



4-20-2018

Bio-Dodecanedioic Acid (DDDA) Production

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Bio-Dodecanedioic Acid (DDDA) Production

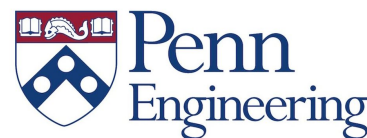
Abstract

The demand for dodecanedioic acid (DDDA) is steadily increasing each year with demand expected to exceed 90.4 kilotons per month in 2023.^{1,1} DDDA is an intermediate chemical used in a variety of end products. Thus, the increase in DDDA demand can largely be attributed to increasing demand for manufacturing nylon, paints, adhesives, and powder coatings. Regionally, Asia Pacific has been observing the fastest growth of all regions at over 6% CAGR.^{1,2} The robust manufacturing base for nylon, along with a growing automotive industry in India and China, will propel DDDA growth into the next decade. The current synthesis process for DDDA relies on a multi step butadiene process. This pathway has large price volatility and supply/demand imbalances due to using a petrochemical feedstock. This proposed process outlines a biologically-sourced alternative to conventional DDDA production, and would be located in Malaysia to access regional organic feedstocks. The proposed DDDA plant is designed to produce 14,000 metric tons per year of DDDA using palm oil, and would be strategically located near rapidly expanding Asia Pacific markets. This project has an estimated IRR of 24.12%, ROI of 18.20%, and a NPV of approximately \$54.1 MM.

Disciplines

Biochemical and Biomolecular Engineering | Chemical Engineering | Engineering

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Department of Chemical and Biomolecular Engineering
220 South 33rd Street
Philadelphia, PA 19104



April 17, 2018

Dear Dr. Raymond Gorte and Professor Bruce Vrana,

Enclosed is a design for the industrial production of dodecanedioic acid (DDDA) using biological feedstocks. This design is based off of patented process technology developed by biotechnology company Verdezyne, Inc. The proposed plant is to be located in an industrial complex in Malaysia with adequate access to palm oil production and treatment infrastructure. The plant is designed to produce 14,000 metric tons of DDDA per year that is competitive with conventionally produced DDDA at a weight purity greater than 99%.

In order to produce DDDA, a genetically altered strain of *Candida* yeast will be grown on a glucose feed of 70.5 g/L within progressively larger fermentation vessels. This cell mass will then be transferred into one of six production fermentation vessels and induced to convert the long chain fatty acids present in a palm oil feedstock into diacid products via changes in environmental pH. Palm oil is to be fed at 120.5 g/L in line with lab-scale patent information. After 24 hours in each of three growth fermenters and 120 hours converting feedstock to diacid products in the production fermenter, the fermentation broth is fed to a surge tank for feed to continuous downstream filtration of biomass. The resulting biomass cake, rich with DDDA and other diacid impurities, is then dried and enters a dissolution stage to solubilize the desired product. The ethyl acetate is filtered and sent to the crystallization process. Ethyl acetate is evaporated to crystallize the diacids, and is then condensed for recycle back to the dissolution stage. The diacids are then separated using melt crystallization, where liquid DDDA is separated from unmelted diacid impurity. The liquid DDDA is then cooled and fed to a flaker for final collection of 99% pure DDDA crystals.

This report contains detailed process designs and descriptions, equipment and utilities costing, economic analysis, and recommendations for the implementation of the proposed design. The proposed plant was found to be economically viable, with an estimated IRR of 24.12% and a total NPV of approximately \$54.1 MM. We recommend investing in this project. The upstream batch processes were modeled using Excel mass balance and process scheduling, while the continuous downstream processes were modeled using Aspen Plus v10. Cost estimates for all equipment were obtained using *Process Design Principles 3rd Edition*, by Seider, Seader.

Sincerely,

Brandon Mills

Meghavi Talati

Greg Winter

Brandon Mills | Meghavi Talati | Greg Winter

Bio-Dodecanedioic Acid (DDDA) Production

Senior Design Project, 459

Project submitted to: Dr. Sean Holleran

Prof. Bruce Vrana

Project proposed by: Dr. Stephen Tieri

Dept. of Chemical and Biomolecular Engineering

School of Engineering and Applied Science

University of Pennsylvania

April 17, 2018

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Section 1

Abstract

The demand for dodecanedioic acid (DDDA) is steadily increasing each year with demand expected to exceed 90.4 kilotons per month in 2023.^{1,1} DDDA is an intermediate chemical used in a variety of end products. Thus, the increase in DDDA demand can largely be attributed to increasing demand for manufacturing nylon, paints, adhesives, and powder coatings. Regionally, Asia Pacific has been observing the fastest growth of all regions at over 6% CAGR.^{1,2} The robust manufacturing base for nylon, along with a growing automotive industry in India and China, will propel DDDA growth into the next decade.

The current synthesis process for DDDA relies on a multi step butadiene process. This pathway has large price volatility and supply/demand imbalances due to using a petrochemical feedstock. This proposed process outlines a biologically-sourced alternative to conventional DDDA production, and would be located in Malaysia to access regional organic feedstocks. The proposed DDDA plant is designed to produce 14,000 metric tons per year of DDDA using palm oil, and would be strategically located near rapidly expanding Asia Pacific markets. This project has an estimated IRR of 24.12%, ROI of 18.20%, and a NPV of approximately \$54.1 MM.

Section 2

Introduction & Objective Time Chart

DDDA is a C12 dicarboxylic acid that is an intermediate in the production of antiseptics, top-grade coatings, painting materials, corrosion inhibitors, and surfactants. Most notably, DDDA is a major component of engineering plastics such as nylon 6,12.^{2.1} Driven by growth in these industrial goods, especially in Asian Pacific markets, the demand for DDDA is projected to grow by approximately 6% through 2023.^{2.2}

DDDA's conventional synthesis pathway requires butadiene. Butadiene is first converted to cyclododecatriene through a cyclotrimerization process. Additional multi-step chemical processes including hydrogenation, air oxidation in the presence of boric acid, and further oxidation by nitric acid, are required to reorganize and cleave the cyclic compound to produce DDDA. This conventional petrochemical synthesis, while the industry standard, has several negative externalities. As a feedstock, butadiene suffers from price volatility tied to crude oil pricing. Low oil prices, expensive shipping costs, and supply-demand imbalances have serious repercussions on the butadiene and elastomers markets. Roughly 98% of butadiene is produced as a coproduct of ethylene, another major petrochemical product.^{2.3} Therefore, trends in petrochemical product markets, such as softening demand in automotive-ethylene markets compared to the rubber-butadiene markets, result in constant supply imbalances. Additionally, butadiene rubber is used as a major feedstock in tires, with over 70% of available polymer produced going into sidewalls and treads.^{2.4} This results in high prices for DDDA producers who must compete with the automotive sector for feedstock. Bill Hyde, senior director of olefins and elastomers for IHS Markit, points out of butadiene prices surges that "(it is) a combination of planned or unplanned outages at butadiene plants, with strong demand at a time when inventories

were low... I wouldn't say there was panic buying, but there was desperation throughout the industry to get the material and do whatever they had to do to get it".^{2.5}

Competition for available butadiene supply raises prices and ultimately drives up the production cost of downstream products. As the demand for DDDA increases, conventional synthesis pathways using butadiene are not expected to meet demand in a cost-effective manner. This has driven interest in decoupling DDDA production from petrochemical pricing and regional availability. Renewably sourced DDDA using plant-oil feedstocks has emerged as a viable industrial alternative

This project proposes a Malaysian-based plant using fermentation processes to produce DDDA using regionally sourced palm oil as a feedstock. Palm oil contains a combined 89% Palmitic saturated acid, oleic monounsaturated acid, and linoleic polyunsaturated acid.^{2.6} These fatty acids are specifically desirable for this fermentation pathway due to the need for long chain fatty acids (C16-C18) for breakdown into DDDA (C12 saturated diacid). The fermentation pathway is discussed in greater detail in Section 10.2.

Palm oil is an ideal feedstock for this process, being a readily available and commercially produced carbon source in the region. The project aims to situate the DDDA production plant close to growing Asian markets via Malaysia. Considering that Malaysia currently accounts for 39% of the world's palm oil production and 44% of exports, much of the processing, distribution, and treatment infrastructure for this renewable process is already in place and ready to be utilized.^{2.7} The creation of a DDDA production hub situated in these markets serves to extract added value from existing agricultural development.

The size of the global DDDA market is predicted to reach \$450MM-\$600MM by the year 2022^{2,8}. Considering the growing demand for DDDA-derived products in rapidly expanding East Asian markets, and the relative availability and lower cost of palm oil compared to butadiene, the economic opportunities become apparent. Additional macro trends that this project's biosynthesis pathway addresses include flexible production, food vs. fuel/bio-materials mitigation, and "green" manufacturing. The genetically engineered yeast used in the fermentation can theoretically be fed any long chain fatty acid feedstock (coconut oil, corn oil, palm kernel oil, soybean oil, etc.). This flexibility then allows for feedstocks not largely consumed by humans to be strategically utilized. This further enables low-value byproducts of palm oil processing to become a high-value "green" products, while reducing the demand for and use of fossil resources.

The process begins with aerobic fermentation. Three growth fermenters are placed in series and feed genetically engineered *Candida sp*, a yeast strain that displays high yield and selectivity for DDDA production, into three production fermenters. Multiple fermenter trains are required to meet the project's annual production output of 14,000 metric tons (MT) per year. The fermentation broth containing the secreted DDDA product is then fed to a surge tank for continuous downstream separation and processing.

To achieve the desired product purity of 99%, several separation operations are done to extract the DDDA from the fermentation broth and separate it from the biomass and diacid coproducts that are produced. The fermentation broth is first filtered for cake, biomass and insoluble DDDA. This cake is then dried and mixed with ethyl acetate to solubilize and separate the valuable diacids. This feed is then processed to ensure only DDDA and no other diacids are

present in the final crystallized product. The final product is of industrial-use purity and is sold at a competitive price point to Asia Pacific markets. The proposed plant is to be located close to sustainably sourced palm oil extraction and processing farms due to feedstock viability and wastewater treatment.

| | |
|--------------------------------------|---|
| Project Name | Bio-Dodecanedioic Acid (DDDA) Production |
| Project Champions | Dr. Sean Holleran, Professor Leonard Fabiano, Dr. Stephen Tieri |
| Project Leaders | Meghavi Talati, Greg Winter, Brandon Mills |
| Specific Goals | Develop a bio-based DDDA plant with a capacity of 14,000 MT/year using regionally sourced palm oil as a feedstock |
| Project Scope | <p>In-scope:</p> <ul style="list-style-type: none"> • Cell growth • Sterilization of media and water fermenter feeds and fermenter sterilization • Design of fed-batch fermentation processes • Design of continuous separation process to meet 99% DDDA purity • Market and profitability analysis <p>Out-of-scope:</p> <ul style="list-style-type: none"> • Procurement of genetically engineering yeast strain • Packaging/distribution of DDDA powered product |
| Deliverables | <p>Business Opportunity Assessment</p> <ul style="list-style-type: none"> • Examine the market for DDDA • Comparison of bio-DDDA to conventionally produced competitors |
| Manufacturing Capability Assessment: | <ul style="list-style-type: none"> • Is the capital investment for plant development/construction reasonable? |
| Timeline | Complete design and economic analysis due by April 17, 2018 |

Section 3: Innovation Map

N/A

Section 4

Market and Competitive Analysis

The global commercial market for DDDA is expected to significantly grow over the next decade due to its variety of applications and the expansion of Asian markets. In 2015, the total market size for DDDA was 58.8 kilotons; by 2023, this market is expected to reach 90.4 kilotons, driven by estimated 5.5% CAGR.^{4.1} On a USD basis, this represents \$599.5MM in sales. Figure 4.1 shows the projected increase in the global DDDA market broken down by market sector.^{4.2} DDDA is used in a wide variety of chemical applications, and growth across industrial chemicals markets including coatings, adhesives, corrosion inhibitors, and plastics all contribute to the growth of demand for DDDA. Specifically, growth in markets for resins constituted the majority of the DDDA market share, making up roughly 60% of the total production on a mass basis in 2015.^{4.3}

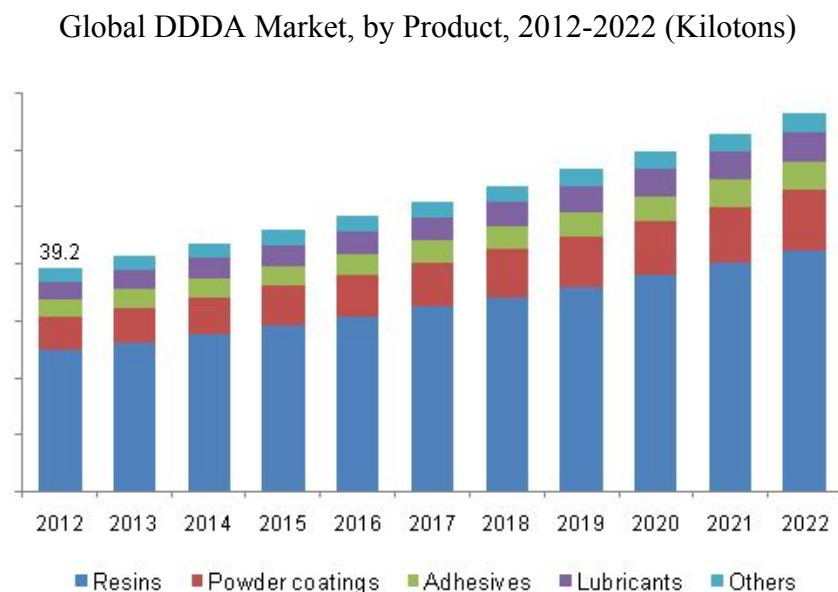


Figure 4.1: DDDA market size and growth projections

One specific resin, nylon 612 is a leading driver in DDDA market growth due to increasing demand and wide applicability in end-use industries such as fragrances, detergents, greases, polyesters, coatings and adhesives. Nylon 612 is known to have optimal heating

properties, allowing it to also be used in the production of engineering thermoplastics. Powder coating and paint applications have also largely influenced DDDA market growth; these markets are projected to grow at a 6.2% CAGR over the next decade, largely driven by expansion in construction and automobile industries in emerging markets.^{4.4}

Regionally, North America and Europe are the largest consumers of DDDA; collectively, these regions accounted for 45% of the total mass of DDDA consumed in 2014.^{4.5} The North American market is expected to see substantial growth, while the European market expects only modest growth due to the high manufacturing cost of nylon curbing manufacturing in Italy, Germany and France.^{4.6} Growth in the Asia Pacific market is anticipated to have the greatest growth potential of all regional markets. The emergence of industrial manufacturing hubs in China and India and the rapid growth in demand for industrial paints and powder coatings are responsible for this global trend.^{4.7} Due to its proximity to these markets, Malaysia was selected as the location of the plant described in this project.

Trends toward environmentally-conscious manufacturing practices have emerged within the chemical intermediates industry. This allows for innovations in biologically-sourced DDDA to be both economically favorable, as well as forward-thinking in regards to regulatory constraints. The first-mover advantage in regards to sustainably-sourced DDDA can be expected to be of much interest within this market sector in near future.

The principal competitors present in the DDDA market are Invista, Cathay Industrial Biotech, Sigma-Aldrich, Evonik, Santa Cruz Biotechnology, UBE Industries and Verdezyne.^{4.8} Traditionally, these incumbent manufacturers produce DDDA from butadiene using a multi-step chemical process. Some disadvantages associated with this feedstock serve to highlight the

benefits of a biologically-sourced alternative. Butadiene is a material that competes with fuel applications; thus, petrochemical synthesis of DDDA competes for raw materials. Therefore, butadiene faces extreme price volatility driven by its constrained supply and increasing demand across other markets. Lastly, because petrochemicals are inherently unsustainable and energy independence is becoming a topic of increased discussion, butadiene may not be the most reliable and secure feedstock in decades to come.

Recently, government subsidies and consumer demand are shifting towards bio-based and sustainable production. The proposed process of producing DDDA using renewable feedstocks and a yeast catalyst, is more sustainable and has the opportunity to be economically viable. This process is competitive with traditional butadiene production. In addition, the possibility to utilize different commercial feedstocks (not examined in this report), offers added flexibility that conventional production lacks. Feedstock flexibility further allows for the elimination of food versus fuel conflicts should they arise and further isolation from price volatility and supply constraints. Lastly, the proprietary biological engineering technology allows for a high level of selectivity of the diacid produced.^{4,9} Should market trends cause increased price in short length diacids, a yeast strain selective to that diacid can be selected for with minimal changes to downstream plant operations. With this in mind, bio-based DDDA is projected to replace about 30% of the butadiene-based industry in the next few years.^{4,10}

One potential disadvantage of using this bio-based route is deforestation and high water usage. This process will incorporate palm oil as a main feedstock and the use of palm oil is a leading cause of tropical deforestation. To combat claims of unsustainable practices, palm oil should be purchased from vendors that are certified by the Roundtable on Sustainable Palm Oil

(RSPO). RSPO Certification ensures that producers limit the land that may be developed for palm oil, curbing deforestation according to the RSPO principles and Criteria (P&C) standards.^{4.11}

Section 5

Customer Requirements

The objective of this project is to produce 14,000 metric tons of DDDA per year. Several co-products of DDDA, including adipic acid, suberic acid, and sebacic acid, are created as undesired products of the fermentation process. While the genetically altered yeast strains can be highly selective for the DDDA pathway, shorter length diacids (C6, C8, and C10 respectively) will be made as well. The standard product purity of competitors for DDDA are as follows: Cathay Industrial Biotech and Sigma-Aldrich, two major current incumbents, produce DDDA with product purities of >99%.^{5.1,5.2} The remaining <1% of the product remain as unspecified impurities. Thus, it can be concluded that the industry standard of DDDA purity using the traditional butadiene method appears to be greater than 99%. In order to compete with established competitors and meet customer requirements, it is essential that the bio-based production route also have product purity near 100%.

The bio-DDDA produced in this process has a projected purity of approximately 99.8%. The anticipated main impurities would consist of the other diacid by-products (suberic acid, sebacic acid, and adipic acid) that were not successfully separated from the DDDA in the crystallization operation, which is seen in Figure 12.7 - Section 500

This constructed process will produce an estimated 14,211 metric tons of DDDA per year, meeting the target production goal of 14,000 metric tons of DDDA per year. This meets the production target, while also building in a 1% buffer should there be unexpected downtime in the batch operations.

Another general customer consideration includes the sustainability of DDDA. The traditional butadiene pathway is non-renewable, while the palm oil pathway discussed is both

biomass-derived and renewable. While not without its environmental impacts, which are discussed in Section 21.1, this production pathway has several transportation and sourcing benefits. Sustainable production allows governments and companies to address their ecological impact while sourcing the same quality of material from their prior petrochemical-reliant process. Should governments require the incorporation of more biomass-derived and sustainable materials, this newly developed process more appropriately fits customer requirements than the traditional butadiene process does.

Section 6

Critical-to-quality (CTQ) Variables

Section 6.1: Fermentation Temperature, Pressure, pH and Dissolved Oxygen

Patented information demonstrates the optimal fermentation conditions to be roughly 37 °C, 1 atm, and 0.5 -1.0 VVM.^{6.1} The fermentation process utilizes a genetically modified *Candida sp.* yeast strain that can be fragile and susceptible to temperature, pressure, and dissolved oxygen level changes. Deviations from ideal reactor conditions could lead to excessive loss of yeast biomass due to death. Deviating from ideal conditions has been also been shown from patented data to largely decrease the yield of DDDA while increasing the yield of other unwanted diacids such as suberic acid, sebacic acid and adipic acid.^{6.2} This decrease in reaction selectivity in the fermentation process is undesirable, as this would significantly raise energy requirements and capital expenditures in the downstream filtration processes, which intend to separate DDDA from unwanted byproducts.

Maintaining pH is also extremely important in the fermentation process, as yeast strains typically have an optimal operating pH range. The patented data recommends operating at a pH between about 5.5 to 7.5, while our specific production process is in the range of 5.8 to 6.0 using a pH inducer.^{6.3} pH largely affects the metabolic processes of enzymes that are used in breaking down sugars; thus, deviating from ideal pH conditions would significantly reduce the resulting fermentation rate. pH is also used as the inducer for the metabolic switch from production of biomass in the more grow fermenters (more basic) to production of diacid metabolites in the production fermenter. This ability to transition metabolic conversion is due to the selective engineering of the yeast strains. The process is detailed in patent US9517996B2, *Purification of Polycarboxylic Acids*.^{6.4}

Section 6.2: Palm Oil Feed

Palm oil composition is important in order to ensure that an adequate supply of highly saturated long-chain fatty acids is available for the biomass in the production fermenter. As shown in Figure 10.1, palm oil is made up of largely saturated and monosaturated fatty acids presented as triglyceride esters.^{6,5} This allows for high availability of carboxylic acids for conversion to dicarboxylic acids. Due to the variability in biological feed stocks influenced by conditions such as temperature, nutrient availability, and age at harvest, the distribution of saturated versus unsaturated alkane chains can vary. Less saturated feedstocks would ultimately require additional metabolic activity to hydrogenate, and can influence DDDA yields relative to other diacid impurities. In order to ensure optimal conversion of palm oil, various feedstocks should be sourced and distributor requirement sheets should be utilized. All feedstock deliveries are to be homogeneously mixed prior to feed into the fermenters in order to further reduce variation between batches. Mixing and aeration would also ensure that the water-palm oil interface is increased and would prevent it from simply separating into distinct layers. This ensures interfacial interactions between the biomass and the feedstock; for the purposes of this process, the biomass can be thought of as a biocatalyst on which conversion of palm oil to diacids occurs.

Section 6.3: Ethyl Acetate Recycle

Downstream crystallization vessels are optimized with design specifications. These specifications specify a recycle stream that contains 99% of the condensed ethyl acetate and an accompanying purge stream to stop accumulation. This is vital because the upstream fermentation process requires a large amount of ethyl acetate in order to solubilize DDDA.

Specifically, the total amount of ethyl acetate fed in is 27,809 kg/hr, with 11,830 kg/hr of new ethyl acetate and 15,979 kg/hr of recycled ethyl acetate, indicating that recycled ethyl acetate accounts for 57.4% of the total ethyl acetate required. In order to avoid the cost of purchasing large amounts of fresh ethyl acetate upstream, an ethyl acetate recycle stream is utilized.

Section 6.4: Filtration

In between the fermentation and crystallization processes, filtration steps are included to ensure optimal recovery of DDDA from biomass. The process includes two separate filtration steps to recover the optimal amount of DDDA.

The first of the two steps involves drying the cake of all water content. The water present in the slurry must be removed for the dissolution step later in the process. Water removal is accomplished via vacuum rotary drum filters and evaporators. The vacuum rotary drums account for 91.5% of water removal and the evaporator accounts for the remaining 8.5%. Specifically, the water inlet to the drums is 12,822 kg/hr and the waste water outlet is 11,735 kg/hr. The remaining 1,087 kg/hr of water left in the cake is removed by the evaporator. A dissolution step is required to simplify the second step of the process, removing the biomass.

The dissolution step adds a substantial amount of ethyl acetate to convert DDDA and other diacids from their solid state to their liquid state. The liquid diacids allow for the centrifugation required to remove the remaining biomass. Design specifications require the ethyl acetate flow rate to be 7 times greater than that of the diacids flow rate at 70°C to convert them from the solid to liquid state.^{6.6} The diacids flow rate after the removal of water is 2,375 kg/hr; therefore, the ethyl acetate needed is 16,625 kg/hr. The ethyl acetate flow rate meets design

specifications, as the stream is 16,629 kg/hr. After the dissolution step, the stream is fed through a decanter centrifuge to remove the biomass.

The decanter centrifuge is assumed to be 99.5% efficient in separating the diacids from the biomass based on advice from industry consultants. The diacids flow rate out of the centrifuge (liquid outlet) is 2,363 kg/hr with no biomass, while the solid outlet has all of the biomass and a small percentage of diacids. The small percentage of diacids in the solid outlet stream are passed through another centrifuge to recover as much DDDA and other diacids as possible to meet production goals. The addition of a second centrifuge requires another dissolution step prior to feeding into the centrifuge. The dissolution step falls under the same design specifications as previously explained. The ethyl acetate recycle stream from crystallization is mixed with a smaller ethyl acetate stream that is heated via heat exchanger. The combined stream is split to provide at least 7 times ethyl acetate flow rate for dissolution. The second decanter centrifuge is also assumed to be 99.5% efficient and removes all biomass from the diacids. The two liquid outlets from the centrifuges are combined and fed into the downstream crystallization process.

Section 7

Product Concepts

N/A

Section 8

Superior Product Concepts

N/A

Section 9

Competitive Patent Analysis

DDDA is an intermediate chemical used in a variety of end products, such as antiseptics, top-grade coatings, surfactants, painting materials, plastics and more. As previously mentioned, the global DDDA growth is expected to grow 5-6% annually, with much of this growth stemming from increased demand for nylon 6,12.^{9.1} Traditionally, the synthetic route of production has been the predominant method to produce DDDA, which is based on using butadiene as the starting material. This synthesis is a multi-step chemical process. Outlined in a patent owned by Invista Technologies, the process begins with a cyclotrimerization step, in which butadiene is contacted with a catalyst which is responsible for trimerization and formation of cyclododecatriene.^{9.2} Next, a reagent that contains oxygen oxidizes the cyclododecatriene into epoxycyclododecatriene. Then, this substance undergoes reduction and rearrangement steps to form a mixture of alcohol and ketone, or cyclododecanol and cyclododecanone, respectively. Finally, another catalyst is introduced to the process with nitric acid, which together react with the aforementioned products to form dodecanedioic acid (DDDA) and other unwanted byproducts such as adipic acid, etc.^{9.3} Similarly, other patents outlining this process from companies such as Exxon Mobil and DuPont have been in existence since 1959 and 1972 respectively.^{9.4,9.5}

The main disadvantage associated with the traditional synthesis process is the utilization of butadiene as a starting material. As previously mentioned, butadiene is a petrochemical that suffers extreme price volatility and uncertainty of supply because of a serious supply-demand imbalance. In addition, butadiene is a material that competes with fuel applications, further limiting the supply that is available for processes like DDDA synthesis. Lastly, the butadiene pathway presents a large environmental burden as it is associated with fossil fuel resources and

higher greenhouse gas emissions. It is clear that the traditional DDDA synthesis is not the ideal method of production in a climate where consumer demand is shifting to favor more sustainable and bio-based chemicals.

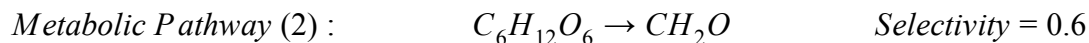
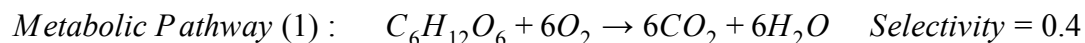
To meet the consumer requirements of chemicals that are more sustainably produced and renewable, a company called Verdezyne developed the first-ever DDDA production process that does not utilize butadiene as a starting point. This fermentation process utilizes a microorganism or yeast as the basis for the bio-based production route. Outlined in a patent filed in 2014 by Verdezyne, the yeast can be used across a multitude of different commercial feedstocks.^{9.6} This allows the flexibility to choose feedstocks that do not compete with food or fuel applications, leading to the utilization of feedstocks that cost less and are not subject to price volatility or uncertainty of supply. This flexibility also allows for the use of renewable and bio-based feedstocks, which provides a huge competitive advantage over the traditional petrochemical process. Ensuring the performance of the technology, Verdezyne's patent also claims to target DDDA with exceptionally high selectivity.^{9.7} Lastly, the DDDA produced from this process is identical in functionality and structure to the DDDA produced from the traditional butadiene process.^{9.8} Thus, there is no change required to the downstream equipment or processes for filtration and crystallization. If time were available for further economic analysis, the recovery of adipic acid, suberic acid and sebacic acid from this process could be investigated in order to sell these byproducts for profit. From both a chemical and an economic standpoint, the process developed by Verdezyne has extreme advantages over the traditional process. This report will further investigate the economic viability of scaling up and utilizing this process to produce 14,000 metric tons of DDDA per year.

Section 10

Preliminary Process Synthesis

Section 10.1: Growth Fermenter

In order to produce DDDA through metabolism of palm oil, cell biomass must first be accumulated in the preceding three growth fermenters. All three growth fermenters (1m³, 10m³, and 100m³) rely on the same assumptions regarding metabolism and conversion of the glucose feed stock into biomass. It was determined that conventional dry mass conversion rates of glucose substrate to cell mass would apply for the genetically modified *Candida sp* yeast strain. Therefore the consumption of glucose was modeled using the stoichiometric balances below, with a 0.4 selectivity towards Metabolic Pathway (1) and a 0.6 selectivity toward Metabolic Pathway (2). Metabolic Pathway (2) represents conversion to biomass, where biomass is modeled as CH_2O . These balances were developed with the aid of Professor Vrana.



It is assumed that all nitrogen needs of the cell mass are met by the media and solubilized gases supplied to the fermentation vessel via the agitator.

Section 10.2: Production Fermenter

Once adequate cell mass has accumulated in the growth fermenter and is transferred into the 500m³ production fermenter, the pH of the broth can be set to approximately 5.8 using NaOH and a feed of long chain fatty acid feedstock (in this case palm oil) in order to induce a metabolic shift towards diacid production.^{10.1} Unlike the consumption of glucose, information surrounding

the stoichiometric conversion of palm oil is not readily available. Additional complications arise when taking into consideration the inhomogeneous nature of this feed stock.

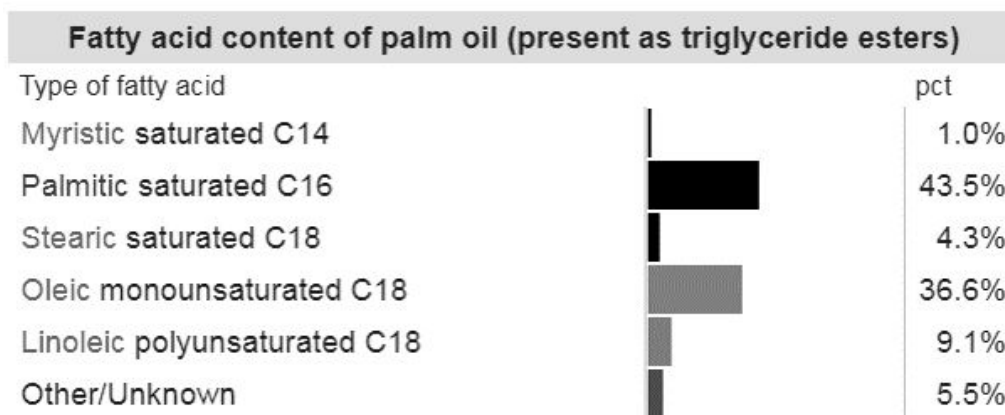


Figure 10.1: Table of palm oil fatty acid content

Palm oil is composed of a variety of fatty acids esterified with glycerol to form triglycerides. These fatty acids concentrations vary depending on a multitude of environmental factors. Therefore, in order to produce stoichiometric conversions, palm oil was modeled as being a triglyceride consisting of its major component, the 16-carbon saturated fatty acid, palmitic acid.^{10.2} As shown in Figure 10.1, palm oil also has high concentrations of monounsaturated C18 oleic acid, but for clarity and due to these fatty acids' similarity, this was omitted in the calculations. As seen in Figure 10.2, the fractional conversion of palm oil to diacid products was based upon available patent information that highlight the yeast strains' high level of specificity surrounding conversion to an individual diacid.^{10.4} Through inhibition of β -oxidation metabolic pathways, the mixed chain-length fatty acid feedstock can be converted to a single diacid product with a specificity of upwards of 90%.^{10.5}

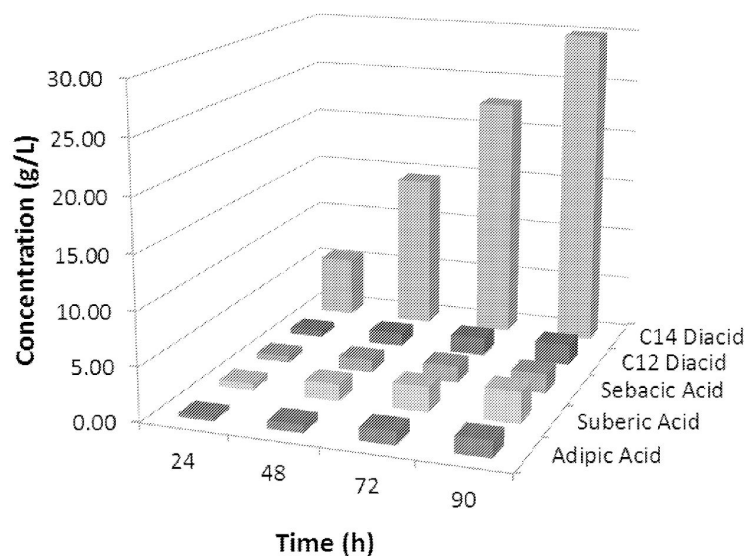


Figure 10.2: Diacid Product Distribution. Graph indicating the high fractional conversion of mixed chain-length fatty acid feedstock to the desired diacid. In this case C14 diacid was selected, however this can be changed through selective genetic engineering of the inoculated yeast strain.

The production of DDDA and associated diacid coproducts was modeled using four reactions, which are shown in Figure 10.3. The production of DDDA makes up the majority (>90%) of the reactions taking place in the vessel once the diacid production has been induced via the pH change. The remaining coproduct reactions were determined by patent information to be relatively evenly distributed.^{10.6} It is important to note that the production of additional biomass is considered to be negligible within the production fermenter and was thus omitted. These reactions outlined in Figure 10.3 are believed to provide an adequate approximation of palm oil conversion and are consistent with the extremely aerobic nature of the process.

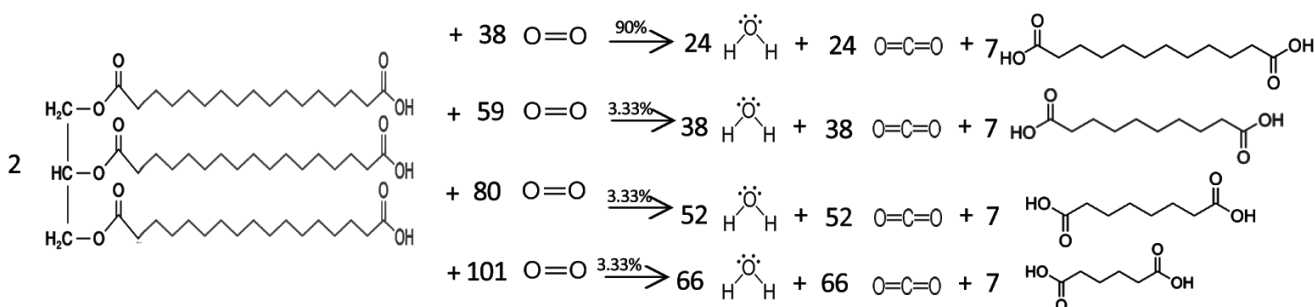


Figure 10.3: Indication of fermentation stoichiometry used for feedstock conversion

Section 10.3: Biomass Separation & Dissolution

Due to the nature of the yeast strain used, all polycarboxylic acids formed in production fermenter are produced extracellularly and precipitate into the fermentation broth. This broth is then fed into a surge tank for continuous downstream processing. Determined from ASPEN data, DDDA's solubility in water is extremely low at 30 mg/L at 25°C. This is consistent for all diacids within the broth. Therefore, the first stage of continuous downstream processing is the filtration of the broth in order to cake the diacids and biomass. This was accomplished through the use of two vacuum rotary drum filters operated in parallel. The resulting cake is roughly 30% by weight water, and thus is conveyed to an evaporator operation in order to produce dry cake for the dissolution operation. This water can be vented to the atmosphere, while the filtered water from the fermentation broth is safe for downstream sterilization and disposal in line with industry standards for palm oil extraction and processing. This will be discussed in greater depth in later sections.

While the diacids in this operation are extremely insoluble in water at all temperatures, their solubility is much higher in heated organic solvents, as seen from ASPEN data in Figure

10.4. By mixing the dry cake with 70°C ethyl acetate, the desired product is solubilized and then the non-diacid impurities and cell mass are filtered off. This ethyl acetate can then be processed to recover the final DDDA product. Further processing is required to purify the DDDA from other diacid impurities.

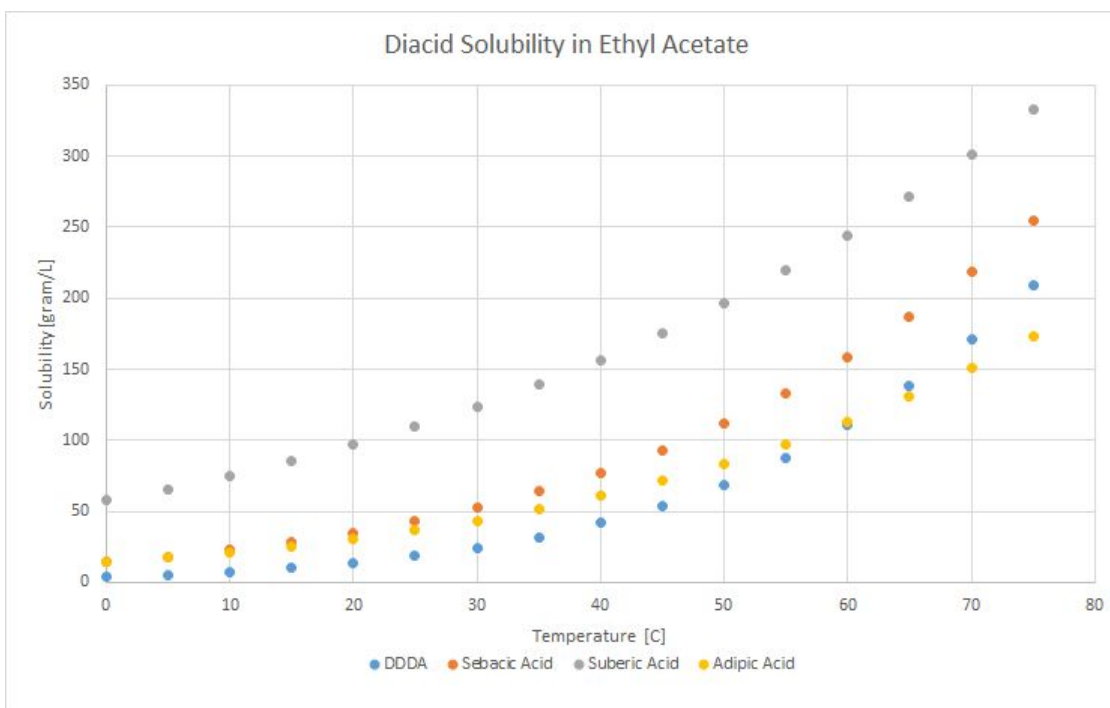


Figure 10.4: Graph of diacid solubility in ethyl acetate as a function of temperature

Section 10.4: Evaporative Crystallization

The downstream processing of the ethyl acetate and solubilized diacid relies on the evaporation of the organic solvent in order to crystallize out the product from a supersaturated solution. The boiling point of ethyl acetate is 77°C at 1 atm. Using an evaporative crystallizer, the mixture is heated to produce ethyl acetate vapor to be condensed and recycled, and a supersaturated ethyl acetate slurry is fed to a direct heat rotary drier to fully dry the powered ethyl acetate. This crystal mixture contains DDDA and quantities of sebacic acid, suberic acid,

and adipic acid. Unfortunately, due to the extremely similar solubilities of all four diacids, it was infeasible to purify the DDDA during the evaporative crystallizer process. In order to produce the desired >99% purity DDDA required of the project statement, a final downstream unit operation is required to separate the various diacids by melting point.

Section 10.5: Melt Crystallization

As stated above, solubility variations were not deemed as an adequate or feasible method by which to separate the diacid impurity (sebacic acid, suberic acid, and adipic acid). The cross-over between the DDDA and adipic acid solubility curves in Figure 10.4 further illustrates this point. Therefore, the diacid separation took inspiration from the separation of para-xylene from xylene mixture via crystallization as discussed by H.A. Mohameed.^{10.7} By taking advantage of the melting point variation between the diacids, liquid DDDA can be separated from the higher melting point diacids. As shown in Table 10.1, DDDA has the lowest melting point of the four diacids of interest. This runs opposite the para-xylene separation process (paraxylene has the highest melting point); however, the same principle applies.

Table 10.1: Illustrates the variation of diacid melting temperatures

| Diacid | Melting Point [°C] |
|--------------|--------------------|
| DDDA | 127 |
| Suberic Acid | 141 |
| Adipic Acid | 152 |
| Sebacic Acid | 268 |

The melt crystallizer tank receives the powdered diacids via conveyor belt and continuously agitates them while heating them to a homogenous temperature of 135°C. This allows for the DDDA to melt while minimizing the diacid impurity. However, this relies on the assumption that the solubility of the other diacids in the liquid DDDA is negligible. While this is a large assumption, no readily available information contradicts this statement. For the purposes of the DDDA separation to achieve >99% purity, additional lab scale research is required.

Section 11

Assembly of Database

Section 11.1: Input Costs

In order to produce DDDA through this process, palm oil, glucose, water and media are required as inputs. The water purchase price was obtained from Chapter 16 of *Seider et. al, 2017*.^{11.1} The prices of palm oil and glucose were found to be \$0.696 per kg and \$0.180 per kg from commodity markets.^{11.2,11.3} The price of media was priced as \$0.027 per kg, as derived from patent data^{11.4}. In addition, we found the palm oil price through online markets to range between \$5/kg to \$10/kg, and utilized a middle price of \$7/kg to provide a more realistic estimation.^{11.4}

Section 11.2: Aspen Simulation Specifications

This process required modeling of the upstream fermentation process in Excel, whereas the downstream filtration and crystallization processes were modeled in ASPEN Plus v10. Our team first modeled the upstream batch process with SuperPro Designer v7.5; however, due to the lack of kinetic information, it was more appropriate to model the process stoichiometry in Excel. Our team then used ASPEN Plus v10 to model the entire continuous downstream process consisting of filtration and crystallization. In order to account for non-ideal properties in the simulation, the non-random two-liquid model (NRTL) was used. Following a guide to choose the correct model from *Separation Process Engineering* written by Wankat, NRTL was chosen because of the presence of water as a second liquid phase, the higher molecular weight compounds present in our process, and the polar interactions that exist between the compounds.^{11.6} Our process consists of solid, liquid and gaseous interactions. For example, DDDA product is recovered as a solid, the slurry entering the crystallization unit is in the liquid phase, and the ethyl acetate is in the vapor phase after being evaporated from the crystallization

unit. Because of all of these considerations, the equations of state generated by the NRTL model most accurately match and represent the phase equilibria considerations in our process.^{11.7}

The downstream design simulation is broken up into a filtration and crystallization section. The filtration section mainly consists of four rotary drum filters and an evaporator in order to separate out water and biomass from the mixture and recover DDDA into the ethyl acetate stream; the final stream leaving this ASPEN simulation thus contains diacids solubilized in ethyl acetate. Primarily, the four rotary drum filters are modeled by SSplit blocks. The first SSplit block B1 models two rotary drum filters in series, in which water is separated out of the incoming stream. The evaporator modeled by Flash2 block B2 is then necessary to remove all of the remaining water after the first SSplit block. The heat exchanger used to model the heating up of the ethyl acetate temperature to its optimal temperature is modeled by the Heater block B11. The RStoic block B4 is used to model the solubilization of diacids into the ethyl acetate. The last two SSplit blocks B5 and B7 then effectively separate the biomass out of the process and help recover any DDDA that did not solubilize into the ethyl acetate in the previous steps.

The operating conditions for the rotary filters and the incoming ethyl acetate streams are determined by the utilization of design specifications. The vacuum rotary drum filter is set to operate so that the resulting wet cake contains 30% water by mass flow. The fresh ethyl acetate stream is set to feed at a rate that will allow the combined ethyl acetate stream to be at a mass flow rate that is seven times the flow of the solubilized diacids. This allows our team to control for the solubility of diacids in the ethyl acetate stream.

The downstream crystallization portion mainly is modeled by an initial evaporation stage, an additional evaporation stage, a melting stage, a filtration step, and a cooling step. The primary evaporative crystallization step is modeled mainly by RStoic block B1, Flash2 blocks B3 and B9 and SSplit block B7. These blocks collectively model the evaporation of most of the ethyl acetate in the process and the subsequent crystallization of the DDDA and other diacids. Additionally, Flash2 block B10 accounts for the condensation of the ethyl acetate vapor into liquid so that it may be recycled earlier in the upstream filtration process. The next step contains another evaporation process, in which the remaining ethyl acetate is vaporized from the remaining wet cake of diacids. This process is modeled primarily by Flash2 blocks B13 and B14. After all of the ethyl acetate is separated from the solid diacids, it is essential to separate DDDA from the remaining diacids. This is depicted by the melt tank stage, in which RStoic block B18 models the phase change of DDDA from solid to liquid. The tank is at a temperature in between the melting point of DDDA and the other three diacids, which allows for the melting of solid DDDA into a liquid. Next, the direct-heat rotary drum filter is modeled by SSplit block B20, which separates the liquid DDDA from the rest of the diacids which are in solid form. Lastly, the flaker is modeled by RStoic block B24. The main purpose of this block is to cool the DDDA liquid into a solid to recover it as a final solid product. The reactor is set at 60°C. In addition to these main blocks, there are several other pumps throughout the process to carry the streams through pipes. These pipes are all operating at 3 bar.

Operating conditions for the evaporative crystallizers were determined by utilization of design specifications and specifying the temperature. The evaporative crystallizer blocks were modeled so that the resulting slurry contained 25% solid and 75% liquid ethyl acetate, in order

for the mixture to be transported. The temperature was also specified to be 86 °C to be above the boiling point of ethyl acetate and ensure evaporation of the substance.

