to motor drives, instruments, office equipment, and lighting. The total electricity demand is 591,3438KW. It is supplied from the state electricity company (50.5KW) and generators (540.8438KW) to meet the electricity needs. Two standard diesel engines, each of 500KW, are used. Another utility is fuel. The fuel used is in the form of fuel oil (oil) of 126.6752 L/hour.

The design of the ethylene dichloride plant is made an evaluation or investment appraisal, which is reviewed by the method; Percent Return of Investment (ROI); Pay Out Time (POT); Break-Even Point (BEP); Shut Down Point (SDP); and Discounted Cash Flow (DCF). It is necessary to interpret several factors, which are; Interpretation of Industrial Capital (Total Capital Investment), which consists of Fixed Capital Investment and Working Capital; Determination of Total Production Costs, which consists of Manufacturing Cost and General Expense; and Sales Price [22].

Based on price calculation of tools at an exchange rate of US, $ 1 equals to IDR 9,843.00, the entire process cost tool is the US $ 2,818,658.64, and the utility tool is the US $ 315,360.53. Fixed Capital Investment calculation includes Physical Plant Cost (PPC), purchase equipment cost (PEC), installation costs, piping costs, instrumentation costs, insulation costs, electricity installation costs, building costs, building costs land and repairs, and utility costs. The total cost of PPC is $ 19,724,005.00. Based on the PPC obtained engineering and construction costs or PEC (20% PPC) of $ 3,944,801 Direct Plant Cost or DPC (PPC + engineering and construction) gained $ 23,668,801.01. Total DPC is used to calculate contractor fees (5% DPC) and contingency (11% DPC), while PEC costs to calculate environmental costs (15% PEC) and plant startup costs (7% PEC). So that the total Fixed Capital Investment (FCI) of $28,240,290.4 or IDR 277,969,178,373.2.

Manufacturing Cost consists of Direct Manufacturing Cost, Indirect Manufacturing Cost, and Fixed Manufacturing Cost (FMC). Direct Manufacturing Cost (DMC) consists of raw material costs, labor, supervision (10% of employee wages), plant supplies, utilities, and royalties, and patents (1% sales price). The total DMC is IDR 112,312,772,106. Indirect Manufacturing Cost (IMC) consists of payroll overhead (15% labor cost), laboratory (10% labor cost), plant overhead (50% labor cost), and packaging and shipping (10% Annual sales). The total IMC is IDR 99,078,000,000. Fixed Manufacturing Cost (FMC) consists of depreciation (9% Fixed Capital Investment), property taxes (1% Fixed Capital Investment), and insurance (1% Fixed Capital Investment), bringing the total FMC to IDR 30,576,609,621. Total Manufacturing Cost of IDR 530,272,926,695.

Working Capital consists of Raw Material Inventory, Process Inventory, Product Inventory, Extended Credit, and Available Cost. Total Working Capital of IDR 115,500,818,768. General Expenses calculations consist of administration, sales expense, research, and finance. Total general expenses amounted to IDR 114,173,926,691. Total Production Cost (Manufacturing Cost + General Expenses) of IDR 644,446,853,386.

Based on these values, economic feasibility is analyzed. From the calculation, the Return on Investments (ROI) before tax is 35%, Pay Out Time (POT) before tax is 2.24 years, Break Event Point (BEP) is 41.35%, Shut Down Point (SDP) is big 21.7% and Discounted Cash Flow (DCF) of 25.56%.

4. Conclusion

Based on a review of low operating conditions (temperature and pressure) and the presence of a plant that was previously made, the Ethylene dichloride (EDC) plant is

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classified as a low-risk plant. The results of the economic evaluation calculations show; a) Percent Return of Investments (ROI) before tax of 35%. This figure shows low-risk factories based on Aries and Newton (1955) that low-risk factories have a minimum ROI before tax of 11%; b) Pay Out Time (POT) before tax, which is 2.24 years. This figure shows low-risk factories based on the opinion of Aries and Newton (1955) that low-risk factories have a maximum POT of 5 years; c) Break-Even Point (BEP) is 41.35%. Chemical plant construction generally has a BEP of 40% - 60%; d) Shut Down Point (SDP) of 21.7%. Chemical plant construction generally has SDP of 30% - 40%; e) Discounted Cash Flow (DCF) of 25.56%. The bank's interest rate in 2008 was 8%, so that the DCF was greater than the loan bank interest rate. Moreover, from the conclusions above, the Ethylene dichloride (EDC) plant of ethylene and chlorine with 40,000 tons/year production rate is feasible to build.

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