Section 12

Process Flow Diagrams and Material Balance

The process flow diagrams presented in the below Figures illustrate the process of DDDA production and purification. Figures 12.1 through to 12.5 illustrate the batch-wise production of biomass and DDDA and associated media sterilization process. Figures 12.1-12.3 shows a closeup of a single fermentation train, including all equipment required for a single seed fermenter and pair of production fermenters. Figures 12.3-12.4 indicate how these batches are scheduled and integrated into a continuous downstream purification process. Figures 12.6-12.7 outline the downstream purification and crystallization of DDDA. Associated Tables outlining flow rate information are also included.

Full Process Outline

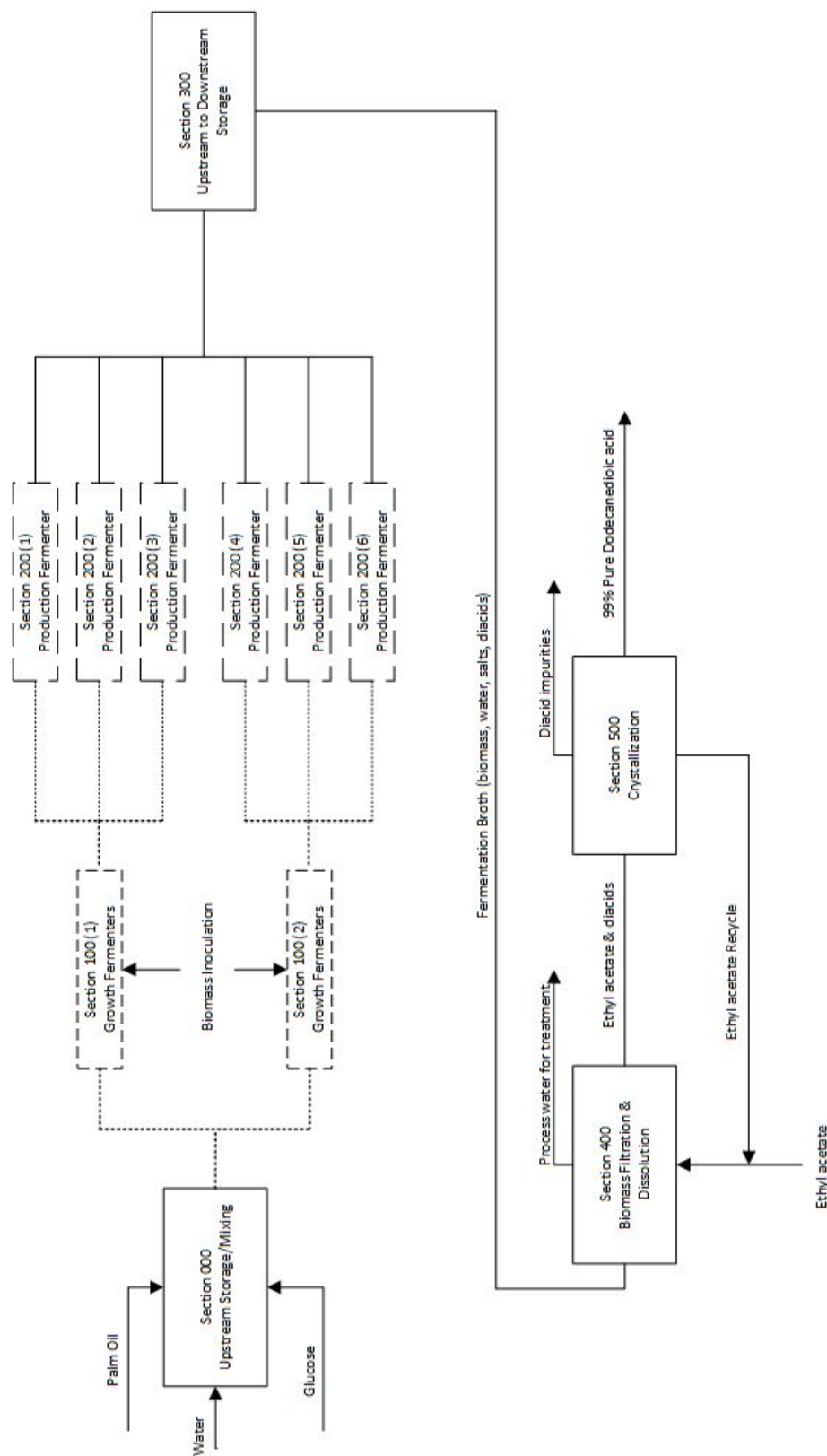


Figure 12.0: Overall process flow diagram. Includes black box approximations of all major processing steps and associated feeds. Dotted lines and boxes represent batch processes and/or parallel process trains. Solid lines represent continuous processes. Detailed stream and equipment information outlined in Figures 12.1-12.7 and Tables 12.1-12.4. Written Process description available in Section 13.

Section 000- Upstream Storage/Mixing

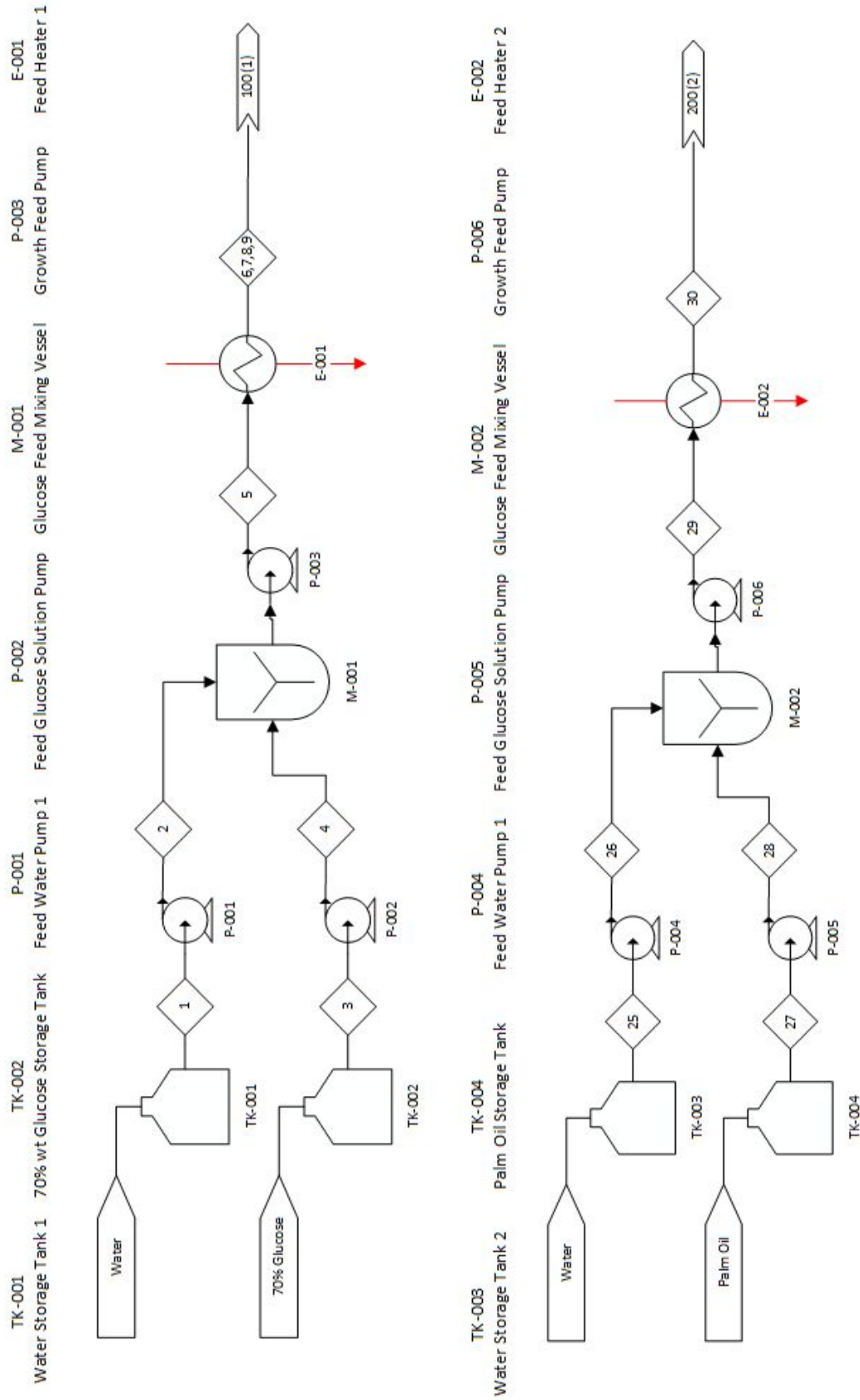


Figure 1: Process flow diagram for glucose, water, and palm oil storage and downstream feeding. Red streams indicate steam heating. Blue streams indicate chilled water feeding.

Section 100- Growth Fermenters

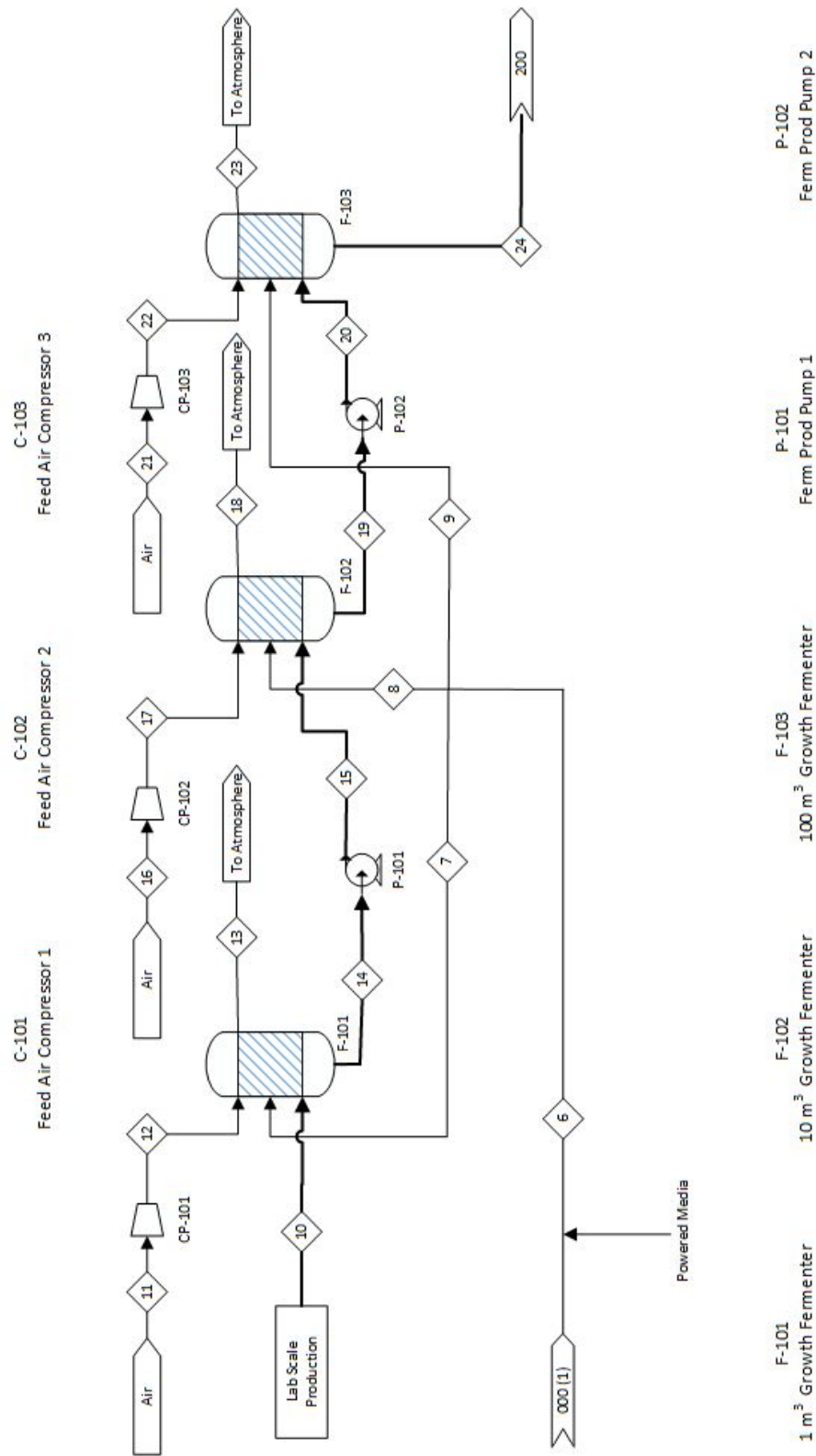


Figure 12.2: Process flow diagram for a single growth fermentation train. Includes all required equipment, including the equipment shared among the two growth trains. Bolded streams indicate streams with contain the genetically altered *Candida* yeast strain for future DDA production. Red streams indicate steam heating. Blue streams indicate chilled water feeding. Blue outlines indicate fermentation cooling jackets (see Energy Balance and Utility Requirements).

Table 12.1: Batch Growth Fermentation Section Stream Report

| STREAM ID: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 |
|---|---------------|---------------|--------------|--------------|---------------|---------------|------------|--------------|---------------|-----------|--------------|
| Temperature (C) | 25 | 25 | 25 | 25 | 25 | 37 | 37 | 37 | 37 | 37 | 37 |
| Pressure (Bar) | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Total Mass (kg/batch) | 82,666 | 82,666 | 8,585 | 8,585 | 91,251 | 91,251 | 830 | 8,335 | 83,349 | 88 | - |
| Component Flow (kg/batch) | | | | | | | | | | | |
| Water | 82,666 | 82,666 | 2,576 | 2,576 | 85,242 | 85,242 | 765 | 7,680 | 76,797 | 85 | - |
| Glucose | 0 | 0 | 6,010 | 6,010 | 6,010 | 6,010 | 54 | 541 | 5,415 | 0 | - |
| Media/Salts | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 114 | 1,137 | 1 | - |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | - |
| Gas Flow Rate (m³/hr) | | | | | | | | | | | 34.44 |
| Air | - | - | - | - | - | - | - | - | - | - | 34.44 |
| Oxygen | - | - | - | - | - | - | - | - | - | - | N/A |
| Nitrogen | - | - | - | - | - | - | - | - | - | - | N/A |
| Carbon Dioxide | - | - | - | - | - | - | - | - | - | - | 0 |
| Water Vapor | - | - | - | - | - | - | - | - | - | - | 0 |

| STREAM ID: | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | |
|---|-------------|------------|------------|--------------|--------------|--------------|--------------|----------------|----------------|---------------|--|
| Temperature (C) | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | |
| Pressure (Bar) | 1 | 1 | 3 | 3 | 1 | 1 | 3 | 3 | 1 | 1 | |
| Total Mass (kg/batch) | - | 865 | 865 | - | - | 8,687 | 8,687 | - | - | 86,903 | |
| Component Flow (kg/batch) | | | | | | | | | | | |
| Water | - | 820 | 820 | - | - | 8,203 | 8,203 | - | - | 82,033 | |
| Glucose | - | 0 | 0 | - | - | 0 | 0 | - | - | 0 | |
| Media/Salts | - | 11 | 11 | - | - | 125 | 125 | - | - | 1,262 | |
| Biomass | - | 34 | 34 | - | - | 359 | 359 | - | - | 3,608 | |
| Gas Flow Rate (m³/hr) | 36.2 | - | - | 345.8 | 363.4 | - | - | 3,457.7 | 3,633.7 | - | |
| Air | N/A | - | - | 345.8 | N/A | - | - | 3,457.7 | N/A | - | |
| Oxygen | 7.5 | - | - | N/A | 75.6 | - | - | N/A | 756.2 | - | |
| Nitrogen | 26.0 | - | - | N/A | 260.7 | - | - | N/A | 2,606.7 | - | |
| Carbon Dioxide | 1.15 | - | - | 0 | 11.6 | - | - | 0 | 115.5 | - | |
| Water Vapor | 1.55 | - | - | 0 | 15.5 | - | - | 0 | 155.2 | - | |

Section 200- Diacid Production Fermenters

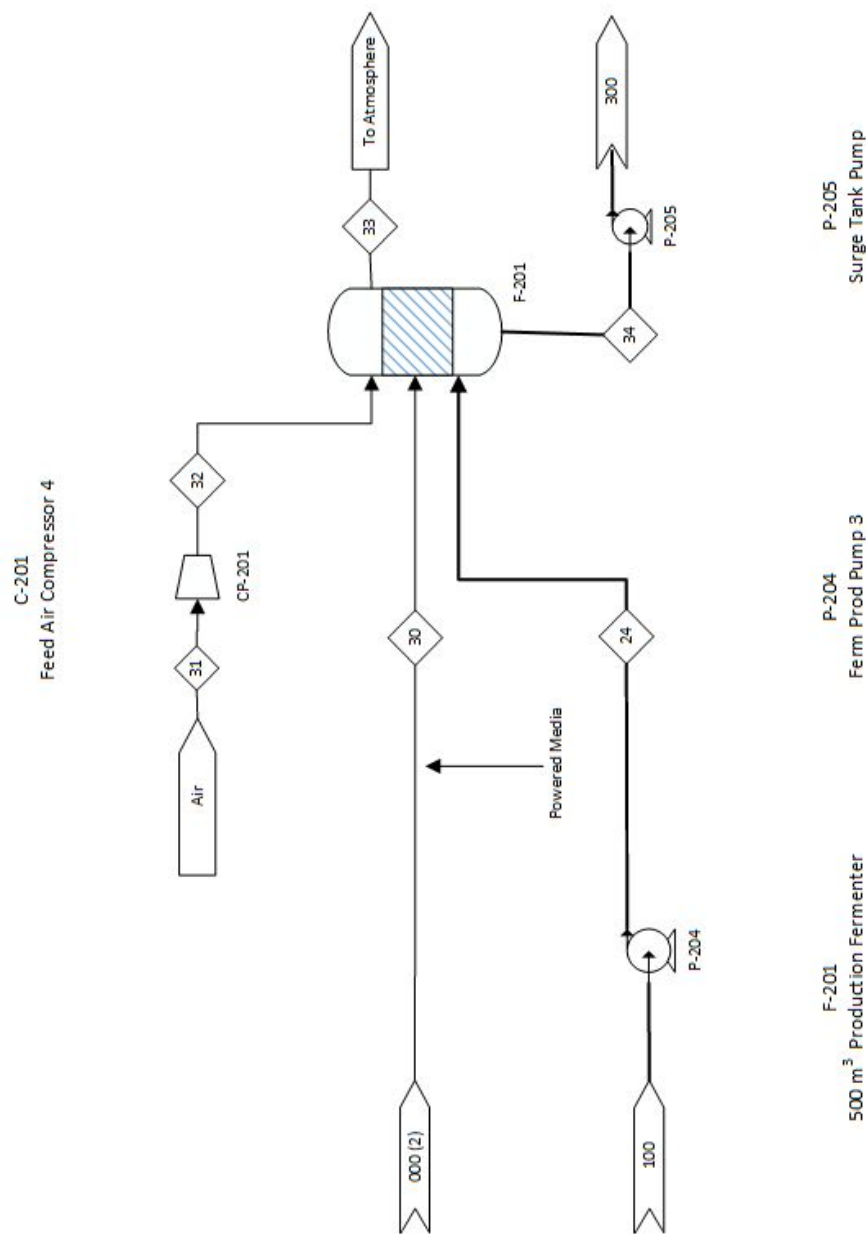


Figure 12.3: Process flow diagram for a single production fermentation train. Includes all required equipment, including the equipment shared among the six production trains. Bolded streams indicate streams with contain the genetically altered *Candida* yeast strain and excreted DDDA. Red streams indicate steam heating. Blue outlines indicate fermentation cooling jackets.

Table 12.2: Batch Production Fermentation Section Stream Report

| STREAM ID: | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 32 | 33 | 34 | |
|---|---------------|----------------|----------------|---------------|---------------|----------------|----------------|--------|---------|----------------|--|
| Temperature (C) | 37 | 25 | 25 | 25 | 25 | 25 | 37 | 37 | 37 | 37 | |
| Pressure (Bar) | 1 | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 1 | 3 | |
| Total Mass (kg/batch) | 86,903 | 342,967 | 342,967 | 79,020 | 79,020 | 421,987 | 429,498 | - | - | 420,149 | |
| Component Flow (kg/batch) | | | | | | | | | | | |
| Water | 82,033 | 342,967 | 342,967 | | | 342,967 | 342,967 | - | - | 341,816 | |
| Palm Oil | 0 | 0 | 0 | 79,020 | 79,020 | 79,020 | 79,020 | - | - | 0 | |
| Media/Salts | 1,262 | 0 | 0 | 0 | 0 | 0 | 7,511 | - | - | 8,773 | |
| Biomass | 3,608 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 3,608 | |
| DDDA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 59,358 | |
| Sebacic acid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 2,198 | |
| Suberic acid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 2,198 | |
| Adipic acid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 2,198 | |
| Gas Flow Rate (m³/hr) | - | - | - | - | - | - | - | 16,974 | 17,621 | - | |
| Air | - | - | - | - | - | - | - | 16,974 | N/A | - | |
| Oxygen | - | - | - | - | - | - | - | 0 | 3,712.3 | - | |
| Nitrogen | - | - | - | - | - | - | - | 0 | 12,796 | - | |
| Carbon Dioxide | - | - | - | - | - | - | - | 0 | 360.2 | - | |
| Water Vapor | - | - | - | - | - | - | - | 0 | 752.5 | - | |

Section 300- Plant-wide Production/Storage

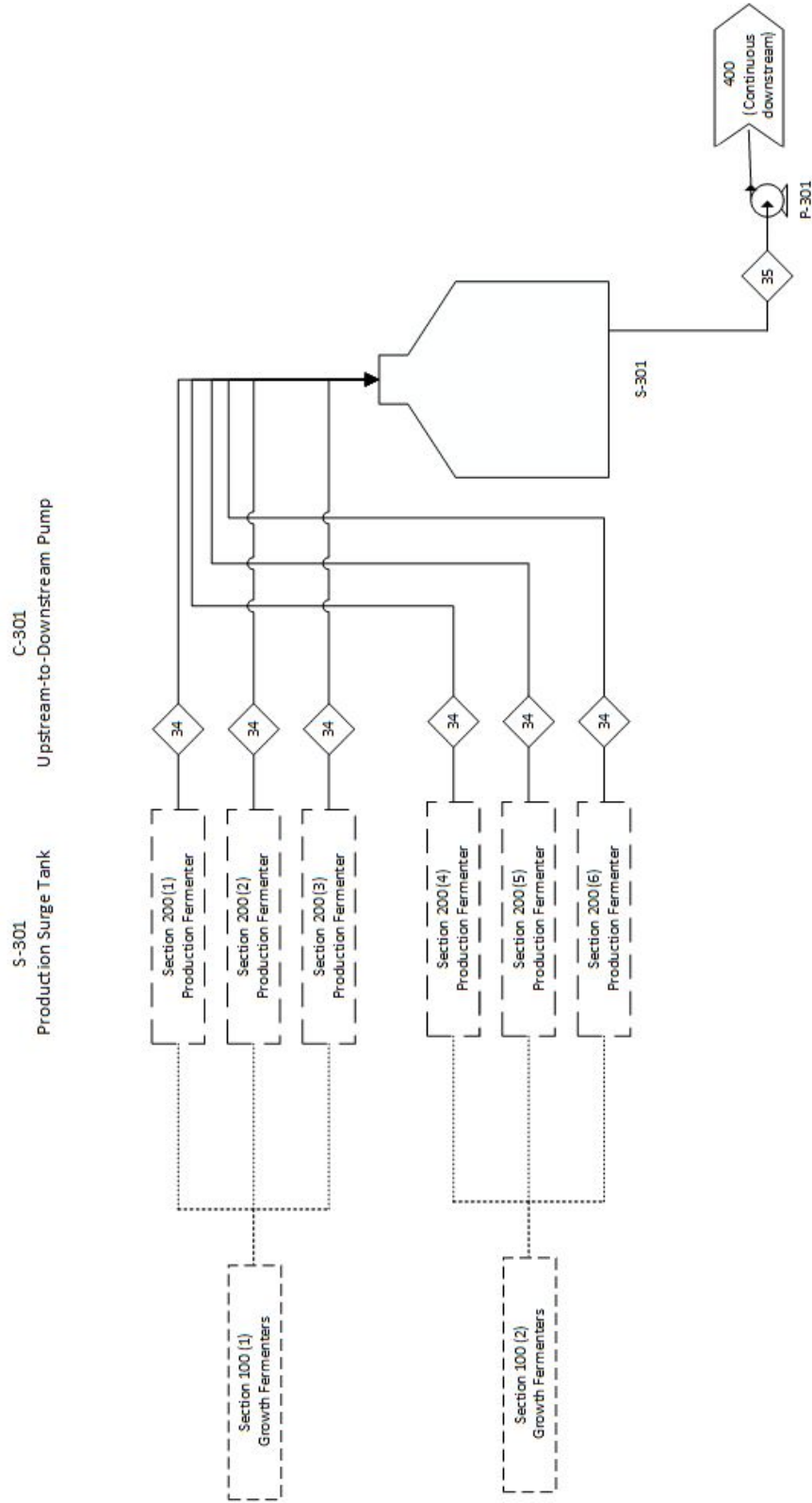
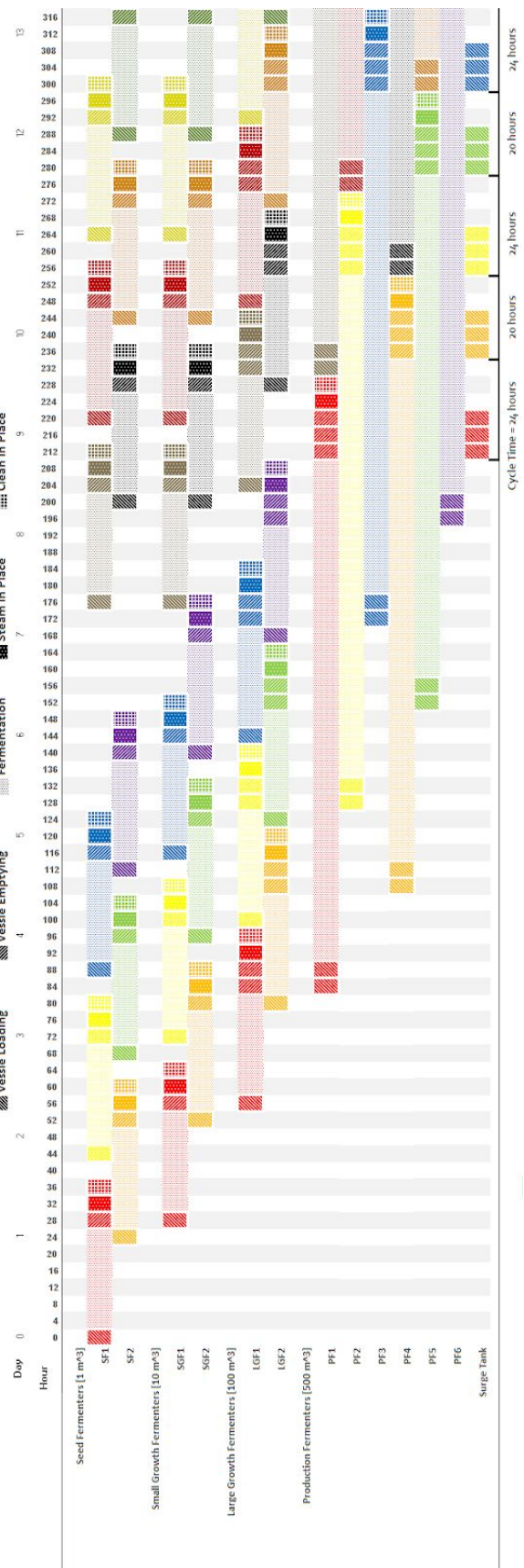
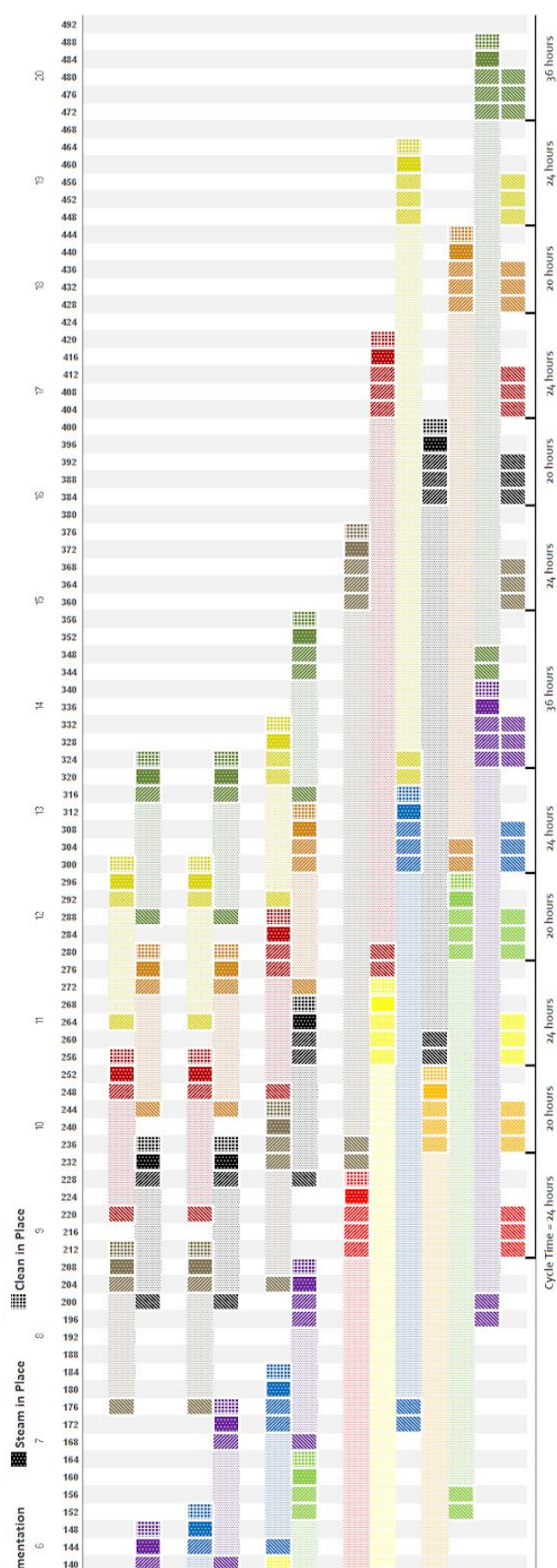


Figure 12.4: Process flow diagram for all batch operations (growth and DDDA production). Each growth train indicated with a wide dashed box. Dashed lines indicate parallel alternating feed and all solid streams indicate dedicated flow to the production surge tank

Figure 12.5: Fermentation Batch Scheduling. Average Cycle Time of 24 hours. Batch Time of 220 hours. Estimated 236 batches/year to meet 14,000 MT goal.



5 batches/year to meet 14,000 MT goal.



Section 400- Biomass Filtration

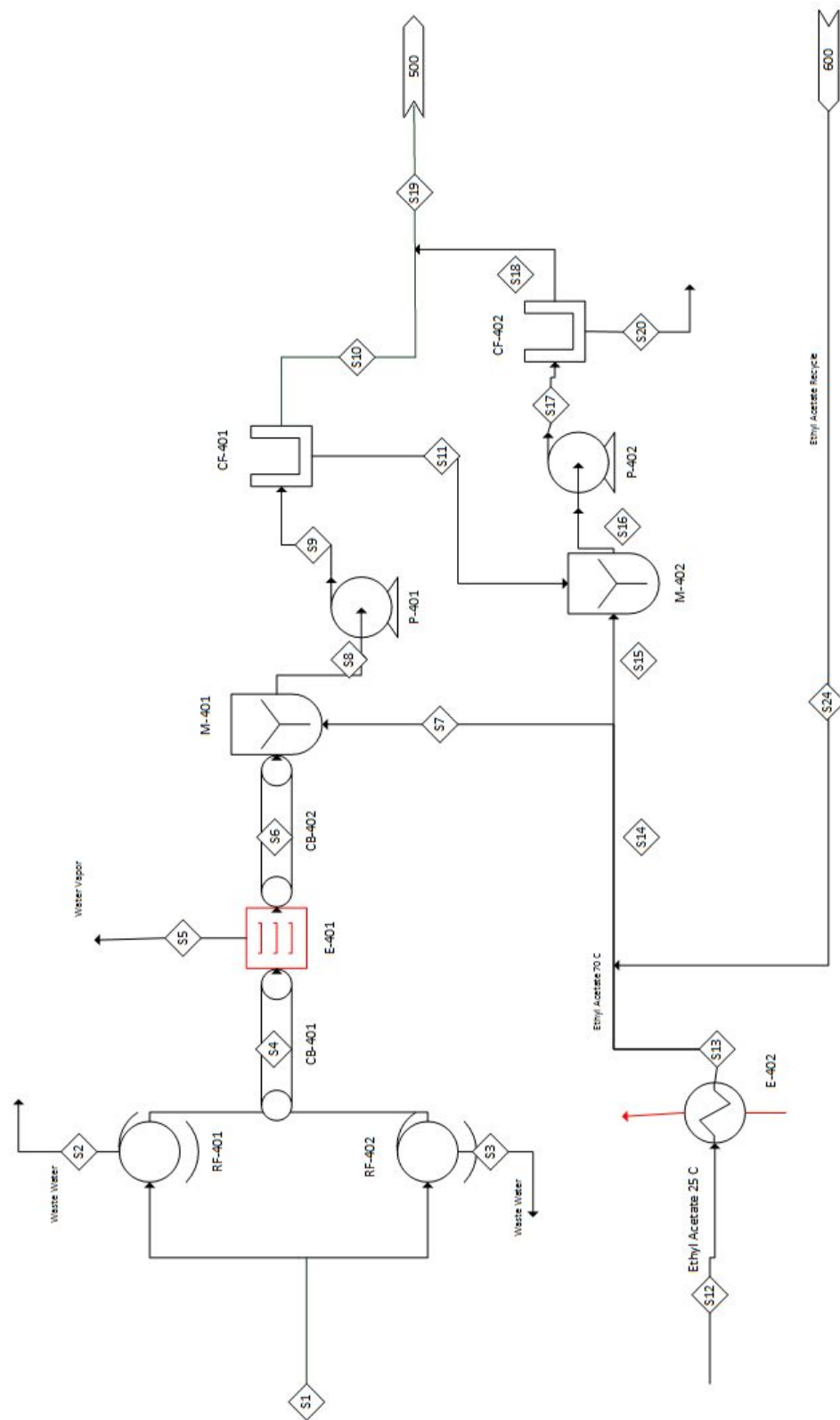


Figure 12.6: Process Flow Diagram for continuous downstream processing of fermentation broth including all associated equipment. Red streams indicate steam heating

Table 12.3: Biomass Filtration Stream Report

| STREAM ID: | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 |
|---------------------------|----------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|----------------|----------------|--------------|
| Temperature (C) | | 37 | 37 | 37 | 115 | 70 | 70 | 70 | 70 | 70 | 70 |
| Pressure (Bar) | | 3.43 | 3.43 | 3.43 | 1 | 1 | 1 | 4 | 5 | 1 | 1 |
| Vapor Fraction | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Total Flow (kg/hr) | 15359.9 | 5873.6 | 5873.6 | 3612.7 | 1087.6 | 2525.1 | 16629.4 | 19154.5 | 19154.5 | 18905.3 | 249.2 |
| Component Flow (kg/hr) | | | | | | | | | | | |
| DDDA | 2148.5 | 5.4 | 5.4 | 2137.8 | | 2137.8 | | 2137.8 | 2137.8 | 2126.6 | 11.2 |
| Sebacic Acid | 79.7 | 0.2 | 0.2 | 79.3 | | 79.3 | | 79.3 | 79.3 | 78.9 | 0.4 |
| Suberic Acid | 79.7 | 0.2 | 0.2 | 79.3 | | 79.3 | | 79.3 | 79.3 | 78.9 | 0.4 |
| Adipic Acid | 79.7 | 0.2 | 0.2 | 79.3 | | 79.3 | | 79.3 | 79.3 | 78.9 | 0.4 |
| Water | 12822.1 | 5867.2 | 5867.2 | 1087.6 | 1087.6 | | | | | | |
| Ethyl Acetate | | | | | | | 16629.4 | 16629.4 | 16629.4 | 16542.2 | 87.2 |
| Biomass | 150.2 | 0.4 | 0.4 | 149.5 | | 149.5 | | 149.5 | 149.5 | | 149.5 |

| STREAM ID: | S12 | S13 | S14 | S15 | S16 | S17 | S18 | S19 | S20 | S24 |
|---------------------------|---------------|---------------|-----------------|-----------|------------|------------|------------|--------------|------------|----------------|
| Temperature (C) | | 25 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| Pressure (Bar) | | 1 | 1 | 4 | 4 | 5 | 1 | 1 | 1 | 3 |
| Vapor Fraction | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total Flow (kg/hr) | 737.26 | 737.26 | 16716.66 | 87 | 336 | 336 | 185 | 19090 | 151 | 15979.4 |
| Component Flow (kg/hr) | | | | | | | | | | |
| DDDA | | | | | 11.2 | 11.2 | 11.10 | 2138 | 0 | |
| Sebacic Acid | | | | | 0.4 | 0.4 | 0.42 | 79 | 0 | |
| Suberic Acid | | | | | 0.4 | 0.4 | 0.42 | 79 | 0 | |
| Adipic Acid | | | | | 0.4 | 0.4 | 0.42 | 79 | 0 | |
| Water | | | | | | | | | | |
| Ethyl Acetate | 737.26 | 737.3 | 16716.66 | 87.3 | 174.5 | 174.5 | 172.7 | 16714.9 | 1.7 | 15979.4 |
| Biomass | | | | | 149.5 | 149.5 | | | 149.5 | |

Table 12.4: Crystallization Section Stream Report

| STREAM ID: | S19 | S20 | S21 | S22 | S23 | S24 | S25 | S26 | S27 | S28 | S29 |
|------------------------------|---------------|---------------|----------------|---------------|---------------|---------------|----------------|--------------|--------------|--------------|--------------|
| Temperature (C) | 70.00 | 86.00 | 86.00 | 76.73 | 76.73 | 76.73 | 95.47 | 86.13 | 86.13 | 86.13 | 115.0 |
| Pressure (Bar) | 3.00 | 1.34 | 1.34 | 1.34 | 1.34 | 3.00 | 3.76 | 3.76 | 3.43 | 3.76 | 1.01 |
| Total Mass (kg/batch) | 18,994 | 15,045 | 189,524 | 15,045 | 15,979 | 15,979 | 180,048 | 9,476 | 5,528 | 3,948 | 2,369 |
| Component Flow (kg/hr) | | | | | | | | | | | |
| Ethyl Acetate | 16,625 | 15,045 | 142,143 | 15,045 | 15,979 | 15,979 | 135,036 | 7,107 | 5,528 | 1,579 | 0 |
| DDDA | 2,132 | 0 | 42,637 | 0 | 0 | 0 | 40,505 | 2,132 | 0 | 2131.837 | 2,132 |
| Sebacic Acid | 79.1 | 0 | 1,581 | 0 | 0 | 0 | 1,502 | 79.1 | 0 | 79.1 | 79.1 |
| Suberic Acid | 79.1 | 0 | 1,581 | 0 | 0 | 0 | 1,502 | 79.1 | 0 | 79.1 | 79.1 |
| Adipic Acid | 79.1 | 0 | 1,581 | 0 | 0 | 0 | 1,502 | 79.1 | 0 | 79.1 | 79.1 |
| Nitrogen | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |

| STREAM ID: | S30 | S31 | S32 | S33 | S34 | S35 | S36 | S37 | S38 | S39 | S40 |
|---------------------------|--------------|------------|--------------|--------------|--------------|--------------|----------|-----------|--------------|----------|--------------|
| Temperature (C) | 135.2 | 135.2 | 135.2 | 135.2 | 135.2 | 60.0 | 25.0 | 115.0 | 115.0 | 115.0 | 76.73 |
| Pressure (Bar) | 3.43 | 1.01 | 2.74 | 2.74 | 2.74 | 1.01 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| Total Mass (kg/hr) | 4,343 | 395 | 3,948 | 1,974 | 1,974 | 1,974 | 3 | 51 | 1,630 | 5 | 1,577 |
| Component Flow (kg/hr) | | | | | | | | | | | |
| Ethyl Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20.7 | 1,600 | 2.30 | 1,577 |
| DDDA | 4,106 | 158 | 3,947 | 1974 | 1,974 | 1,974 | 0 | 0 | 0 | 0 | 0 |
| Sebacic Acid | 79.2 | 79.0 | 0.1 | 0.05 | 0.05 | 0.05 | 0 | 0 | 0 | 0 | 0 |
| Suberic Acid | 79.2 | 79.0 | 0.1 | 0.05 | 0.05 | 0.05 | 0 | 0 | 0 | 0 | 0 |
| Adipic Acid | 79.2 | 79.0 | 0.1 | 0.05 | 0.05 | 0.05 | 0 | 0 | 0 | 0 | 0 |
| Nitrogen | 0 | 0 | 0 | 0 | 0 | 0 | 3.32 | 29.86 | 29.86 | 2.95 | 0.00 |

| STREAM ID: | S41 | S42 | S43 | | | | | | | | |
|------------------------------|---------------|------------|-----------|--|--|--|--|--|--|--|--|
| Temperature (C) | 76.73 | 76.73 | 115.0 | | | | | | | | |
| Pressure (Bar) | 1.38 | 1.70 | 2.74 | | | | | | | | |
| Total Mass (kg/batch) | 16,141 | 161 | 47 | | | | | | | | |
| Component Flow (kg/hr) | | | | | | | | | | | |
| Ethyl Acetate | 16,141 | 161 | 20.7 | | | | | | | | |
| DDDA | 0 | 0 | 0 | | | | | | | | |
| Sebacic Acid | 0 | 0 | 0 | | | | | | | | |
| Suberic Acid | 0 | 0 | 0 | | | | | | | | |
| Adipic Acid | 0 | 0 | 0 | | | | | | | | |
| Nitrogen | 0 | 0 | 26.5 | | | | | | | | |

Section 13

Process Description

Section 13.1: Feed & Feed Storage

Storage tanks are employed in order to ensure adequate supply of water and feedstock to the fermentation process. The storage tanks were sized in such a way to ensure a one and a half days supply of water, glucose solution, and palm oil to the process. This sizing ensures that with a 24 hour cycle time, the storage tanks should never be much more than 50% depleted. This is vital for ensuring that the annual batch goal is not affected by a shortage of available feedstock to the fermenters. All feedstocks are mixed prior to feed to the fermenter in order to ensure homogenous distribution of metabolites. All fermenters are filled prior to inoculation and are supplied with the appropriate quantities of media and salts. See the scheduling Gantt chart in Figure 12.5 for more information around the staggered nature of the batch feeding.

Section 13.2: Growth Fermenters

The fermentation process begins with the loading of 2.0 kg of genetically modified *Candida sp.* yeast with appropriate media into the 1 m³ fermenter. For the purposes of this report, this supply of starting biomass is assumed to be an upfront cost of lab scale production in rotary flasks that does not factor into plant-scale production. This biomass is inoculated into a continuously-agitated fermenter with a cooling jacket to ensure a stable temperature of 37°C and adequate aeration of the vessel. Ambient air passes continuously through a multistage air compressor at a rate of 34 m³/hr. This equates to just upwards of 0.57 VVM and is in line with lab scale aeration rates outlined in patent material. These flow rate were analyzed to ensure adequate supply of solubilized oxygen for conversion by the yeast strain; ten times the required stoichiometric requirement of oxygen was bubbled into the fermenter at the advice of industry

consultants. Biomass was considered to act as a biocatalyst and oxygen and substrate conversion rates were determined to be within expected ranges for the yeast strain selected. Based on lab-scale patent information, the feed concentration of solubilized glucose fed was 70.5 g/L.^{13.1} This supply was expected to be nearly fully depleted at the onset of unloading from the current tank to the loading of the next growth fermenter.

These conditions, as well as the feedstock and air flow rates were maintained for each subsequent growth fermenter. That is, each ten times scale up of the fermenter was accompanied by a ten times scale up of the ambient air and glucose feed. The 1m³ growth fermenter, as well as the 10m³ and 100m³ growth fermenter, has a holding time of 24 hours and produces biomass, carbon dioxide, and water as outlined in Section 10.1. The growth rates in each of the fermenters fell within the expected specific growth rate range (0.4-0.6 hr⁻¹) for yeast strains. In addition to the 24-hour fermentation time, the Gantt chart in Figure 12.5 accounts for the loading, unloading, and cleaning/steaming time for each fermenter. The heat produced as a product of aerobic combustion is managed by cooling jackets supplied with chilled water. This is vital for ensuring adequate temperature control on vessels due to the relative fragility of the genetically altered yeast strain used. Each batch, these chilled water jackets remove, 3.6 kW, 35.9 kW, and 358.9 kW of heat from the 1m³, 10m³, and 100m³ fermenter respectively. These three fermenters cumulative produce 3,608 kg for feed to the production fermenter. This mass, along with an accompanying 83,295 kg of fermentation broth, is then pumped into the production fermenter for conversion of palm oil feedstock into diacid feed stock. As shown in Figure 12.4 and Figure 12.5, two of these growth trains provide biomass to three production fermenter trains each. This

is made possible due to the relative holding time of the growth fermenters compared to the production fermenters.

Section 13.3: Production Fermenters

Each 500 m³ production fermenter is inoculated with 3,608 kg of cell mass supplied by a 100 m³ growth fermenter. Using pH control, these genetically engineered yeast cells can be induced to convert carbon feed stocks into specific metabolites.^{13.2} As seen in patent data, long chain fatty acids such as palm oil can be metabolized into extracellular diacid metabolites as a product of pH induction to more basic conditions.^{13.3} Keeping in line with lab scale reports, conversion to biomass is bypassed within the production fermenter and the cells are modeled to exclusively convert palmitic triglyceride to diacids, carbon dioxide, and water as outlined in Section 10.2. The fermentation holding time is approximately 120 hours, over which ambient air is fed at approximately 0.6 VVM (See Table 12.2). Similarly to the growth fermenters, the feedstock/water mixture is continuously agitated and bubble in order to provide adequate mixing. This is especially important for the palm oil/water interface due to their low solubility in each other. For the purposes of modeling the fatty acid conversion within the fermenter, it is presumed that the mass transfer interface between the yeast cell and the feedstock is adequate for full conversion of palm oil during the 120 hour fermentation period. Further research to validate this interfacial assumption should be done prior to project implementation. Should the palm oil not fully be consumed, it is reasonable to assume, due to their relative specific gravities that unconverted palm oil could be skimmed off the surge tank for recycle. After fermentation, the diacid-rich broth of the six production trains is pumped to a surge tank for continuous downstream filtration. These fermentation trains are scheduled in such a way that the surge tank

is sized to accommodate two full batches while as the same time discharging broth at a rate of one batch per 24 hours. This allows for accumulation variability and adds a volume buffer should upstream or downstream complications arise.

Section 13.4: Separations/Filtration

The effluent stream from Section 300 is seen as a slurry and enters section 400 to remove water and biomass. In practice, there is a high possibility the slurry contains monoacids and hydroxy acids in addition to the biomass and diacids impurities. More data and equipment is needed to remove all these impurities so for simplicity, it is assumed biomass, adipic acid (C6), suberic acid (C8), and sebacic acid (C10) are the only impurities that need to be filtered from the DDDA product.

Stream 1 is split evenly into two vacuum rotary drum filters. The drum filters collectively remove 11,734 kg/hr of water out of the initial 12,822 kg/hr. In practice, a sample of the slurry is tested to optimize what size drum and material is needed to perform the necessary filtration. These drums can also be accompanied with a filter aid (diatomaceous earth or perlite) but we have chosen not to utilize a filter aid due to the unknown effects of filter resistance, cake resistance, and cake thickness.^{13.4} The drums also remove a small amount of biomass and diacids, 0.7 kg/hr and 12 kg/hr respectively. The diacids lost will try to be recovered further downstream in the centrifuges. Stream 2 and Stream 3 are recombined into Stream 4 and are now seen as a wet cake. The wet cake is transported on a conveyor through an evaporator where it removes the remaining 1,088 kg/hr of water (Stream 5). The now dried cake (Stream 6) is transported into a mixing vessel to undergo dissolution.

Stream 7 is introduced into Stream 6 in accordance with the design specifications explained in Section 6.4. The ethyl acetate solubilizes DDDA and other diacids leaving the biomass as the only solid left in the stream to be filtered. A similar process occurs between streams 11 and 15. Stream 7 is the result of the splitting of stream 14. The split on stream 14 is 0.99 to stream 7 and 0.01 to stream 15. The ethyl acetate in the process is a mix of the recycle stream from section 500 (Stream 24) and an external feed passing through a heat exchanger (Streams 12, 13). The pure ethyl acetate streams in this process after the heat exchanger are all at 70°C (Streams 7, 13, 14, 15, 24). 1,469.9 kg/hr of steam is required at 186 C to heat 737.26 kg/hr of ethyl acetate from 25°C (Stream 12) to 70°C (Stream 13). The steam temperature is reduced 163°C after passing through the heat exchanger. Stream 14 is split to add ethyl acetate into streams 6 and 11 before centrifugation.

After the dissolution step streams 8 and 16 are passed through a centrifugal pump to prepare for centrifugation. Stream 9 goes through a large decanter centrifuge that separates 99% of the product DDDA from the biomass. Specifically, 2,126.6 kg/hr of DDDA is recovered from the initial 2,137.8 kg/hr. The lost 11.2 kg/hr of DDDA goes through another dissolution step (stream 15) and passes through a similar smaller centrifugal pump (stream 16). Stream 17, the stream entering the decanter centrifuge effectively separates similarly to stream 9. The centrifuge that stream 17 goes through is much smaller than the centrifuge stream 9 goes through due to the lower flow rate. The total flow rate of stream 9 is 19154.5 kg/hr while stream 17 is 336 kg/hr. It is assumed both centrifuges operate equally efficient despite their different sizes.

The larger decanter centrifuges separates stream 9 into stream 10 (liquid outlet) and stream 11 (solid outlet). The liquid outlet has ethyl acetate and now liquid DDDA and other

diacids. The solid outlet has all the biomass and a small percentage of DDDA and diacids. The option to recover this small percentage of diacids are considered due to the losses in the vacuum rotary drum filters and the market price DDDA and its byproducts. The solid biomass in stream 11 is fed to the minor mixing tank in order to solubilize any remaining DDDA before treatment in the smaller decanter centrifuge. The liquid outlets of both centrifuges (Stream 10, 18) are combined (Stream 19) and sent downstream to the crystallization process (section 500). Stream 19 has a flow rate of 19,090 kg/hr. This flow rate is required to solubilize the 2,132 kg/hr of DDDA that is leaving this process. The solubility of DDDA in this stream is upwards of 130 g/L. This is comparable to available patent regarding polycarboxylic acid purification techniques.^{13.5}

Section 13.5: Crystallization

The effluent stream from Section 400, Stream 19, enters Section 500 in order to initiate crystallization and separate the DDDA from the ethyl acetate and three other diacids. Stream 19 enters the kettle evaporator and is heated to 86°C to evaporate 16,622 kg/hr ethyl acetate in Stream 20 and send forward a 189,524 kg/hr mixture in Stream 21 containing crystallized DDDA, suberic acid, sebacic acid and adipic acid in ethyl acetate. A temperature of 86°C was used to ensure that the ethyl acetate in the mixture would sufficiently vaporize. Stream 20 is then passed through a condenser in order to liquify the ethyl acetate into Stream 22 to allow it to be recycled into Section 400 for reuse in filtration. Prior to recycling, Stream 22 first is combined with Stream 40, which will be discussed later in this section; these two streams combine into Stream 41 which is stored in a storage tank. The storage tank is maintained at 70°C and ambient pressure in order to ensure the ethyl acetate remains in liquid form. Each tank is constructed so

that it can contain two days flow to account for variability in upstream and downstream production. The stream effluent, Stream 23, from the storage tank is then passed through a pump at 3 bar, and this resulting Stream 24 is sent to Section 400 for recycle in filtration section.

Stream 21 is then split into two streams, 95% of which is recycled to the kettle evaporator via Stream 25, and 5% continues onto the rotary filter via Stream 26. The purpose of the recycle stream is to provide sufficient liquid to allow for 25% solids slurry in the effluent of the kettle evaporator (Stream 21) so that it can transport co-product diacid solids. The recycle is also present to provide a stream to pass the heat exchanger and heat the kettle evaporator. Next, the rotary filter is intended as a secondary method to further separate out ethyl acetate before the slurry is sent to the diacid dryer, reducing energy requirements needed to vaporize off more ethyl acetate. Leaving the rotary filter as supernatant, there is 5,528 kg/hr of ethyl acetate that is recycled via Stream 27 into the kettle evaporator. The purpose of this recycle stream is also to provide sufficient liquid to allow for a 25% solids slurry in the effluent of the kettle evaporator (Stream 21) so that it can transport co-product diacid solids. Next, Stream 28 also leaves the rotary filter and contains a 3,948 kg/hr slurry of diacids and ethyl acetate which continues onto the diacid dryer.

Stream 28 continues to the diacid dryer, where it is at a temperature of 115°C and pressure of 1 bar. This diacid dryer is present in order to evaporate off the remaining ethyl acetate from the wet cake of solid diacids. The vaporized ethyl acetate leaves in Stream 38, most of which is combined with nitrogen gas in Stream 36 to create Stream 37. This incoming stream commences the drying operation to evaporate the remaining ethyl acetate from the wet cake; it is

used as a gentle nitrogen sweep to help keep the ethyl acetate flowing out of the dryer. The dry cake of solid diacids leaves the diacid dryer in Stream 29.

The melt tank is intended to take advantage of the diacid melting points in order to separate the DDDA from the other diacids. The melt tank is kept at a temperature of 135°C, which, as mentioned previously, is maintained because it is between the melting points of DDDA and the other diacids (see Table 10.1). Then, Stream 28, the slurry of solid diacids in liquid DDDA, is pumped forward to the rotary filter in order to separate the two phases. The rotary filter results in two streams, Stream 31 and Stream 32. Stream 31, containing the solidified diacid impurities leaves the system. Stream 32 leaves the rotary filter as liquid DDDA. It is split into Stream 34 that is then sent forward to the flaker in order to chill the liquid DDDA into solid DDDA and Stream 33 which is recycled to the melt tank in order to allow for enough liquid to carry the solid co-product diacids. Stream 34 enters the flaker as a liquid and exits as solidified DDDA in Stream 35 by maintaining the stream at a temperature of 60°C. The flow rate of solid DDDA leaving the flaker for packaging and distribution is 1974 kg/hr. These meets the yearly production goal of 14,000 MT/year assuming full plant capacity and a 300 day production year.

Section 14

Energy Balance and Utility Requirements

Section 14.1: Process Utilities

Table 14.1: Net utility requirements per batch/hour (where applicable) and per operating year by process unit and utility type

| <i>Utility</i> | <i>Process Equipment ID</i> | Quantity (per hour) | Quantity (per year) | Quantity (Annual Cost) |
|--|---------------------------------|--------------------------------|--------------------------------|-----------------------------------|
| Electricity (\$0.07/kWh) | P-001 | 42.9 (kWh) | 154,486 (kW) | \$10,814 |
| | P-002 | 4.5 | 16,043 | \$1,123 |
| | P-003 | 47.4 | 170,529 | \$11,937 |
| | P-004 | 178.0 | 640,939 | \$44,866 |
| | P-005 | 41.0 | 147,673 | \$10,337 |
| | P-006 | 219.1 | 788,612 | \$55,203 |
| | (2 fermentation trains) P-101 | 1.8 x2 | 6,466 x2 | \$905 |
| | (2 fermentation trains) P-102 | 18.0 x2 | 64,937 x2 | \$9,091 |
| | (2 fermentation trains) P-204 | 180.4 x2 | 649,619 x2 | \$90,947 |
| | (6 fermentation trains) P-205 | 872.4 x6 | 3,140,706 x6 | \$1,319,097 |
| | P-301 | 191.4 | 688,912 | \$48,224 |
| | P-401 | 238.6 | 859,105 | \$60,137 |
| | P-402 | 4.2 | 15,070 | \$1,055 |
| | P-501 | 2,361.2 | 8,500,357 | \$595,025 |
| | P-502 | 49.2 | 177,077 | \$12,395 |
| | P-503 | 199.1 | 716,699 | \$50,169 |
| | P-504 | 54.1 | 194,795 | \$13,636 |
| | (2 fermentation trains) CP-101 | 3.4 x2 | 12,402 x2 | \$1,736 |
| | (2 fermentation trains) CP-102 | 34.6 x2 | 124,667 x2 | \$17,453 |
| | (2 fermentation trains) CP-103 | 346.3 x2 | 1,246,561x2 | \$174,519 |
| | (6 fermentation trains) CP-201 | 979.2 x6 | 6,119,424 x6 | \$2,570,158 |
| | CP-501 | 979.2 | 3,523,996 | \$246,750 |
| | M-001 | 3.7 | 13,482 | \$944 |
| | M-002 | 17.3 | 62,346 | \$4,364 |
| | M-401 | 3,086.6 | 11,111,679 | \$777,818 |
| | M-402 | 0.7 | 2,685 | \$188 |
| | RF-401 | 8.2 | 29,530 | \$2,067 |

| | | | | |
|----------------------------------|--------------|--------------|---------------------|--------------------|
| | RF-402 | 8.2 | 29,530 | \$2,067 |
| | RF-501 | 8.2 | 29,530 | \$2,067 |
| | RF-502 | 3.0 | 10,738 | \$752 |
| | CB-401 | 11.2 | 40,268 | \$2,819 |
| | CB-402 | 11.2 | 40,268 | \$2,819 |
| | CB-501 | 7.5 | 26,845 | \$1,879 |
| | CF-401 | 14.9 | 53,690 | \$3,758 |
| | CF-402 | 11.2 | 40,268 | \$2,819 |
| | FL-501 | 8.9 | 32,214 | \$2,255 |
| Total | | | | \$6,152,192 |
| Nitrogen | RD-501 | 7.33 (lb/hr) | 52,780 (lb/year) | \$590 |
| (\$0.01/lb) | Total | | | \$590 |
| Low Pressure Steam | E-001 | 183 (lb/hr) | 1,319,137 (lb/year) | \$7,915 |
| (50 psig) | E-002 | 2,549 | 18,352,002 | \$110,112 |
| (\$7/1000 lb) | E-401 | 2,850 | 20,517,039 | \$123,102 |
| | E-402 | 70 | 506,483 | \$3,039 |
| | KE-501/E-501 | 6,022 | 43,355,801 | \$260,135 |
| | RD-501 | 632 | 4,551,280 | \$27,308 |
| | MT-501 | 360 | 2,588,613 | \$15,532 |
| Total | | | | \$547,142 |
| Chilled Water | F-101 (x2) | 98 (gal/hr) | 7.03E+05 (gal/year) | \$70 |
| (gal) | F-102 (x2) | 980 | 7.06E+06 | \$706 |
| (\$0.1/1000 gal) | F-103 (x2) | 9,803 | 7.06E+07 | \$7058 |
| | F-201 (x6) | 48,120 | 3.46E+08 | \$34647 |
| | C-501 | 43,073 | 3.10E+08 | \$31013 |
| | C-502 | 5,010 | 3.61E+07 | \$3607 |
| Total (cost w/duplicates) | | | | \$258,168 |

Section 15

Equipment List and Unit Descriptions

Section 15.1: Seed/Growth Fermenters

F-101, F-102 & F-103

Each seed fermenter (1m^3) and both the small and large growth fermenters (10m^3 and 100m^3) were designed to ensure appropriate scale-up to avoid stationary phase cell growth. Following specifications in the patented processes, the growth retention time in each fermenter was set to 24 hours.^{15.1} This is in line with the the accepted specific growth rate of 0.5 hr^{-1} and results in an approximate 10 times scale up in total biomass. The working volume for each fermenter was set to 85% of its total capacity and was sized in such as way that the water produced in fermentation did not exceed these threshold. The glucose feedstock was fed into the process at 70.5 g/L water and air was continuously feed at $0.5\text{-}0.6\text{ VVM}$. The pH of the fermenter is maintained at 5.8 using pH control systems and NaOH salts found in the fermentation media. The conversational yield of glucose to biomass using the stoichiometry and selectivity discussed in Section 10.1 was found to be $0.62\text{ g dry cell mass/g glucose fed}$. The exhaust gas (excess air and produced carbon dioxide) were vented to the atmosphere.

The heat produced via metabolism of the glucose feed was calculated based upon oxygen consumption rates in each fermenter. The temperature of the seed fermenters were maintained at 37°C using an appropriately sized heating jacket fed with 98 gal/hr of chilled water entering at 7.22°C (45°F) and leaving at 15.56 (60°F). The area of the cooling jacket for the seed fermenter was sized and found to require 4.12 ft^2 for appropriate heat transfer. This area supports the use of a jacket to maintain temperature and did not require additional cooling coils to meet required

heat transfer. This was found to be the case for all fermenters, and the 10 times scale up of each growth fermenter was associated with a 10 times scale up of associated utilities.

The seed fermenters (F-101) are 2 feet in diameter by 14 feet tall. The first growth fermenters (F-102) are 4 feet in diameter by 33 feet tall. The second growth fermenters (F-103) are 12 feet in diameter by 33 feet tall. All fermenters are constructed of stainless steel 316 in order to prevent against rust and corrosion.^{15.2} The total bare module cost of the fermenters indicated on their Unit Specification Sheet and in the Equipment Costing Summary (Table 17.1) include the agitator and chilled water jackets. The combined total bare module cost for all growth fermenter trains is roughly \$5MM.

Section 15.2: Production Fermenters

F-201

In order to meet project production output, six production fermentation vessels are utilized. Three production fermenters are fed using a single growth fermentation train and are scheduled (see Figure 12.5) in such a way to produce an average of one batch per 24-hour period. The growth retention time for the production fermenter set to 120 hours. This increased length of time relative to the growth fermenters allows for the biomass present in the 500 m³ production vessels to consume and convert 79,000 kg/batch of palm oil into the diacid products outlined in Section 10.2. The conversion of palm oil to DDDA was determined to be 0.75 g DDDA/g palm oil fed and produced a diacid yield of approximately 130 g/L of diacid in the fermentation broth. This represents a productivity of 0.9 g DDDA/L-hr over the 144 run time for

a single production fermenter. This is in line with the expected fermentor productivity of 1 g/L-hr indicated by industry consultants.

Similar to the growth fermenters, the production fermenters were sized to ensure working volume that did not exceed 85% total capacity. The palm oil feedstock was fed into the process at 120.5 g/L water and air was continuously feed at 0.5-0.6 VVM. The pH of the fermenter is maintained at 6.0 using pH control systems and NaOH salts found in the fermentation media. The exhaust gas (excess air and produced carbon dioxide) were vented to the atmosphere.

The heat produced via metabolism of the glucose feed was calculated based upon oxygen consumption rates in each fermenter. The temperature of the production fermenters were maintained at 37°C using an appropriately sized heating jacket fed with 48,120 gal/hr of chilled water entering at 7.22°C (45°F) and leaving at 15.56 (60°F). The area of the cooling jacket for the production fermenter was sized and found to require 2,814 ft² for appropriate heat transfer. This area supports the use of a jacket to maintain temperature and did not require additional cooling coils to meet required heat transfer. Each production fermenter (F-201) is 18.6 feet in diameter and 65 feet tall. All fermenters are constructed of stainless steel 316 in order to prevent against rust and corrosion.^{15.3} The total bare module cost for each production fermenter includes the associated cost of its agitator and chilled water jackets. As indicated in the Unit Specification Sheet and in the Equipment Costing Summary (Table 17.1), each production fermenter costs \$5.9MM. The combined total bare module cost for all production fermenter trains is approximately \$35.4MM.

Section 15.3: Air Compressors

CP-101, CP-102, CP-103, & CP-201

The air compressors for the fermenters are required to feed air into each fermenter at 3.0 bar absolute. Pressure losses located between the air compressors and fermenters due piping, control systems, filters, and the air spargers are accounted for and are estimated to represent a 1 bar pressure drop. This results in each compressor to have a requirement of 4.5 bar. Each compressor was modeled as a multistage (two-stage) compressor. The air compressors in the fermentation sections serve to sterilize and feed their associated volumetric flow rate of air into the fermentation vessels via the agitators. In this section, air compressors CP-101, CP-102, CP-103, and CP-201 each serviced two fermentation trains. Thus, each of these pumps was costed for requiring twice the amount of utilities. In total, CP-101 requires 6.9 kWh, CP-102 requires 69.3 kWh, and CP-103 requires 692.5 kWh. This utility requirement is associated to the required 10 times volumetric scale up of flow of air sparged into each fermentation tank. Similarly, Pump-201 services the six production fermentation trains and was costed for requiring six times the amount of utilities for a single production fermenter. In total, P-205 requires 4,000 kWh. Total, compressors account for approximately \$3.5MM annually in utilities. Stainless steel 316 was selected for reliability and resistance to weathering.^{15.4}

Section 15.4: Mixers

M-001 & M-002

These two mixing vessels create a stream of water and glucose (M-001) and palm oil and water (M-002). The mixing vessels were sized and cost as pressure vessels with agitators made

of stainless steel due to high corrosion and rust resistance.^{15.5} The maximum volume in M-001 and M-002 is 500 gallons and 2300 gallons respectively. M-001 is 7 feet in diameter, 33 feet in length, and costs \$21,6000. M-002 is 10 feet in diameter, 40 feet in length, and costs \$3,84,500.

M-401 & M-402

These two mixing vessels are used to solubilize the diacids from the biomass. The mixing vessels contain diacid and ethyl acetate at 70°C per operation recommendations.^{15.6} These mixing vessels also contain agitators to ensure the proficient mixing of the cakes. The vessels were sized and cost as vertical pressure vessels made of stainless steel. Both of these mixing tanks will be constructed out of stainless steel to avoid corrosion from the heated ethyl acetate.^{15.7} The maximum volume in M-401 and M-402 is 100 gallons and 2 gallons respectively. The M-401 is 3.3 feet in diameter, 16.4 feet in length, and costs \$66,700. M-402 is 2 feet in diameter, 8 feet in length, and costs \$28,430.

Section 15.5: Storage Vessels

TK-001, TK-002, TK-003, TK-004, TK-501

Upstream storage vessels TK-001, TK-002, TK-003, and TK-004 were all sized in order to ensure one and a half days supply of water, glucose solution, and palm oil. These sizes were based upon the required volumes of associated feed required for the three growth ferments (F-101, F-102, and F-103) and the production fermenter (F-201) and the cycle time of 24 hours. The total storage of the four upstream tanks are 130m³, 15m³, 530 m³, and 145 m³ respectively. Each tank was constructed from 316 stainless steel to ensure minimal corrosion.^{15.8} TK-501, the ethyl acetate recycle tank, is insulated and sized to feed 15,979 kg/hr of ethyl acetate back to the

dissolution process in M-401. This vessel assumes a retention time of 30 min and is 7.7 feet in diameter and 77 feet in height. The cost of all associated storage tanks in this plant is just under \$20MM.

Section 15.6: Rotary Drum

RF 401 & RF 402

The purpose of these two drums is to remove 70% of the water from the incoming slurry. Professor Vrana recommended a capacity of 6,000 lb solids/ft²/day to calculate the size of the drums. Although only a fraction of the drum is full at a given time the whole drum area is used for estimated size. Calculations can be found in Appendix A. The filtering area was found to be 26 ft². Two drums made of stainless steel will be purchased that meet the criteria of the calculated filter area. In the event of failure, the drums are large enough where one drum can remove the water from the slurry. Alar Corp. model AV330 was selected for these two drums.^{15.9} Because this model is a self-cleaning rotary filter, dead time to clean the drum is not considered. This model drum cost is \$116,900.

RF-501

The purpose of this drum is to remove a majority of ethyl acetate from the stream to purify the DDDA before crystallization. A capacity of 6,000 lb solids/ft²/day was used to calculate the size of the drum. The filtering area was found to be 35.4 ft² and Alar Corp model AV340 was selected for this drum.^{15.10} The cost of this drum is \$127,700.

RF 502

The purpose of this drum is to remove liquid DDDA from the other diacid impurities. Similarly to RF-401 and RF-402, a capacity of 6,000 lb solids/ft²/day was used to calculate the size of the drum. See the Appendix for this calculation. The filtering area was found to be 2.4 ft² and Alar Corp model AV110 was selected for this drum.^{15.11} This model drum cost is \$114,850.

Section 15.7: Centrifuges

CF-401 & CF-402

These two centrifuges are used to filter off the biomass from the diacids. The streams introduced into these centrifuges contain diacids in the liquid state due to dissolution as well as solid biomass. The models for the centrifuges were selected based upon a volumetric flow rate capacity. The volumetric flow rate into CF-401 is 97 gpm so a centrifuge with capacity of 120 gpm was selected. The model for CF-401 is Alfa Laval NX 418 Decanter.^{15.12} Similarly, the volumetric flow rate into CF-402 is 1.5 gpm so a centrifuge with a capacity of 40 gpm was selected. The 40 gpm capacity is the smallest decanter centrifuge Dolfin Centrifuge provides.^{15.13} The model for CF-402 is Alfa Laval NX 314 Decanter. The costs of CF-401 and CF-402 are \$312,600 and \$126,200 respectively.

Section 15.8: Heat Exchangers

E-001 & E-002

These two heat exchangers heat streams from 25°C to 37°C, the recommended fermentation temperature.^{15.14} The design of the heat exchangers is fixed head shell-and-tube.

Both sides are constructed with stainless steel to prevent rusting from the high temperature steam.^{15.15} E-001 heats a stream containing water and glucose and E-002 heats a stream containing water and palm oil. The steam required for both of these heat exchangers is calculated as utility costs and can be found in Appendix A. The costs of E-001 and E-002 are \$88,100 and \$38,900 respectively.

E-402

The purpose of this heat exchanger is to heat the ethyl acetate from 25°C to 70 °C so the diacids can be dissolved in mixing vessel M-401 and M-402. This is accomplished with a fixed-head shell-and-tube heat exchanger. Both sides were constructed of stainless steel to prevent rust. Steam at 168°C would be introduced on the shell side of the exchanger. The heat duty required to heat ethyl acetate was calculated was found to be 65000 BTU/hr. The log mean temperature calculated was found to be 126.7 °C. Assuming an overall heat transfer coefficient of 120 BTU/hr-ft²-°F the heating area required was found to be 2.4 ft². The cost of this equipment is \$150,800.

Section 15.9: Kettle Evaporator

KE-501

The kettle evaporator KE-501 is intended to evaporate ethyl acetate from the mixture of diacids in ethyl acetate and to correspondingly crystallize the diacids. The kettle evaporator was maintained at 86°C to be above the boiling point of ethyl acetate. In addition, the evaporator was designed on ASPEN to result in an effluent stream that is at least 75% liquid ethyl acetate in order to allow for the transport of diacid solids. This was designed on the advice of industry

consultants. The evaporator was costed as a shell-and-tube heat exchanger. The total heat duty required for evaporation of ethyl acetate was determined to be 1,629 kW and the log mean temperature was found to be 174°F. Taking these two values into account and assuming an overall heat transfer coefficient of 120 BTU/hr-ft²-°F, the heating area required was found to be 267 ft². 6,022 lb/hr of low pressure 50 psig steam was condensed at 137°C in order to meet the heat duty required. The material of construction used was stainless steel because of its high resistance to rusting and corrosion. The calculations for heat transfer associated with this piece of equipment can be found in Appendix A and the total fixed and variable costs can be found in Sections 17 and 14 respectively.

Section 15.10: Diacid Dryer

RD-501

The purpose of the diacid dryer is to evaporate the remaining ethyl acetate from the wet cake of diacids. The dryer is maintained at a temperature of 115°C and atmospheric pressure. The diacid dryer was modeled as a direct-heat rotary dryer and the cost was determined based on guidelines in Chapter 16 of *Seider et. al.*^{15,16} The total heat duty required to evaporate the ethyl acetate was 171 kW and the heat transfer coefficient was 120 BTU/hr-ft²-°F. Based on these values, the surface area and log mean temperature were found to be 28 ft² and 173°F. In addition, 632 lb/hr of 50 psig low pressure steam were supplied to meet the heat duty required for evaporation. These calculations can be found in Appendix A. Lastly, the material of construction was stainless steel because of its high resistance to corrosion and rusting.^{15,17}

Section 15.11: Melting Tank

MT-501

The input to the melting tank consists of dry diacid solids. The purpose of the melting tank is to melt the solid DDDA into liquid, while retaining the rest of the diacids as solids. In order to maintain a temperature in between the diacid melting points, the melting tank is maintained at 135°C and 3.4 bar. Based on the advice of Professor Vrana, the melting tank was modeled as a vertical pressure vessel with an agitator. The diameter and length of the pressure vessel were determined to be 1 and 10 meters based on a volumetric flow rate through the vessel of 3.8 m³/hr and a length to diameter ratio of 10:1 . The agitator was modeled as a turbine and was also costed according to the volumetric flow rate through the tank and a residence time of 30 minutes. In order to maintain the melting tank at the specified conditions, 360 lb/hr of 50 psig low pressure steam were utilized. Lastly, the material of construction was chosen to be stainless steel 316 because of the high resistance to corrosion and rusting.^{15,18}

Section 15.12: Flaker

FL-501

The purpose of the flaker was to allow the liquid DDDA to cool to solid DDDA in order to recover it as a final product. The flaker was maintained at a temperature of 60°C and atmospheric pressure in order to ensure that the equipment was appropriately below the freezing point of DDDA. Based on the advice of Professor Vrana, the flaker was modeled as a conveyor belt with a bare module factor of 10 in order to account for the costs all of the peripheral equipment. The volumetric flow rate of solids through the belt was 2.04 m³/hr and a residence

time of 15 minutes was assumed. The length and width of the conveyor belt were then determined to be 46 ft and 4.6 ft respectively based on the volumetric flow rate, the residence time, and a length to width ratio of 10:1. Lastly, the electrical requirement was associated with the motors to run the flaker and was approximated to be 8.9 kWh.

Section 15.13: Conveyor Belt

CB-401, CB-402 & CB-501

The three conveyor belts used in this process are CB-401, CB-402 and CB-501. These conveyor belts are used in the transportation of solids. CB-501 is used in in order to transfer the dry cake of diacids from the diacid dryer to the melt tank. It was maintained at 115°C and atmospheric pressure. CB-401 is used to transfer the diacid cake from the rotary drums to the evaporator and CB-402 is used to transfer the cake from the evaporator the mixer in the filtration process. CB-401 was designed at a temperature of 37°C and pressure of 3.43 bar. CB-402 transports evaporator effluent and thus was designed to operate at a temperature of 70°C and atmospheric pressure. The conveyor belts were costed according to Chapter 16 of *Seider et. al, 2017*; a residence time of 15 minutes was assumed in order to find the length and width of each belt.^{15,19} These calculations can be found in Appendix A. The electrical requirement for CB-501, CB-401 and CB-402 were found to be 7.5 kWh, 11.2 kWh and 11.2 kWh respectively.

Section 15.14: Pumps

P-001, P-002, P-003, P-004, P-005, P-006, P-101, P-102, P-204, P-205 & P-301

The pumps involved in fermentation were intended to maintain a specific flow rate of fluid through the pipes. In this section, Pumps P-101, P-102 and P-204 each serviced two

fermentation trains. Thus, each of these pumps was costed for requiring twice the amount of utilities. In total, P-101 requires 3.6 kWh, P-102 requires 36 kWh and P-204 requires 361 kWh. Similarly, Pump-205 serviced six fermentation trains and was costed for requiring six times the amount of utilities. In total, P-205 requires 5,234 kWh. A material of stainless steel 316 was selected as it is more rust and corrosion resistant than most metals. In order to cost the pumps, guidelines in *Seider et. al* were followed and centrifugal pump of Horizontal Split Case (HSC) with 1 stage and a shaft rpm of 3,600 was chosen.^{15,20} The total fixed and variable costs of each pump are outlined in sections 17 and 14 respectively.

P-401 & P-402

The pumps P-401 and P-402 were also intended to maintain a specific flow rate of fluid through the pipes in the filtration portion of the process. Pump P-401 was modeled with ASPEN to maintain a flow of 84 gpm using 239 kWh of electricity. Pump P-402 was also modeled with ASPEN to maintain a flow rate of 1.5 gpm using 4.2 kWh of electricity. A material of stainless steel 316 was selected as it is more rust and corrosion resistant than most metals. In order to cost the pumps, guidelines in *Seider et. al* were followed and centrifugal pump of Horizontal Split Case (HSC) with 1 stage and a shaft rpm of 3,600 was chosen.^{15,21} The total fixed and variable costs of each pump are outlined in sections 17 and 14 respectively.

P-501, P-502, P-503 & P-504

The pumps P-501, P-502, P-503 and P-504 were intended to maintain a specific flow rate of fluid through the pipes using a specific amount of electricity in the crystallization portion. For example, pump P-503 was modeled with ASPEN to maintain a flow of 86 gpm in the

crystallization process using 200 kWh of electricity. A material of stainless steel 316 was selected as it is more rust and corrosion resistant than most metals. In order to cost the pumps, guidelines in *Seider et. al* were followed and centrifugal pump of Horizontal Split Case (HSC) with 1 stage and a shaft rpm of 3,600 was chosen.^{15,22} The total fixed and variable costs of each pump are outlined in sections 17 and 14 respectively.

Section 16

Unit Specification Sheets

| Water Storage Tank | | |
|------------------------------------|---|------------------------|
| Identification: | Item | <i>Storage Tank</i> |
| | Item No. | <i>TK-001</i> |
| | No. Required | 1 |
| Function: | Store Supply Water | |
| Operation: | Batch | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | Supply | 1 |
| Temperature (°C) | | 25 |
| Pressure (bar) | | 1 |
| Mass Flow (kg/hr) | | 3444.4 |
| Component Mass Flow (kg/hr) | | |
| Water | | 3444.4 |
| Glucose | | 0 |
| Palm Oil | | 0 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Diameter (ft) | 8 |
| | Length (ft) | 90 |
| | Total storage volume (ft ³) | 4523.9 |
| Purchase Cost | | \$482,300 |
| Bare Module Cost | | \$2,006,300 |
| Comments: | | |

| Water Storage Tank | | |
|------------------------------------|---|------------------------|
| Identification: | Item | <i>Storage Tank</i> |
| | Item No. | <i>TK-002</i> |
| | No. Required | 1 |
| Function: | Store Supply Water | |
| Operation: | Batch | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | Supply | 25 |
| Temperature (°C) | | 25 |
| Pressure (bar) | | 1 |
| Mass Flow (kg/hr) | | 14290.3 |
| Component Mass Flow (kg/hr) | | |
| Water | | 14290.3 |
| Glucose | | 0 |
| Palm Oil | | 0 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Diameter (ft) | 13 |
| | Length (ft) | 140 |
| | Total storage volume (ft ³) | 18582.5 |
| Purchase Cost | | \$1,313,200 |
| Bare Module Cost | | \$5,463,000 |
| Comments: | | |

| Glucose Solution Storage Tank | | |
|------------------------------------|---|------------------------|
| Identification: | Item | <i>Storage Tank</i> |
| | Item No. | <i>TK-003</i> |
| | No. Required | 1 |
| Function: | Store Supply Glucose Solution | |
| Operation: | Batch | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | Supply | 3 |
| Temperature (°C) | | 25 |
| Pressure (bar) | | 1 |
| Mass Flow (kg/hr) | | 357.7 |
| Component Mass Flow (kg/hr) | | |
| Water | | 107.3 |
| Glucose | | 250.4 |
| Palm Oil | | 0 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Diameter (ft) | 4 |
| | Length (ft) | 40 |
| | Total storage volume (ft ³) | 502.7 |
| Purchase Cost | | \$131,500 |
| Bare Module Cost | | \$546,900 |
| Comments: | | |

| Palm Oil Storage Tank | | |
|------------------------------------|---|------------------------|
| Identification: | Item | <i>Storage Tank</i> |
| | Item No. | <i>TK-004</i> |
| | No. Required | 1 |
| Function: | Store Supply Palm Oil | |
| Operation: | Batch | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | Supply | 27 |
| Temperature (°C) | | 25 |
| Pressure (bar) | | 1 |
| Mass Flow (kg/hr) | | 3292.5 |
| Component Mass Flow (kg/hr) | | |
| Water | | 0 |
| Glucose | | 0 |
| Palm Oil | | 3292.5 |
| Design Data: | Material of Construction: 316 Stainless | 316 Stainless |
| | Diameter (ft) | 8 |
| | Length (ft) | 100 |
| | Total storage volume (ft ³) | 5026.5 |
| Purchase Cost | | \$508,900 |
| Bare Module Cost | | \$2,117,200 |
| Comments: | | |

| Water Pump | | |
|------------------------------------|---------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-001</i> |
| | No. Required | 1 |
| Function: | Pump Water from TK-001 | |
| Operation: | Batch | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 1 | 2 |
| Temperature (°C) | 25 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 3444.4 | |
| Component Mass Flow (kg/hr) | | |
| Water | 3444.4 | |
| Glucose | 0 | |
| Palm Oil | 0 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 42.9 kWh electricity | \$10,800 |
| Purchase Cost | | \$12,100 |
| Bare Module Cost: | | \$39,900 |
| Comments: | | |

| Water Pump | | |
|------------------------------------|---------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-004</i> |
| | No. Required | 1 |
| Function: | Pump Water from TK-002 | |
| Operation: | Batch | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 25 | 26 |
| Temperature (°C) | 25 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 14290.3 | |
| Component Mass Flow (kg/hr) | | |
| Water | 14290.3 | |
| Glucose | 0 | |
| Palm Oil | 0 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 178.0 kWh | \$44,900 |
| Purchase Cost | | \$8,900 |
| Bare Module Cost: | | \$29,400 |
| Comments: | | |

| Glucose Pump | | |
|------------------------------------|-----------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-002</i> |
| | No. Required | 1 |
| Function: | Pump Glucose Solution from TK-003 | |
| Operation: | Batch | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 3 | 4 |
| Temperature (°C) | 25 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 357.7 | |
| Component Mass Flow (kg/hr) | | |
| Water | 107.3 | |
| Glucose | 250.4 | |
| Palm Oil | 0 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 4.5 kWh | \$1,100 |
| Purchase Cost | | \$40,700 |
| Bare Module Cost: | | \$134,200 |
| Comments: | | |

| Palm Oil Pump | | |
|------------------------------------|---------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-005</i> |
| | No. Required | 1 |
| Function: | Pump Palm Oil from TK-004 | |
| Operation: | Batch | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 27 | 28 |
| Temperature (°C) | 25 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 3292.5 | |
| Component Mass Flow (kg/hr) | | |
| Water | 0 | |
| Glucose | 0 | |
| Palm Oil | 3292.5 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 41.0 kWh | \$10,300 |
| Purchase Cost | | \$12,300 |
| Bare Module Cost: | | \$40,600 |
| Comments: | | |

| Growth Feed Mixing Vessel | | |
|---------------------------------------|---|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>M-001</i> |
| | No. Required | 1 |
| Function: | Mix water and glucose solution | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | 2,4 | 5 |
| Temperature (°C) | 25 | 25 |
| Component Mass Flow (kg/batch) | | |
| Water | 85242 | 85242 |
| Glucose | 6010 | 6010 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 7 |
| | Vessel Height (ft) | 33 |
| | Final Working Volume (ft ³) | 1109.4 |
| | Pressure at Vessel Base (psia) | 115 |
| | Resonance Time (hr) | 0.5 |
| Cost of Utilities/year: | 3.7 kWh | \$944 |
| Purchase Cost | | \$205,400 |
| Bare Module Cost: | | \$854,600 |
| Associated Cost: | Agitator | \$126,100 |
| Total Bare Module Cost: | | \$980,700 |
| Comments: | | |

| Production Feed Mixing Vessel | | |
|---------------------------------------|---|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>M-002</i> |
| | No. Required | 1 |
| Function: | Mix Water and Palm Oil | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | 26,28 | 29 |
| Temperature (°C) | 25 | |
| Component Mass Flow (kg/batch) | | |
| Water | 342967 | 342967 |
| Palm Oil | 79020 | 79020 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 10 |
| | Vessel Height (ft) | 40 |
| | Final Working Volume (ft ³) | 2995.5 |
| | Pressure at Vessel Base (psia) | 115 |
| | Resonance Time (hr) | 0.5 |
| Cost of Utilities/year: | 17.3 kWh | \$4,400 |
| Purchase Cost | | \$359,900 |
| Bare Module Cost: | | \$1,497,000 |
| Associated Cost: | Agitator | \$302,000 |
| Total Bare Module Cost: | | \$1,799,000 |
| Comments: | | |

| Growth Fermenter Feed Pump | | |
|------------------------------------|-------------------------------------|---------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-003</i> |
| | No. Required | 1 |
| Function: | Pump Water/Glucose Mixture to E-001 | |
| Operation: | Batch | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream Out) | |
| Stream ID | 5 | |
| Temperature (°C) | 25 | |
| Pressure (bar) | 3 | |
| Mass Flow (kg/hr) | 3802.1 | |
| Component Mass Flow (kg/hr) | | |
| Water | 3551.7 | |
| Glucose | 250.4 | |
| Palm Oil | 0 | |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 47.4 kWh | \$11,900 |
| Purchase Cost | | \$11,700 |
| Bare Module Cost: | | \$38,700 |
| Comments: | | |

| Production Fermenter Feed Pump | | |
|------------------------------------|--------------------------------------|---------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-006</i> |
| | No. Required | 1 |
| Function: | Pump Palm Oil/Water Mixture to E-002 | |
| Operation: | Batch | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream Out) | |
| Stream ID | 29 | |
| Temperature (°C) | 25 | |
| Pressure (bar) | 3 | |
| Mass Flow (kg/hr) | 17582.8 | |
| Component Mass Flow (kg/hr) | | |
| Water | 14290.3 | |
| Glucose | 0 | |
| Palm Oil | 3292.5 | |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 219.1 kWh | \$55,200 |
| Purchase Cost | | \$8,800 |
| Bare Module Cost: | | \$28,900 |
| Comments: | | |

| Growth Feed Heat Exchanger | | |
|--------------------------------|---|--------------------------------------|
| Identification: | Item | <i>Shell and tube heat exchanger</i> |
| | Item No. | <i>E-001</i> |
| | No. Required | 1 |
| Function: | Heat Water/Glucose Mixture | |
| Operation: | Batch | |
| Type: | Shell and Tube | |
| Materials Handled: | Tube Side | Shell Side |
| Stream IN | 5 | Steam |
| Stream OUT | 6 | |
| Mass Flow Rate (kg/hr) | 3802.1 | |
| Inlet Temp (°C) | 25 | |
| Outlet Temp (°C) | 37 | |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft ² -hr): | 120 |
| | LMTD (°F): | 258.2 |
| | Surface Area (ft ²) | 5.5 |
| | Heat Duty (BTU/hr): | 169141.9 |
| | Material of Construction: | 316 Stainless |
| Cost of Utilities/year: | 183 lb/hr steam | \$7,900 |
| Purchase Cost | | \$88,100 |
| Bare Module Cost: | | \$279,400 |
| Comments: | | |

| Production Feed Heat Exchanger | | |
|--------------------------------|---|-------------------------------|
| Identification: | Item | Shell and tube heat exchanger |
| | Item No. | E-002 |
| | No. Required | 1 |
| Function: | Heat Palm oil/Water Mixture | |
| Operation: | Batch | |
| Type: | Shell and Tube | |
| Materials Handled: | Tube Side | Shell Side |
| Stream IN | 29 | Steam |
| Stream OUT | 30 | |
| Mass Flow Rate (kg/hr) | 17582.8 | |
| Inlet Temp (°C) | 25 | |
| Outlet Temp (°C) | 37 | |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft ² -hr): | 120 |
| | LMTD (°F): | 98.6 |
| | Surface Area (ft ²) | 76 |
| | Heat Duty (BTU/hr): | 2482676 |
| | Material of Construction: | 316 Stainless |
| Cost of Utilities/year: | 2549 lb/hr steam | \$110,100 |
| Purchase Cost | | \$38,900 |
| Bare Module Cost: | | \$123,300 |
| Comments: | | |

| Seed Fermenter [1m ³] | | |
|---|---|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>F-101</i> |
| | No. Required | 2 |
| Function: | Initial growth of biomass and media | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | S7,S10, S12 | S13,S14 |
| Temperature (°C) | 37 | 37 |
| Component Mass Flow (kg/batch) | | |
| Water | 850 | 820 |
| Glucose | 54 | 0 |
| Media | 11 | 11 |
| Biomass | 2 | 34 |
| Gas Flow Rate (m³/hr) | | |
| Air | 0 | 0 |
| Oxygen | 0 | 7.5 |
| Nitrogen | 0 | 26.0 |
| Carbon Dioxide | 0 | 1.15 |
| Water Vapor | 0 | 1.55 |
| Design Data: | Material of Construct | Stainless Steel 316 |
| | Vessel Diameter (ft) | 2 |
| | Vessel Height (ft) | 14 |
| | Final Working Volume (ft ³) | 44 |
| | Pressure at Vessel Base (psia) | 115 |
| Cost of Utilities/year: | 98 gal/hr cooling water | \$70 x2 |
| Purchase Cost | | \$36,400 x2 |
| Bare Module Cost: | | \$158,000 x2 |
| Associated Cost: | Agitator & Cooling Jacket | \$6,600 x2 |
| Total Bare Module Cost: | | \$164,600 x2 |
| Comments: | | |

| Growth Fermenter [10m³] | | |
|---|---|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>F-102</i> |
| | No. Required | 2 |
| Function: | Continued growth of biomass and media | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | S8,S15,S17 | S18,S19 |
| Temperature (°C) | 37 | 37 |
| Component Mass Flow (kg/batch) | | |
| Water | 8500 | 8203 |
| Glucose | 541 | 0 |
| Media | 125 | 125 |
| Biomass | 34 | 339 |
| Gas Flow Rate (m³/hr) | | |
| Air | 345.8 | 0 |
| Oxygen | 0 | 75.6 |
| Nitrogen | 0 | 260.7 |
| Carbon Dioxide | 0 | 11.6 |
| Water Vapor | 0 | 15.5 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 4 |
| | Vessel Height (ft) | 33 |
| | Final Working Volume (ft ³) | 414.7 |
| | Pressure at Vessel Base (psia) | 115 |
| Cost of Utilities/year: | 980 gal/hr cooling water | \$700 x2 |
| Purchase Cost | | \$111,000 x2 |
| Bare Module Cost: | | \$486,500 x2 |
| Associated Cost: | Agitator & Cooling Jacket | \$24,500 x2 |
| Total Bare Module Cost: | | \$511,000 x2 |
| Comments: | | |

| Growth Fermenter [100m³] | | |
|--|---|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>F-103</i> |
| | No. Required | 2 |
| Function: | Continued growth of biomass and media | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | S9,S20,S22 | S23,S24 |
| Temperature (°C) | 37 | 37 |
| Component Mass Flow (kg/batch) | | |
| Water | 85000 | 82033 |
| Glucose | 5415 | 0 |
| Media | 1262 | 1262 |
| Biomass | 359 | 3608 |
| Gas Flow Rate (m³/hr) | | |
| Air | 3457.7 | 0 |
| Oxygen | 0 | 756.2 |
| Nitrogen | 0 | 2606.7 |
| Carbon Dioxide | 0 | 115.5 |
| Water Vapor | 0 | 115.2 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 12 |
| | Vessel Height (ft) | 33 |
| | Final Working Volume (ft ³) | 3732.2 |
| | Pressure at Vessel Base (psia) | 115 |
| Cost of Utilities/year: | 9803 gal/hr cooling water | \$7,000 x2 |
| Purchase Cost | | \$400,600 x2 |
| Bare Module Cost: | | \$1,966,300 x2 |
| Associated Cost: | Agitator & Cooling Jacket | \$412,500 x2 |
| Total Bare Module Cost: | | \$2,378,800 |
| Comments: | | |

| Production Fermenter [500m ³] | | |
|---|---|-----------------|
| Identification: | Item | Vertical Vessel |
| | Item No. | F-201 |
| | No. Required | 6 |
| Function: | Conversion of Palm Oil to Diacids | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | S24, S30, S32 | S33,S34 |
| Temperature (°C) | 37 | 37 |
| Component Mass Flow (kg/batch) | | |
| Water | 425000 | 341816 |
| Glucose | 0 | 0 |
| Media/Salts | 8773 | 8773 |
| Biomass | 3608 | 3608 |
| DDDA | 0 | 59358 |
| Sebacic Acid | 0 | 2198 |
| Suberic Acid | 0 | 2198 |
| Adipic Acid | 0 | 2198 |
| Gas Flow Rate (m ³ /hr) | | |
| Air | 16974 | 0 |
| Oxygen | 0 | 3712.3 |
| Nitrogen | 0 | 12796 |
| Carbon Dioxide | 0 | 360.2 |
| Water Vapor | 0 | 752.5 |
| Design Data: | Material of Construction | 316 Stainless |
| | Vessel Diameter (ft) | 18.6 |
| | Vessel Height (ft) | 65 |
| | Final Working Volume (ft ³) | 17661.6 |
| | Pressure at Vessel Base (psia) | 115 |
| Cost of Utilities/year: | 48120 gal/hr cooling water | \$34,600 |
| Purchase Cost | | \$1,180,400 x6 |
| Bare Module Cost: | | \$5,910,400 x6 |
| Associated Cost: | Agitator and Cooling Jacket | \$1,000,000 x6 |
| Total Bare Module Cost: | | \$6,910,400 x6 |
| Comments: | | |

| F-101 Air Compressor | | |
|---|---|-------------------------------|
| Identification: | Item | <i>Multi-stage compressor</i> |
| | Item No. | <i>CP-101</i> |
| | No. Required | 1 |
| Function: | Pressurize air fed to F-101 | |
| Operation: | Continuous | |
| Type: | 2-Stage Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 11 | 12 |
| Air Flow Rate (m³/hr) | 34.4 | 34.4 |
| Temperature (°C) | | 37 |
| Pressure (bar) | | 3 |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 10 |
| | Drive Type | Electrical |
| Cost of Utilities/year: | 6.9 kWh | \$1,700 |
| Purchase Cost | | \$34,100 |
| Bare Module Cost: | | \$73,400 |
| Associated Cost: | HEPA Filters | \$ |
| Comments: | Cost of HEPA filters included in bare module cost | |

| F-102 Air Compressor | | |
|---|---|-------------------------------|
| Identification: | Item | <i>Multi-stage compressor</i> |
| | Item No. | <i>CP-102</i> |
| | No. Required | 1 |
| Function: | Pressurize air fed to F-102 | |
| Operation: | Continuous | |
| Type: | 2-Stage Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 16 | 17 |
| Air Flow Rate (m³/hr) | 345.8 | 345.8 |
| Temperature (°C) | | 3 |
| Pressure (bar) | | 37 |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 10 |
| | Drive Type | Electrical |
| Cost of Utilities/year: | 69.3 kWh | \$17,500 |
| Purchase Cost | | \$82,000 |
| Bare Module Cost: | | \$176,300 |
| Associated Cost: | HEPA Filters | \$ |
| Comments: | Cost of HEPA filters included in bare module cost | |

| F-103 Air Compressor | | |
|---|---|-------------------------------|
| Identification: | Item | <i>Multi-stage compressor</i> |
| | Item No. | <i>CP-103</i> |
| | No. Required | 1 |
| Function: | Pressurize air fed to F-103 | |
| Operation: | Continuous | |
| Type: | 2-Stage Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 21 | 22 |
| Air Flow Rate (m³/hr) | 3457.7 | 3457.7 |
| Temperature (°C) | | 37 |
| Pressure (bar) | | 3 |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 10 |
| | Drive Type | Electrical |
| Cost of Utilities/year: | 692.5 kWh | \$174,500 |
| Purchase Cost | | \$196,700 |
| Bare Module Cost: | | \$422,800 |
| Associated Cost: | HEPA Filters | \$ |
| Comments: | Cost of HEPA filters included in bare module cost | |

| F-201 Air Compressor | | |
|---|---|-------------------------------|
| Identification: | Item | <i>Multi-stage compressor</i> |
| | Item No. | <i>CP-201</i> |
| | No. Required | 1 |
| Function: | Pressurize air fed to F-201 | |
| Operation: | Continuous | |
| Type: | 2-Stage Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 31 | 32 |
| Air Flow Rate (m³/hr) | 16974 | 16974 |
| Temperature (°C) | | 37 |
| Pressure (bar) | | 3 |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 10 |
| | Drive Type | Electrical |
| Cost of Utilities/year: | 3399.7 kWh | \$856,700 |
| Purchase Cost | | \$360,000 |
| Bare Module Cost: | | \$773,900 |
| Associated Cost: | HEPA Filters | \$ |
| Comments: | Cost of HEPA filters included in bare module cost | |

| F-101 Products Pump | | |
|------------------------------------|---------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-101</i> |
| | No. Required | 1 |
| Function: | Pump output from F-101 to F-102 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 14 | 15 |
| Temperature (°C) | 37 | 37 |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 865 | |
| Component Mass Flow (kg/hr) | | |
| Water | 820 | |
| Glucose | 0 | |
| Media/Salts | 11 | |
| Biomass | 34 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 1.8 kWh | \$500 |
| Purchase Cost | | \$60,000 |
| Bare Module Cost: | | \$197,900 |
| Comments: | | |

| F-102 Products Pump | | |
|------------------------------------|---------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-102</i> |
| | No. Required | 1 |
| Function: | Pump output from F-102 to F-103 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 19 | 20 |
| Temperature (°C) | 37 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 8687 | |
| Component Mass Flow (kg/hr) | | |
| Water | 8203 | |
| Glucose | 0 | |
| Media/Salts | 125 | |
| Biomass | 359 | |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 500 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 18.0 kWh | \$4,500 |
| Purchase Cost | | \$14,400 |
| Bare Module Cost: | | \$47,600 |
| Comments: | | |

| F-103 Products Pump | | |
|------------------------------------|---------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-204</i> |
| | No. Required | 1 |
| Function: | Pump output from F-103 to F-201 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 24 | |
| Temperature (°C) | 37 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 86903 | |
| Component Mass Flow (kg/hr) | | |
| Water | 82033 | |
| Glucose | 0 | |
| Media/Salts | 1262 | |
| Biomass | 3608 | |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 1000 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 180.4 kWh | \$45,500 |
| Purchase Cost | | \$9,200 |
| Bare Module Cost: | | \$30,300 |
| Comments: | | |

| F-201 Products Pump | | |
|------------------------------------|---------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-205</i> |
| | No. Required | 1 |
| Function: | Pump output from F-201 to S-301 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 34 | |
| Temperature (°C) | 37 | |
| Pressure (bar) | 1 | 3 |
| Mass Flow (kg/hr) | 420149 | |
| Component Mass Flow (kg/hr) | | |
| Water | 34186 | 34186 |
| Glucose | 0 | 0 |
| Media/Salts | 8773 | 8773 |
| Biomass | 3608 | 3608 |
| DDDA | 59358 | 59358 |
| Sebacic Acid | 2198 | 2198 |
| Suberic Acid | 2198 | 2198 |
| Adipic Acid | 2198 | 2198 |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 1000 |
| | Max Motor HP: | |
| Cost of Utilities/year: | 872.4 kWh | \$219,800 |
| Purchase Cost | | \$9,100 |
| Bare Module Cost: | | \$30,000 |
| Comments: | | |

| Surge Tank | | |
|------------------------------------|---|------------------------|
| Identification: | Item | <i>Storage Tank</i> |
| | Item No. | <i>S-301</i> |
| | No. Required | 1 |
| Function: | Store fermented products | |
| Operation: | Batch to Continuous | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | Batchwise | 35 (S1) |
| | <i>See Figure 12.5</i> | |
| Temperature (°C) | | 37 |
| Pressure (bar) | | 3 |
| Mass Flow (kg/hr) | | |
| Component Mass Flow (kg/hr) | | |
| | Water | 12822.1 |
| | Glucose | 0 |
| | Palm Oil | 0 |
| Design Data: | Material of Construction | 316 Stainless |
| | Vessel Diameter (ft) | 18.6 |
| | Vessel Height (ft) | 65 |
| | Final Working Volume (ft ³) | 17661.6 |
| | Pressure at Vessel Base (psia) | 115 |
| Purchase Cost | | \$ 1,606,300 |
| Bare Module Cost | | \$ 6,682,400 |
| Comments: | | |

| Surge Pump | | |
|------------------------------------|--|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-301</i> |
| | No. Required | 1 |
| Function: | Pump output from surge tank to RF-501 & RF-502 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 35 | S1 |
| Temperature (°C) | 37 | |
| Pressure (bar) | 3 | 3.43 |
| Mass Flow (kg/hr) | 15359.9 | 15359.9 |
| Component Mass Flow (kg/hr) | | |
| Water | 12822.1 | 12822.1 |
| Glucose | 0 | 0 |
| Media/Salts | 0 | 0 |
| Biomass | 150.2 | 150.2 |
| DDDA | 2148.5 | 2148.5 |
| Sebacic Acid | 79.7 | 79.7 |
| Suberic Acid | 79.7 | 79.7 |
| Adipic Acid | 79.7 | 79.7 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 1000 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 191.4 kWh | \$48,200 |
| Purchase Cost | | \$8,800 |
| Bare Module Cost: | | \$29,200 |
| Comments: | | |

| Vacuum Rotary Drum Filter | | | |
|---------------------------|---|-------------------|-----------------------|
| Identification: | Item | | Filtration System |
| | Item No. | | RF-401 & RF-402 |
| | No. Required | | 1 (each) |
| Function: | Remove a majority of water from S1 | | |
| Operation: | Continuous | | |
| Type: | Alar Corp AV330 | | |
| Materials Handled: | Feed (Stream In) | Cake (Solid Out) | Supernatant (Liq Out) |
| Stream ID | S1 | S4 | S2/S3 |
| Temperature (°C) | 37 | 37 | 37 |
| Pressure (bar) | 3.43 | 3.43 | 3.43 |
| Mass Flow (kg/hr) | 15359.9 | 3612.7 | 11747.2 |
| Component Flow (kg/hr) | | | |
| Water | 12822.1 | 1087.6 | 11734.5 |
| Glucose | 0 | 0 | 0 |
| Media/Salts | 0 | 0 | 0 |
| Biomass | 150.2 | 149.5 | 0.7 |
| DDDA | 2148.5 | 2137.8 | 2137.8 |
| Sebacic Acid | 79.7 | 79.3 | 0.4 |
| Suberic Acid | 79.7 | 79.3 | 0.4 |
| Adipic Acid | 79.7 | 79.3 | 0.4 |
| Design Data: | Material of Construction | Stainless steel | |
| | Pressure | 1 bar | |
| | Diameter | 3 fta | |
| | Length | 3 ft | |
| | Function height | 3 ft | |
| | Orientation | Horizontal | |
| | Frac. of Drum Full | 0.4 | |
| | Speed | 0.5 rpm | |
| | Capacity | 2727.3 kg/ft²/day | |
| | Motor | 13 hp | |
| Cost of Utilities/year: | 8.2 kWh | \$2,000 x2 | |
| Purchase Cost | | \$116,900 x2 | |
| Bare Module Cost: | | \$237,300 x2 | |
| Comments: | Quote from Alar Corp. This drum filter is auto cleansing so dead time is not considered | | |

| Cake Dryer | | | |
|--------------------------------|---|------------------|---------------------|
| Identification: | Item | | <i>Evaporator</i> |
| | Item No. | | <i>E-401</i> |
| | No. Required | | 1 |
| Function: | Dry remaining water residing in diacid cake | | |
| Operation: | Continuous | | |
| Type: | | | |
| Materials Handled: | Feed (Stream In) | Cake (Solid Out) | Exhaust (Vapor Out) |
| Stream ID | S4 | S6 | S5 |
| Temperature (°C) | 37 | 37 | 115 |
| Pressure (bar) | 3.43 | 1 | 1 |
| Mass Flow (kg/hr) | 3612.7 | 2525.1 | 1087.6 |
| Component Flow (kg/hr) | | | |
| Water | 1087.6 | 0 | 1087.6 |
| Glucose | 0 | 0 | 0 |
| Media/Salts | 0 | 0 | 0 |
| Biomass | 149.5 | 149.5 | 0 |
| DDDA | 2137.8 | 2137.8 | 0 |
| Sebacic Acid | 79.3 | 79.3 | 0 |
| Suberic Acid | 79.3 | 79.3 | 0 |
| Adipic Acid | 79.3 | 79.3 | 0 |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft ² -hr): | | 120 |
| | LMTD (°F): | | 217.7 |
| | Surface Area (ft ²) | | 107.7 |
| | Heat Duty (BTU/hr): | | 2813795.6 |
| | Material of Construction: | | 316 Stainless |
| Cost of Utilities/year: | 2850 lb/hr steam | \$123,100 | |
| Purchase Cost | | \$38,900 | |
| Bare Module Cost: | | \$123,300 | |
| Comments: | | | |

| Cake Drying Belt | | |
|------------------------------------|---|----------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>CB-401 & CB-402</i> |
| | No. Required | 1 (each) |
| Function: | Move moist cake through cake evaporator | |
| Operation: | Continuous | |
| Type: | Conveyor | |
| Materials Handled: | Feed (Pre-Dryer) | Discharge (Post-Dryer) |
| Stream ID | S4 | S6 |
| Mass Flow Rate (kg/hr) | 3612.7 | 2525.1 |
| Component Mass Flow (kg/hr) | | |
| Water | 1087.6 | 0 |
| Glucose | 0 | 0 |
| Media/Salts | 0 | 0 |
| Biomass | 149.5 | 149.5 |
| DDDA | 2137.8 | 2137.8 |
| Sebacic Acid | 79.3 | 79.3 |
| Suberic Acid | 79.3 | 79.3 |
| Adipic Acid | 79.3 | 79.3 |
| Design Data: | Material of Construction | 316 Stainless |
| | Volume on Belt (ft ³) | 22.3 |
| | Height of Slurry (ft) | 0.08 |
| | Length (ft) | 51.7 |
| | Width (ft) | 5.2 |
| Cost of Utilities/year: | 11.2 kWh | \$2,800 x2 |
| Purchase Cost | | \$190,400 |
| Bare Module Cost: | | \$306,500 |
| Comments: | | |

| Major Ethyl Acetate Mixing Vessel | | |
|-----------------------------------|---|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>M-401</i> |
| | No. Required | 1 |
| Function: | Add ethyl acetate to cake to solubilize diacids | |
| Operation: | Continuous | |
| Materials Handled: | Inlet | Outlet |
| Temperature (°C) | 70 | 70 |
| Component Mass Flow (kg/batch) | | |
| Ethyl Acetate | | 16629 |
| Biomass | 149.5 | 149.5 |
| DDDA | 2137.8 | 2137.8 |
| Sebacic Acid | 79.3 | 79.3 |
| Suberic Acid | 79.3 | 79.3 |
| Adipic Acid | 79.3 | 79.3 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 3.3 |
| | Vessel Height (ft) | 16.4 |
| | Final Working Volume (ft ³) | 138.7 |
| | Pressure at Vessel Base (psia) | 115 |
| | Resonance Time (hr) | 0.5 |
| Cost of Utilities/year: | 3086.6 kWh | \$777,800 |
| Purchase Cost | | \$62,600 |
| Bare Module Cost: | | \$260,300 |
| Associated Cost: | Agitator | \$50,700 |
| Total Bare Module Cost: | | \$311,000 |
| Comments: | | |

| Minor Ethyl Acetate Mixing Vessel | | |
|---------------------------------------|--|------------------------|
| Identification: | Item | <i>Vertical Vessel</i> |
| | Item No. | <i>M-402</i> |
| | No. Required | 1 |
| Function: | Secondary dissolution step for those that failed to convert in M-401 | |
| Operation: | Continuous | |
| Materials Handled: | Inlet | Outlet |
| Temperature (°C) | 70 | 70 |
| Component Mass Flow (kg/batch) | | |
| Ethyl Acetate | 86.8 | 174.1 |
| Biomass | 149.5 | 149.5 |
| DDDA | 11.2 | 11.2 |
| Sebacic Acid | 0.4 | 0.4 |
| Suberic Acid | 0.4 | 0.4 |
| Adipic Acid | 0.4 | 0.4 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 2 |
| | Vessel Height (ft) | 8 |
| | Final Working Volume (ft ³) | 17.3 |
| | Pressure at Vessel Base (psia) | 115 |
| | Resonance Time (hr) | 0.5 |
| Cost of Utilities/year: | 0.7 kWh | \$200 |
| Purchase Cost | | \$28,000 |
| Bare Module Cost: | | \$116,400 |
| Associated Cost: | Agitator | \$5,500 |
| Total Bare Module Cost: | | \$121,900 |
| Comments: | | |

| Major Ethyl/Biomass Slurry Pump | | |
|------------------------------------|------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-401</i> |
| | No. Required | 1 |
| Function: | Pump liquid diacids to C-401 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 8 | 9 |
| Temperature (°C) | 70 | 70 |
| Pressure (bar) | 5 | 1 |
| Mass Flow (kg/hr) | 19154.5 | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | 16629 | |
| Biomass | 149.5 | |
| DDDA | 2137.8 | |
| Sebacic Acid | 79.3 | |
| Suberic Acid | 79.3 | |
| Adipic Acid | 79.3 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 500 |
| | Max Motor HP: | 1560 |
| Utilities: | 238.6 kWh | \$60,100 |
| Purchase Cost | | \$8,700 |
| Bare Module Cost: | | \$28,800 |
| Comments: | | |

| Minor Ethyl/Biomass Slurry Pump | | |
|------------------------------------|------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-402</i> |
| | No. Required | 1 |
| Function: | Pump liquid diacids to C-402 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | 16 | 17 |
| Temperature (°C) | 70 | |
| Pressure (bar) | 5 | 1 |
| Mass Flow (kg/hr) | 336 | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | 174.1 | |
| Biomass | 149.5 | |
| DDDA | 11.2 | |
| Sebacic Acid | 0.4 | |
| Suberic Acid | 0.4 | |
| Adipic Acid | 0.4 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 4.2 kWh | \$1,000 |
| Purchase Cost | | \$111,600 |
| Bare Module Cost: | | \$368,300 |
| Comments: | | |

| Ethyl Acetate Heat Exchanger | | |
|--------------------------------|---|-------------------------------|
| Identification: | Item | Shell and tube heat exchanger |
| | Item No. | E-402 |
| | No. Required | 1 |
| Function: | Heat feedstock ethyl acetate from 25 C to 70 C | |
| Operation: | Continuous | |
| Type: | shell and tube | |
| Materials Handled: | Tube Side | Shell Side |
| Stream IN | S12 | Steam |
| Stream OUT | S13 | |
| Mass Flow Rate (kg/hr) | 737.26 | |
| Inlet Temp (°C) | 25 | 186 |
| Outlet Temp (°C) | 70 | 163 |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft ² -hr): | 120 |
| | LMTD (°C): | 126.7 |
| | Surface Area (ft ²) | 2.4 |
| | Heat Duty (BTU/hr): | 64942.12 |
| | Material of Construction: | 316 stainless |
| Cost of Utilities/year: | 70 lb/hr steam | \$3,000 |
| Purchase Cost | | \$150,800 |
| Bare Module Cost: | | \$478,000 |
| Comments: | | |

| Major Centrifuge | | | |
|-------------------------|--------------------------------------|------------------|-----------------------|
| Identification: | Item | | Filtration System |
| | Item No. | | CF-401 |
| | No. Required | | 1 |
| Function: | Separate biomass from liquid diacids | | |
| Operation: | Continuous | | |
| Type: | Alfa Laval NX 418 Decanter | | |
| Materials Handled: | Feed (Stream In) | Cake (Solid Out) | Supernatant (Liq Out) |
| Stream ID | S9 | S11 | S10 |
| Temperature (°C) | 70 | 70 | 70 |
| Pressure (bar) | 1 | 1 | 1 |
| Mass Flow (kg/hr) | 19154.5 | 249.1 | 18905.4 |
| Component Flow (kg/hr) | | | |
| Ethyl Acetate | 16629.4 | 87.2 | 16542.2 |
| Biomass | 149.5 | 149.5 | |
| DDDA | 2137.8 | 11.2 | 2126.6 |
| Sebacic Acid | 79.3 | 0.4 | 78.9 |
| Suberic Acid | 79.3 | 0.4 | 78.9 |
| Adipic Acid | 79.3 | 0.4 | 78.9 |
| Design Data: | Capacity | 120 GPM | |
| | Material of Construction: | 316 Stainless | |
| | Speed | 4000 rpm | |
| | Motor | 20 hp | |
| | Voltage | 460 V | |
| Cost of Utilities/year: | 14.9 kWh | \$3,800 | |
| Purchase Cost | | \$312,600 | |
| Bare Module Cost: | | \$634,700 | |
| Comments: | | | |

| Minor Centrifuge | | | |
|-------------------------|---|------------------|-----------------------|
| Identification: | Item | | Filtration System |
| | Item No. | | CF-402 |
| | No. Required | | 1 |
| Function: | Second pass for diacids caught in solid out from CF-401 | | |
| Operation: | Continuous | | |
| Type: | Alfa Laval NX314 Decanter | | |
| Materials Handled: | Feed (Stream In) | Cake (Solid Out) | Supernatant (Liq Out) |
| STream ID | S17 | S20 | S18 |
| Temperature (°C) | 70 | 70 | 70 |
| Pressure (bar) | 1 | 1 | 1 |
| Mass Flow (kg/hr) | 336 | 151 | 185 |
| Component Flow (kg/hr) | | | |
| Ethyl Acetate | 174.5 | 1.7 | 172.7 |
| Biomass | 149.5 | 149.5 | |
| DDDA | 11.2 | 0.1 | 11.1 |
| Sebacic Acid | 0.4 | | 0.4 |
| Suberic Acid | 0.4 | | 0.4 |
| Adipic Acid | 0.4 | | 0.4 |
| Design Data: | Capacity | 40 GPM | |
| | Material of Construction: | 316 Stainless | |
| | Speed | 3250 rpm | |
| | Motor | 15 hp | |
| | Voltage | 460 V | |
| Cost of Utilities/year: | 11.2 kWh | \$2,800 | |
| Purchase Cost | | \$126,200 | |
| Bare Module Cost: | | \$256,200 | |
| Comments: | | | |

| Kettle Evaporator | | |
|--------------------------------|---|---------------------------|
| Identification: | Item | <i>Heating Vessel</i> |
| | Item No. | <i>KE-501 & E-501</i> |
| | No. Required | 1 |
| Function: | Evaporate ethyl acetate from stream | |
| Operation: | Continuous | |
| Type: | | |
| Materials Handled: | Tube Side | Shell Side |
| Stream IN | S19,S27,S25 | |
| Stream OUT | S21 | Steam |
| Mass Flow Rate (kg/hr) | 5976 | |
| Inlet Temp (°C) | 70 | |
| Outlet Temp (°C) | 86 | |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft ² -hr): | 120 |
| | LMTD (°F): | 173.6 |
| | Surface Area: (ft ²) | 266.8 |
| | Length (ft) | 131.2 |
| | Diameter (ft) | 13.1 |
| | Heat Duty (BTU/hr): | 5559150.3 |
| | Material of Construction: | 316 Stainless |
| | Resonance Time (hr) | 0.5 |
| Cost of Utilities/year: | 6022 lb/hr steam | \$260,100 |
| Purchase Cost | | \$108,700 |
| Bare Module Cost: | | \$344,700 |
| Comments: | | |

| Kettle Evaporator Pump | | |
|------------------------------------|-------------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-501</i> |
| | No. Required | 1 |
| Function: | Pump solution from KE-501 to RF-501 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | S21 | S25,S26 |
| Temperature (°C) | 86 | 95.47/86.13 |
| Pressure (bar) | 1.34 | 3.76 |
| Mass Flow kg/hr | | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | 142143 | 142143 |
| DDDA | 42637 | 42637 |
| Sebacic Acid | 1581 | 1581 |
| Suberic Acid | 1581 | 1581 |
| Adipic Acid | 1581 | 1581 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 2361.2 kWh | \$595,000 |
| Purchase Cost | | \$9,900 |
| Bare Module Cost: | | \$32,900 |
| Comments: | | |

| Major Ethyl Acetate Condenser | | |
|--------------------------------|--|------------------|
| Identification: | Item | <i>Condenser</i> |
| | Item No. | <i>C-501</i> |
| | No. Required | 1 |
| Function: | Condense evaporated ethyl acetate | |
| Operation: | Continuous | |
| Type: | | |
| Materials Handled: | Tube Side | Shell Side |
| Stream IN | S20 | Chilled Water |
| Stream OUT | S22 | |
| Mass Flow Rate (kg/hr) | 15045 | |
| Inlet Temp (°C) | 86 | |
| Outlet Temp (°C) | 76.73 | |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft ² -hr) | 120 |
| | LMTD (°F): | 109.7 |
| | Surface Area (ft ²) | 408.7 |
| | Heat Duty (BTU/hr): | -5381953.2 |
| | Material of Construction: | 316 Stainless |
| Cost of Utilities/year: | 43073 gal/hr cooling water | \$31,000 |
| Purchase Cost | | \$47,300 |
| Bare Module Cost: | | \$149,900 |
| Comments: | | |

| Diacid/Ethyl Acetate Rotary Filter | | | |
|------------------------------------|---|--------------------------------|-------------------|
| Identification: | Item | | <i>Evaporator</i> |
| | Item No. | | <i>RF-501</i> |
| | No. Required | | 1 |
| Function: | Remove a majority of ethyl acetate from diacids | | |
| Operation: | Continuous | | |
| Type: | Alarp Corp AV340 | | |
| Materials Handled: | Feed (Stream In) | Recycle | Slurry |
| Stream ID | S26 | S27 | S28 |
| Temperature (°C) | 86.13 | 86.13 | 86.13 |
| Pressure (bar) | 3.76 | 3.43 | 3.76 |
| Mass Flow (kg/hr) | | | |
| Component Flow (kg/hr) | | | |
| Ethyl Acetate | 7107 | 5528 | 1579 |
| DDDA | 2132 | 0 | 2131.8 |
| Sebacic Acid | 79.1 | 0 | 79.1 |
| Suberic Acid | 79.1 | 0 | 79.1 |
| Adipic Acid | 79.1 | 0 | 79.1 |
| Design Data: | Material of Construction | Stainless steel | |
| | Pressure | 1 bar | |
| | Diameter | 3 ft | |
| | Length | 4 ft | |
| | Function height | 3 ft | |
| | Orientation | Horizontal | |
| | Frac. of Drum Full | 0.4 | |
| | Speed | 0.5 rpm | |
| | Capacity | 2727.3 kg/ft ² /day | |
| | Motor | 11 hp | |
| Cost of Utilities/year: | 8.2 kWh | \$2,000 | |
| Purchase Cost | | \$127,700 | |
| Bare Module Cost: | | \$259,200 | |
| Comments: | Drum is auto cleansing so dead time is not considered | | |

| Diacid Slurry Pump | | |
|------------------------------------|-----------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-502</i> |
| | No. Required | 1 |
| Function: | Pump output from RF-501 to RD-501 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | | S28 |
| Temperature (°C) | 86.13 | |
| Pressure (bar) | 3.43 | 3.76 |
| Mass Flow (kg/hr) | | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | 1579 | |
| Biomass | 0 | |
| DDDA | 2131.8 | |
| Sebacic Acid | 79.1 | |
| Suberic Acid | 79.1 | |
| Adipic Acid | 79.1 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 49.2 kWh | \$12,400 |
| Purchase Cost | | \$13,000 |
| Bare Module Cost: | | \$43,600 |
| Comments: | | |

| Diacid/Nitrogen Rotary Dryer | | | |
|-------------------------------------|--|-----------|--------------------------|
| Identification: | Item | | <i>Filtration System</i> |
| | Item No. | | <i>RD-501</i> |
| | No. Required | | 1 |
| Function: | Dry ethyl acetate from solid diacids | | |
| Operation: | Continuous | | |
| Type: | | | |
| Materials Handled: | Slurry | Solids | Exhaust |
| Stream ID | S28, S37 | S29 | S38 |
| Temperature (°C) | 86.13/115 | 115 | 115 |
| Pressure (bar) | 3.43/1.7 | 1.7 | 1.7 |
| Mass Flow (kg/hr) | | | |
| Component Flow (kg/hr) | | | |
| Nitrogen | 29.86 | 0 | 29.86 |
| Ethyl Acetate | 1599.7 | 0 | 1599.7 |
| DDDA | 2131.8 | 2131.8 | 0 |
| Sebacic Acid | 79.1 | 79.1 | 0 |
| Suberic Acid | 79.1 | 79.1 | 0 |
| Adipic Acid | 79.1 | 79.1 | 0 |
| Design Data: | Material of Construction 316 Stainless | | |
| | Diameter (ft) | 7.7 | |
| | Length (ft) | 77 | |
| | Volume (ft³) | 3553.8 | |
| | Resonance Time (hr) | 0.5 | |
| Cost of Utilities/year: | 632 lb/hr steam | \$27,300 | |
| Purchase Cost | | \$83,600 | |
| Bare Module Cost: | | \$172,300 | |
| Comments: | | | |

| Nitrogen Compressor | | |
|---|--|-------------------------------|
| Identification: | Item | <i>Multi-stage compressor</i> |
| | Item No. | <i>CP-501</i> |
| | No. Required | 1 |
| Function: | | |
| Operation: Continuous | | |
| Type: 2-Stage Centrifugal | | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | S38 | S40,S43 |
| Temperature (°C) | 115 | 76.73/115 |
| Pressure (bar) | 1.7 | 1.7/2.74 |
| Gas Flow Rate (m³/hr) | | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | 1599.7 | 1577/20.7 |
| Nitrogen | 29.86 | 0/26.5 |
| Design Data: | Material of Construction | 316 Stainless |
| | Head (ft) | 100 |
| | Drive Type | Electrical |
| Cost of Utilities/year: | 1958.3 kWh | \$493,400 |
| Purchase Cost | | \$356,000 |
| Bare Module Cost: | | \$773,900 |
| Associated Cost: | HEPA Filters | \$ |
| Comments: | Pricing of HEPA filters included in bare module cost | |

| Minor Ethyl Acetate Condenser | | |
|--------------------------------|--|------------------|
| Identification: | Item | <i>Condenser</i> |
| | Item No. | <i>C-502</i> |
| | No. Required | 1 |
| Function: | Condense evaporated ethyl acetate to be recycled | |
| Operation: | Continuous | |
| Type: | | |
| Materials Handled: | Tube Side | Shell Side |
| Stream IN | | |
| Stream OUT | S40 | Chilled Water |
| Mass Flow Rate (kg/hr) | 1577 | |
| Inlet Temp (°C) | 115 | |
| Outlet Temp (°C) | 76.73 | |
| Design Data: | Heat Transfer Coefficient (BTU/°F-ft²*hr): | 120 |
| | LMTD (°F): | 136.01 |
| | Surface Area (ft²) | 38.4 |
| | Heat Duty (BTU/hr): | -606028.6 |
| | Material of Construction: | 316 Stainless |
| Cost of Utilities/year: | 5010 gal/hr cooling water | \$3,600 |
| Purchase Cost | | \$42,100 |
| Bare Module Cost: | | \$133,500 |
| Comments: | | |

| Diacid Transport Belt | | |
|------------------------------------|-------------------------------------|----------------------|
| Identification: | Item | <i>Conveyor Belt</i> |
| | Item No. | <i>CB-501</i> |
| | No. Required | 1 |
| Function: | Transport solid diacids into MT-501 | |
| Operation: | Continuous | |
| Type: | | |
| Materials Handled: | Feed (Pre-Dryer) | |
| Stream ID | S29 | |
| Mass Flow Rate (kg/hr) | 2369..3 | |
| Component Mass Flow (kg/hr) | | |
| DDDA | 2132 | |
| Sebacic Acid | 79.1 | |
| Suberic Acid | 79.1 | |
| Adipic Acid | 79.1 | |
| Design Data: | Material of Construction | 316 Stainless |
| | Volume on Belt (ft ³) | 21 |
| | Height of Slurry (ft) | 0.08 |
| | Length (ft) | 50 |
| | Width (ft) | 5 |
| Cost of Utilities/year: | 7.5 kWh | \$1,900 |
| Purchase Cost | | \$73,500 |
| Bare Module Cost: | | \$118,300 |
| Comments: | | |

| Diacid Melting Tank | | |
|---------------------------------------|---|-------------------------------------|
| Identification: | Item | <i>Vertical Vessel with Heating</i> |
| | Item No. | <i>MT-501</i> |
| | No. Required | 1 |
| Function: | Melt DDDA | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | S29 | S30,S33 |
| Temperature (°C) | 115 | 135.2 |
| Pressure (bar) | 1.01 | 2.74 |
| Component Mass Flow (kg/batch) | | |
| DDDA | 2132 | 6080 |
| Sebacic Acid | 79.1 | 79.3 |
| Suberic Acid | 79.1 | 79.3 |
| Adipic Acid | 79.1 | 79.3 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 0.33 |
| | Vessel Height (ft) | 3.3 |
| | Final Working Volume (ft ³) | 10 |
| Cost of Utilities/year: | 360 lb/hr steam | \$15,500 |
| Purchase Cost | | \$6,200 |
| Bare Module Cost: | | \$25,900 |
| Associated Cost: | Agitator | \$17,400 |
| | Heating Jacket | \$22,400 |
| Total Bare Module Cost: | | \$65,700 |
| Comments: | | |

| Ethyl Acetate Recycle Tank | | |
|---------------------------------------|--|-------------------------------------|
| Identification: | Item | <i>Vertical Vessel with Heating</i> |
| | Item No. | <i>TK-501</i> |
| | No. Required | 1 |
| Function: | Store condensed ethyl acetate to be recycled back into S13 | |
| Operation: | Batch | |
| Materials Handled: | Inlet | Outlet |
| Stream ID | S41 | S23,S42 |
| Temperature (°C) | 76.73 | 76.73 |
| Pressure (bar) | 1.38 | 1.34,1.7 |
| Component Mass Flow (kg/batch) | | |
| Ethyl Acetate | 16141 | 15979,161 |
| DDDA | 0 | 0 |
| Nitrogen | 0 | 0 |
| Design Data: | Material of Construct | 316 Stainless |
| | Vessel Diameter (ft) | 8 |
| | Vessel Height (ft) | 40 |
| | Final Working Volume (ft ³) | 74330 |
| | Pressure at Vessel Base (psia) | 115 |
| Purchase Cost | | \$ 206,100 |
| Bare Module Cost: | | \$ 857,500 |
| Associated Cost: | Agitator | \$ |
| | Heating Jacket | \$ |
| Total Bare Module Cost: | | \$ |
| Comments: | Cost of agitator and heating jacket included in bare module cost | |

| Ethyl Acetate Recycle Pump | | |
|------------------------------------|--------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-503</i> |
| | No. Required | 1 |
| Function: | Recycle ethyl acetate into S13 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | S23 | S24 |
| Temperature (°C) | | 76.73 |
| Pressure (bar) | 1.34 | 3 |
| Mass Flow (kg/hr) | | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | | 15979 |
| DDDA | | 0 |
| Sebacic Acid | | 0 |
| Suberic Acid | | 0 |
| Adipic Acid | | 0 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 199.1 kWh | \$50,200 |
| Purchase Cost | | \$8,700 |
| Bare Module Cost: | | \$28,600 |
| Comments: | | |

| Diacid Pump | | |
|------------------------------------|------------------------------------|------------------------|
| Identification: | Item | <i>Pump</i> |
| | Item No. | <i>P-504</i> |
| | No. Required | 1 |
| Function: | Pump diacids from MT-501 to RF-502 | |
| Operation: | Continuous | |
| Type: | Centrifugal | |
| Materials Handled: | Feed (Stream In) | Discharge (Stream Out) |
| Stream ID | | S30 |
| Temperature (°C) | 135.2 | |
| Pressure (bar) | 1.01 | 3.43 |
| Mass Flow (kg/hr) | | |
| Component Mass Flow (kg/hr) | | |
| Ethyl Acetate | 0 | |
| Biomass | 0 | |
| DDDA | 4106 | |
| Sebacic Acid | 79.2 | |
| Suberic Acid | 79.2 | |
| Adipic Acid | 79.2 | |
| Design Data: | Material of Construction: | 316 Stainless |
| | Head (ft) | 100 |
| | Max Motor HP: | 1560 |
| Cost of Utilities/year: | 54.1 kWh | \$13,600 |
| Purchase Cost | | \$30,400 |
| Bare Module Cost: | | \$101,500 |
| Comments: | | |

| Vacuum Rotary Drum Filter | | | |
|---------------------------|---|------------------------|-------------------|
| Identification: | Item | | Filtration System |
| | Item No. | | RF-502 |
| | No. Required | | 1 |
| Function: | Separate liquid DDDA from other diacid impurities | | |
| Operation: | Continuous | | |
| Type: | Alar Corp AV110 | | |
| Materials Handled: | Feed (Stream In) | Impurities (Solid Out) | Product (Liq Out) |
| Stream ID | S30 | S31 | S32 |
| Temperature (°C) | 135.2 | 135.2 | 135.2 |
| Pressure (bar) | 3.43 | 1.01 | 2.74 |
| Mass Flow (kg/hr) | 4343 | 395 | 3948 |
| Component Flow (kg/hr) | | | |
| DDDA | 4106 | 158 | 3948 |
| Sebacic Acid | 79.2 | 79 | 0.2 |
| Suberic Acid | 79.2 | 79 | 0.2 |
| Adipic Acid | 79.2 | 79 | 0.2 |
| Design Data: | Material of Construction | Stainless steel | |
| | Pressure | 1 bar | |
| | Diameter | 1 ft | |
| | Length | 1 ft | |
| | Function height | 1 ft | |
| | Orientation | Horizontal | |
| | Frac. of Drum Full | 0.4 | |
| | Speed | 0.5 rpm | |
| | Capacity | 2727.3 kg/ft²/day | |
| | Motor | 4 hp | |
| Cost of Utilities/year: | 3.0 kWh | \$800 | |
| Purchase Cost | | \$114,800 | |
| Bare Module Cost: | | \$233,100 | |
| Comments: | Drum is auto cleansing so dead time is not considered | | |

| DDDA Flaker | | |
|------------------------------------|---------------------------|------------------------|
| Identification: | Item | <i>Conveyer Belt</i> |
| | Item No. | <i>FL-501</i> |
| | No. Required | 1 |
| Function: | Crystallize liquid DDDA | |
| Operation: | Continuous | |
| Type: | | |
| Materials Handled: | Feed (Pre-Dryer) | Discharge (Post-Dryer) |
| Stream ID | S34 | S35 |
| Temperature (°C) | 135.2 | 60 |
| Mass Flow Rate (kg/hr) | | 1974.15 |
| Component Mass Flow (kg/hr) | | |
| DDDA | | 1974 |
| Sebacic Acid | | 0.05 |
| Suberic Acid | | 0.05 |
| Adipic Acid | | 0.05 |
| Design Data: | Material of Construction: | 316 Stainless |
| | Length | 46.5 |
| | Width | 4.6 |
| Cost of Utilities/year: | 8.9 kWh | \$2,300 |
| Purchase Cost | | \$63,300 |
| Bare Module Cost: | | \$632,800 |
| Comments: | | |

Section 17

Equipment Cost Summary

Table 17.1: Equipment Costing Summary

| <i>Process Equipment ID</i> | Type | Cp, Purchase Cost (\$) | Bare Module Factor | Cbm, Bare Module Cost (\$) |
|-----------------------------|-------------------|------------------------|--------------------|----------------------------|
| TK-001 | Storage | \$482,300 | 4.16 | \$2,006,300 |
| TK-002 | Storage | \$131,500 | 4.16 | \$546,900 |
| TK-003 | Storage | \$1,313,200 | 4.16 | \$5,463,000 |
| TK-004 | Storage | \$508,900 | 4.16 | \$2,117,200 |
| TK-501 | Storage | \$206,100 | 4.16 | \$857,500 |
| S-301 | Storage | \$1,606,300 | 4.16 | \$6,682,400 |
| P-001 | Process Machinery | \$12,100 | 3.30 | \$39,900 |
| P-002 | Process Machinery | \$40,700 | 3.30 | \$134,200 |
| P-003 | Process Machinery | \$11,700 | 3.30 | \$158,000 |
| P-004 | Process Machinery | \$8,900 | 3.30 | \$29,400 |
| P-005 | Process Machinery | \$12,300 | 3.30 | \$40,600 |
| P-006 | Process Machinery | \$8,800 | 3.30 | \$28,900 |
| P-101 | Process Machinery | \$60,000 | 3.30 | \$197,900 |
| P-102 | Process Machinery | \$14,400 | 3.30 | \$47,600 |
| P-204 | Process Machinery | \$9,200 | 3.30 | \$30,300 |
| P-205 | Process Machinery | \$9,100 | 3.30 | \$30,000 |
| P-301 | Process Machinery | \$8,800 | 3.30 | \$29,200 |
| P-401 | Process Machinery | \$8,700 | 3.30 | \$28,800 |
| P-402 | Process Machinery | \$111,600 | 3.30 | \$368,300 |
| P-501 | Process Machinery | \$9,900 | 3.30 | \$32,900 |
| P-502 | Process Machinery | \$13,000 | 3.30 | \$43,600 |
| P-503 | Process Machinery | \$8,700 | 3.30 | \$28,600 |
| P-504 | Process Machinery | \$30,400 | 3.30 | \$101,500 |
| CP-101 | Compressor | \$34,100 | 2.15 | \$73,400 |
| CP-102 | Compressor | \$82,000 | 2.15 | \$176,300 |
| CP-103 | Compressor | \$196,600 | 2.15 | \$422,800 |
| CP-201 | Compressor | \$360,000 | 2.15 | \$773,900 |
| CP-501 | Compressor | \$10,700 | 2.15 | \$23,000 |

| | | | | |
|--------------|-------------------|-------------|------|-------------|
| E-001 | Heater | \$88,100 | 3.17 | \$279,400 |
| E-002 | Heater | \$38,900 | 3.17 | \$123,200 |
| E-401 | Heater | \$38,900 | 3.17 | \$123,300 |
| E-402 | Heater | \$150,800 | 3.17 | \$478,000 |
| M-001 | Mixing Vessel | \$215,700 | 4.28 | \$980,700 |
| M-002 | Mixing Vessel | \$384,500 | 4.28 | \$1,799,000 |
| M-401 | Mixing Vessel | \$66,700 | 4.28 | \$311,000 |
| M-402 | Mixing Vessel | \$28,400 | 4.28 | \$121,900 |
| F-101 (x2) | Growth Fermenter | \$36,400 | 4.16 | \$158,000 |
| F-102 (x2) | Growth Fermenter | \$111,000 | 4.16 | \$486,500 |
| F-103 (x2) | Growth Fermenter | \$400,600 | 4.16 | \$1,966,300 |
| F-201 (x6) | Growth Fermenter | \$1,180,400 | 4.16 | \$5,910,400 |
| RF-401 | Rotary Filter | \$116,900 | 2.03 | \$237,300 |
| RF-402 | Rotary Filter | \$116,900 | 2.03 | \$237,300 |
| RF-501 | Rotary Filter | \$127,700 | 2.03 | \$259,200 |
| RF-502 | Rotary Filter | \$114,800 | 2.03 | \$233,100 |
| CB-401 | Conveyer Belt | \$112,000 | 1.61 | \$180,400 |
| CB-402 | Conveyer Belt | \$78,300 | 1.61 | \$126,100 |
| CB-501 | Conveyer Belt | \$73,500 | 1.61 | \$118,300 |
| CF-401 | Centrifuge | \$312,600 | 2.03 | \$634,700 |
| CF-402 | Centrifuge | \$126,200 | 2.03 | \$256,200 |
| KE-501/E-501 | Kettle Evaporator | \$108,700 | 3.17 | \$344,700 |
| C-501 | Condenser | \$47,300 | 3.17 | \$149,900 |
| C-502 | Condenser | \$42,100 | 3.17 | \$133,600 |
| RD-501 | Diacid Dryer | \$83,600 | 2.06 | \$172,300 |
| MT-501 | Melting Tank | \$17,400 | 3.5 | \$65,700 |
| FL-501 | Flaker | \$63,300 | 10 | \$632,800 |

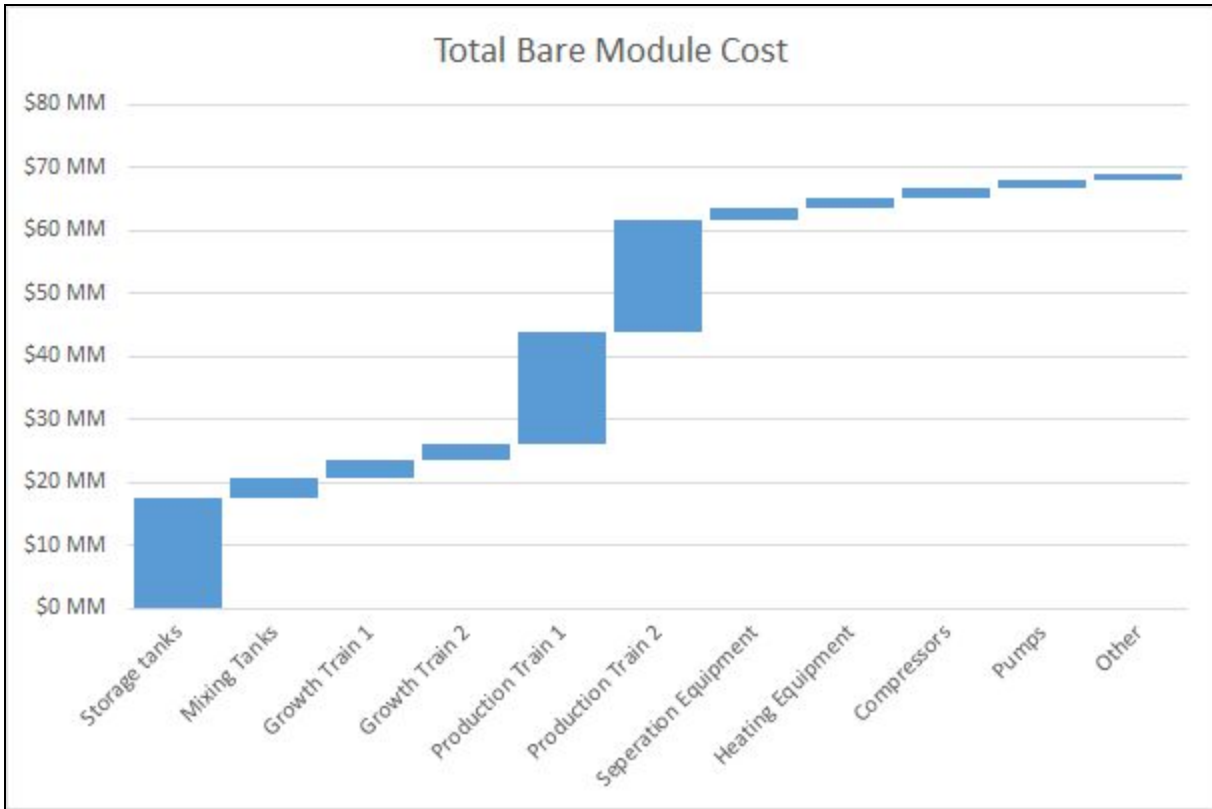


Figure 17.1: Total Bare Module Cost for Plant Equipment. Cost is continually summed throughout the figure. Size of bar represents relative cost of equipment listed

In order to build this plant, there is a total capital investment (TCI) required of approximately \$106 MM is required. \$69 MM of this total will be spent towards purchasing and installing equipment pieces such as fermenters, heaters, compressors, and more. There is a breakdown of the capital investment in Figure 17.1 by the type of equipment. The majority of equipment investment is allocated to the equipment associated with the two fermentation production trains. This seems logical as the six production fermentation vessels are responsible for the value creation stage of the proposed design.

Section 17.1: Unit Costing Considerations

Section 17.1.1: Pumps, Compressors and Agitator

The pumps, compressors and the agitator in this section were all costed according to the equations in Table 16.32 of *Seider et. al, 2017*.^{17.1} The purchase costs for the pumps required the flow rates through each pump in gallons per minute and the pressure head in feet for each pump. In order to cost each compressor, the flow through each compressor in cubic feet per minute was required. Lastly, in order to cost the agitator, the agitator horsepower was required. Each of these unit costing inputs was either retrieved from ASPEN simulation results or was calculated by supplementary equations in Chapter 16 of *Seider et. al, 2017*.^{17.2}

Section 17.1.2: Heat Exchangers and Condensers

The four heaters were costed according to the heat exchanger equations in Chapter 16 of *Seider et. al, 2017*.^{17.3} In order to use these equations, the surface area in square feet and the material of construction (stainless steel) were required. This same process was required for condensers.

In order to calculate the required surface area of the heat exchangers, the weighted heat capacity of all stream components, the mass flow rates of the stream, and the desired temperature change must all be known. For heat exchangers, as opposed to evaporators, no information regarding phase change heat of vaporization was required. This heat duty, the log mean temperature difference of the stream and the heating fluid, as well as an estimated heat transfer coefficient for the device used, allowed for an estimated surface area to be determined. This value was then used to inform the purchase cost of said equipment and bare module factors were

taken into consideration. In order to calculate the surface area of condensers, the total sensible and latent heat was divided by the log mean temperature difference and the heat transfer coefficient. More in-depth calculations can be found in the Appendix.

Section 17.1.3: Kettle Evaporator and Diacid Dryer

In order to cost the kettle evaporator, the equation for a shell-and-tube heat exchanger was utilized from Chapter 16 in *Seider et. al, 2017*.^{17.4} In order to determine the purchase cost, the surface area and material of construction of the heat exchanger were required. The surface area in square feet was determined by dividing the total sensible and latent heat by the heat transfer coefficient and the log mean temperature difference. The material of construction was again chosen to be stainless steel.

Costing of the diacid dryer was done according to the equation for a direct-heat rotary dryer in Chapter 16 of *Seider et. al, 2017*. In order to cost the diacid dryer, the surface area in square feet was required. Calculating the surface area was performed similarly to the kettle evaporator sizing process; the sum of the sensible and latent heat transferred was divided by the heat transfer coefficient and the log-mean temperature difference. The total heat included the heat required to heat the ethyl acetate, vaporize it and heat the vapor to the temperature of the vessel.

Section 17.1.4: Melting Tank and Flaker

In order to find the purchase cost of the melting tank, equations for a vertical pressure vessel and agitator were utilized from Chapter 16 from *Seider et. al, 2017*.^{17.5} In addition, a multiplier was added to account for a heating jacket, as advised by Professor Vrana. In order to cost the vertical pressure vessel, the diameter and length of the tank, the maximum allowable

pressure, and the material of construction were required. The diameter and length were determined by specifying the volumetric flow rate and the residence time of the tank. The maximum allowable pressure was determined by specifying the tank temperature, and the material of construction was set to be stainless steel.

In order to cost the flaker, Professor Vrana advised our team to determine the purchase cost of a conveyor belt with similar dimensions, and to utilize a bare module cost of 10 in order to account for all of the peripheral equipment required. The equation to cost a conveyor belt was found in Chapter 16 of Seider et. al, 2017.^{17.6} The surface area of the conveyor belt was required and was determined by evaluating the volumetric flow rate of material passing through the flaker.

Section 17.1.5: Rotary Filter, Conveyer Belt, and Centrifuges

The purchase costs for rotary filters, conveyer belts and centrifuges were calculated according to equations in Section 16 of *Seider et. al, 2017*.^{17.7} In order to cost the rotary filters, the surface area in square feet was required. This was determined by evaluating the flow of solids through the filters and comparing this to filtering area specifications on a size chart by ALAR Engineering Corporation.^{17.8} In order to determine the purchase costs of conveyor belts, the width and length of the conveyor belt were required. These dimensions were calculated from the flow rate of material traveling on the belt. Lastly, to evaluate the purchase cost of the centrifuges, the flow rate of solids through each centrifuge was required and was obtained from ASPEN simulation process results.

Section 17.1.6: Storage Tanks

The purchase costs of the storage tanks were determined by using equations for Vertical Pressure Vessels in Chapter 16 of *Seider et. al, 2017*.^{17,9} In order to cost for the storage tanks, the diameter, length, maximum allowable stress in psi and material of construction of the vessels were required. The diameter and length were calculated by sizing for the volume of the tank and utilizing a length to diameter ratio of 10, as advised by Professor Vrana. The material of construction was assumed to be stainless steel and the maximum allowable stress was determined by the temperature of the vessel.

Section 17.1.7: Fermenters, Mixing Vessels, and Agitators

The fermenters were costed according to vertical pressure vessel and agitator equations in Chapter 16 of *Seider et. al, 2017*.^{17,10} In order to confirm the accuracy of this equipment fit, the surface area correlated to heat transfer was calculated and compared to the vessel size to confirm that the vessel was appropriate for sizing the fermenter. Then, a factor of 1.15 was multiplied to account for the cost of the heating jacket, as advised by Professor Vrana. An agitator was also costed based on Table 17.2 provided by Dr. Bockrath.

The mixing vessel costs were also calculated according to equations for vertical pressure vessels and agitators in Chapter 16 of *Seider et. al, 2017*. As mentioned previously, the dimensions of the tank and material of construction were required to determine the cost of the tank. The dimensions of the tank were found from the volumetric flow through the vessel and the material of construction was set to be stainless steel.

Table 17.2 : Fermentation agitator sizing table courtesy of Dr. Bockrath

| Working volume, M3 | Tank diam., M | Liquid level, M | Tank SS, M | OTR, mmol/h | Airflow, m3/h | Agitator motor size, kW | Compressor motor size, kW | Agitator speed, rpm | ~ impeller size, 4 impellers, M | ~ Seal shaft diam., mm | ~ Extension shaft diam, pipe size | Total brake power, kW | Annual power cost, \$K | Agitator capital cost, \$K |
|--------------------|---------------|-----------------|------------|-------------|---------------|-------------------------|---------------------------|---------------------|---------------------------------|------------------------|-----------------------------------|-----------------------|------------------------|----------------------------|
| 80 | 3.47 | 8.68 | 11.8 | 50 | 1100 | 75 | 75 | 125 | 1.07 | 95 | 6" sch80 | 122 | 75 | 160 |
| 80 | 3.47 | 8.68 | 11.8 | 100 | 2210 | 149 | 149 | 125 | 1.25 | 119 | 8" sch 80 | 255.9 | 157 | 230 |
| 80 | 3.47 | 8.68 | 11.8 | 150 | 3400 | 224 | 261 | 155 | 1.20 | 127 | 8" sch 80 | 394.9 | 242 | 330 |
| 80 | 3.47 | 8.68 | 11.8 | 200 | 4590 | 298 | 335 | 155 | 1.28 | 139 | 8" sch 120 | 536.7 | 329 | 420 |
| 280 | 5.27 | 13.17 | 18.0 | 50 | 3400 | 224 | 261 | 100 | 1.52 | 147 | 8" sch 120 | 399.2 | 245 | 380 |
| 280 | 5.27 | 13.17 | 18.0 | 100 | 6970 | 410 | 559 | 125 | 1.55 | 167 | 10" sch 120 | 833.1 | 511 | 590 |
| 280 | 5.27 | 13.17 | 18.0 | 150 | 10600 | 671 | 894 | 125 | 1.70 | 196 | 12" sch 120 | 1282 | 786 | 780 |
| 280 | 5.27 | 13.17 | 18.0 | 200 | 14300 | 894 | 1118 | 125 | 1.81 | 216 | 12" sch 120 | 1741 | 1068 | 1100 |
| 500 | 6.39 | 15.98 | 21.5 | 50 | 5870 | 335 | 559 | 100 | 1.69 | 168 | 10" sch 120 | 705.3 | 432 | 530 |
| 500 | 6.39 | 15.98 | 21.5 | 100 | 12100 | 745 | 1118 | 125 | 1.72 | 203 | 12" sch 120 | 1469 | 901 | 1200 |
| 500 | 6.39 | 15.98 | 21.5 | 150 | 18200 | 1118 | 1831 | 125 | 1.88 | 233 | 14" sch 160 | 2259 | 1385 | 1500 |
| 500 | 6.39 | 15.98 | 21.5 | 200 | 24500 | 1490 | 2235 | 125 | 2.01 | 256 | 16" sch 120 | 3065 | 1879 | 1800 |
| 750 | 7.32 | 18.29 | 24.9 | 50 | 8500 | 559 | 745 | 84 | 2.01 | 211 | 12" sch 120 | 1038 | 637 | 840 |
| 750 | 7.32 | 18.29 | 24.9 | 100 | 17300 | 1118 | 1490 | 125 | 1.84 | 233 | 14" sch 80 | 2160 | 1325 | 1600 |
| 750 | 7.32 | 18.29 | 24.9 | 150 | 26200 | 1676 | 2235 | 125 | 2.02 | 266 | 16" sch 120 | 3317 | 2034 | 2000 |
| 750 | 7.32 | 18.29 | 24.9 | 200 | 35400 | 2235 | 2980 | 125 | 2.15 | 293 | 18" sch 120 | 4498 | 2758 | 2700 |
| 1000 | 8.05 | 20.13 | 27.2 | 50 | 11000 | 596 | 1118 | 84 | 2.11 | 216 | 14" sch 80 | 1368 | 839 | 860 |
| 1000 | 8.05 | 20.13 | 27.2 | 100 | 22600 | 1490 | 2235 | 100 | 2.21 | 276 | 16" sch 120 | 2840 | 1741 | 2000 |
| 1000 | 8.05 | 20.13 | 27.2 | 150 | 34300 | 2235 | 2980 | 125 | 2.11 | 293 | 18" sch 120 | 4360 | 2674 | 2700 |
| 1000 | 8.05 | 20.13 | 27.2 | 200 | 45900 | 2980 | 4470 | 125 | 2.26 | 323 | 18" sch 120 | 5908 | 3623 | 3600 |
| 1400 | 9.01 | 22.52 | 30.2 | 50 | 15100 | 894 | 1490 | 68 | 2.53 | 265 | 16" sch 120 | 1891 | 1160 | 1800 |
| 1400 | 9.01 | 22.52 | 30.2 | 100 | 30600 | 1676 | 2980 | 100 | 2.34 | 287 | 18" sch 120 | 3922 | 2405 | 2200 |
| 1400 | 9.01 | 22.52 | 30.2 | 150 | 46600 | 2608 | 4470 | 125 | 2.24 | 309 | 18" sch 120 | 6012 | 3687 | 3100 |
| 1400 | 9.01 | 22.52 | 30.2 | 200 | 62700 | 3725 | 5588 | 125 | 2.38 | 348 | 20" sch 80 | 8143 | 4993 | 3900 |
| 2200 | 10.47 | 26.19 | 35.2 | 50 | 23500 | 1490 | 2235 | 68 | 2.76 | 314 | 18" sch 120 | 2926 | 1794 | 3000 |
| 2200 | 10.47 | 26.19 | 35.2 | 100 | 47900 | 2608 | 4470 | 84 | 2.83 | 353 | 20" sch 120 | 6065 | 3719 | 4100 |
| 2200 | 10.47 | 26.19 | 35.2 | 150 | 72400 | 4470 | 6705 | 100 | 2.79 | 398 | 22" sch 120 | 9294 | 5699 | 5000 |
| 2200 | 10.47 | 26.19 | 35.2 | 200 | 97600 | 5588 | 8940 | 100 | 2.97 | 429 | 24" sch 120 | 12586 | 7718 | 5800 |
| 3000 | 11.61 | 29.04 | 38.8 | 50 | 30600 | 1490 | 3725 | 56 | 3.25 | 335 | 20" sch 120 | 4018 | 2464 | 3400 |
| 3000 | 11.61 | 29.04 | 38.8 | 100 | 62000 | 3725 | 6705 | 84 | 2.96 | 397 | 22" sch 120 | 8303 | 5091 | 4700 |
| 3000 | 11.61 | 29.04 | 38.8 | 150 | 94500 | 5588 | 11200 | 100 | 2.91 | 429 | 24" sch 120 | 12703 | 7789 | 6200 |
| 3000 | 11.61 | 29.04 | 38.8 | 200 | 1E+05 | 7450 | 14900 | 100 | 3.11 | 472 | 26" x 2" | 17210 | 7823 | 7800 |
| 4000 | 12.78 | 31.96 | 42.4 | 50 | 40100 | 2235 | 4470 | 56 | 3.39 | 383 | 22" sch 120 | 5323 | 10554 | 4300 |
| 4000 | 12.78 | 31.96 | 42.4 | 100 | 81100 | 4470 | 8940 | 68 | 3.52 | 453 | 26" x 2" | 10984 | 6735 | 6100 |
| 4000 | 12.78 | 31.96 | 42.4 | 150 | 1E+05 | 6705 | 14900 | 84 | 3.39 | 483 | 26" x 2" | 16789 | 10295 | 7700 |
| 4000 | 12.78 | 31.96 | 42.4 | 200 | 2E+05 | 8940 | 18625 | 100 | 3.26 | 501 | 28" x 2" | 22693 | 13915 | 9500 |

Section 18

Fixed Capital Investment Summary

The total capital investment for the plant was calculated according to the process outlined in Chapter 17 of *Seider et. al, 2017*.^{18.1} The total bare module cost for equipment was calculated by multiplying the total purchase cost of the equipment times the bare-module factor. The total bare module cost for all fermentation, filtration and crystallization equipment was calculated to be \$69 MM.

The costs included in the total capital investment are the costs associated with site preparation, service facilities, contractor fees, land and plant start-up. Table 18.1 shows each component of the total capital investment and the method in which each was calculated.

Table 18.1: Total Capital Investment (TCI) Components. This table demonstrates the various components of TCI and their method of calculation.

| Component of Total Capital Investment | Method of Calculation |
|---|------------------------------------|
| Cost of Site Preparations | 5% of Total Bare Module Costs |
| Cost of Service Facilities | 5% of Total Bare Module Costs |
| Cost of Contingencies and Contractor Fees | 18% of Direct Permanent Investment |
| Cost of Land | 2% of Total Depreciable Capital |
| Cost of Plant Start-Up | 10% of Total Depreciable Capital |

Finally, a summary of the total investment required for this project is included in Table 18.2. The total permanent investment required in order to start up the plant is \$100 MM. As seen, the total bare module cost of equipment makes up the majority of this initial investment with \$69 MM.

Table 18.2: Total Capital Investment Breakdown. This table outlines the components of the total investment required for the startup of the plant.

| Investment Summary | | | |
|--|----|------------|-----------------------|
| <u>Total Bare Module Costs:</u> | | | |
| Fabricated Equipment | \$ | 50,151,499 | |
| Process Machinery | \$ | 1,248,446 | |
| Spares | \$ | - | |
| Storage | \$ | 17,673,377 | |
| Other Equipment | \$ | - | |
| Catalysts | \$ | - | |
| Computers, Software, Etc. | \$ | - | |
| <u>Total Bare Module Costs:</u> | | | \$ 69,073,323 |
| <u>Direct Permanent Investment</u> | | | |
| Cost of Site Preparations: | \$ | 3,453,666 | |
| Cost of Service Facilities: | \$ | 3,453,666 | |
| Allocated Costs for utility plants and related facilities: | \$ | - | |
| <u>Direct Permanent Investment</u> | | | \$ 75,980,655 |
| <u>Total Depreciable Capital</u> | | | |
| Cost of Contingencies & Contractor Fees | \$ | 13,676,518 | |
| <u>Total Depreciable Capital</u> | | | \$ 89,657,173 |
| <u>Total Permanent Investment</u> | | | |
| Cost of Land: | \$ | 1,793,143 | |
| Cost of Royalties: | \$ | - | |
| Cost of Plant Start-Up: | \$ | 8,965,717 | |
| Total Permanent Investment - Unadjusted | | | \$ 100,416,033 |
| Site Factor | | | 1.00 |
| <u>Total Permanent Investment</u> | | | \$ 100,416,033 |

Section 19

Operating Costs- Cost of Manufacturing

Section 19.1: Variable Operating Costs

The total variable operating costs are broken up into raw materials, utilities and general expenses, as outlined in Chapter 17 of *Seider et. al, 2017*.^{19.1} The raw materials for this plant are water, glucose, palm oil, media salts and ethyl acetate, as outlined in Table 19.1. In total, the raw materials constitute \$17.7MM of the total variable operating costs. The utilities costs are composed of costs for low pressure steam, cooling water, electricity and nitrogen, as shown in Table 19.2. The utilities cost make up a total of about \$6.96MM. Lastly, the general expenses are broken down into selling/transfer expenses, direct research, allocated research, administrative expenses and management incentive compensation. The method in which these are calculated are outlined in Table 19.3. General expenses make up a total of \$11.5MM.

Table 19.1: Raw Material Costs. This table outlines the total annual costs of raw materials in the process

| Raw Material | Estimated Cost (\$/kg) | Required Ratio (/lb of DDDA) | Total Annual Cost (\$MM/year) |
|---------------|------------------------|------------------------------|-------------------------------|
| Water | (\$0.00027) | 0.65 kg/lb DDDA | (\$0.00550MM) |
| Glucose | (\$0.180) | 0.046 kg/lb DDDA | (\$0.259MM) |
| Palm Oil | (\$0.696) | 0.60 kg/lb DDDA | (\$13.1MM) |
| Media Salts | (\$0.027) | 0.067 kg/lb DDDA | (\$0.0567MM) |
| Ethyl Acetate | (\$0.80) | 0.17 kg/lb DDDA | (\$4.28MM) |
| Total | | | (\$17.7MM) |

The cost of process water was found to be \$0.00027/kg from Table 17.1 in *Seider et. al, 2017*.^{19.2} Palm oil and glucose prices are determined by global commodities prices. These commodity prices determined the cost of palm oil and glucose to be \$0.696/kg and \$0.180/kg

respectively.^{19.3,19.4} The ethyl acetate price was found on Alibaba as \$800 per metric ton.^{19.5}

Lastly, the cost of media salts was determined by performing a weighted average of the cost of each component part in the media.^{19.5}

Table 19.2: Utilities Costs. This table demonstrates the annual utilities costs.

| Utilities | Cost | Required Ratio (per lb DDDA) | Quantity (per year) | Total Cost (\$/op-yr) |
|--------------------|----------------|---------------------------------|------------------------|--------------------------|
| Low Pressure Steam | (\$0.006/lb) | 2.911 | 91.2MM lb | (\$0.55MM) |
| Cooling Water | (\$0.0001/gal) | 82.40 | 2.58MM gal | (\$0.26MM) |
| Electricity | (\$0.07/kWh) | 2.81 | 87.7MM kWh | (\$6.14MM) |
| Nitrogen | (\$0.01/lb) | 0.0017 | 0.053MM lb | (\$0.00050MM) |
| Total | | | | (\$6.96MM) |

The costs of low pressure steam, cooling water and electricity were determined from Table 17.1 of *Seider et. al, 2017*.^{19.6} The cost of nitrogen was given by Professor Vrana to be \$0.01/lb. As seen in Table 19.2, utilities constitute about \$6.96M of variable costs. Electricity alone is the largest contributor to the utilities cost and accounts for about 88% of the entire cost.

Table 19.3: General Expense Data. This table outlines the components of General Expenses and their estimated annual costs

| Component of General Expenses | Relationship to Sales | Total Annual Cost (\$/yr) |
|-----------------------------------|--------------------------|------------------------------|
| Selling/Transfer Expenses | 3.0% | (\$2.98MM) |
| Direct Research | 4.8% | (\$4.77MM) |
| Allocated Research | 0.50% | (\$0.50MM) |
| Administrative Expense | 2.0% | (\$1.99MM) |
| Management Incentive Compensation | 1.3% | (\$1.24MM) |
| Total | 11.6% | (\$11.5MM) |

As seen in Table 19.3, the components of general expenses are calculated in relation to the sales of the plant. This data was obtained from Chapter 17 of *Seider et. al, 2017*.^{19.7} General expenses associated with the plant make up \$11.5MM of variable costs.

Section 19.2: Fixed Operating Costs

The total fixed operating costs are broken up into operations, maintenance and operating overhead.

Table 19.4. Fixed Operations Costs. This table demonstrates the estimated total annual costs tied to labor-related operations

| Operations (labor-related) | Estimated Cost | Total Annual Cost (\$MM/yr) |
|---------------------------------------|----------------------------------|-----------------------------|
| Direct Wages and Benefits | \$40/operator hour | (\$2.08MM) |
| Direct Salaries and Benefits | 15% of Direct Wages and Benefits | (\$0.31MM) |
| Operating Supplies and Services | 6% of Direct Wages and Benefits | (\$0.12MM) |
| Technical Assistance to Manufacturing | \$60,000/yr/operating shift | (\$1.50MM) |
| Control Laboratory | \$65,000/yr/operating shift | (\$1.63MM) |
| Total | | (\$5.64MM) |

As seen in Table 19.4, the total fixed operations cost is \$5.64 MM. The number of daily operating shifts was assumed to be five, which each shift containing five operators. These assumptions were based on data from Table 17.3 in *Seider et. al, 2017* for batch and continuous operations.^{19.8}

Table 19.5. Fixed Maintenance Costs. This table displays the components of site maintenance and their estimated total annual costs.

| Maintenance | Estimated Cost | Total Annual Cost (\$MM/yr) |
|------------------------|--|------------------------------------|
| Wages and Benefits | 4.5% Total Depreciable Capital | (\$4.03MM) |
| Salaries and Benefits | 25% of Maintenance Wages and Benefits | (\$1.01MM) |
| Materials and Services | 100% of Maintenance Wages and Benefits | (\$4.03MM) |
| Maintenance Overhead | 5% of Maintenance Wages and Benefits | (\$0.20MM) |
| Total | | (\$9.28MM) |

The next component of fixed operating cost is the maintenance associated with the plant, as outlined in Table 19.5. The total maintenance cost contributes \$9.28 MM and makes up the largest portion of the fixed operating cost. The method of calculating each component of maintenance is displayed in Table 19.5.

Table 19.6 Fixed Operating Overhead, Taxes, and Insurance Costs. This table demonstrates total estimated annual costs related to operating overhead, taxes and insurance.

| Operating Overhead, Taxes, and Insurance | Estimated Cost | Total Annual Cost (\$MM/yr) |
|---|---|------------------------------------|
| General Plant Overhead | 7.1% of Maintenance and Operations Wages and Benefits | (\$0.528MM) |
| Mechanical Department Services | 2.4% of Maintenance and Operations Wages and Benefits | (\$0.178MM) |
| Employee Relations Department | 5.9% of Maintenance and Operations Wages and Benefits | (\$0.439MM) |
| Business Services | 7.4% of Maintenance and Operations Wages and Benefits | (\$0.550MM) |
| Property Taxes and Insurance | 2% of Total Depreciable Capital | (\$1.79MM) |
| Total | | (\$3.49MM) |

Lastly, the combination of operating overhead costs, taxes and insurance are shown in Table 19.6. These costs constitute \$3.49MM and make up the smallest portion of the fixed operating costs.

The total annual fixed operating cost, as seen in Tables 19.4-19.6 is \$18.4MM. The total operating costs, including both fixed and variable, is about \$36MM.

Section 20

Profitability Analyses - Business Case

Section 20.1: Plant Base Case Profitability

The production of DDDA as a metabolite of genetically engineered yeast using palm oil feedstock shows considerable potential as a profitable venture within the Asia Pacific chemicals market. The viability of this project is dependent on the ability to find funds or venture capital financing for the considerable upfront total capital investment associated with the process equipment.

The total capital investment for this project is \$107 MM. The working capital associated with this project is relatively low; this is due to the assumption supported by consultants that the construction time for the project will be approximately one year. Working capital is defined as the cost of current assets (DDDA inventory, accounts receivable, raw materials stores, etc.) minus the cost of liabilities such as accounts payable. With this definition in mind, the ratio of current assets to liabilities over the first three years of construction/scale up was found to be 5.64:1, clearly indicating the ability to pay back investors even on a short-term basis. The present value of the working capital is approximately \$6.3 MM and is outlined in Table 20.1.

Table 20.1: Summary of working capital requirements for the proposed project over the first three years of production (the capacity factors during this time were 0%, 50%, and 67% respectively)

| Working Capital | | | | |
|--|---------------------|------------------------------|---------------------|--|
| | 2019 | 2020 | 2021 | |
| Accounts Receivable | \$ 4,088,138 | \$ 1,362,713 | \$ 1,362,713 | |
| Cash Reserves | \$ 1,042,489 | \$ 347,496 | \$ 347,496 | |
| Accounts Payable | \$ (1,014,715) | \$ (338,238) | \$ (338,238) | |
| DDDA Inventory | \$ 545,085 | \$ 181,695 | \$ 181,695 | |
| Raw Materials | \$ 48,586 | \$ 16,195 | \$ 16,195 | |
| Total | \$ 4,709,582 | \$ 1,569,861 | \$ 1,569,861 | |
| <i>Present Value at 15%</i> | <i>\$ 4,095,289</i> | <i>\$ 1,187,040</i> | <i>\$ 1,032,209</i> | |
| <u>Total Capital Investment</u> | | <u>\$ 106,730,571</u> | | |

Following the first two years of operational scale up from 50%, the DDDA production plant will operate at 100% production capacity for 300 days each year. This allows for a production buffer by building in the assumption of production that does not necessarily operate continuously 365 days per year. This is an important assumption for this plant due to the strong reliance on batch process scheduling for the upstream fermentation process. Should these operations not be optimally scheduled at all times, downtime can occur, increasing the batch cycle time and driving down capacity.

Table 20.2 outlines several measures of profitability both at the onset of construction and for the third production year, the first year where the plant is operating at its maximum production capacity. Over the lifetime of the plant, the internal rate of return (IRR) is calculated to be 24.12%. This is approximately 1.6 times the nominal interest rate specified of 15%. The return on investment for this project is 18.20%.

Table 20.2: Profitability metrics for the DDDA production process. These measures of profitability use the averaged, base case pricing calculations and a nominal interest rate of 15%. Deviations from these values will be discussed in the sensitivity analysis.

| Profitability Measures | |
|--|---------------|
| The Internal Rate of Return (IRR) for this project is | 24.12% |
| The Net Present Value (NPV) of this project in 2018 is | \$ 54,081,800 |
| ROI Analysis (Third Production Year) | |
| Annual Sales | 82,898,350 |
| Annual Costs | (48,560,623) |
| Depreciation | (8,033,283) |
| Income Tax | (6,313,067) |
| Net Earnings | 19,991,378 |
| Total Capital Investment | 109,835,198 |
| ROI | 18.20% |

While this project offers a positive ROI, in order to understand the value creation opportunities of this project, they must be put in perspective relative to the larger chemical industry and other alternative investment opportunities. Over the past three years (2017-2015), the S&P 500, an American stock market index based on the market capitalizations of 500 large companies having common stock listed on the NYSE or NASDAQ, had an average returns of 11.72%.^{20.1} Evonik, a major player in the DDDA market and a major global manufacturer of specialty chemicals averaged 8.99% total returns over the last three years.^{20.2} While other industries may provide stronger year-over-year returns, the Dow Jones Industrial Average had returns of 25.08% in 2017.^{20.3} This project clearly represents a profitable and market competitive investment, especially within the specialty chemicals marketplace.

The net present value (NPV) of the base case profitability analysis was determined to be approximately \$54.1 MM. The assumptions for this base case is that DDDA is sold at a price of \$7/kg, a competitive price consistent with butadiene sourced DDDA, and the price controlling raw material (palm oil) costs \$696/metric ton.^{20.4} These assumptions resulted in a year over year revenue of \$98.5 MM at the capacity factor of 100% for 300 days per year. Figure 20.1 outlines the cumulative free cash flow generated over the 15-year operation period. Based on this figure, the breakeven period for this investment takes place during the fourth fiscal quarter of 2025.

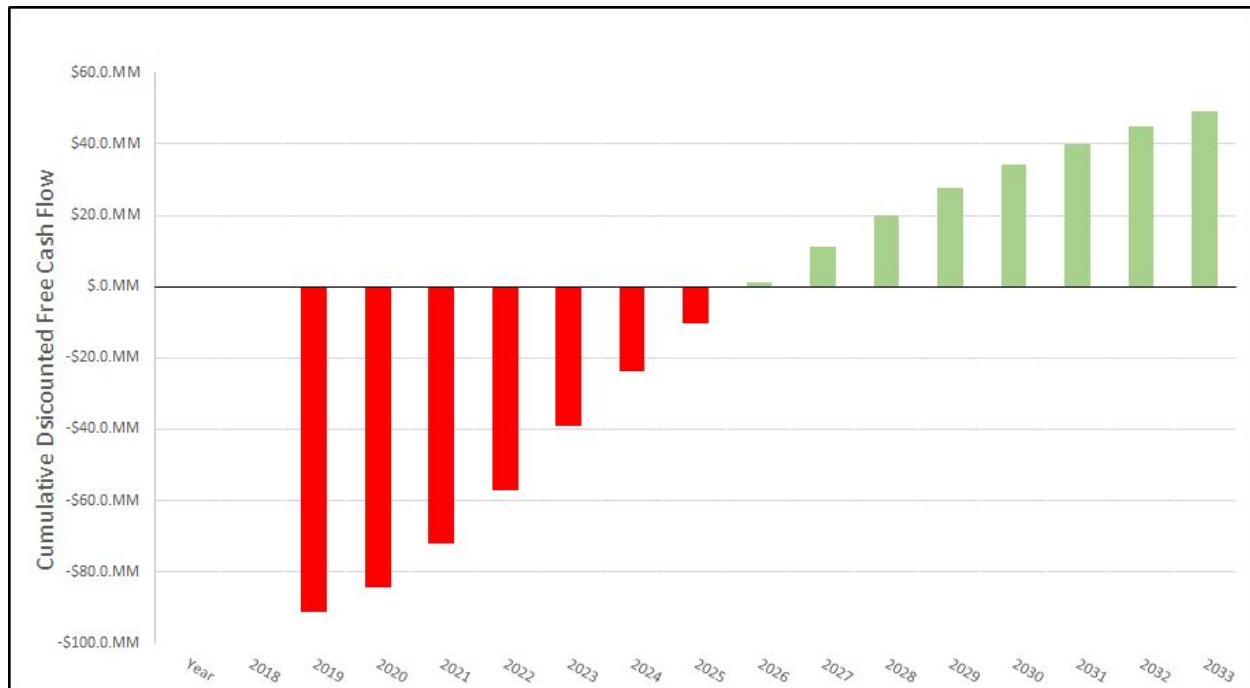


Figure 20.1: Cumulative discounted free cash flow for the DDDA production plant over a 15 year production lifespan assuming base case pricing structure for DDDA and palm oil

The profitability of this project as it is currently represented has a strong dependency on the length of the construction period for the production plant. Due to the high direct permanent investment and negative cash flows associated with site construction and the absence of DDDA production, the ROI for the project is strongly based on how quickly 100% capacity can be reached. Moving forward, exhaustive construction scheduling should be ensured in order to protect against this externality.

Table 20.3: Summary of annual earnings, investment depreciation, and taxes (24% in Malaysia) in order to calculate yearly cash flow for the base case pricing model

| Cash Flow Summary | | | | | | | | | | | | | | | |
|-------------------|-----------------|--------|--------------|------------|---------------|-----------------|--------------|--------------|--------------|---------------------|----------------|-------------|--------------|---------------|-------------------------------------|
| Year | Percentage of | | Product Unit | | | | | | | | | | | | |
| | Design Capacity | Price | | Sales | Capital Costs | Working Capital | Var Costs | Fixed Costs | Depreciation | Depletion Allowance | Taxable Income | Taxes | Net Earnings | Cash Flow | Cumulative Net Present Value at 15% |
| 2018 | 0% | | | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019 | 0% | | | - | (100,416,000) | (4,709,800) | - | - | - | - | - | - | - | (105,125,600) | (91,413,600) |
| 2020 | 50% | \$3.18 | | 49,739,000 | - | (1,569,900) | (18,090,600) | (18,409,700) | (4,482,900) | - | 8,755,900 | (2,101,400) | 6,654,500 | 9,567,500 | (84,179,200) |
| 2021 | 67% | \$3.18 | | 66,318,700 | - | (1,569,900) | (24,120,700) | (18,409,700) | (8,517,400) | - | 15,270,800 | (3,695,000) | 11,605,800 | 18,553,400 | (71,990,000) |
| 2022 | 83% | \$3.18 | | 82,898,400 | - | (1,569,900) | (30,150,900) | (18,409,700) | (7,665,700) | - | 26,672,000 | (6,401,300) | 20,270,700 | 26,366,600 | (56,904,900) |
| 2023 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (6,903,800) | - | 37,983,600 | (9,116,100) | 28,867,500 | 35,771,100 | (39,120,300) |
| 2024 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (6,213,200) | - | 38,674,000 | (9,281,800) | 29,392,200 | 35,605,500 | (23,727,100) |
| 2025 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,585,600) | - | 39,301,600 | (9,432,400) | 29,869,200 | 35,454,800 | (10,388,300) |
| 2026 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,289,800) | - | 39,597,400 | (9,503,400) | 30,094,100 | 35,383,800 | 1,168,800 |
| 2027 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,289,800) | - | 39,597,400 | (9,503,400) | 30,094,100 | 35,383,800 | 11,227,100 |
| 2028 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,298,700) | - | 39,598,500 | (9,501,200) | 30,097,200 | 35,386,000 | 19,979,900 |
| 2029 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,289,800) | - | 39,597,400 | (9,503,400) | 30,094,100 | 35,383,800 | 27,579,400 |
| 2030 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,298,700) | - | 39,598,500 | (9,501,200) | 30,097,200 | 35,386,000 | 34,193,300 |
| 2031 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,289,800) | - | 39,597,400 | (9,503,400) | 30,094,100 | 35,383,800 | 39,944,200 |
| 2032 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,298,700) | - | 39,598,500 | (9,501,200) | 30,097,200 | 35,386,000 | 44,945,300 |
| 2033 | 100% | \$3.18 | | 99,478,000 | - | - | (36,181,100) | (18,409,700) | (5,289,800) | - | 39,597,400 | (9,503,400) | 30,094,100 | 35,383,800 | 49,293,700 |
| 2034 | 100% | \$3.18 | | 99,478,000 | - | 9,419,200 | (36,181,100) | (18,409,700) | (5,298,700) | - | 39,598,500 | (9,501,200) | 30,097,200 | 44,805,100 | 54,081,800 |

Section 20.2: Fixed & Variable Cost Sensitivity

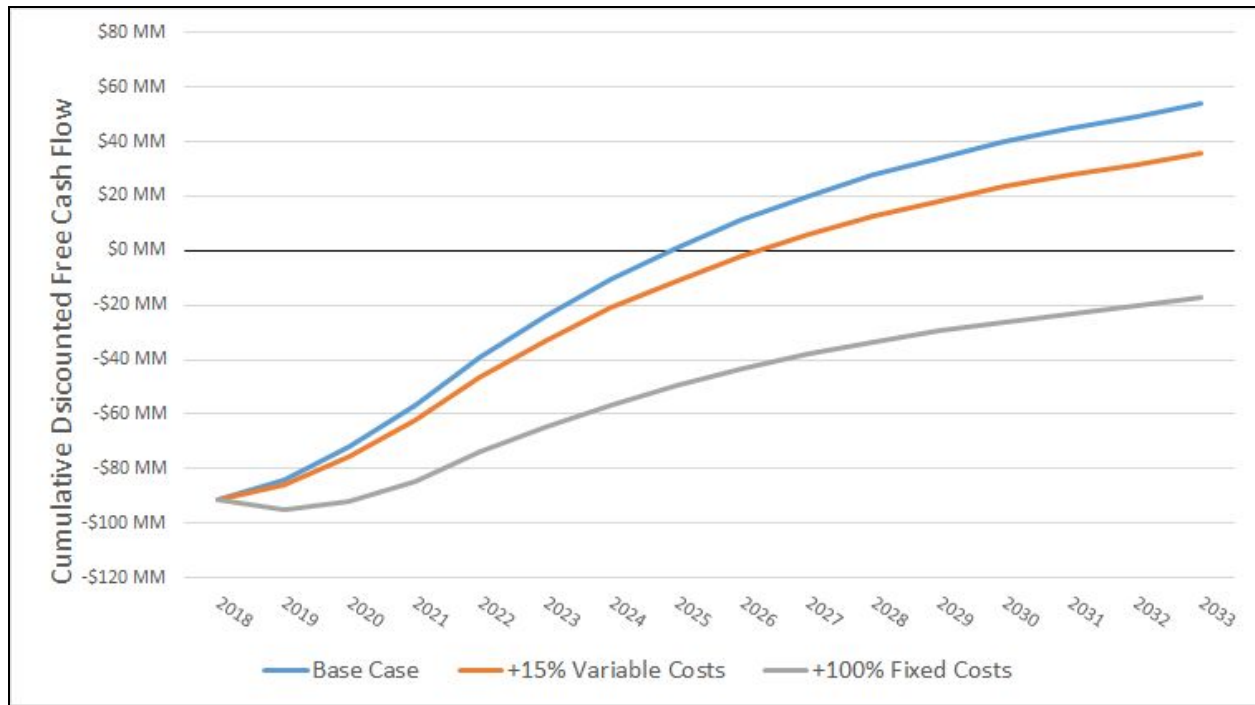


Figure 20.2: Cumulative discounted cash flow as a function of changing fixed and variable costs. Sensitivity for a 100% increase in fixed cost and a 15% increase in variable costs were explored.

Figure 20.2 outlines the strong dependency of the project to changes in the cost of equipment relative to changes in the cost of raw materials. This process relies heavily upon multistep fermentation, separation, and purification processes. These processes rely upon many expensive units of equipment, specifically the fermentation tanks, and this sensitivity is clearly indicated by the \$20 MM deficit produced by the 2 times increase in fixed costs. Comparatively, minor (<15%) fluctuations in variable costs do not appear to have nearly as strong of an influence on profitability; water, glucose, palm oil, and ethyl acetate are relatively low cost inputs relative to the value creation of the fermentation process. This variable costs influence on profitability is also a product of the utilities, specifically low pressure steam in the evaporation operations.

Further analysis of the influence of variation in raw materials pricing is discussed in Section 20.3.

Section 20.3: DDDA Sale Price Sensitivity

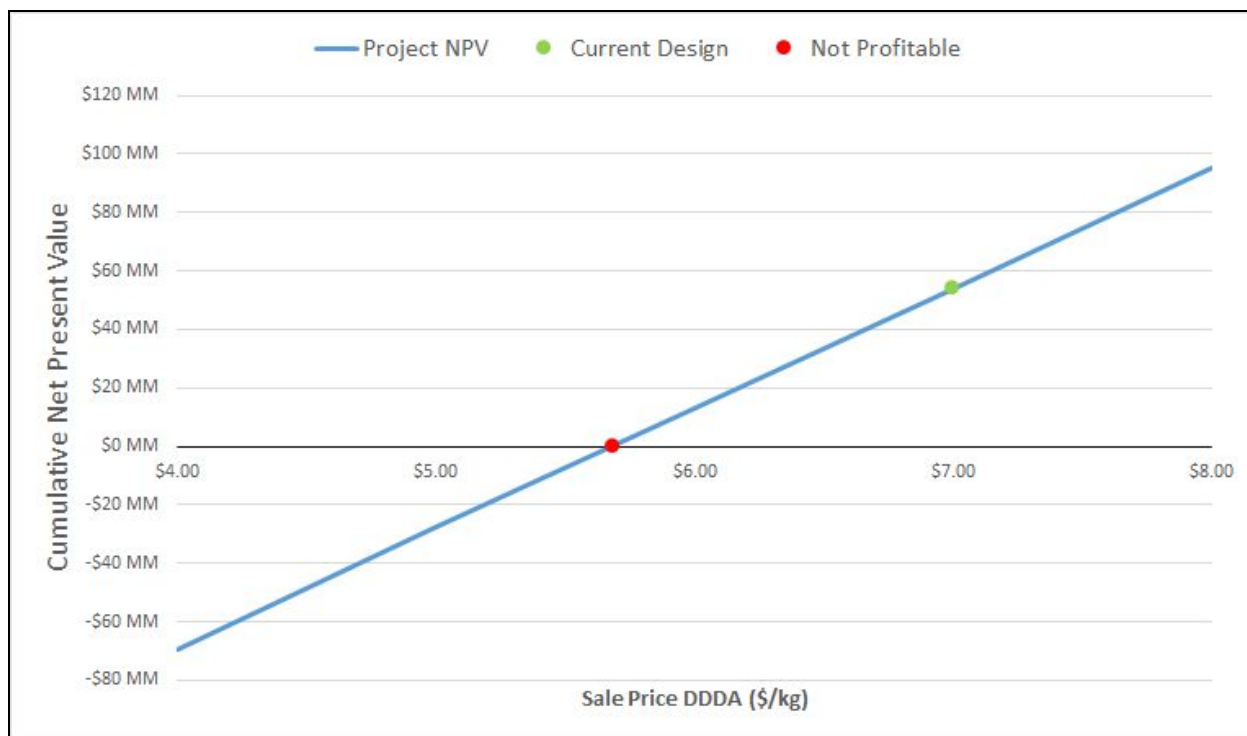


Figure 20.3: Effect of DDDA sale price on overall project profitability. The Current Design dot represents the base case pricing structure. The price of the manipulated variable was adjusted in order to find the price at which the project is no longer viable given no other changes to the process.

Figure 20.3 shows the strong dependence of project profitability on the sale price of DDDA. This dependency is not particularly surprising considering sale price is one of the strongest sliders for overall revenue. In this case, the breakeven price, the price at which the DDDA production plant will generate no profit over its 15-year production lifespan, is \$5.68/kg DDDA. This price is below the average sale price of DDDA by \$1.32/kg as of April 2018. Currently, bulk distributors can expect to sell one ton of 98.9% purity DDDA for \$7,900/ton (\$7.9/kg).^{20.5} With the demand for DDDA growing at 5-6% annually and a market with strong

inverse price swings related to butadiene availability (see Section 20.4), the sales price of DDDA is only expected to rise. While the base case of this profitability analysis assumed a conservative sale price of \$7/kg, this plant could feasible have NPV approaching \$100 MM. Should the sale price of DDDA stay locked in at \$8/kg across the 15 year life cycle of the plant, the ROI would be 25.15%.

Section 20.4: Palm Oil Sale Price Sensitivity

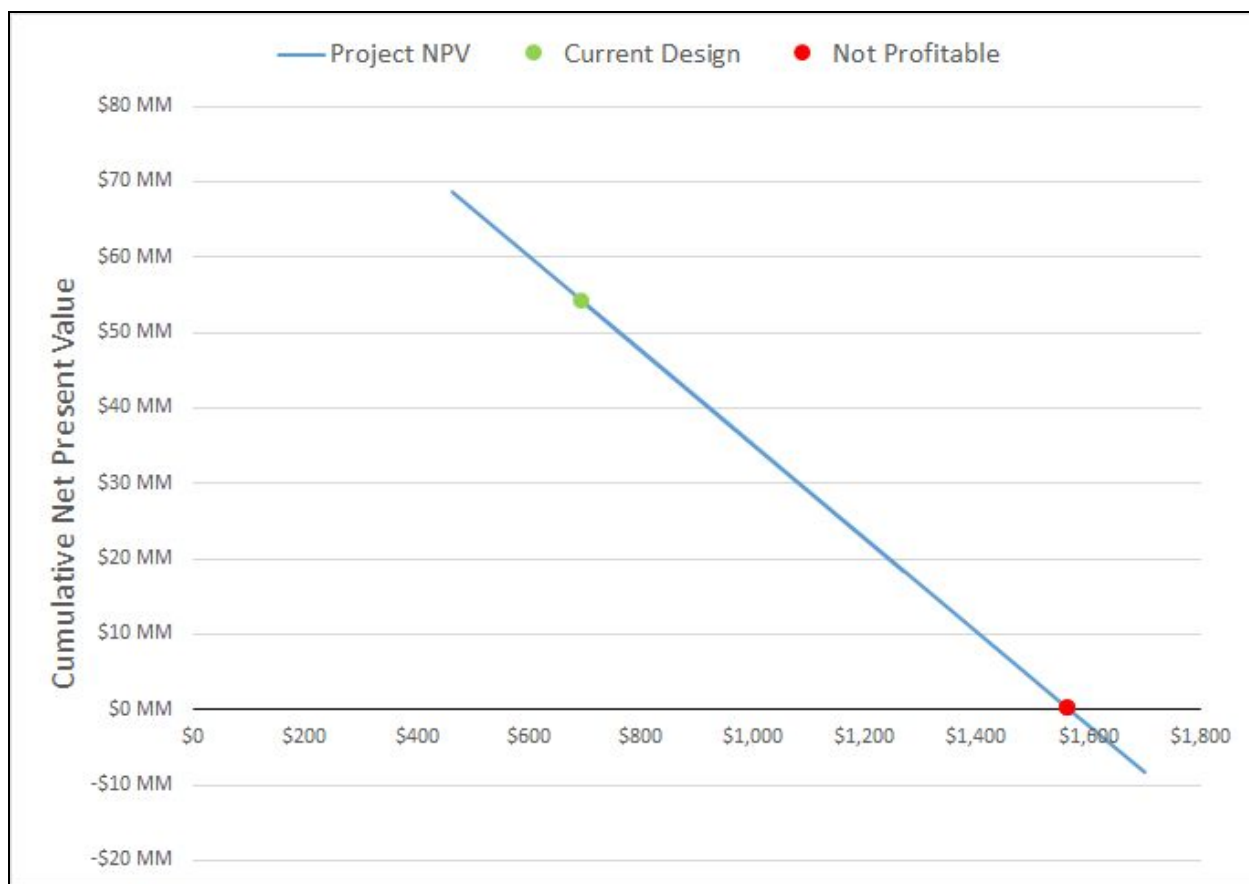


Figure 20.4: Effect of palm oil sale price on overall project profitability. The Current Design dot represents the base case pricing structure. The price of the manipulated variable was adjusted in order to find the price at which the project is no longer viable given no other changes to the process.

By a considerable margin, palm oil represents the largest raw material input for the production of DDDA. 0.6 kg (1.32 lb) of palm oil are required to produce 1.00 lb of DDDA.

other the process water, this represents the largest mass contribution to the feedstock per pound of product produce. Water however, is considerably cheaper than the fat acid feedstock; As shown in Figure 20.4, palm oil costs approximately \$696/MT (\$0.70/kg). The only raw material input to the process more expensive than palm oil is ethyl acetate, the organic solvent used in purification, at \$0.80/kg. Due to the approximate 99% recycle of ethyl acetate outlined in the Sections 13, the quantity of ethyl acetate per pound of product is far lower than palm oil at 0.17 kg (0.37 lb) per 1.00 lb DDDA. Therefore, sensitivity to variation in palm oil was the raw material analyzed for sensitivity.



Figure 20.5: Outlines that profitable pricing region for palm oil relative to 15 years of Asian Pacific palm oil pricing. There appears to be not historic context in which palm oil prices alone would result in this project becoming unprofitable.

Figure 20.4 and Figure 20.5 clearly indicate that the process is much more insensitive to palm oil prices than DDDA prices. Palm oil prices would need to reach historic highs in order to be the sole contributor to hindering project viability. \$696/MT was selected as the base case

palm oil price point because it was a medium price, and because it was the most recently quoted price for palm oil in the region.

Section 20.5: Palm Oil vs Butadiene Price Variability

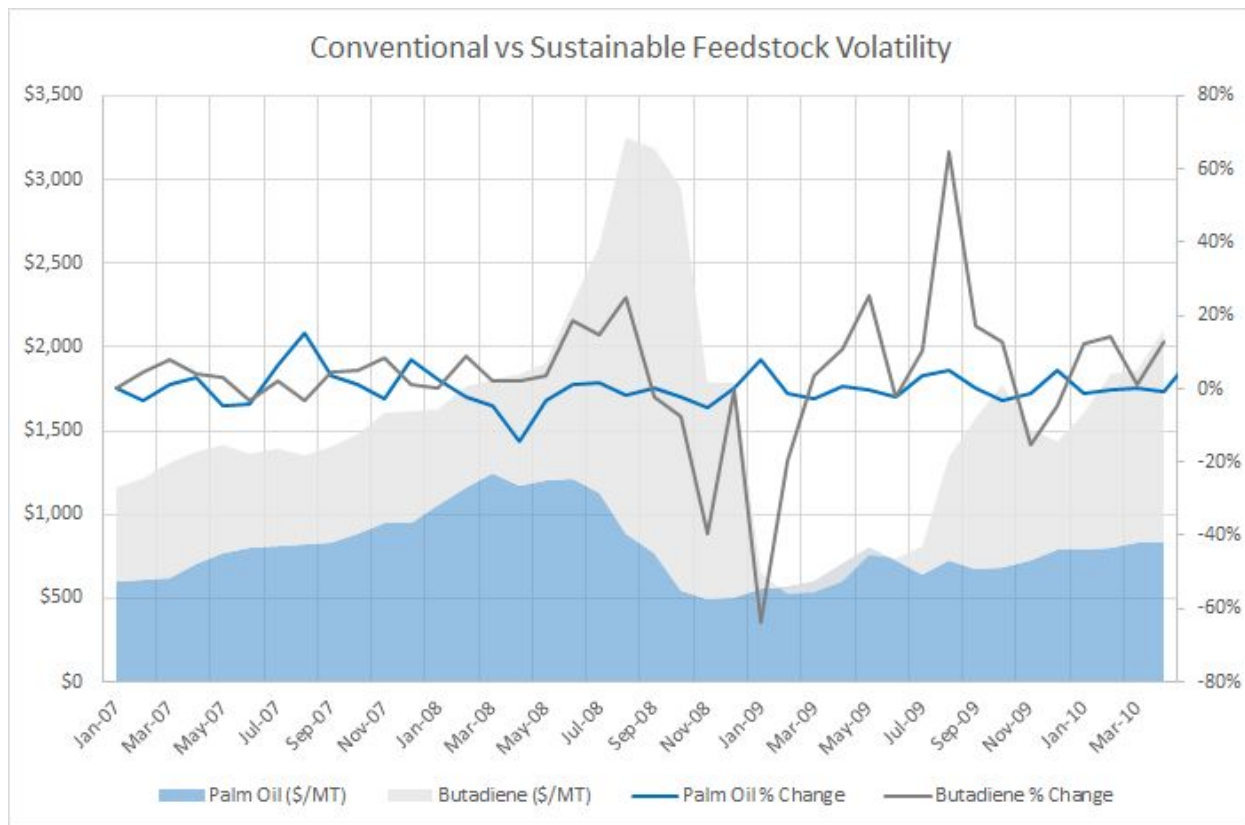


Figure 20.6: Feedstock Volatility over 3 years. The trend present in this figure is estimated to be cyclic. Variations in the peaks may occur.

As discussed in the Section 4: Market and Competition Analysis, butadiene pricing is very susceptible to price swings due changes in crude oil production. This price volatility does not affect this process, but is a far more important sensitivity for conventional petrochemical production. Comparing the month to month price fluctuation of palm oil to butadiene highlights the value added of having a reliable feedstock supply. Should palm oil prices have price fluctuation of 60% similar to butadiene in summer of 2009, it becomes clear that its price could feasibly approach the Not Profitable line in Figure 20.5. While the conversion efficiency and

mass ratio of butadiene for conventional DDDA production are not within the scope of this project, it is clear that raw materials sensitivity is much more of a consideration for the petrochemical synthesis of DDDA than the biological synthesis of DDDA. Under the base case pricing discussed, this project will produce value for shareholders and stakeholders.

Section 21

Other Important Considerations

Section 21.1 Environmental Considerations

DDDA and the other diacid impurities have no substantial negative environmental impact.^{21.1} Water contamination is not a concern because the diacids are readily biodegradable, with low bioaccumulation potential. Wastewater treatment is largely focused on treating biomass, media, and salts since there is no known toxicity of diacids in water.^{21.2}

This process evaporates a large amount of water vapor, nitrogen, and ethyl acetate. The biggest concern being the release of ethyl acetate, a volatile organic compound. Ethyl acetate released from this plant can cause significant air pollution and health effects further explained in Section 21.3. This process aims to minimize the release of ethyl acetate by condensing the vapor and recycling it.

Deforestation related to utilizing palm oil is a major environmental concern that is further explained in Section 21.4. This DDDA process will increase demand for palm oil, which will result in more deforestation. This domino effect is only regulated by the market size of DDDA that is subject to stringent regulations on volatile organic compounds (VOC) emissions. However, our team is choosing to purchase palm oil from vendors that are certified by the Roundtable on Sustainable Palm Oil (RSPO). RSPO Certification ensures that producers are limiting the land that may be developed for palm oil, curbing deforestation according to the RSPO principles and Criteria (P&C) standard.^{21.3}

Section 21.2 Process Controller Considerations

All the fermenters require height and temperature controllers. The temperature needs to be maintained across all seed, growth, and production fermenters to ensure a stable environment

for the conversion of palm oil to DDDA. Height controllers are needed to maximize the output from each fermenter ensuring our annual production goal is met.

The filtration section requires a valve before the rotary drums and a controller on the ethyl acetate stream leading into the mixing vessels. The valve before the drums will be kept open so they both operate in parallel. In the case a drum fails the valve will be closed, switching flow to the working drum while the failed drum undergoes maintenance. The controller on the ethyl acetate stream is set to meet design specifications explained in Section 6.4.

No controllers or valves are necessary for the crystallization part of the process. All equipment is running continuously. Failure of equipment in this part of the process will have to be maintained in the 60 days of non-operating time.

Section 21.3 Safety and Health Concerns

Primary health concern is the high exposure to ethyl acetate. The amount of ethyl acetate recycling through the plant can cause a number of adverse health problems in short term and long term exposure. Short term exposure can induce nausea and vomiting while long term exposure can induce eye, lung heart, kidney, or liver problems. The allowable exposure to ethyl acetate for workers over an 8 hour shift is 200 ppm.^{21.4}

Section 21.4 Plant Location, Startup, and Layout

The proposed plant will be located in Malaysia, preferably near a water treatment facility. Deforestation is a concern to plant palm to meet the current demands of DDDA. The plant will preferably be near a palm farm to provide feedstock and reduce transportation costs. The layout of the plant needs to be designed in a way which prioritizes worker safety and mitigates the risks of high exposure to VOCs. The plant needs to meet Malaysia regulations for VOC emissions,

building codes, and wastewater treatment. The startup cost for the plant includes site preparation, service facilities, land cost and contractor fees as explained in section 18.

Section 22

Conclusion and Recommendations

Analysis of the proposed process design suggests that the biological synthesis of dodecanedioic acid (DDDA) warrants further investigation of viability and more rigorous economic analysis. As dictated by the project objective, 14,000 metric tons of DDDA were modeled to be produced per year for sale to Asian Pacific markets. The product was of greater than 99% purity and met or exceeded known customer requirements set by conventionally sourced DDDA. Economic analysis estimates the NPV of the project to be \$54.1MM with an IRR of 24.12%. Prior to continued development of the described process, design calculations and processes (see Appendix A) should be revised to confirm accuracy. Assumptions surrounding equipment capacities and operating costs should additionally be refined.

Areas for additional model optimization include the fermentor, evaporation utilities, and water usage. A kinetic model of fermentation may serve as a more accurate model of growth rates and allow for the optimization of feedstock supply. Additional integration of heat utilities outside of heated organic solvent recycle may help to push down annual utilities costs. Finally, reprocessing of water in the fermentation units may allow for decreased feed of process water to existing regional palm oil extraction and water treatment infrastructure. Additional patent data must first be explored prior to implementation of the aforementioned model optimizations.

Separation of the diacid impurities (sebacic acid, suberic acid, adipic acid) from DDDA in ethyl acetate by solubility was determined to be infeasible due to their similar solubility properties. For this reason, the diacid melt crystallization unit was designed to take advantage of the diacids' different melting points to purify DDDA. This design was based upon industry consultant recommendations to analyze para-xylene separation from an m-xylene mixture. Should the window for melt crystallization be infeasible in practice, or should the diacid

impurities simply solubilize into the liquid DDDA, the diacid purification technique will have to be re-designed. Currently no research is apparent that refutes the feasibility of the process described in this proposed design.

The profitability of the proposed design relies most heavily upon the market price of DDDA and the total capital costs associated with multiple fermentation trains required to meet production goals. Sensitivity analysis indicates that a 20% decrease in the sale price of DDDA for the modeled base case could endanger the project viability. Similarly, a sizable (>50%) change in the calculated fixed cost of the equipment would have the same effect. While the former does not appear likely to occur due to the rising demand for DDDA relative to conventional supply, more rigorous analysis of total permanent capital is recommended to ensure the costs associated with equipment were not underestimated.

We caution against using optimistic cost information, keeping in mind associated uncertainties in the proposed design. However, based upon all available data provided, we do recommend investing in this project.

Section 23

Acknowledgements

Our group would like to express our gratitude to Professor Gorte for helping us stay focused on the physical aspects of the problem rather than focusing on simulations. Professor Gorte has helped with ideas in all three main components of this process fermentation, filtration, and crystallization and provided resources necessary to design this plant. Professor Seider and Dr. Wattenbarger we would also like to thank for helping us work out the mass balance on the fermentation

We would also like to thank the many industrial consultants that met with us throughout the semester and provided invaluable insight towards the specifics of equipment and problems we may run into in this process. Dr. Jeffrey Cohen, Ms. Mariella P. Juhasz, Mr. Gary Sawyer, Dr. Daniel Green, Dr. Arthur W. Etchells and many more along with Professor Seider who this would not be possible with, thank you.

Lastly we would like to thank Mr. Tieri, Professor Vrana, and Mr. Fabiano for their significant help in trouble-shooting aspen, designing pieces of equipment such as rotary filters, evaporators, crystallizers, etc. Their knowledge on aspen and process design was truly helpful, allowing us to finish this project on time.

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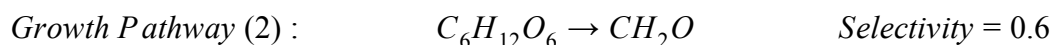
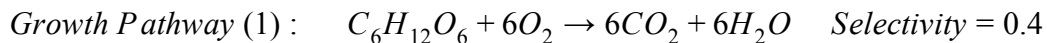
Section 25

Appendices

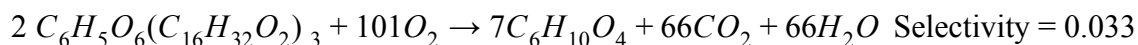
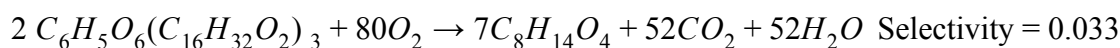
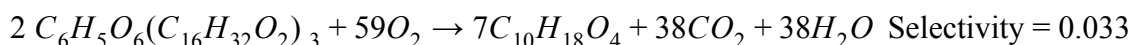
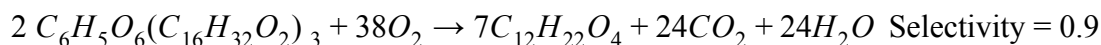
Appendix A: Sample Calculations

Fermentation Reaction Calculations

The following chemical reactions were derived using elemental balances. Certain species such as biomass and palm oil fatty acid triglycerides were given approximated stoichiometries for the purposes of balance simplification



Production Pathways: DDDA, Sebacic acid, Suberic Acid, and Adipic Acid (Figure 10.3)



Fermentation Air Feed Calculations

$$\frac{\text{kg air feed}}{\text{batch}} \times \frac{m^3 \text{ air}}{1.1455 \text{ kg air}} \times \frac{\text{vessle}}{m^3} \times \frac{1}{\text{batch minutes}} = \frac{\text{vessle volumes}}{\text{minute}} = \text{VVM}$$

Sample Calculation: $1m^3$ growth fermenter

$$\frac{946.9 \text{ kg air feed}}{\text{batch}} \times \frac{m^3 \text{ air}}{1.1455 \text{ kg air}} \times \frac{\text{vessle}}{1 m^3} \times \frac{1}{24 * 60 \text{ min}} = \frac{\text{vessle volumes}}{\text{minute}} = 0.57$$

Filtration Calculations

Drum Size:

Slurry stream 1 from section 400 has a solids flow rate of 2898.31 kg/hr. The solids are only diacids and biomass.

$$\begin{aligned}\text{Filter Area} &= \text{solids flow rate} / \text{capacity} = \frac{2898.31 \text{ kg}}{\text{hr}} \div \frac{6000 \text{ lb}}{\text{ft}^2\text{-day}} \\ &= \frac{2898.31 \text{ kg}}{\text{hr}} \times \frac{\text{ft}^2\text{-day}}{6000 \text{ lb}} \times \frac{2.2 \text{ lb}}{\text{kg}} \times \frac{24 \text{ hr}}{\text{day}} \\ &= 25.5 \text{ ft}^2 \text{ (round up to manufactured sizes)}\end{aligned}$$

Filter Area= 28.3 ft² (diameter: 3 feet, length: 3 feet)

Batch to Continuous Transition Calculation

In order to avoid build up of volume of fermentation broth to be processed in the continuous downstream processes, the flow rates used in the Aspen filtration report were set by the upstream production rate. This ensured that the surge tank would not need to be much larger than a factor larger than the size of a single batch.

$$\text{Averaged inlet flow} = \frac{\text{Batch volume}}{\text{Cycle Time}} = \frac{420 \text{ m}^3}{24 \text{ hours}} = 17.5 \frac{\text{m}^3}{\text{hours}} = \text{Required Downstream Processing Time}$$

Dissolution Calculations

Per patent information and solubility information outlined in Section 10, the ethyl acetate flow rate was set to 7 times greater than the flow rate of diacids. The solubility of diacids in the dissolution step was then calculated to ensure full solubilization of the products. The solubilities were found to be within the accept range for the diacids at the given temperature.

Example Calculations: M-401

$$\text{Diacid flowrate} = 2375.6 \frac{\text{kg}}{\text{hour}}$$

$$\text{Required Ethyl Acetate} = 2375.6 \frac{\text{kg}}{\text{hour}} \times 7 \frac{\text{kg eth ac}}{\text{kg diacid}} = 16629.2$$

$$\text{Ethyl Acetate feed} = 16629.9 - \text{Eth Ac Recycle} = 737.26 \frac{\text{kg}}{\text{hour}}$$

$$\text{Diacid Sol} = (2375.6 \frac{\text{kg}}{\text{hour}} \times \frac{1000 \text{ g}}{1 \text{ kg}}) \div (16629.9 \frac{\text{kg}}{\text{hour}} \times \frac{1 \text{ m}^3}{902 \text{ kg eth ac}} \times \frac{1000 \text{ L}}{1 \text{ m}^3}) = 128.9 \frac{\text{g diacid}}{\text{L eth ac}}$$

Fermentation Cooling Jacket Sizing & Heat Duty

The heat duty of all fermenters was calculated based upon the combustion of oxygen. This calculation and information regarding the cooling utility, chilled water, was used the size the area of the heating jacket. These heat transfer areas were compared to the internal area of the vessels in which they were required to fit, and were confirmed in all cases to be smaller. The heat transfer coefficient was estimated based on material to be 120 BTU/hr* ft^2 *F. This indicated that additional cooling coils were not required in order to maintain the internal temperature of the vessels. The quantity of utilities duty on each vessel was also calculated and informed utilities calculations is Section 14.

Sample Calculations: F-103

$$\text{Chilled Water Heat Duty} = 2870000 \frac{\text{mmol } O_2 \text{ combusted}}{\text{hour}} \times 0.45 \frac{\text{kJ}}{\text{mmol } O_2 \text{ combusted}} = 359.0 \text{ kW} \times 3412.14 \frac{\text{BTU/hr}}{\text{kW}} = 1224950 \frac{\text{BTU}}{\text{hour}}$$

$$LMTD = \frac{(T_{Hin} - T_{Cout}) - (T_{Hout} - T_{Cin})}{\ln\left(\frac{T_{Hin} - T_{Cout}}{T_{Hout} - T_{Cin}}\right)} = \frac{(98.6 - 80) - (77 - 60)}{\ln\left(\frac{98.6 - 80}{77 - 60}\right)} = 24.7^\circ\text{F}$$

$$\text{Surface Area}(A) = \frac{Q}{U \times LMTD} = \frac{1224950 \frac{\text{BTU}}{\text{hour}}}{120 \frac{\text{BTU}}{\text{hr} \cdot \text{ft}^2 \cdot ^\circ\text{F}} \times 24.7^\circ\text{F}} = 413.3 \text{ ft}^2$$

$$\text{Utility mass flow (m)} = \frac{Q}{C_p \times \Delta T} = \frac{359 \text{ kW}}{4.179 \frac{\text{J}}{\text{g} \cdot ^\circ\text{F}} \times (15.56^\circ\text{C} - 7.22^\circ\text{C})} = 10307 \frac{\text{g}}{\text{s}} = 37107 \frac{\text{kg}}{\text{hr}} = 9803 \frac{\text{gal}}{\text{hr}}$$

Heating/Evaporation Calculation & Sizing

The heat duty associated with preheating and reheating liquids throughout this process were calculated using low pressure steam. Using the flow rates of the streams being heated, their heat capacities, and the desired temperature change across the heat exchangers, the heat duty Q was calculated. It was assumed in all calculations that low pressure steam was fed into all heat exchangers as saturated steam at its vapor pressure. Low pressure steam was assumed to condense across the heat exchanger, releasing heat related to its heat of vaporization at the specified temperature and pressure. No heat transfer losses were factored into these calculations. Future considerations should seek to insert real-world inefficiencies into these heat transfer calculations.

Sample Calculations: E-402

$$\text{LP Steam Heat Duty (Q)} = \frac{m_{\text{stream}}}{c_{p \text{ weighted}} \times \Delta T} = \frac{93310 \text{ kg/hour}}{2.22 \frac{\text{J}}{\text{kg} \cdot \text{K}} \times (37^\circ\text{C} - 25^\circ\text{C})} = 689.6 \text{ kW} = 2353100 \frac{\text{BTU}}{\text{hr}}$$

$$\text{LMTD} = \frac{(T_{\text{Hin}} - T_{\text{Cout}}) - (T_{\text{Hout}} - T_{\text{Cin}})}{\ln\left(\frac{T_{\text{Hin}} - T_{\text{Cout}}}{T_{\text{Hout}} - T_{\text{Cin}}}\right)} = \frac{(186 - 37) - (163 - 25)}{\ln\left(\frac{186 - 37}{163 - 25}\right)} = 143^\circ\text{C} = 258^\circ\text{F}$$

$$\text{Surface Area (A)} = \frac{Q}{U \times \text{LMTD}} = \frac{2353100 \frac{\text{BTU}}{\text{hour}}}{120 \frac{\text{BTU}}{\text{ft}^2 \cdot ^\circ\text{F}} \times 258^\circ\text{F}} = 76 \text{ ft}^2$$

$$\text{Utility mass flow (m)} = \frac{Q}{\Delta H_{\text{vap}}} = \frac{689.6 \text{ kW}}{2147 \text{ kJ/kg}} = 0.32 \frac{\text{kg}}{\text{s}} = 2549 \frac{\text{lb}}{\text{hr}}$$

The evaporation units in this process were calculated similarly to the heating calculations above, but included additional calculations to account for the required phase change across the block. The heat transfer coefficient was estimated based on material to be 120 BTU/hr*ft²*F. A general outline of these calculations can be seen below.

Sample Calculations: E-401

Water Evap= 1088 kg/hr = 60422 mol/hr

Q=33145 kJ/hr= 9.21 kW

Liquid heating

Total Q= 771 kW=2630723 BTU/hr

inlet temp= 37 C

outlet temp= 100 C

Q=286256.32 kJ/hr=79.52 kW

T hot in= 186 C=336.8 F

T hot out= 163 C= 325.4 F

T cold in= 37 C=98.6 F

T cold out= 115 C=239 F

Vaporization

Q= 245616.33 kJ/hr= 682.27 kW

LMTD= 172.6 F

Gas Heating

U= 120 BTU/hr-ft²-F

inlet temp= 100 C

Q=U*A*LMTD

outlet temp= 115 C

A=127 ft²

Conveyor Belt Sizing Calculations

The need to feed solid materials at points throughout this process requires the sizing of conveyor belts for materials transport. The volumetric flow rate of materials was used to find the required length and width of these pieces of equipment. This informed later costing analysis using *Process Design Principles 3rd Edition*, by Seider, Seader.

Sample Calculation: CB-401

$$\text{Volumetric Flow Across Belt} = 3.613 \frac{\text{m}^3}{\text{hour}}$$

$$\text{Resonance Time} = 0.25 \text{ hours}$$

$$\text{Required Belt Volume} = \text{Resonance Time} * \text{Flow Rate} = 0.9 \text{m}^3 = 31.9 \text{ft}^3$$

$$\text{Belt Surface Area} = \text{Belt Volume} * \text{Slurry Depth} = 31.9 \text{ft}^3 \div 1 \text{in} \times \frac{1 \text{ft}}{12 \text{in}} = 383 \text{ft}^2$$

$$\text{Belt } \frac{L}{W} \text{ Ratio} = 10$$

$$\text{Belt Length} = 62 \text{ ft}$$

$$\text{Belt Width} = 6.2 \text{ ft}$$

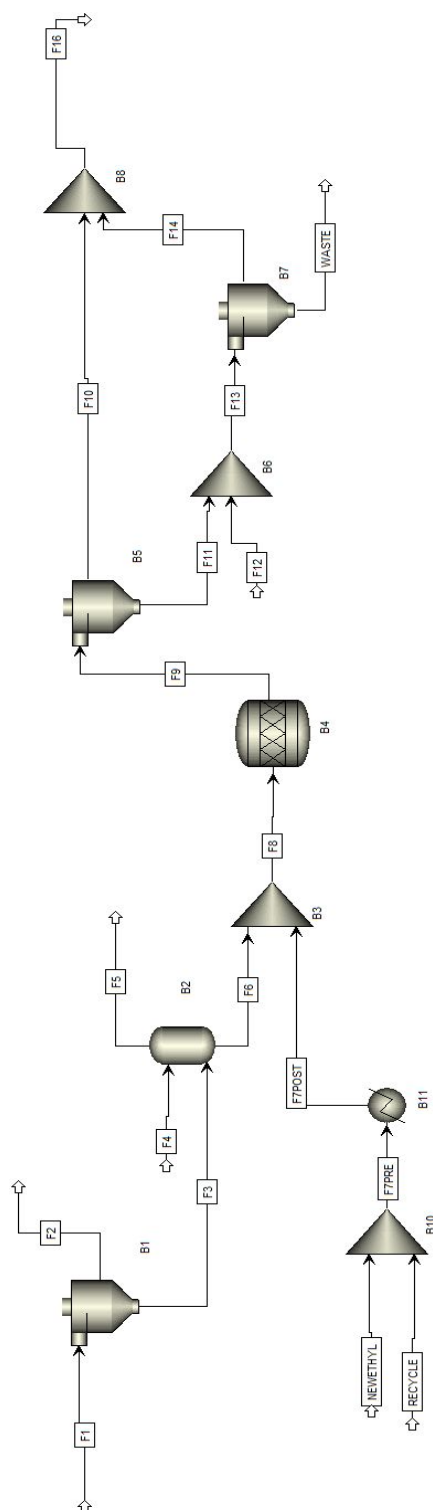
Appendix B: Excel, Aspen Plus Input Summary, Block Report, and Stream Reports

Fermentation Excel Spreadsheet

| | | | | | | | |
|--------------------------------------|-------------|---------------|-----------|--------------------------------|----------------|----------------|----------------------|
| seed frm growth | | | | production fermentation | | | |
| | 180 g | | glucose | | 1882 g/L | | palm oil |
| 256.8 | 76.8 g | | oxygen | 3232.4 | 1350.4 g/L | | oxygen |
| | 108 g | | biomass | | 1179.2 g/L | | CO2 |
| | 105.6 g | | CO2 | | 482.4 g/L | | water |
| 256.8 | 43.2 g | | water | | 1413.72 g/L | | DDDA |
| | 10% | O2 saturation | | | 52.36 g/L | | Sebacic acid |
| | | | | | 52.36 g/L | | Suberic acid |
| | | | Densities | | 52.36 g/L | | Adipic acid |
| | | | water | 1000 g/L | 3232.4 | 0 g/L | Biomass |
| | | | | | 10% | O2 saturation | |
| Fermentor One 1m³ | | | | | | | |
| | Lab in | media in | water in | glucose in | air in | exhaust out | ferm out 1 |
| water (LITERS) | 850 | | | | | 866.00 | 86.60% occupy |
| water | 85,000 | | 765,000 | | | 42,435 | 820,448 |
| glucose | | | | 53,933 | | | - |
| media | | 11,322 | | | | | 11,322 |
| air | | | | | 946,924 | | |
| biomass | 1,870 | | | | | | 34,230 |
| CO2 | | | | | | 31,640 | |
| nitrogen | | | | | | 713,870 | IN 1.864E+06 |
| oxygen | | | | | | 207,101 | OUT 1.861E+06 |
| | 22.00 | 13.32 | | 70.50 | 826.65 | 868.71 | 41.72 |
| | gram cell/L | g media/L | | g gluc/L | m ³ | m ³ | gram cell/L |
| | in stream | overall | | in stream | inlet gas | outlet gas | in stream |
| | | | | | | | |
| Fermentor Two 10m³ | | | | | | | |
| | Ferm in 2 | media in | water in | glucose in | air in | exhaust out | ferm out 1 |
| water (LITERS) | 8500 | | | | | 8676.07 | 86.76% occupy |
| water | 820,448 | | 7,679,552 | | | 426,535 | 8,203,343 |
| glucose | - | | | 541,408 | | | - |
| media | 11,322 | 113,657.36 | | | | | 113,657 |
| air | | | | | 9,505,819 | | |
| biomass | 34,230 | | | | | | 359,075 |
| CO2 | | | | | | 317,626 | |
| nitrogen | | | | | | 7,166,278 | IN 1.871E+07 |
| oxygen | | | | | | 2,079,008 | OUT 1.867E+07 |
| | 41.72 | 13.37 | | 70.50 | 8298.40 | 8720.65 | 43.77 |
| | gram cell/L | g media/L | | g gluc/L | m ³ | m ³ | gram cell/L |
| | in stream | overall | | in stream | inlet gas | outlet gas | in stream |
| | | | | | 287.1630433 | | |

| Fermentor Three 100m ³ | | | | | | | |
|--|-------------|--------------|---------------|---------------|----------------|----------------|-------------|
| | Ferm in 2 | media in | water in | glucose in | air in | exhaust out | ferm out 1 |
| water (LITERS) | 85000 | | | | | | 86777.55 |
| water | 8,203,343 | | 76,796,657.22 | | | 4,266,016 | 82,033,384 |
| glucose | - | | | 5,414,164 | | | - |
| media | 113,657 | 1,136,590.53 | | | | | 1,136,591 |
| air | | | | | 95,059,600 | | |
| biomass | 353,075 | | | | | | 3,607,573 |
| CO2 | | | | | | 3,176,310 | |
| nitrogen | | | | | | 71,663,848 | IN |
| oxygen | | | | | | 20,790,391 | OUT |
| | 43.77 | 13.37 | | 70.50 | 82985.25 | 87207.83 | 43.98 |
| | gram cell/L | g media/L | | g gluc/L | m ³ | m ³ | gram cell/L |
| | in stream | overall | | in stream | inlet gas | outlet gas | in stream |
| | | | | | | | |
| PRODUCTION FERMENTOR 500m ³ | | | | | | | |
| | Ferm in 2 | media in | water in | palm oil in | air in | exhaust out | ferm out 1 |
| water (LITERS) | 425000 | | | | | | 418887.48 |
| water | 82,033,384 | | 342,966,616 | | | 103,438,745 | 341,815,777 |
| glucose | - | | | | | | |
| media | 1,136,591 | 7,510,963 | | | | | 7,510,963 |
| air | | | | | 2,333,205,383 | | |
| biomass | 3,607,573 | | | | | | 3,607,573 |
| CO2 | | | | | | 49,511,054 | |
| nitrogen | | | | | | 1,758,964,638 | |
| oxygen | | | | | | 510,293,038 | |
| Palm Oil | | | | 79,019,508.40 | | | |
| DDDA | | | | | | | 59,357,842 |
| Sebacic acid | | | | | | | 2,198,439 |
| Suberic acid | | | | | | | 2,198,439 |
| Adipic acid | | | | | | | 2,198,439 |
| | 43.98 | 17.67 | | 230.40 | 2036844.51 | 2114541.66 | 10.55 |
| | gram cell/L | g media/L | | g palm oil/L | m ³ | m ³ | gram cell/L |
| | in stream | overall | | in stream | inlet gas | outlet gas | in stream |
| | | | | | | | |

Filtration Flowsheet



Filtration Input Summary

```
;
;Input Summary created by Aspen Plus Rel. 36.0 at 10:24:00 Tue Apr 10,
2018
;Directory \\nestor\winterg\CBE 459- Senior Design\filtration final
Filename C:\Users\winterg\AppData\Local\Temp\~ap6b15.txt
;

DYNAMICS
  DYNAMICS RESULTS=ON

IN-UNITS MET VOLUME-FLOW='cum/hr' ENTHALPY-FLO='Gcal/hr' &
  HEAT-TRANS-C='kcal/hr-sqm-K' PRESSURE=bar TEMPERATURE=C &
  VOLUME=cum DELTA-T=C HEAD=meter MASS-DENSITY='kg/cum' &
  MOLE-ENTHALP='kcal/mol' MASS-ENTHALP='kcal/kg' HEAT=Gcal &
  MOLE-CONC='mol/l' PDROP=bar SHORT-LENGTH=mm

DEF-STREAMS MIXCISLD ALL

SIM-OPTIONS MASS-BAL-CHE=YES ADSCNVG=NO

MODEL-OPTION

DESCRIPTION "
  Solids Simulation with Metric Units :
  C, bar, kg/hr, kmol/hr, Gcal, cum/hr.

  Property Method: None

  Flow basis for input: Mass
"

DATABASES 'APV100 PURE35' / 'APV100 AQUEOUS' / 'APV100 SOLIDS' &
  / 'APV100 INORGANIC' / 'NISTV100 NIST-TRC' / &
  'APV100 HYSYS' / NOASPENPCD

PROP-SOURCES 'APV100 PURE35' / 'APV100 AQUEOUS' / &
  'APV100 SOLIDS' / 'APV100 INORGANIC' / &
  'NISTV100 NIST-TRC' / 'APV100 HYSYS'

COMPONENTS
  DDDA C12H22O4-N3 /
  SEBAC-01 C10H18O4 /
  SUBER-01 C8H14O4-D1 /
  ADIPI-01 C6H10O4-D1 /
  WATER H2O /
  ETHYL-01 C4H8O2-3 /
  DEXTR-01 C6H12O6 /
  BIOMASS FE /
  NITROGEN N2

CISOLID-COMPS DDDA SEBAC-01 SUBER-01 ADIPI-01 BIOMASS

SOLVE
  RUN-MODE MODE=SIM

FLOWSHEET
  BLOCK B3 IN=F6 F7POST OUT=F8
  BLOCK B5 IN=F9 OUT=F10 F11
  BLOCK B1 IN=F1 OUT=F3 F2
```

```

BLOCK B2 IN=F3 F4 OUT=F5 F6
BLOCK B4 IN=F8 OUT=F9
BLOCK B6 IN=F11 F12 OUT=F13
BLOCK B7 IN=F13 OUT=WASTE F14
BLOCK B8 IN=F14 F10 OUT=F16
BLOCK B10 IN=RECYCLE NEWETHYL OUT=F7PRE
BLOCK B11 IN=F7PRE OUT=F7POST

PROPERTIES SOLIDS

ESTIMATE ALL

PROP-SET ALL-SUBS VOLFLMX MASSVFRA MASSSFRA RHOMX MASSFLOW &
      TEMP PRES UNITS='kg/cum' SUBSTREAM=ALL
; "Entire Stream Flows, Density, Phase Frac, T, P"

STREAM F1
  SUBSTREAM MIXED TEMP=37. PRES=35. <psig> MASS-FLOW=12822.1
  MASS-FRAC WATER 1.
  SUBSTREAM CISOLID TEMP=37. PRES=35. <psig> MASS-FLOW=2537.8
  MASS-FRAC DDDA 0.8466 / SEBAC-01 0.0314 / SUBER-01 &
    0.0314 / ADIPI-01 0.0314 / BIOMASS 0.0592

STREAM F2
  SUBSTREAM MIXED TEMP=37. PRES=1. &
    MASS-FLOW=149000. <Mtons/year>
  MASS-FRAC WATER 1.

STREAM F4
  SUBSTREAM MIXED TEMP=20. PRES=10. <psig> &
    VOLUME-FLOW=10. <cuft/min>
  MASS-FRAC NITROGEN 1.

STREAM F7PRE
  SUBSTREAM MIXED TEMP=70. PRES=1. MASS-FLOW=11830.
  MASS-FRAC ETHYL-01 1.

STREAM F12
  SUBSTREAM MIXED TEMP=70. PRES=1. MASS-FLOW=2000.
  MASS-FRAC ETHYL-01 1.

STREAM NEWETHYL
  SUBSTREAM MIXED TEMP=25. PRES=1. MASS-FLOW=11830.
  MASS-FRAC ETHYL-01 1.

STREAM RECYCLE
  SUBSTREAM MIXED TEMP=77. PRES=3. MASS-FLOW=15979.4
  MASS-FRAC ETHYL-01 1.

BLOCK B3 MIXER
  PARAM

BLOCK B6 MIXER
  PARAM

BLOCK B8 MIXER
  PARAM

BLOCK B10 MIXER

```



```

PARAM

BLOCK B11 HEATER
  PARAM TEMP=70. PRES=4. DPPARMOPT=NO

BLOCK B2 FLASH2
  PARAM TEMP=115. PRES=1.

BLOCK B4 RSTOIC
  PARAM TEMP=70. PRES=0. HEAT-OF-REAC=YES
  STOIC 1 CISOLID DDDA -1. / MIXED DDDA 1.
  STOIC 2 CISOLID SEBAC-01 -1. / MIXED SEBAC-01 1.
  STOIC 3 CISOLID SUBER-01 -1. / MIXED SUBER-01 1.
  STOIC 4 CISOLID ADIPI-01 -1. / MIXED ADIPI-01 1.
  CONV 1 CISOLID DDDA 1.
  CONV 2 CISOLID SEBAC-01 1.
  CONV 3 CISOLID SUBER-01 1.
  CONV 4 CISOLID ADIPI-01 1.
  HEAT-RXN REACNO=1 CID=DDDA H-REAC=21755.7 PHASE=L / &
    REACNO=2 CID=SEBAC-01 H-REAC=13198. PHASE=L / REACNO=3 &
    CID=SUBER-01 H-REAC=17540.7 PHASE=L / REACNO=4 &
    CID=ADIPI-01 H-REAC=14951. PHASE=L

BLOCK B1 SSPLIT
  FRAC MIXED F3 0.4
  FRAC CISOLID F3 0.995

BLOCK B5 SSPLIT
  FRAC MIXED F11 0.2
  FRAC CISOLID F11 0.99
  DEF-KEY KEYNO=1 COMPS=DDDA SEBAC-01 SUBER-01 ADIPI-01
  DEF-KEY KEYNO=2 COMPS=BIOMASS

BLOCK B7 SSPLIT
  FRAC MIXED WASTE 0.2
  FRAC CISOLID WASTE 1.

DESIGN-SPEC EAFEED
  DEFINE SOLIDSIN STREAM-VAR STREAM=F6 SUBSTREAM=CISOLID &
    VARIABLE=MASS-FLOW UOM="kg/hr"
  DEFINE TARGSOLD LOCAL-PARAM INIT-VAL=0.2
  DEFINE DDDA MASS-FLOW STREAM=F6 SUBSTREAM=CISOLID &
    COMPONENT=DDDA UOM="kg/hr"
  DEFINE AA MASS-FLOW STREAM=F6 SUBSTREAM=CISOLID &
    COMPONENT=ADIPI-01 UOM="kg/hr"
  DEFINE SEBA MASS-FLOW STREAM=F6 SUBSTREAM=CISOLID &
    COMPONENT=SEBAC-01 UOM="kg/hr"
  DEFINE SUBA MASS-FLOW STREAM=F6 SUBSTREAM=CISOLID &
    COMPONENT=SUBER-01 UOM="kg/hr"
  DEFINE EA STREAM-VAR STREAM=F7POST SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW UOM="kg/hr"
  SPEC "(DDDA+AA+SEBA+SUBA)/(DDDA+AA+SEBA+SUBA+EA)" TO "0.1"
  TOL-SPEC "0.0001"
  VARY STREAM-VAR STREAM=NEWETHYL SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW UOM="tonne/year"
  LIMITS "50000" "200000"

EO-CONV-OPTI

CALCULATOR BIOMCAKE

```

```

DEFINE SOLIDSIN STREAM-VAR STREAM=F9 SUBSTREAM=CISOLID &
    VARIABLE=MASS-FLOW UOM="kg/hr"
DEFINE MOISTURE LOCAL-PARAM
DEFINE LIQUIDIN STREAM-VAR STREAM=F9 SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW UOM="kg/hr"
DEFINE FRAC BLOCK-VAR BLOCK=B5 SENTENCE=FRAC VARIABLE=FRAC &
    ID1=MIXED ID2=F11
DEFINE CAKELIQ LOCAL-PARAM
C
F    MOISTURE = 0.4
F    CAKELIQ = SOLIDSIN/(1-MOISTURE)*MOISTURE
F    FRAC = CAKELIQ/LIQUIDIN
READ-VARS SOLIDSIN LIQUIDIN
WRITE-VARS MOISTURE FRAC CAKELIQ
EXECUTE BEFORE BLOCK B5

CALCULATOR CAKEWSH1
    DEFINE NEWFEED STREAM-VAR STREAM=NEWETHYL SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW UOM="kg/hr"
    DEFINE SOLIDS1 STREAM-VAR STREAM=F6 SUBSTREAM=CISOLID &
        VARIABLE=MASS-FLOW UOM="kg/hr"
    DEFINE BIOMASS MASS-FLOW STREAM=F6 SUBSTREAM=CISOLID &
        COMPONENT=BIOMASS UOM="kg/hr"
    DEFINE RECYCLE MASS-FLOW STREAM=RECYCLE SUBSTREAM=MIXED &
        COMPONENT=ETHYL-01 UOM="kg/hr"
F    NEWFEED = (7*(SOLIDS1-BIOMASS))-RECYCLE
READ-VARS SOLIDS1 BIOMASS RECYCLE
WRITE-VARS NEWFEED

CALCULATOR CAKEWSH2
    DEFINE EAFEED2 STREAM-VAR STREAM=F12 SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW UOM="kg/hr"
    DEFINE SOLIDS STREAM-VAR STREAM=F11 SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW UOM="kg/hr"
    DEFINE ETHYL MASS-FLOW STREAM=F11 SUBSTREAM=MIXED &
        COMPONENT=ETHYL-01 UOM="kg/hr"
F    EAFEED2 = 7 * (SOLIDS-ETHYL)
READ-VARS SOLIDS
WRITE-VARS EAFEED2

CALCULATOR FERMCAGE
    DEFINE SOLIDSIN STREAM-VAR STREAM=F1 SUBSTREAM=CISOLID &
        VARIABLE=MASS-FLOW UOM="kg/hr"
    DEFINE MOISTURE LOCAL-PARAM
    DEFINE LIQUIDIN STREAM-VAR STREAM=F1 SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW UOM="kg/hr"
    DEFINE FRAC BLOCK-VAR BLOCK=B1 SENTENCE=FRAC VARIABLE=FRAC &
        ID1=MIXED ID2=F3
    DEFINE CAKELIQ LOCAL-PARAM
C
F    MOISTURE = 0.3
F    CAKELIQ = SOLIDSIN/(1-MOISTURE)*MOISTURE
F    FRAC = CAKELIQ/LIQUIDIN
READ-VARS SOLIDSIN LIQUIDIN
WRITE-VARS MOISTURE FRAC CAKELIQ
EXECUTE BEFORE BLOCK B1

CALCULATOR FILTER2
    DEFINE SOLIDSIN STREAM-VAR STREAM=F13 SUBSTREAM=CISOLID &
        VARIABLE=MASS-FLOW UOM="kg/hr"

```

```

DEFINE MOISTURE LOCAL-PARAM
DEFINE LIQUIDIN STREAM-VAR STREAM=F13 SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW UOM="kg/hr"
DEFINE FRAC BLOCK-VAR BLOCK=B7 SENTENCE=FRAC VARIABLE=FRAC &
    ID1=MIXED ID2=WASTE
DEFINE CAKELIQ LOCAL-PARAM
C
F    MOISTURE = 0.4
F    CAKELIQ = SOLIDSIN/(1-MOISTURE)*MOISTURE
F    FRAC = CAKELIQ/LIQUIDIN
READ-VARS SOLIDSIN LIQUIDIN
WRITE-VARS MOISTURE FRAC CAKELIQ

CONVERGENCE CETHACE SECANT
SPEC EAFEEED

STREAM-REPOR MOLEFLOW MASSFLOW PROPERTIES=ALL-SUBS

PROPERTY-REP PCES

PROP-TABLE SOLUB-1 FLASHCURVE
    IN-UNITS MET VOLUME-FLOW='cum/hr' ENTHALPY-FLO='Gcal/hr' &
        HEAT-TRANS-C='kcal/hr-sqm-K' PRESSURE=bar TEMPERATURE=C &
        VOLUME=cum DELTA-T=C HEAD=meter MASS-DENSITY='kg/cum' &
        MOLE-ENTHALP='kcal/mol' MASS-ENTHALP='kcal/kg' HEAT=Gcal &
        MOLE-CONC='mol/l' PDROP=bar SHORT-LENGTH=mm
    BLOCK-OPTION FREE-WATER=NO
    MASS-FLOW ETHYL-01 11830.
    VARY PRES
    RANGE VARVALUE=LIST LIST=1.013250000
    VARY TEMP
    RANGE VARVALUE=RANGE LOWER=0 UPPER=100.0000000 NPOINT=20
    PARAM NPHASE=2
    ANALYSIS ANAL-TYPE=SOLUB SOLUTE=DDDA SEBAC-01 SUBER-01 &
        ADIPI-01

DISABLE
    DESIGN-SPEC EAFEEED
;
;
;
;
;

```

Filtration Block Report

```

BLOCK:  B1          MODEL: SSPLIT
-----
INLET STREAM:      F1
OUTLET STREAMS:    F3      F2
PROPERTY OPTION SET: SOLIDS  IDEAL LIQUID / IDEAL GAS

***  MASS AND ENERGY BALANCE  ***
IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
  MOLE(KMOL/HR )      725.151      725.151      0.00000
  MASS(KG/HR   )      15359.9      15359.9      0.00000
  ENTHALPY(GCAL/HR )   -51.2816     -51.2816     -
0.138557E-15

***  CO2 EQUIVALENT SUMMARY  ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION    0.00000      KG/HR

***  INPUT DATA  ***

FRACTION OF FLOW
SUBSTRM=      STRM=      FRAC=
      MIXED      F3      0.084825
      CISOLID     F3      0.99500

***  RESULTS  ***

STRM= F3      SUBSTRM= MIXED  SPLIT FRACT=      0.084825
                  CISOLID      0.99500

STRM= F2      SUBSTRM= MIXED  SPLIT FRACT=      0.91518
                  CISOLID      0.0050000

BLOCK:  B2          MODEL: FLASH2
-----
INLET STREAMS:      F3      F4
OUTLET VAPOR STREAM: F5
OUTLET LIQUID STREAM: F6
PROPERTY OPTION SET: SOLIDS  IDEAL LIQUID / IDEAL GAS

***  MASS AND ENERGY BALANCE  ***
IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
  MOLE(KMOL/HR )      74.9083      74.9083      0.00000
  MASS(KG/HR   )      3645.99      3645.99
0.249451E-15
  ENTHALPY(GCAL/HR )   -6.94453     -6.19001     -0.108650

***  CO2 EQUIVALENT SUMMARY  ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION    0.00000      KG/HR

```

```

*** INPUT DATA ***
TWO PHASE TP FLASH
SPECIFIED TEMPERATURE C 115.000
SPECIFIED PRESSURE BAR 1.00000
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

*** RESULTS ***
OUTLET TEMPERATURE C 115.00
OUTLET PRESSURE BAR 1.0000
HEAT DUTY GCAL/HR 0.75452
VAPOR FRACTION 1.0000

V-L PHASE EQUILIBRIUM :
COMP F(I) X(I) Y(I) K(I)
1.6887 WATER 0.98072 0.99998 0.98072
1751.2 NITROGEN 0.19281E-01 0.18958E-04 0.19281E-01

BLOCK: B3 MODEL: MIXER
-----
INLET STREAMS: F6 F7POST
OUTLET STREAM: F8
PROPERTY OPTION SET: SOLIDS IDEAL LIQUID / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
IN OUT RELATIVE
DIFF.
TOTAL BALANCE
MOLE (KMOL/HR ) 202.091 202.091 0.00000
MASS (KG/HR ) 19154.5 19154.5 0.00000
ENTHALPY (GCAL/HR ) -24.0336 -24.0336
0.118392E-08

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E 0.00000 KG/HR
PRODUCT STREAMS CO2E 0.00000 KG/HR
NET STREAMS CO2E PRODUCTION 0.00000 KG/HR
UTILITIES CO2E PRODUCTION 0.00000 KG/HR
TOTAL CO2E PRODUCTION 0.00000 KG/HR

*** INPUT DATA ***
TWO PHASE FLASH
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000
OUTLET PRESSURE: MINIMUM OF INLET STREAM PRESSURES

BLOCK: B4 MODEL: RSTOIC
-----
INLET STREAM: F8
OUTLET STREAM: F9
PROPERTY OPTION SET: SOLIDS IDEAL LIQUID / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

```

| DIFF. | IN | OUT | GENERATION | RELATIVE |
|---------------------|----------|----------|--------------|----------|
| TOTAL BALANCE | | | | |
| MOLE (KMOL/HR) | 202.091 | 202.091 | 0.195156E-15 | |
| 0.00000 | | | | |
| MASS (KG/HR) | 19154.5 | 19154.5 | | |
| 0.00000 | | | | |
| ENTHALPY (GCAL/HR) | -24.0336 | -24.0867 | | |
| 0.220392E-02 | | | | |

```

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION   0.00000      KG/HR

```

```

*** INPUT DATA ***
STOICHIOMETRY MATRIX:

```

```

REACTION # 1:
SUBSTREAM MIXED :
DDDA      1.00
SUBSTREAM CISOLID :
DDDA      -1.00

```

```

REACTION # 2:
SUBSTREAM MIXED :
SEBAC-01  1.00
SUBSTREAM CISOLID :
SEBAC-01  -1.00

```

```

REACTION # 3:
SUBSTREAM MIXED :
SUBER-01   1.00
SUBSTREAM CISOLID :
SUBER-01  -1.00

```

```

REACTION # 4:
SUBSTREAM MIXED :
ADIPI-01  1.00
SUBSTREAM CISOLID :
ADIPI-01  -1.00

```

```

REACTION CONVERSION SPECS: NUMBER= 4
REACTION # 1:
SUBSTREAM:CISOLID KEY COMP:DDDA CONV FRAC: 1.000
REACTION # 2:
SUBSTREAM:CISOLID KEY COMP:SEBAC-01 CONV FRAC: 1.000
REACTION # 3:
SUBSTREAM:CISOLID KEY COMP:SUBER-01 CONV FRAC: 1.000
REACTION # 4:
SUBSTREAM:CISOLID KEY COMP:ADIPI-01 CONV FRAC: 1.000

```

```

HEAT OF REACTION SPECIFICATIONS:

```

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION |
|--------------------|------------------------|---------------------|
|--------------------|------------------------|---------------------|

| | | KCAL/MOL |
|---|----------|----------|
| 1 | DDDA | 21756. |
| 2 | SEBAC-01 | 13198. |
| 3 | SUBER-01 | 17541. |
| 4 | ADIPI-01 | 14951. |

TWO PHASE TP FLASH
 SPECIFIED TEMPERATURE C 70.0000
 PRESSURE DROP BAR 0.0
 MAXIMUM NO. ITERATIONS 30
 CONVERGENCE TOLERANCE 0.000100000
 SIMULTANEOUS REACTIONS
 GENERATE COMBUSTION REACTIONS FOR FEED SPECIES NO

*** RESULTS ***
 OUTLET TEMPERATURE C 70.000
 OUTLET PRESSURE BAR 1.0000
 HEAT DUTY GCAL/HR 223.16
 VAPOR FRACTION 0.0000

HEAT OF REACTIONS:

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION KCAL/MOL |
|--------------------|------------------------|---------------------------------|
| 1 | DDDA | 21756. |
| 2 | SEBAC-01 | 13198. |
| 3 | SUBER-01 | 17541. |
| 4 | ADIPI-01 | 14951. |

REACTION EXTENTS:

| REACTION NUMBER | REACTION EXTENT KMOL/HR |
|--------------------|-------------------------------|
| 1 | 9.2823 |
| 2 | 0.39203 |
| 3 | 0.45517 |
| 4 | 0.54254 |

V-L PHASE EQUILIBRIUM :

| COMP | F(I) | X(I) | Y(I) | K(I) |
|----------|--------|--------|--------|------|
| ETHYL-01 | 1.0000 | 1.0000 | 1.0000 | |

0.79401

BLOCK: B5 MODEL: SSPLIT

 INLET STREAM: F9
 OUTLET STREAMS: F10 F11
 PROPERTY OPTION SET: SOLIDS IDEAL LIQUID / IDEAL GAS

| | *** MASS AND ENERGY BALANCE *** | *** | RELATIVE |
|-----------------|---------------------------------|---------|----------|
| DIFF. | IN | OUT | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 202.091 | 202.091 | 0.00000 |

| | | | |
|---------------------|----------|----------|---------|
| MASS (KG/HR) | 19154.5 | 19154.5 | - |
| 0.189928E-15 | | | |
| ENTHALPY (GCAL/HR) | -24.0867 | -24.0867 | 0.00000 |

```

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000    KG/HR
PRODUCT STREAMS CO2E    0.00000    KG/HR
NET STREAMS CO2E PRODUCTION 0.00000    KG/HR
UTILITIES CO2E PRODUCTION 0.00000    KG/HR
TOTAL CO2E PRODUCTION   0.00000    KG/HR

```

*** INPUT DATA ***

```

KEY= 1  CPT.= DDDA
        SEBAC-01
        SUBER-01
        ADIPI-01

```

```

KEY= 2  CPT.= BIOMASS

```

FRACTION OF FLOW

| | | | |
|----------|-------|-------|-----------|
| SUBSTRM= | STRM= | FRAC= | |
| MIXED | F11 | | 0.0052438 |
| CISOLID | F11 | | 0.99000 |

*** RESULTS ***

| | | | |
|-----------|----------------|--------------|-----------|
| STRM= F10 | SUBSTRM= MIXED | SPLIT FRACT= | 0.99476 |
| | CISOLID | | 0.0100000 |
| STRM= F11 | SUBSTRM= MIXED | SPLIT FRACT= | 0.0052438 |
| | CISOLID | | 0.99000 |

BLOCK: B6 MODEL: MIXER

```

-----
INLET STREAMS:      F11      F12
OUTLET STREAM:      F13
PROPERTY OPTION SET: SOLIDS   IDEAL LIQUID / IDEAL GAS

```

*** MASS AND ENERGY BALANCE ***

| | IN | OUT | RELATIVE |
|---------------------|-----------|-----------|----------|
| DIFF. | | | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 4.68535 | 4.68535 | 0.00000 |
| MASS (KG/HR) | 334.850 | 334.850 | |
| 0.169758E-15 | | | |
| ENTHALPY (GCAL/HR) | -0.237168 | -0.237168 | |
| 0.214301E-07 | | | |

```

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000    KG/HR
PRODUCT STREAMS CO2E    0.00000    KG/HR
NET STREAMS CO2E PRODUCTION 0.00000    KG/HR
UTILITIES CO2E PRODUCTION 0.00000    KG/HR
TOTAL CO2E PRODUCTION   0.00000    KG/HR

```

*** INPUT DATA ***

```

TWO PHASE FLASH
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

```


OUTLET PRESSURE: MINIMUM OF INLET STREAM PRESSURES

BLOCK: B7 MODEL: SSPLIT

INLET STREAM: F13
OUTLET STREAMS: WASTE F14
PROPERTY OPTION SET: SOLIDS IDEAL LIQUID / IDEAL GAS

| | *** | MASS AND ENERGY BALANCE | *** | |
|---------------------|-----|-------------------------|-----------|----------|
| | | IN | OUT | RELATIVE |
| DIFF. | | | | |
| TOTAL BALANCE | | | | |
| MOLE (KMOL/HR) | | 4.68535 | 4.68535 | 0.00000 |
| MASS (KG/HR) | | 334.850 | 334.850 | |
| 0.169758E-15 | | | | |
| ENTHALPY (GCAL/HR) | | -0.237168 | -0.237168 | - |
| 0.117029E-15 | | | | |

| *** CO2 EQUIVALENT SUMMARY *** | | |
|--------------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| FRACTION OF FLOW | | |
|------------------|-------|---------|
| SUBSTRM= | STRM= | FRAC= |
| MIXED | WASTE | 0.52800 |
| CISOLID | WASTE | 1.00000 |

*** RESULTS ***

| | | | |
|-------------|----------------|--------------|---------|
| STRM= WASTE | SUBSTRM= MIXED | SPLIT FRACT= | 0.52800 |
| | CISOLID | | 1.00000 |
| STRM= F14 | SUBSTRM= MIXED | SPLIT FRACT= | 0.47200 |
| | CISOLID | | 0.0 |

BLOCK: B8 MODEL: MIXER

INLET STREAMS: F14 F10
OUTLET STREAM: F16
PROPERTY OPTION SET: SOLIDS IDEAL LIQUID / IDEAL GAS

| | *** | MASS AND ENERGY BALANCE | *** | |
|---------------------|-----|-------------------------|----------|----------|
| | | IN | OUT | RELATIVE |
| DIFF. | | | | |
| TOTAL BALANCE | | | | |
| MOLE (KMOL/HR) | | 199.356 | 199.356 | 0.00000 |
| MASS (KG/HR) | | 18995.0 | 18995.0 | 0.00000 |
| ENTHALPY (GCAL/HR) | | -24.0734 | -24.0734 | |
| 0.231418E-07 | | | | |

| *** CO2 EQUIVALENT SUMMARY *** | | |
|--------------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |

```

TOTAL CO2E PRODUCTION          0.00000      KG/HR

*** INPUT DATA ***
TWO PHASE FLASH
MAXIMUM NO. ITERATIONS          30
CONVERGENCE TOLERANCE          0.000100000
OUTLET PRESSURE: MINIMUM OF INLET STREAM PRESSURES

BLOCK: B10      MODEL: MIXER
-----
INLET STREAMS:      RECYCLE      NEWETHYL
OUTLET STREAM:      F7PRE
PROPERTY OPTION SET: SOLIDS      IDEAL LIQUID / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
MOLE (KMOL/HR )      188.742      188.742      0.00000
MASS (KG/HR )      16629.4      16629.4      0.00000
ENTHALPY (GCAL/HR )      -21.2434      -21.2434
0.259389E-08

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E      0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION      0.00000      KG/HR

*** INPUT DATA ***
TWO PHASE FLASH
MAXIMUM NO. ITERATIONS          30
CONVERGENCE TOLERANCE          0.000100000
OUTLET PRESSURE: MINIMUM OF INLET STREAM PRESSURES

BLOCK: B11      MODEL: HEATER
-----
INLET STREAM:      F7PRE
OUTLET STREAM:      F7POST
PROPERTY OPTION SET: SOLIDS      IDEAL LIQUID / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
MOLE (KMOL/HR )      188.742      188.742      0.00000
MASS (KG/HR )      16629.4      16629.4      0.00000
ENTHALPY (GCAL/HR )      -21.2434      -21.2859
0.199614E-02

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E      0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION      0.00000      KG/HR

*** INPUT DATA ***
TWO PHASE TP FLASH

```

| | | |
|------------------------|-----|---------|
| SPECIFIED TEMPERATURE | C | 70.0000 |
| SPECIFIED PRESSURE | BAR | 4.00000 |
| MAXIMUM NO. ITERATIONS | | 30 |
| CONVERGENCE TOLERANCE | | |
| 0.000100000 | | |

| *** RESULTS *** | | |
|-----------------------|---------|--------------|
| OUTLET TEMPERATURE | C | 70.000 |
| OUTLET PRESSURE | BAR | 4.0000 |
| HEAT DUTY | GCAL/HR | -0.42490E-01 |
| OUTLET VAPOR FRACTION | | 0.0000 |

V-L PHASE EQUILIBRIUM :

| COMP | F(I) | X(I) | Y(I) | K(I) |
|----------|--------|--------|--------|------|
| ETHYL-01 | 1.0000 | 1.0000 | 1.0000 | |
| 0.19850 | | | | |

F1 F10 F11 F12 F13

| | | | | | |
|---------------------|-----------|-----------|-----------|----------|-----|
| STREAM ID | F1 | F10 | F11 | F12 | F13 |
| FROM : | ---- | B5 | B5 | ---- | B6 |
| TO : | B1 | B8 | B6 | B6 | B7 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 1.5360+04 | 1.8907+04 | 247.6494 | 87.2005 | |
| 334.8499 | | | | | |
| GCAL/HR | -51.2816 | -23.9611 | -0.1255 | -0.1116 | - |
| 0.2372 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | MIXED | MIXED | LIQUID | |
| MIXED | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 9.2336 | 4.8674-02 | 0.0 | |
| 4.8674-02 | | | | | |
| SEBAC-01 | 0.0 | 0.3900 | 2.0557-03 | 0.0 | |
| 2.0557-03 | | | | | |
| SUBER-01 | 0.0 | 0.4528 | 2.3868-03 | 0.0 | |
| 2.3868-03 | | | | | |
| ADIPI-01 | 0.0 | 0.5397 | 2.8450-03 | 0.0 | |
| 2.8450-03 | | | | | |
| WATER | 711.7347 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 187.7524 | 0.9897 | 0.9897 | |
| 1.9794 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 2126.5491 | 11.2099 | 0.0 | |
| 11.2099 | | | | | |
| SEBAC-01 | 0.0 | 78.8727 | 0.4158 | 0.0 | |
| 0.4158 | | | | | |
| SUBER-01 | 0.0 | 78.8727 | 0.4158 | 0.0 | |
| 0.4158 | | | | | |
| ADIPI-01 | 0.0 | 78.8727 | 0.4158 | 0.0 | |
| 0.4158 | | | | | |
| WATER | 1.2822+04 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 1.6542+04 | 87.2005 | 87.2005 | |
| 174.4010 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 711.7347 | 198.3685 | 1.0457 | 0.9897 | |
| 2.0354 | | | | | |
| KG/HR | 1.2822+04 | 1.8905+04 | 99.6577 | 87.2005 | |
| 186.8582 | | | | | |
| CUM/HR | 12.9508 | 21.7509 | 0.1147 | 0.1041 | |
| 0.2187 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 37.0000 | 70.0000 | 70.0000 | 70.0000 | |
| 70.0000 | | | | | |
| PRES BAR | 3.4264 | 1.0000 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|---------------------|------------|------------|------------|------------|-----|
| LFRAC | 1.0000 | 0.9465 | 0.9465 | 1.0000 | |
| 0.9725 | | | | | |
| SFRAC | 0.0 | 5.3517-02 | 5.3517-02 | 0.0 | |
| 2.7494-02 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | -68.0463 | -120.7910 | -120.7910 | -112.7776 | - |
| 116.8945 | | | | | |
| KCAL/KG | -3777.1463 | -1267.4267 | -1267.4267 | -1280.0171 | - |
| 1273.3022 | | | | | |
| GCAL/HR | -48.4309 | -23.9611 | -0.1263 | -0.1116 | - |
| 0.2379 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -38.2583 | -151.4349 | -151.4349 | -111.8447 | - |
| 132.1841 | | | | | |
| CAL/GM-K | -2.1237 | -1.5890 | -1.5890 | -1.2694 | - |
| 1.4398 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 5.4957-02 | 9.1200-03 | 9.1200-03 | 9.5109-03 | |
| 9.3060-03 | | | | | |
| KG/CUM | 990.0590 | 869.1749 | 869.1749 | 837.9697 | |
| 854.3282 | | | | | |
| AVG MW | 18.0153 | 95.3041 | 95.3041 | 88.1063 | |
| 91.8042 | | | | | |
| SUBSTREAM: CISOLID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 9.3290 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.3940 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.4575 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.5453 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 2.6902 | 2.6767-02 | 2.6499 | 0.0 | |
| 2.6499 | | | | | |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 2148.5015 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 79.6869 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 79.6869 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 79.6869 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 150.2378 | 1.4949 | 147.9917 | 0.0 | |
| 147.9917 | | | | | |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 13.4159 | 2.6767-02 | 2.6499 | 0.0 | |
| 2.6499 | | | | | |
| KG/HR | 2537.8000 | 1.4949 | 147.9917 | 0.0 | |
| 147.9917 | | | | | |
| CUM/HR | 2.0329 | 1.8785-04 | 1.8597-02 | 0.0 | |
| 1.8597-02 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 37.0000 | 70.0000 | 70.0000 | MISSING | |
| 70.0000 | | | | | |
| PRES BAR | 3.4264 | 1.0000 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | MISSING | 0.0 |

| | | | | | |
|-----------|------------|-----------|-----------|---------|-----|
| LFRAC | 0.0 | 0.0 | 0.0 | MISSING | 0.0 |
| SFRAC | 1.0000 | 1.0000 | 1.0000 | MISSING | |
| 1.0000 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | -212.4807 | 0.2865 | 0.2865 | MISSING | |
| 0.2865 | | | | | |
| KCAL/KG | -1123.2606 | 5.1303 | 5.1303 | MISSING | |
| 5.1303 | | | | | |
| GCAL/HR | -2.8506 | 7.6692-06 | 7.5925-04 | MISSING | |
| 7.5925-04 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -688.8238 | 0.8949 | 0.8949 | MISSING | |
| 0.8949 | | | | | |
| CAL/GM-K | -3.6414 | 1.6023-02 | 1.6023-02 | MISSING | |
| 1.6023-02 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 6.5994-03 | 0.1425 | 0.1425 | MISSING | |
| 0.1425 | | | | | |
| KG/CUM | 1248.3652 | 7957.8207 | 7957.8207 | MISSING | |
| 7957.8207 | | | | | |
| AVG MW | 189.1642 | 55.8470 | 55.8470 | MISSING | |
| 55.8470 | | | | | |

TOTAL STREAM PROPERTIES:

| | | | | | |
|--------------------|-----------|-----------|-----------|----------|-----|
| *** ALL PHASES *** | | | | | |
| MASSFLOW KG/HR | | | | | |
| DDDA | 2148.5015 | 2126.5491 | 11.2099 | 0.0 | |
| 11.2099 | | | | | |
| SEBAC-01 | 79.6869 | 78.8727 | 0.4158 | 0.0 | |
| 0.4158 | | | | | |
| SUBER-01 | 79.6869 | 78.8727 | 0.4158 | 0.0 | |
| 0.4158 | | | | | |
| ADIPI-01 | 79.6869 | 78.8727 | 0.4158 | 0.0 | |
| 0.4158 | | | | | |
| WATER | 1.2822+04 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 1.6542+04 | 87.2005 | 87.2005 | |
| 174.4010 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 150.2378 | 1.4949 | 147.9917 | 0.0 | |
| 147.9917 | | | | | |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| VOLFLMX CUM/HR | 14.9837 | 21.7511 | 0.1333 | 0.1041 | |
| 0.2373 | | | | | |
| MASSVFRA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MASSSFRA | 0.1652 | 0.1251 | 0.6479 | 0.0 | |
| 0.4792 | | | | | |
| RHOMX KG/CUM | 1025.1044 | 869.2361 | 1858.4646 | 837.9697 | |
| 1410.9847 | | | | | |
| TEMP C | 37.0000 | 70.0000 | 70.0000 | 70.0000 | |
| 70.0000 | | | | | |
| PRES BAR | 3.4264 | 1.0000 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |

F14 F16 F2 F3 F4

| | | | | | |
|-----------|-----|------|------|----|------|
| STREAM ID | F14 | F16 | F2 | F3 | F4 |
| FROM : | B7 | B8 | B1 | B1 | ---- |
| TO : | B8 | ---- | ---- | B2 | B2 |

| | | | | | |
|---------------------|------------|------------|------------|------------|-----|
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 88.1971 | 1.8995+04 | 1.1747+04 | 3612.7396 | |
| 33.2499 | | | | | |
| GAL/HR | -0.1123 | -24.0734 | -44.3371 | -6.9445 | - |
| 4.1283-05 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | MIXED | MIXED | LIQUID | LIQUID | |
| VAPOR | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 2.2974-02 | 9.2566 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 9.7030-04 | 0.3909 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 1.1266-03 | 0.4539 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 1.3428-03 | 0.5410 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 651.3621 | 60.3726 | 0.0 |
| ETHYL-01 | 0.9343 | 188.6867 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.1869 | | | | | |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 5.2911 | 2131.8401 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.1962 | 79.0690 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.1962 | 79.0690 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.1962 | 79.0690 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 1.1734+04 | 1087.6286 | 0.0 |
| ETHYL-01 | 82.3173 | 1.6624+04 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 33.2499 | | | | | |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.9607 | 199.3292 | 651.3621 | 60.3726 | |
| 1.1869 | | | | | |
| KG/HR | 88.1971 | 1.8994+04 | 1.1734+04 | 1087.6286 | |
| 33.2499 | | | | | |
| CUM/HR | 0.1032 | 21.8541 | 11.8523 | 1.0985 | |
| 16.9901 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 70.0000 | 69.9999 | 37.0000 | 37.0000 | |
| 20.0000 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 3.4264 | 3.4264 | |
| 1.7027 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1.0000 | | | | | |
| LFRAC | 0.9725 | 0.9466 | 1.0000 | 1.0000 | 0.0 |
| SFRAC | 2.7494-02 | 5.3392-02 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -116.8945 | -120.7722 | -68.0463 | -68.0463 | - |
| 3.4782-02 | | | | | |
| KCAL/KG | -1273.3022 | -1267.4540 | -3777.1463 | -3777.1463 | - |
| 1.2416 | | | | | |
| GAL/HR | -0.1123 | -24.0734 | -44.3228 | -4.1081 | - |
| 4.1283-05 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -132.1841 | -151.3421 | -38.2583 | -38.2583 | - |
| 1.1484 | | | | | |
| CAL/GM-K | -1.4398 | -1.5883 | -2.1237 | -2.1237 | - |
| 4.0996-02 | | | | | |

| | | | | | |
|---------------------|-----------|-----------|------------|------------|-----|
| DENSITY: | | | | | |
| MOL/CC | 9.3060-03 | 9.1209-03 | 5.4957-02 | 5.4957-02 | |
| 6.9860-05 | | | | | |
| KG/CUM | 854.3282 | 869.1048 | 990.0590 | 990.0590 | |
| 1.9570 | | | | | |
| AVG MW | 91.8042 | 95.2873 | 18.0153 | 18.0153 | |
| 28.0135 | | | | | |
| SUBSTREAM: CISOLID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 4.6645-02 | 9.2823 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 1.9700-03 | 0.3920 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 2.2873-03 | 0.4552 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 2.7263-03 | 0.5425 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 2.6767-02 | 1.3451-02 | 2.6767 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 10.7425 | 2137.7590 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.3984 | 79.2885 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.3984 | 79.2885 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.3984 | 79.2885 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 1.4949 | 0.7512 | 149.4866 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.0 | 2.6767-02 | 6.7079-02 | 13.3488 | 0.0 |
| KG/HR | 0.0 | 1.4949 | 12.6890 | 2525.1110 | 0.0 |
| CUM/HR | 0.0 | 1.8785-04 | 1.0164-02 | 2.0227 | 0.0 |
| STATE VARIABLES: | | | | | |
| TEMP C | MISSING | 69.9999 | 37.0000 | 37.0000 | |
| MISSING | | | | | |
| PRES BAR | MISSING | 1.0000 | 3.4264 | 3.4264 | |
| 1.7027 | | | | | |
| VFRAC | MISSING | 0.0 | 0.0 | 0.0 | |
| MISSING | | | | | |
| LFRAC | MISSING | 0.0 | 0.0 | 0.0 | |
| MISSING | | | | | |
| SFRAC | MISSING | 1.0000 | 1.0000 | 1.0000 | |
| MISSING | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | MISSING | 0.2865 | -212.4807 | -212.4807 | |
| MISSING | | | | | |
| KCAL/KG | MISSING | 5.1303 | -1123.2606 | -1123.2606 | |
| MISSING | | | | | |
| GKAL/HR | MISSING | 7.6692-06 | -1.4253-02 | -2.8364 | |
| MISSING | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | MISSING | 0.8949 | -688.8238 | -688.8238 | |
| MISSING | | | | | |
| CAL/GM-K | MISSING | 1.6023-02 | -3.6414 | -3.6414 | |
| MISSING | | | | | |
| DENSITY: | | | | | |
| MOL/CC | MISSING | 0.1425 | 6.5994-03 | 6.5994-03 | |
| MISSING | | | | | |

| | | | | |
|---------|---------|-----------|-----------|-----------|
| KG/CUM | MISSING | 7957.8208 | 1248.3652 | 1248.3652 |
| MISSING | | | | |
| AVG MW | MISSING | 55.8470 | 189.1642 | 189.1642 |
| MISSING | | | | |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW KG/HR

| | | | | | |
|----------------|-----------|-----------|-----------|-----------|-----|
| DDDA | 5.2911 | 2131.8401 | 10.7425 | 2137.7590 | 0.0 |
| SEBAC-01 | 0.1962 | 79.0690 | 0.3984 | 79.2885 | 0.0 |
| SUBER-01 | 0.1962 | 79.0690 | 0.3984 | 79.2885 | 0.0 |
| ADIPI-01 | 0.1962 | 79.0690 | 0.3984 | 79.2885 | 0.0 |
| WATER | 0.0 | 0.0 | 1.1734+04 | 1087.6286 | 0.0 |
| ETHYL-01 | 82.3173 | 1.6624+04 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 1.4949 | 0.7512 | 149.4866 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | |
| 33.2499 | | | | | |
| VOLFLMX CUM/HR | 0.1032 | 21.8543 | 11.8625 | 3.1213 | |
| 16.9901 | | | | | |
| MASSVFRA | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1.0000 | | | | | |
| MASSSFRA | 6.6667-02 | 0.1248 | 1.0802-03 | 0.6989 | 0.0 |
| RHOMX KG/CUM | 854.3282 | 869.1658 | 990.2804 | 1157.4532 | |
| 1.9570 | | | | | |
| TEMP C | 70.0000 | 69.9999 | 37.0000 | 37.0000 | |
| 20.0000 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 3.4264 | 3.4264 | |
| 1.7027 | | | | | |

F5 F6 F7 F7POST F7PRE

| | | | | | |
|---------------------|-----------|-----------|-----------|-----------|-----|
| STREAM ID | F5 | F6 | F7 | F7POST | |
| F7PRE | | | | | |
| FROM : | B2 | B2 | ---- | B11 | B10 |
| TO : | ---- | B3 | ---- | B3 | B11 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 1120.8785 | 2525.1110 | 2.2815+04 | 1.6629+04 | |
| 1.6629+04 | | | | | |
| GCAL/HR | -3.4423 | -2.7477 | -29.2041 | -21.2859 | - |
| 21.2434 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | VAPOR | MISSING | LIQUID | LIQUID | |
| LIQUID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 60.3726 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 258.9533 | 188.7421 | |
| 188.7421 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 1.1869 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |

| | | | | | |
|---------------------|-------------------------|-----------|------------|------------|-----|
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 1087.6286 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 2.2815+04 | 1.6629+04 | |
| 1.6629+04 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 33.2499 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 61.5595 | 0.0 | 258.9533 | 188.7421 | |
| 188.7421 | | | | | |
| KG/HR | 1120.8785 | 0.0 | 2.2815+04 | 1.6629+04 | |
| 1.6629+04 | | | | | |
| CUM/HR | 1986.6522 | 0.0 | 27.2270 | 19.8448 | |
| 20.0030 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 115.0000 | MISSING | 70.0000 | 70.0000 | |
| 75.0633 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 1.0000 | 4.0000 | |
| 1.0000 | | | | | |
| VFRAC | 1.0000 | MISSING | 0.0 | 0.0 | 0.0 |
| LFRAC | 0.0 | MISSING | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| SFRAC | 0.0 | MISSING | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -55.9183 | MISSING | -112.7776 | -112.7776 | - |
| 112.5525 | | | | | |
| KCAL/KG | -3071.0741 | MISSING | -1280.0171 | -1280.0171 | - |
| 1277.4620 | | | | | |
| GCAL/HR | -3.4423 | MISSING | -29.2041 | -21.2859 | - |
| 21.2434 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -8.0662 | MISSING | -111.8447 | -111.8447 | - |
| 111.2040 | | | | | |
| CAL/GM-K | -0.4430 | MISSING | -1.2694 | -1.2694 | - |
| 1.2622 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 3.0987-05 | MISSING | 9.5109-03 | 9.5109-03 | |
| 9.4357-03 | | | | | |
| KG/CUM | 0.5642 | MISSING | 837.9697 | 837.9697 | |
| 831.3439 | | | | | |
| AVG MW | 18.2081 | MISSING | 88.1063 | 88.1063 | |
| 88.1063 | | | | | |
| | | | | | |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 9.2823 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.3920 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.4552 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.5425 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 2.6767 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 2137.7590 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 79.2885 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|--------------------------|-----------|------------|-----------|-----------|-----|
| SUBER-01 | 0.0 | 79.2885 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 79.2885 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 149.4866 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.0 | 13.3488 | 0.0 | 0.0 | 0.0 |
| KG/HR | 0.0 | 2525.1110 | 0.0 | 0.0 | 0.0 |
| CUM/HR | 0.0 | 2.0628 | 0.0 | 0.0 | 0.0 |
| STATE VARIABLES: | | | | | |
| TEMP C | MISSING | 115.0000 | MISSING | MISSING | |
| MISSING | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 1.0000 | 4.0000 | |
| 1.0000 | | | | | |
| VFRAC | MISSING | 0.0 | MISSING | MISSING | |
| MISSING | | | | | |
| LFRAC | MISSING | 0.0 | MISSING | MISSING | |
| MISSING | | | | | |
| SFRAC | MISSING | 1.0000 | MISSING | MISSING | |
| MISSING | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | MISSING | -205.8396 | MISSING | MISSING | |
| MISSING | | | | | |
| KCAL/KG | MISSING | -1088.1528 | MISSING | MISSING | |
| MISSING | | | | | |
| GCAL/HR | MISSING | -2.7477 | MISSING | MISSING | |
| MISSING | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | MISSING | -669.7870 | MISSING | MISSING | |
| MISSING | | | | | |
| CAL/GM-K | MISSING | -3.5408 | MISSING | MISSING | |
| MISSING | | | | | |
| DENSITY: | | | | | |
| MOL/CC | MISSING | 6.4711-03 | MISSING | MISSING | |
| MISSING | | | | | |
| KG/CUM | MISSING | 1224.0949 | MISSING | MISSING | |
| MISSING | | | | | |
| AVG MW | MISSING | 189.1642 | MISSING | MISSING | |
| MISSING | | | | | |
| TOTAL STREAM PROPERTIES: | | | | | |
| *** ALL PHASES *** | | | | | |
| MASSFLOW KG/HR | | | | | |
| DDDA | 0.0 | 2137.7590 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 79.2885 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 79.2885 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 79.2885 | 0.0 | 0.0 | 0.0 |
| WATER | 1087.6286 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 2.2815+04 | 1.6629+04 | |
| 1.6629+04 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 149.4866 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 33.2499 | 0.0 | 0.0 | 0.0 | 0.0 |
| VOLFLMX CUM/HR | 1986.6522 | 2.0628 | 27.2270 | 19.8448 | |
| 20.0030 | | | | | |
| MASSVFRA | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 |
| MASSSFRA | 0.0 | 1.0000 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|----------|--------|----------|-----------|----------|----------|
| RHOMX | KG/CUM | 0.5642 | 1224.0949 | 837.9697 | 837.9697 |
| 831.3439 | | | | | |
| TEMP | C | 115.0000 | 115.0000 | 70.0000 | 70.0000 |
| 75.0633 | | | | | |
| PRES | BAR | 1.0000 | 1.0000 | 1.0000 | 4.0000 |
| 1.0000 | | | | | |

F8 F9 NEWETHYL RECYCLE WASTE

| | | | | | |
|---------------------|-----------|-----------|----------|-----------|------|
| STREAM ID | F8 | F9 | NEWETHYL | RECYCLE | |
| WASTE | | | | | |
| FROM : | B3 | B4 | ---- | ---- | B7 |
| TO : | B4 | B5 | B10 | B10 | ---- |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 1.9154+04 | 1.9154+04 | 649.9710 | 1.5979+04 | |
| 246.6528 | | | | | |
| GCAL/HR | -24.0336 | -24.0867 | -0.8460 | -20.3973 | - |
| 0.1249 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | MIXED | LIQUID | LIQUID | |
| MIXED | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 9.2823 | 0.0 | 0.0 | |
| 2.5700-02 | | | | | |
| SEBAC-01 | 0.0 | 0.3920 | 0.0 | 0.0 | |
| 1.0854-03 | | | | | |
| SUBER-01 | 0.0 | 0.4552 | 0.0 | 0.0 | |
| 1.2602-03 | | | | | |
| ADIPI-01 | 0.0 | 0.5425 | 0.0 | 0.0 | |
| 1.5021-03 | | | | | |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 188.7421 | 188.7421 | 7.3771 | 181.3650 | |
| 1.0451 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 2137.7590 | 0.0 | 0.0 | |
| 5.9188 | | | | | |
| SEBAC-01 | 0.0 | 79.2885 | 0.0 | 0.0 | |
| 0.2195 | | | | | |
| SUBER-01 | 0.0 | 79.2885 | 0.0 | 0.0 | |
| 0.2195 | | | | | |
| ADIPI-01 | 0.0 | 79.2885 | 0.0 | 0.0 | |
| 0.2195 | | | | | |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 1.6629+04 | 1.6629+04 | 649.9710 | 1.5979+04 | |
| 92.0837 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 188.7421 | 199.4142 | 7.3771 | 181.3650 | |
| 1.0747 | | | | | |
| KG/HR | 1.6629+04 | 1.9005+04 | 649.9710 | 1.5979+04 | |
| 98.6611 | | | | | |

| | | | | | |
|---------------------|-------------------------|------------|------------|------------|-----|
| CUM/HR | 20.0192 | 21.8656 | 0.7273 | 19.2805 | |
| 0.1155 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 75.5731 | 70.0000 | 25.0000 | 77.0000 | |
| 70.0000 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 1.0000 | 3.0000 | |
| 1.0000 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 0.9465 | 1.0000 | 1.0000 | |
| 0.9725 | | | | | |
| SFRAC | 0.0 | 5.3517-02 | 0.0 | 0.0 | |
| 2.7494-02 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | -112.5297 | -120.7910 | -114.6852 | -112.4657 | - |
| 116.8945 | | | | | |
| KCAL/KG | -1277.2032 | -1267.4267 | -1301.6681 | -1276.4774 | - |
| 1273.3022 | | | | | |
| GCAL/HR | -21.2391 | -24.0874 | -0.8460 | -20.3973 | - |
| 0.1256 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -111.1396 | -151.4349 | -117.7300 | -110.9597 | - |
| 132.1841 | | | | | |
| CAL/GM-K | -1.2614 | -1.5890 | -1.3362 | -1.2594 | - |
| 1.4398 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 9.4281-03 | 9.1200-03 | 1.0143-02 | 9.4067-03 | |
| 9.3060-03 | | | | | |
| KG/CUM | 830.6721 | 869.1749 | 893.6285 | 828.7871 | |
| 854.3282 | | | | | |
| AVG MW | 88.1063 | 95.3041 | 88.1063 | 88.1063 | |
| 91.8042 | | | | | |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 9.2823 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.3920 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.4552 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.5425 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 2.6767 | 2.6767 | 0.0 | 0.0 | |
| 2.6499 | | | | | |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 2137.7590 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 79.2885 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 79.2885 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 79.2885 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 149.4866 | 149.4866 | 0.0 | 0.0 | |
| 147.9917 | | | | | |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 13.3488 | 2.6767 | 0.0 | 0.0 | |
| 2.6499 | | | | | |
| KG/HR | 2525.1110 | 149.4866 | 0.0 | 0.0 | |
| 147.9917 | | | | | |

| | | | | | |
|--------------------------|------------|-----------|----------|-----------|-----|
| CUM/HR | 2.0424 | 1.8785-02 | 0.0 | 0.0 | |
| 1.8597-02 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 75.5731 | 70.0000 | MISSING | MISSING | |
| 70.0000 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 1.0000 | 3.0000 | |
| 1.0000 | | | | | |
| VFRAC | 0.0 | 0.0 | MISSING | MISSING | 0.0 |
| LFRAC | 0.0 | 0.0 | MISSING | MISSING | 0.0 |
| SFRAC | 1.0000 | 1.0000 | MISSING | MISSING | |
| 1.0000 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | -209.3450 | 0.2865 | MISSING | MISSING | |
| 0.2865 | | | | | |
| KCAL/KG | -1106.6839 | 5.1303 | MISSING | MISSING | |
| 5.1303 | | | | | |
| GCAL/HR | -2.7945 | 7.6692-04 | MISSING | MISSING | |
| 7.5925-04 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -679.3033 | 0.8949 | MISSING | MISSING | |
| 0.8949 | | | | | |
| CAL/GM-K | -3.5911 | 1.6023-02 | MISSING | MISSING | |
| 1.6023-02 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 6.5359-03 | 0.1425 | MISSING | MISSING | |
| 0.1425 | | | | | |
| KG/CUM | 1236.3639 | 7957.8207 | MISSING | MISSING | |
| 7957.8207 | | | | | |
| AVG MW | 189.1642 | 55.8470 | MISSING | MISSING | |
| 55.8470 | | | | | |
| TOTAL STREAM PROPERTIES: | | | | | |
| *** ALL PHASES *** | | | | | |
| MASSFLOW KG/HR | | | | | |
| DDDA | 2137.7590 | 2137.7590 | 0.0 | 0.0 | |
| 5.9188 | | | | | |
| SEBAC-01 | 79.2885 | 79.2885 | 0.0 | 0.0 | |
| 0.2195 | | | | | |
| SUBER-01 | 79.2885 | 79.2885 | 0.0 | 0.0 | |
| 0.2195 | | | | | |
| ADIPI-01 | 79.2885 | 79.2885 | 0.0 | 0.0 | |
| 0.2195 | | | | | |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 1.6629+04 | 1.6629+04 | 649.9710 | 1.5979+04 | |
| 92.0837 | | | | | |
| DEXTR-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BIOMASS | 149.4866 | 149.4866 | 0.0 | 0.0 | |
| 147.9917 | | | | | |
| NITROGEN | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| VOLFLMX CUM/HR | 22.0615 | 21.8843 | 0.7273 | 19.2805 | |
| 0.1341 | | | | | |
| MASSVFRA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MASSSFRA | 0.1318 | 0.1318 | 0.0 | 0.0 | |
| 0.6267 | | | | | |
| RHOMX KG/CUM | 868.2294 | 875.2596 | 893.6285 | 828.7871 | |
| 1839.5824 | | | | | |
| TEMP C | 75.5731 | 70.0000 | 25.0000 | 77.0000 | |
| 70.0000 | | | | | |

| | | | | | |
|--------|-----|--------|--------|--------|--------|
| PRES | BAR | 1.0000 | 1.0000 | 1.0000 | 3.0000 |
| 1.0000 | | | | | |

F1
--

| | |
|---------------------|-------------------------|
| STREAM ID | F1 |
| FROM : | ---- |
| TO : | B1 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.5360+04 |
| GCAL/HR | -51.2816 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 711.7347 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 1.2822+04 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 711.7347 |
| KG/HR | 1.2822+04 |
| CUM/HR | 12.9508 |
| STATE VARIABLES: | |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -68.0463 |
| KCAL/KG | -3777.1463 |
| GCAL/HR | -48.4309 |
| ENTROPY: | |
| CAL/MOL-K | -38.2583 |
| CAL/GM-K | -2.1237 |
| DENSITY: | |
| MOL/CC | 5.4957-02 |
| KG/CUM | 990.0590 |
| AVG MW | 18.0153 |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.3290 |

| | |
|-------------------|------------|
| SEBAC-01 | 0.3940 |
| SUBER-01 | 0.4575 |
| ADIPI-01 | 0.5453 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6902 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2148.5015 |
| SEBAC-01 | 79.6869 |
| SUBER-01 | 79.6869 |
| ADIPI-01 | 79.6869 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 150.2378 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 13.4159 |
| KG/HR | 2537.8000 |
| CUM/HR | 2.0329 |
| STATE VARIABLES: | |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -212.4807 |
| KCAL/KG | -1123.2606 |
| GCAL/HR | -2.8506 |
| ENTROPY: | |
| CAL/MOL-K | -688.8238 |
| CAL/GM-K | -3.6414 |
| DENSITY: | |
| MOL/CC | 6.5994-03 |
| KG/CUM | 1248.3652 |
| AVG MW | 189.1642 |

TOTAL STREAM PROPERTIES:

```

*** ALL PHASES ***
MASSFLOW KG/HR
  DDDA          2148.5015
  SEBAC-01      79.6869
  SUBER-01      79.6869
  ADIPI-01      79.6869
  WATER         1.2822+04
  ETHYL-01      0.0
  DEXTR-01      0.0
  BIOMASS       150.2378
  NITROGEN      0.0
VOLFLMX CUM/HR  14.9837
MASSVFRA       0.0
MASSSFRA       0.1652
RHOMX KG/CUM   1025.1044
TEMP C         37.0000
PRES BAR       3.4264

```



```

F2
--

STREAM ID          F2
FROM :            B1
TO :              ----
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR            1.1747+04
  GCAL/HR          -44.3371
SUBSTREAM: MIXED
PHASE:             LIQUID
COMPONENTS: KMOL/HR
  DDDA              0.0
  SEBAC-01          0.0
  SUBER-01          0.0
  ADIPI-01          0.0
  WATER             651.3621
  ETHYL-01          0.0
  DEXTR-01          0.0
  BIOMASS            0.0
  NITROGEN           0.0
COMPONENTS: KG/HR
  DDDA              0.0
  SEBAC-01          0.0
  SUBER-01          0.0
  ADIPI-01          0.0
  WATER             1.1734+04
  ETHYL-01          0.0
  DEXTR-01          0.0
  BIOMASS            0.0
  NITROGEN           0.0
TOTAL FLOW:
  KMOL/HR           651.3621
  KG/HR             1.1734+04
  CUM/HR            11.8523
STATE VARIABLES:
  TEMP   C          37.0000
  PRES   BAR         3.4264
  VFRAC              0.0
  LFRAC              1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL          -68.0463
  KCAL/KG           -3777.1463
  GCAL/HR          -44.3228
ENTROPY:
  CAL/MOL-K         -38.2583
  CAL/GM-K          -2.1237
DENSITY:
  MOL/CC            5.4957-02
  KG/CUM            990.0590
AVG MW              18.0153

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR
  DDDA              4.6645-02
  SEBAC-01          1.9700-03
  SUBER-01          2.2873-03
  ADIPI-01          2.7263-03

```

| | |
|-------------------|------------|
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 1.3451-02 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 10.7425 |
| SEBAC-01 | 0.3984 |
| SUBER-01 | 0.3984 |
| ADIPI-01 | 0.3984 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.7512 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 6.7079-02 |
| KG/HR | 12.6890 |
| CUM/HR | 1.0164-02 |
| STATE VARIABLES: | |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -212.4807 |
| KCAL/KG | -1123.2606 |
| GKAL/HR | -1.4253-02 |
| ENTROPY: | |
| CAL/MOL-K | -688.8238 |
| CAL/GM-K | -3.6414 |
| DENSITY: | |
| MOL/CC | 6.5994-03 |
| KG/CUM | 1248.3652 |
| AVG MW | 189.1642 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----------|
| MASSFLOW KG/HR | |
| DDDA | 10.7425 |
| SEBAC-01 | 0.3984 |
| SUBER-01 | 0.3984 |
| ADIPI-01 | 0.3984 |
| WATER | 1.1734+04 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.7512 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 11.8625 |
| MASSVFRA | 0.0 |
| MASSSFRA | 1.0802-03 |
| RHOMX KG/CUM | 990.2804 |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |

F3

--

| | |
|-------------------------|------------|
| STREAM ID | F3 |
| FROM : | B1 |
| TO : | B2 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 3612.7396 |
| GCAL/HR | -6.9445 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 60.3726 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 1087.6286 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 60.3726 |
| KG/HR | 1087.6286 |
| CUM/HR | 1.0985 |
| STATE VARIABLES: | |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -68.0463 |
| KCAL/KG | -3777.1463 |
| GCAL/HR | -4.1081 |
| ENTROPY: | |
| CAL/MOL-K | -38.2583 |
| CAL/GM-K | -2.1237 |
| DENSITY: | |
| MOL/CC | 5.4957-02 |
| KG/CUM | 990.0590 |
| AVG MW | 18.0153 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.2823 |
| SEBAC-01 | 0.3920 |
| SUBER-01 | 0.4552 |
| ADIPI-01 | 0.5425 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |

| | |
|-------------------|------------|
| BIOMASS | 2.6767 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2137.7590 |
| SEBAC-01 | 79.2885 |
| SUBER-01 | 79.2885 |
| ADIPI-01 | 79.2885 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 149.4866 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 13.3488 |
| KG/HR | 2525.1110 |
| CUM/HR | 2.0227 |
| STATE VARIABLES: | |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -212.4807 |
| KCAL/KG | -1123.2606 |
| GCAL/HR | -2.8364 |
| ENTROPY: | |
| CAL/MOL-K | -688.8238 |
| CAL/GM-K | -3.6414 |
| DENSITY: | |
| MOL/CC | 6.5994-03 |
| KG/CUM | 1248.3652 |
| AVG MW | 189.1642 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----------|
| MASSFLOW KG/HR | |
| DDDA | 2137.7590 |
| SEBAC-01 | 79.2885 |
| SUBER-01 | 79.2885 |
| ADIPI-01 | 79.2885 |
| WATER | 1087.6286 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 149.4866 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 3.1213 |
| MASSVFRA | 0.0 |
| MASSSFRA | 0.6989 |
| RHOMX KG/CUM | 1157.4532 |
| TEMP C | 37.0000 |
| PRES BAR | 3.4264 |

F4

--

| | |
|-----------|------|
| STREAM ID | F4 |
| FROM : | ---- |
| TO : | B2 |

| | |
|---------------------|------------|
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 33.2499 |
| GCAL/HR | -4.1283-05 |
| SUBSTREAM: MIXED | |
| PHASE: | VAPOR |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 1.1869 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 33.2499 |
| TOTAL FLOW: | |
| KMOL/HR | 1.1869 |
| KG/HR | 33.2499 |
| CUM/HR | 16.9901 |
| STATE VARIABLES: | |
| TEMP C | 20.0000 |
| PRES BAR | 1.7027 |
| VFRAC | 1.0000 |
| LFRAC | 0.0 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -3.4782-02 |
| KCAL/KG | -1.2416 |
| GCAL/HR | -4.1283-05 |
| ENTROPY: | |
| CAL/MOL-K | -1.1484 |
| CAL/GM-K | -4.0996-02 |
| DENSITY: | |
| MOL/CC | 6.9860-05 |
| KG/CUM | 1.9570 |
| AVG MW | 28.0135 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----|
| MASSFLOW KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |

| | |
|---------------------|------------|
| NITROGEN | 33.2499 |
| VOLFLMX CUM/HR | 16.9901 |
| MASSVFRA | 1.0000 |
| MASSSFRA | 0.0 |
| RHOMX KG/CUM | 1.9570 |
| TEMP C | 20.0000 |
| PRES BAR | 1.7027 |
| F5 | |
| -- | |
| STREAM ID | F5 |
| FROM : | B2 |
| TO : | ---- |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1120.8785 |
| GCAL/HR | -3.4423 |
| SUBSTREAM: MIXED | |
| PHASE: | VAPOR |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 60.3726 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 1.1869 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 1087.6286 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 33.2499 |
| TOTAL FLOW: | |
| KMOL/HR | 61.5595 |
| KG/HR | 1120.8785 |
| CUM/HR | 1986.6522 |
| STATE VARIABLES: | |
| TEMP C | 115.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 1.0000 |
| LFRAC | 0.0 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -55.9183 |
| KCAL/KG | -3071.0741 |
| GCAL/HR | -3.4423 |
| ENTROPY: | |
| CAL/MOL-K | -8.0662 |
| CAL/GM-K | -0.4430 |
| DENSITY: | |
| MOL/CC | 3.0987-05 |
| KG/CUM | 0.5642 |

AVG MW 18.2081

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----------|
| MASSFLOW KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 1087.6286 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 33.2499 |
| VOLFLMX CUM/HR | 1986.6522 |
| MASSVFRA | 1.0000 |
| MASSSFRA | 0.0 |
| RHOMX KG/CUM | 0.5642 |
| TEMP C | 115.0000 |
| PRES BAR | 1.0000 |

F6

--

| | |
|-----------|----------|
| STREAM ID | F6 |
| FROM : | B2 |
| TO : | B3 |
| CLASS: | MIXCISLD |

| | |
|---------------|-----------|
| TOTAL STREAM: | |
| KG/HR | 2525.1110 |
| GCAL/HR | -2.7477 |

| | |
|---------------------|-------------------------|
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |

| | |
|----------|--------|
| DDDA | 9.2823 |
| SEBAC-01 | 0.3920 |
| SUBER-01 | 0.4552 |
| ADIPI-01 | 0.5425 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6767 |
| NITROGEN | 0.0 |

| | |
|-------------------|-----------|
| COMPONENTS: KG/HR | |
| DDDA | 2137.7590 |
| SEBAC-01 | 79.2885 |
| SUBER-01 | 79.2885 |
| ADIPI-01 | 79.2885 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 149.4866 |
| NITROGEN | 0.0 |

| | |
|-------------|-----------|
| TOTAL FLOW: | |
| KMOL/HR | 13.3488 |
| KG/HR | 2525.1110 |
| CUM/HR | 2.0628 |

| | |
|------------------|----------|
| STATE VARIABLES: | |
| TEMP C | 115.0000 |

| | | |
|-----------|-----|------------|
| PRES | BAR | 1.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 0.0 |
| SFRAC | | 1.0000 |
| ENTHALPY: | | |
| KCAL/MOL | | -205.8396 |
| KCAL/KG | | -1088.1528 |
| GCAL/HR | | -2.7477 |
| ENTROPY: | | |
| CAL/MOL-K | | -669.7870 |
| CAL/GM-K | | -3.5408 |
| DENSITY: | | |
| MOL/CC | | 6.4711-03 |
| KG/CUM | | 1224.0949 |
| AVG MW | | 189.1642 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | | |
|----------------|--------|-----------|
| MASSFLOW KG/HR | | |
| DDDA | | 2137.7590 |
| SEBAC-01 | | 79.2885 |
| SUBER-01 | | 79.2885 |
| ADIPI-01 | | 79.2885 |
| WATER | | 0.0 |
| ETHYL-01 | | 0.0 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 149.4866 |
| NITROGEN | | 0.0 |
| VOLFLMX | CUM/HR | 2.0628 |
| MASSVFRA | | 0.0 |
| MASSSFRA | | 1.0000 |
| RHOMX | KG/CUM | 1224.0949 |
| TEMP | C | 115.0000 |
| PRES | BAR | 1.0000 |

F7

--

| | |
|---------------------|-----------|
| STREAM ID | F7 |
| FROM : | ---- |
| TO : | ---- |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 2.2815+04 |
| GCAL/HR | -29.2041 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 258.9533 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |

| | |
|------------------|------------|
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 2.2815+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 258.9533 |
| KG/HR | 2.2815+04 |
| CUM/HR | 27.2270 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -112.7776 |
| KCAL/KG | -1280.0171 |
| GCAL/HR | -29.2041 |
| ENTROPY: | |
| CAL/MOL-K | -111.8447 |
| CAL/GM-K | -1.2694 |
| DENSITY: | |
| MOL/CC | 9.5109-03 |
| KG/CUM | 837.9697 |
| AVG MW | 88.1063 |

TOTAL STREAM PROPERTIES:

| | | |
|--------------------|--------|-----------|
| *** ALL PHASES *** | | |
| MASSFLOW KG/HR | | |
| DDDA | | 0.0 |
| SEBAC-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| ADIPI-01 | | 0.0 |
| WATER | | 0.0 |
| ETHYL-01 | | 2.2815+04 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| VOLFLMX | CUM/HR | 27.2270 |
| MASSVFRA | | 0.0 |
| MASSSFRA | | 0.0 |
| RHOMX | KG/CUM | 837.9697 |
| TEMP | C | 70.0000 |
| PRES | BAR | 1.0000 |

F7POST

| | |
|---------------|-----------|
| STREAM ID | F7POST |
| FROM : | B11 |
| TO : | B3 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.6629+04 |
| GCAL/HR | -21.2859 |

SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR

| | |
|----------|----------|
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 188.7421 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 1.6629+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 188.7421 |
| KG/HR | 1.6629+04 |
| CUM/HR | 19.8448 |

STATE VARIABLES:

| | |
|----------|---------|
| TEMP C | 70.0000 |
| PRES BAR | 4.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -112.7776 |
| KCAL/KG | -1280.0171 |
| GCAL/HR | -21.2859 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -111.8447 |
| CAL/GM-K | -1.2694 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 9.5109-03 |
| KG/CUM | 837.9697 |
| AVG MW | 88.1063 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***
 MASSFLOW KG/HR

| | |
|----------|-----------|
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 1.6629+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |

VOLFLMX CUM/HR 19.8448
 MASSVFRA 0.0
 MASSSFRA 0.0

| | | |
|--------------------------|--------|------------|
| RHOMX | KG/CUM | 837.9697 |
| TEMP | C | 70.0000 |
| PRES | BAR | 4.0000 |
| F7PRE | | |
| ----- | | |
| STREAM ID | | F7PRE |
| FROM : | | B10 |
| TO : | | B11 |
| CLASS: | | MIXCISLD |
| TOTAL STREAM: | | |
| KG/HR | | 1.6629+04 |
| GCAL/HR | | -21.2434 |
| SUBSTREAM: MIXED | | |
| PHASE: | | LIQUID |
| COMPONENTS: KMOL/HR | | |
| DDDA | | 0.0 |
| SEBAC-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| ADIPI-01 | | 0.0 |
| WATER | | 0.0 |
| ETHYL-01 | | 188.7421 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| COMPONENTS: KG/HR | | |
| DDDA | | 0.0 |
| SEBAC-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| ADIPI-01 | | 0.0 |
| WATER | | 0.0 |
| ETHYL-01 | | 1.6629+04 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 188.7421 |
| KG/HR | | 1.6629+04 |
| CUM/HR | | 20.0030 |
| STATE VARIABLES: | | |
| TEMP | C | 75.0633 |
| PRES | BAR | 1.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 1.0000 |
| SFRAC | | 0.0 |
| ENTHALPY: | | |
| KCAL/MOL | | -112.5525 |
| KCAL/KG | | -1277.4620 |
| GCAL/HR | | -21.2434 |
| ENTROPY: | | |
| CAL/MOL-K | | -111.2040 |
| CAL/GM-K | | -1.2622 |
| DENSITY: | | |
| MOL/CC | | 9.4357-03 |
| KG/CUM | | 831.3439 |
| AVG MW | | 88.1063 |
| TOTAL STREAM PROPERTIES: | | |

```

*** ALL PHASES ***
MASSFLOW KG/HR
  DDDA              0.0
  SEBAC-01          0.0
  SUBER-01          0.0
  ADIPI-01          0.0
  WATER             0.0
  ETHYL-01          1.6629+04
  DEXTR-01          0.0
  BIOMASS            0.0
  NITROGEN           0.0
VOLFLMX  CUM/HR      20.0030
MASSVFRA              0.0
MASSSFRA              0.0
RHOMX    KG/CUM      831.3439
TEMP     C            75.0633
PRES     BAR          1.0000

F8
--

STREAM ID              F8
FROM :                 B3
TO :                   B4
CLASS:                 MIXCISLD
TOTAL STREAM:
  KG/HR                 1.9154+04
  GCAL/HR               -24.0336
SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: KMOL/HR
  DDDA              0.0
  SEBAC-01          0.0
  SUBER-01          0.0
  ADIPI-01          0.0
  WATER             0.0
  ETHYL-01          188.7421
  DEXTR-01          0.0
  BIOMASS            0.0
  NITROGEN           0.0
COMPONENTS: KG/HR
  DDDA              0.0
  SEBAC-01          0.0
  SUBER-01          0.0
  ADIPI-01          0.0
  WATER             0.0
  ETHYL-01          1.6629+04
  DEXTR-01          0.0
  BIOMASS            0.0
  NITROGEN           0.0
TOTAL FLOW:
  KMOL/HR            188.7421
  KG/HR              1.6629+04
  CUM/HR             20.0192
STATE VARIABLES:
  TEMP     C            75.5731
  PRES     BAR          1.0000
  VFRAC              0.0
  LFRAC            1.0000
  SFRAC            0.0

```

| | | |
|--------------------------|--|------------|
| ENTHALPY: | | |
| KCAL/MOL | | -112.5297 |
| KCAL/KG | | -1277.2032 |
| GCAL/HR | | -21.2391 |
| ENTROPY: | | |
| CAL/MOL-K | | -111.1396 |
| CAL/GM-K | | -1.2614 |
| DENSITY: | | |
| MOL/CC | | 9.4281-03 |
| KG/CUM | | 830.6721 |
| AVG MW | | 88.1063 |
| SUBSTREAM: CISOLID | | |
| STRUCTURE: CONVENTIONAL | | |
| COMPONENTS: KMOL/HR | | |
| DDDA | | 9.2823 |
| SEBAC-01 | | 0.3920 |
| SUBER-01 | | 0.4552 |
| ADIPI-01 | | 0.5425 |
| WATER | | 0.0 |
| ETHYL-01 | | 0.0 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 2.6767 |
| NITROGEN | | 0.0 |
| COMPONENTS: KG/HR | | |
| DDDA | | 2137.7590 |
| SEBAC-01 | | 79.2885 |
| SUBER-01 | | 79.2885 |
| ADIPI-01 | | 79.2885 |
| WATER | | 0.0 |
| ETHYL-01 | | 0.0 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 149.4866 |
| NITROGEN | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 13.3488 |
| KG/HR | | 2525.1110 |
| CUM/HR | | 2.0424 |
| STATE VARIABLES: | | |
| TEMP C | | 75.5731 |
| PRES BAR | | 1.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 0.0 |
| SFRAC | | 1.0000 |
| ENTHALPY: | | |
| KCAL/MOL | | -209.3450 |
| KCAL/KG | | -1106.6839 |
| GCAL/HR | | -2.7945 |
| ENTROPY: | | |
| CAL/MOL-K | | -679.3033 |
| CAL/GM-K | | -3.5911 |
| DENSITY: | | |
| MOL/CC | | 6.5359-03 |
| KG/CUM | | 1236.3639 |
| AVG MW | | 189.1642 |
| TOTAL STREAM PROPERTIES: | | |
| *** ALL PHASES *** | | |
| MASSFLOW KG/HR | | |
| DDDA | | 2137.7590 |

| | |
|----------------|-----------|
| SEBAC-01 | 79.2885 |
| SUBER-01 | 79.2885 |
| ADIPI-01 | 79.2885 |
| WATER | 0.0 |
| ETHYL-01 | 1.6629+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 149.4866 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 22.0615 |
| MASSVFRA | 0.0 |
| MASSSFRA | 0.1318 |
| RHOMX KG/CUM | 868.2294 |
| TEMP C | 75.5731 |
| PRES BAR | 1.0000 |

F9
--

| | |
|---------------------|------------|
| STREAM ID | F9 |
| FROM : | B4 |
| TO : | B5 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.9154+04 |
| GCAL/HR | -24.0867 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.2823 |
| SEBAC-01 | 0.3920 |
| SUBER-01 | 0.4552 |
| ADIPI-01 | 0.5425 |
| WATER | 0.0 |
| ETHYL-01 | 188.7421 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2137.7590 |
| SEBAC-01 | 79.2885 |
| SUBER-01 | 79.2885 |
| ADIPI-01 | 79.2885 |
| WATER | 0.0 |
| ETHYL-01 | 1.6629+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 199.4142 |
| KG/HR | 1.9005+04 |
| CUM/HR | 21.8656 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.9465 |
| SFRAC | 5.3517-02 |
| ENTHALPY: | |
| KCAL/MOL | -120.7910 |
| KCAL/KG | -1267.4267 |

| | |
|--------------------------|-------------------------|
| GCAL/HR | -24.0874 |
| ENTROPY: | |
| CAL/MOL-K | -151.4349 |
| CAL/GM-K | -1.5890 |
| DENSITY: | |
| MOL/CC | 9.1200-03 |
| KG/CUM | 869.1749 |
| AVG MW | 95.3041 |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6767 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 149.4866 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.6767 |
| KG/HR | 149.4866 |
| CUM/HR | 1.8785-02 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | 0.2865 |
| KCAL/KG | 5.1303 |
| GCAL/HR | 7.6692-04 |
| ENTROPY: | |
| CAL/MOL-K | 0.8949 |
| CAL/GM-K | 1.6023-02 |
| DENSITY: | |
| MOL/CC | 0.1425 |
| KG/CUM | 7957.8207 |
| AVG MW | 55.8470 |
| TOTAL STREAM PROPERTIES: | |
| *** ALL PHASES *** | |
| MASSFLOW KG/HR | |
| DDDA | 2137.7590 |
| SEBAC-01 | 79.2885 |
| SUBER-01 | 79.2885 |
| ADIPI-01 | 79.2885 |

| | |
|----------------|-----------|
| WATER | 0.0 |
| ETHYL-01 | 1.6629+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 149.4866 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 21.8843 |
| MASSVFRA | 0.0 |
| MASSSFRA | 0.1318 |
| RHOMX KG/CUM | 875.2596 |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |

F10

| | |
|---------------------|------------|
| STREAM ID | F10 |
| FROM : | B5 |
| TO : | B8 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.8907+04 |
| GCAL/HR | -23.9611 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.2336 |
| SEBAC-01 | 0.3900 |
| SUBER-01 | 0.4528 |
| ADIPI-01 | 0.5397 |
| WATER | 0.0 |
| ETHYL-01 | 187.7524 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2126.5491 |
| SEBAC-01 | 78.8727 |
| SUBER-01 | 78.8727 |
| ADIPI-01 | 78.8727 |
| WATER | 0.0 |
| ETHYL-01 | 1.6542+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 198.3685 |
| KG/HR | 1.8905+04 |
| CUM/HR | 21.7509 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.9465 |
| SFRAC | 5.3517-02 |
| ENTHALPY: | |
| KCAL/MOL | -120.7910 |
| KCAL/KG | -1267.4267 |
| GCAL/HR | -23.9611 |
| ENTROPY: | |
| CAL/MOL-K | -151.4349 |

| | |
|--------------------------|-------------------------|
| CAL/GM-K | -1.5890 |
| DENSITY: | |
| MOL/CC | 9.1200-03 |
| KG/CUM | 869.1749 |
| AVG MW | 95.3041 |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6767-02 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 1.4949 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.6767-02 |
| KG/HR | 1.4949 |
| CUM/HR | 1.8785-04 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | 0.2865 |
| KCAL/KG | 5.1303 |
| GCAL/HR | 7.6692-06 |
| ENTROPY: | |
| CAL/MOL-K | 0.8949 |
| CAL/GM-K | 1.6023-02 |
| DENSITY: | |
| MOL/CC | 0.1425 |
| KG/CUM | 7957.8207 |
| AVG MW | 55.8470 |
| TOTAL STREAM PROPERTIES: | |
| *** ALL PHASES *** | |
| MASSFLOW KG/HR | |
| DDDA | 2126.5491 |
| SEBAC-01 | 78.8727 |
| SUBER-01 | 78.8727 |
| ADIPI-01 | 78.8727 |
| WATER | 0.0 |
| ETHYL-01 | 1.6542+04 |
| DEXTR-01 | 0.0 |

| | |
|----------------|----------|
| BIOMASS | 1.4949 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 21.7511 |
| MASSVFRA | 0.0 |
| MASSSFRA | 0.1251 |
| RHOMX KG/CUM | 869.2361 |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |

F11

| | |
|---------------------|------------|
| STREAM ID | F11 |
| FROM : | B5 |
| TO : | B6 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 247.6494 |
| GCAL/HR | -0.1255 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: KMOL/HR | |
| DDDA | 4.8674-02 |
| SEBAC-01 | 2.0557-03 |
| SUBER-01 | 2.3868-03 |
| ADIPI-01 | 2.8450-03 |
| WATER | 0.0 |
| ETHYL-01 | 0.9897 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 11.2099 |
| SEBAC-01 | 0.4158 |
| SUBER-01 | 0.4158 |
| ADIPI-01 | 0.4158 |
| WATER | 0.0 |
| ETHYL-01 | 87.2005 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 1.0457 |
| KG/HR | 99.6577 |
| CUM/HR | 0.1147 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.9465 |
| SFRAC | 5.3517-02 |
| ENTHALPY: | |
| KCAL/MOL | -120.7910 |
| KCAL/KG | -1267.4267 |
| GCAL/HR | -0.1263 |
| ENTROPY: | |
| CAL/MOL-K | -151.4349 |
| CAL/GM-K | -1.5890 |
| DENSITY: | |
| MOL/CC | 9.1200-03 |

| | |
|--------------------------|-----------|
| KG/CUM | 869.1749 |
| AVG MW | 95.3041 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6499 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 147.9917 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.6499 |
| KG/HR | 147.9917 |
| CUM/HR | 1.8597-02 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | 0.2865 |
| KCAL/KG | 5.1303 |
| GCAL/HR | 7.5925-04 |
| ENTROPY: | |
| CAL/MOL-K | 0.8949 |
| CAL/GM-K | 1.6023-02 |
| DENSITY: | |
| MOL/CC | 0.1425 |
| KG/CUM | 7957.8207 |
| AVG MW | 55.8470 |
| TOTAL STREAM PROPERTIES: | |
| *** ALL PHASES *** | |
| MASSFLOW KG/HR | |
| DDDA | 11.2099 |
| SEBAC-01 | 0.4158 |
| SUBER-01 | 0.4158 |
| ADIPI-01 | 0.4158 |
| WATER | 0.0 |
| ETHYL-01 | 87.2005 |
| DEXTR-01 | 0.0 |
| BIOMASS | 147.9917 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 0.1333 |

| | | |
|---------------------|--------|------------|
| MASSVFRA | | 0.0 |
| MASSSFRA | | 0.6479 |
| RHOMX | KG/CUM | 1858.4646 |
| TEMP | C | 70.0000 |
| PRES | BAR | 1.0000 |
| F12 | | |
| --- | | |
| STREAM ID | | F12 |
| FROM : | | ---- |
| TO : | | B6 |
| CLASS: | | MIXCISLD |
| TOTAL STREAM: | | |
| KG/HR | | 87.2005 |
| GCAL/HR | | -0.1116 |
| SUBSTREAM: MIXED | | |
| PHASE: | | LIQUID |
| COMPONENTS: KMOL/HR | | |
| DDDA | | 0.0 |
| SEBAC-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| ADIPI-01 | | 0.0 |
| WATER | | 0.0 |
| ETHYL-01 | | 0.9897 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| COMPONENTS: KG/HR | | |
| DDDA | | 0.0 |
| SEBAC-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| ADIPI-01 | | 0.0 |
| WATER | | 0.0 |
| ETHYL-01 | | 87.2005 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 0.9897 |
| KG/HR | | 87.2005 |
| CUM/HR | | 0.1041 |
| STATE VARIABLES: | | |
| TEMP | C | 70.0000 |
| PRES | BAR | 1.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 1.0000 |
| SFRAC | | 0.0 |
| ENTHALPY: | | |
| KCAL/MOL | | -112.7776 |
| KCAL/KG | | -1280.0171 |
| GCAL/HR | | -0.1116 |
| ENTROPY: | | |
| CAL/MOL-K | | -111.8447 |
| CAL/GM-K | | -1.2694 |
| DENSITY: | | |
| MOL/CC | | 9.5109-03 |
| KG/CUM | | 837.9697 |
| AVG MW | | 88.1063 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | | |
|----------------|--------|----------|
| MASSFLOW KG/HR | | |
| DDDA | | 0.0 |
| SEBAC-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| ADIPI-01 | | 0.0 |
| WATER | | 0.0 |
| ETHYL-01 | | 87.2005 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| VOLFLMX | CUM/HR | 0.1041 |
| MASSVFRA | | 0.0 |
| MASSSFRA | | 0.0 |
| RHOMX | KG/CUM | 837.9697 |
| TEMP | C | 70.0000 |
| PRES | BAR | 1.0000 |

F13

| | |
|---------------------|-----------|
| STREAM ID | F13 |
| FROM : | B6 |
| TO : | B7 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 334.8499 |
| GCAL/HR | -0.2372 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: KMOL/HR | |
| DDDA | 4.8674-02 |
| SEBAC-01 | 2.0557-03 |
| SUBER-01 | 2.3868-03 |
| ADIPI-01 | 2.8450-03 |
| WATER | 0.0 |
| ETHYL-01 | 1.9794 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 11.2099 |
| SEBAC-01 | 0.4158 |
| SUBER-01 | 0.4158 |
| ADIPI-01 | 0.4158 |
| WATER | 0.0 |
| ETHYL-01 | 174.4010 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.0354 |
| KG/HR | 186.8582 |
| CUM/HR | 0.2187 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |

| | |
|-------------------------|------------|
| LFRAC | 0.9725 |
| SFRAC | 2.7494-02 |
| ENTHALPY: | |
| KCAL/MOL | -116.8945 |
| KCAL/KG | -1273.3022 |
| GCAL/HR | -0.2379 |
| ENTROPY: | |
| CAL/MOL-K | -132.1841 |
| CAL/GM-K | -1.4398 |
| DENSITY: | |
| MOL/CC | 9.3060-03 |
| KG/CUM | 854.3282 |
| AVG MW | 91.8042 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6499 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 147.9917 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.6499 |
| KG/HR | 147.9917 |
| CUM/HR | 1.8597-02 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | 0.2865 |
| KCAL/KG | 5.1303 |
| GCAL/HR | 7.5925-04 |
| ENTROPY: | |
| CAL/MOL-K | 0.8949 |
| CAL/GM-K | 1.6023-02 |
| DENSITY: | |
| MOL/CC | 0.1425 |
| KG/CUM | 7957.8207 |
| AVG MW | 55.8470 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | | |
|---------------------|--------|-----------|
| MASSFLOW KG/HR | | |
| DDDA | | 11.2099 |
| SEBAC-01 | | 0.4158 |
| SUBER-01 | | 0.4158 |
| ADIPI-01 | | 0.4158 |
| WATER | | 0.0 |
| ETHYL-01 | | 174.4010 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 147.9917 |
| NITROGEN | | 0.0 |
| VOLFLMX | CUM/HR | 0.2373 |
| MASSVFRA | | 0.0 |
| MASSSFRA | | 0.4792 |
| RHOMX | KG/CUM | 1410.9847 |
| TEMP | C | 70.0000 |
| PRES | BAR | 1.0000 |
| F14 | | |
| --- | | |
| STREAM ID | | F14 |
| FROM : | | B7 |
| TO : | | B8 |
| CLASS: | | MIXCISLD |
| TOTAL STREAM: | | |
| KG/HR | | 88.1971 |
| GCAL/HR | | -0.1123 |
| SUBSTREAM: MIXED | | |
| PHASE: | | MIXED |
| COMPONENTS: KMOL/HR | | |
| DDDA | | 2.2974-02 |
| SEBAC-01 | | 9.7030-04 |
| SUBER-01 | | 1.1266-03 |
| ADIPI-01 | | 1.3428-03 |
| WATER | | 0.0 |
| ETHYL-01 | | 0.9343 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| COMPONENTS: KG/HR | | |
| DDDA | | 5.2911 |
| SEBAC-01 | | 0.1962 |
| SUBER-01 | | 0.1962 |
| ADIPI-01 | | 0.1962 |
| WATER | | 0.0 |
| ETHYL-01 | | 82.3173 |
| DEXTR-01 | | 0.0 |
| BIOMASS | | 0.0 |
| NITROGEN | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 0.9607 |
| KG/HR | | 88.1971 |
| CUM/HR | | 0.1032 |
| STATE VARIABLES: | | |
| TEMP | C | 70.0000 |
| PRES | BAR | 1.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 0.9725 |
| SFRAC | | 2.7494-02 |
| ENTHALPY: | | |

| | |
|-----------|------------|
| KCAL/MOL | -116.8945 |
| KCAL/KG | -1273.3022 |
| GCAL/HR | -0.1123 |
| ENTROPY: | |
| CAL/MOL-K | -132.1841 |
| CAL/GM-K | -1.4398 |
| DENSITY: | |
| MOL/CC | 9.3060-03 |
| KG/CUM | 854.3282 |
| AVG MW | 91.8042 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----------|
| MASSFLOW KG/HR | |
| DDDA | 5.2911 |
| SEBAC-01 | 0.1962 |
| SUBER-01 | 0.1962 |
| ADIPI-01 | 0.1962 |
| WATER | 0.0 |
| ETHYL-01 | 82.3173 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 0.1032 |
| MASSVFRA | 0.0 |
| MASSSFRA | 6.6667-02 |
| RHOMX KG/CUM | 854.3282 |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |

F16

| | |
|---------------------|-----------|
| STREAM ID | F16 |
| FROM : | B8 |
| TO : | ---- |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.8995+04 |
| GCAL/HR | -24.0734 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.2566 |
| SEBAC-01 | 0.3909 |
| SUBER-01 | 0.4539 |
| ADIPI-01 | 0.5410 |
| WATER | 0.0 |
| ETHYL-01 | 188.6867 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2131.8401 |
| SEBAC-01 | 79.0690 |
| SUBER-01 | 79.0690 |
| ADIPI-01 | 79.0690 |
| WATER | 0.0 |
| ETHYL-01 | 1.6624+04 |

| | |
|-------------------------|------------|
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 199.3292 |
| KG/HR | 1.8994+04 |
| CUM/HR | 21.8541 |
| STATE VARIABLES: | |
| TEMP C | 69.9999 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.9466 |
| SFRAC | 5.3392-02 |
| ENTHALPY: | |
| KCAL/MOL | -120.7722 |
| KCAL/KG | -1267.4540 |
| GCAL/HR | -24.0734 |
| ENTROPY: | |
| CAL/MOL-K | -151.3421 |
| CAL/GM-K | -1.5883 |
| DENSITY: | |
| MOL/CC | 9.1209-03 |
| KG/CUM | 869.1048 |
| AVG MW | 95.2873 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6767-02 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 1.4949 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.6767-02 |
| KG/HR | 1.4949 |
| CUM/HR | 1.8785-04 |
| STATE VARIABLES: | |
| TEMP C | 69.9999 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | 0.2865 |
| KCAL/KG | 5.1303 |
| GCAL/HR | 7.6692-06 |

ENTROPY:
 CAL/MOL-K 0.8949
 CAL/GM-K 1.6023-02
 DENSITY:
 MOL/CC 0.1425
 KG/CUM 7957.8208
 AVG MW 55.8470

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***
 MASSFLOW KG/HR
 DDDA 2131.8401
 SEBAC-01 79.0690
 SUBER-01 79.0690
 ADIPI-01 79.0690
 WATER 0.0
 ETHYL-01 1.6624+04
 DEXTR-01 0.0
 BIOMASS 1.4949
 NITROGEN 0.0
 VOLFLMX CUM/HR 21.8543
 MASSVFRA 0.0
 MASSSFRA 0.1248
 RHOMX KG/CUM 869.1658
 TEMP C 69.9999
 PRES BAR 1.0000

NEWETHYL

STREAM ID NEWETHYL
 FROM : ----
 TO : B10
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 649.9710
 GCAL/HR -0.8460
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 SEBAC-01 0.0
 SUBER-01 0.0
 ADIPI-01 0.0
 WATER 0.0
 ETHYL-01 7.3771
 DEXTR-01 0.0
 BIOMASS 0.0
 NITROGEN 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 SEBAC-01 0.0
 SUBER-01 0.0
 ADIPI-01 0.0
 WATER 0.0
 ETHYL-01 649.9710
 DEXTR-01 0.0
 BIOMASS 0.0
 NITROGEN 0.0

TOTAL FLOW:

| | |
|---------|----------|
| KMOL/HR | 7.3771 |
| KG/HR | 649.9710 |
| CUM/HR | 0.7273 |

STATE VARIABLES:

| | |
|----------|---------|
| TEMP C | 25.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -114.6852 |
| KCAL/KG | -1301.6681 |
| GKAL/HR | -0.8460 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -117.7300 |
| CAL/GM-K | -1.3362 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 1.0143-02 |
| KG/CUM | 893.6285 |
| AVG MW | 88.1063 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

MASSFLOW KG/HR

| | |
|----------------|----------|
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 649.9710 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 0.7273 |
| MASSVFRA | 0.0 |
| MASSSFRA | 0.0 |
| RHOMX KG/CUM | 893.6285 |
| TEMP C | 25.0000 |
| PRES BAR | 1.0000 |

RECYCLE

| | |
|---------------------|-----------|
| STREAM ID | RECYCLE |
| FROM : | ---- |
| TO : | B10 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.5979+04 |
| GKAL/HR | -20.3973 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |

| | |
|-------------------|------------|
| ETHYL-01 | 181.3650 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 1.5979+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 181.3650 |
| KG/HR | 1.5979+04 |
| CUM/HR | 19.2805 |
| STATE VARIABLES: | |
| TEMP C | 77.0000 |
| PRES BAR | 3.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -112.4657 |
| KCAL/KG | -1276.4774 |
| GCAL/HR | -20.3973 |
| ENTROPY: | |
| CAL/MOL-K | -110.9597 |
| CAL/GM-K | -1.2594 |
| DENSITY: | |
| MOL/CC | 9.4067-03 |
| KG/CUM | 828.7871 |
| AVG MW | 88.1063 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----------|
| MASSFLOW KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 1.5979+04 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 19.2805 |
| MASSVFRA | 0.0 |
| MASSFRA | 0.0 |
| RHOMX KG/CUM | 828.7871 |
| TEMP C | 77.0000 |
| PRES BAR | 3.0000 |

WASTE

| | |
|-----------|-------|
| STREAM ID | WASTE |
|-----------|-------|

| | |
|-------------------------|------------|
| FROM : | B7 |
| TO : | ---- |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 246.6528 |
| GCAL/HR | -0.1249 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: KMOL/HR | |
| DDDA | 2.5700-02 |
| SEBAC-01 | 1.0854-03 |
| SUBER-01 | 1.2602-03 |
| ADIPI-01 | 1.5021-03 |
| WATER | 0.0 |
| ETHYL-01 | 1.0451 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 5.9188 |
| SEBAC-01 | 0.2195 |
| SUBER-01 | 0.2195 |
| ADIPI-01 | 0.2195 |
| WATER | 0.0 |
| ETHYL-01 | 92.0837 |
| DEXTR-01 | 0.0 |
| BIOMASS | 0.0 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 1.0747 |
| KG/HR | 98.6611 |
| CUM/HR | 0.1155 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.9725 |
| SFRAC | 2.7494-02 |
| ENTHALPY: | |
| KCAL/MOL | -116.8945 |
| KCAL/KG | -1273.3022 |
| GCAL/HR | -0.1256 |
| ENTROPY: | |
| CAL/MOL-K | -132.1841 |
| CAL/GM-K | -1.4398 |
| DENSITY: | |
| MOL/CC | 9.3060-03 |
| KG/CUM | 854.3282 |
| AVG MW | 91.8042 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 2.6499 |

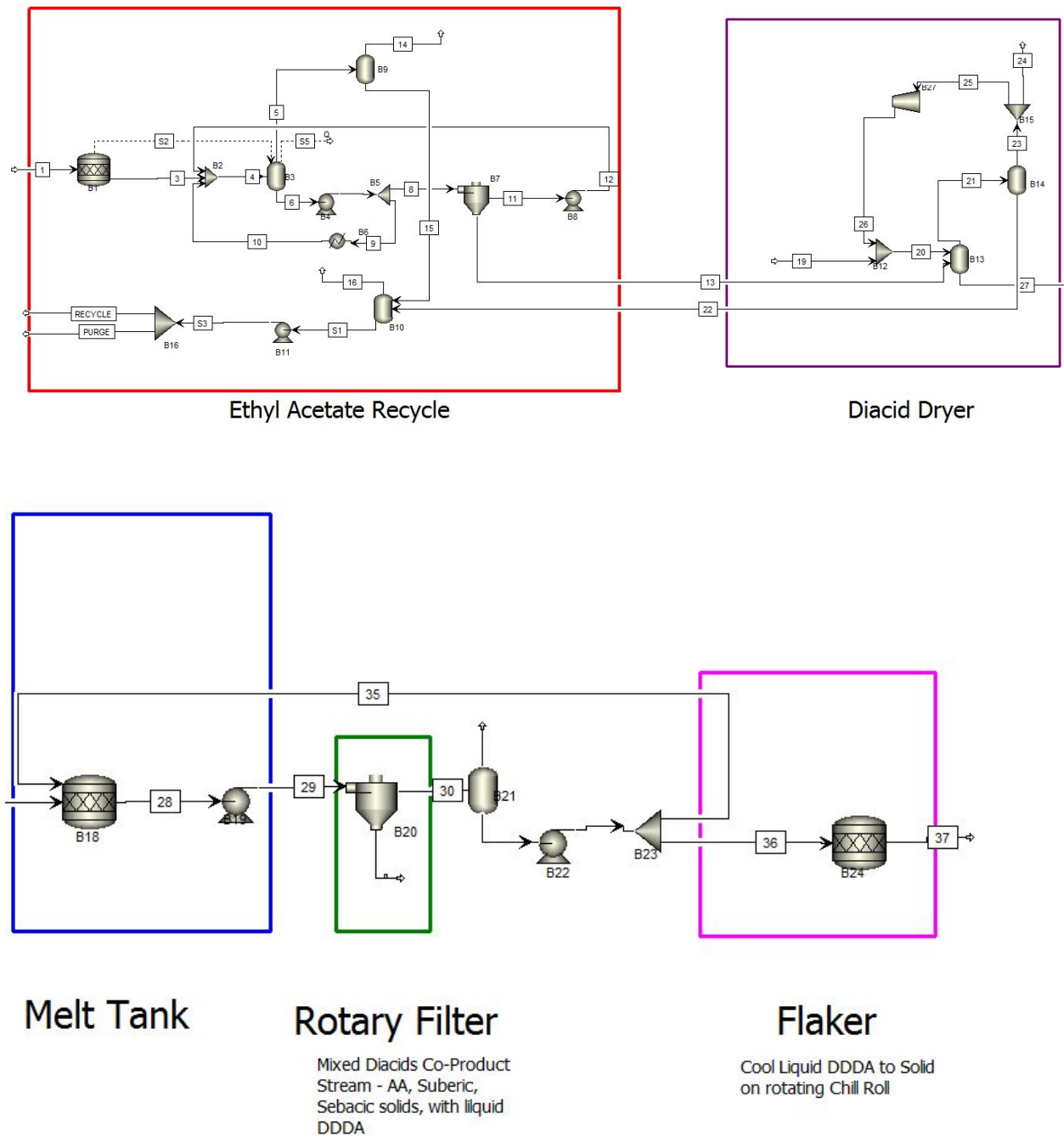
| | |
|-------------------|-----------|
| NITROGEN | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| SEBAC-01 | 0.0 |
| SUBER-01 | 0.0 |
| ADIPI-01 | 0.0 |
| WATER | 0.0 |
| ETHYL-01 | 0.0 |
| DEXTR-01 | 0.0 |
| BIOMASS | 147.9917 |
| NITROGEN | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 2.6499 |
| KG/HR | 147.9917 |
| CUM/HR | 1.8597-02 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | 0.2865 |
| KCAL/KG | 5.1303 |
| GCAL/HR | 7.5925-04 |
| ENTROPY: | |
| CAL/MOL-K | 0.8949 |
| CAL/GM-K | 1.6023-02 |
| DENSITY: | |
| MOL/CC | 0.1425 |
| KG/CUM | 7957.8207 |
| AVG MW | 55.8470 |

TOTAL STREAM PROPERTIES:

*** ALL PHASES ***

| | |
|----------------|-----------|
| MASSFLOW KG/HR | |
| DDDA | 5.9188 |
| SEBAC-01 | 0.2195 |
| SUBER-01 | 0.2195 |
| ADIPI-01 | 0.2195 |
| WATER | 0.0 |
| ETHYL-01 | 92.0837 |
| DEXTR-01 | 0.0 |
| BIOMASS | 147.9917 |
| NITROGEN | 0.0 |
| VOLFLMX CUM/HR | 0.1341 |
| MASSVFRA | 0.0 |
| MASSSFRA | 0.6267 |
| RHOMX KG/CUM | 1839.5824 |
| TEMP C | 70.0000 |
| PRES BAR | 1.0000 |

Crystallization Flowsheet



Crystallization Input Summary

```
;
;Input Summary created by Aspen Plus Rel. 36.0 at 10:33:58 Tue Apr 10,
2018
;Directory \\nestor\winterg\CBE 459- Senior Design\crystalizer final
(1)_2 Filename C:\Users\winterg\AppData\Local\Temp\~ap898c.txt
;

DYNAMICS
  DYNAMICS RESULTS=ON

IN-UNITS MET VOLUME-FLOW='cum/hr' ENTHALPY-FLO='Gcal/hr' &
  HEAT-TRANS-C='kcal/hr-sqm-K' PRESSURE=bar TEMPERATURE=C &
  VOLUME=cum DELTA-T=C HEAD=meter MASS-DENSITY='kg/cum' &
  MOLE-ENTHALP='kcal/mol' MASS-ENTHALP='kcal/kg' &
  MOLE-VOLUME='cum/kmol' HEAT=Gcal MOLE-CONC='mol/l' &
  PDROP=bar SHORT-LENGTH=mm

DEF-STREAMS MIXCISLD ALL

SIM-OPTIONS MASS-BAL-CHE=YES NPHASE=2

MODEL-OPTION

DESCRIPTION "
  Chemical Simulation with Metric Units :
  C, bar, kg/hr, kmol/hr, Gcal/hr, cum/hr.

  Property Method: NRTL

  Flow basis for input: Mole

  Stream report composition: Mole flow
  "

DATABANKS 'APV100 PURE35' / 'APV100 AQUEOUS' / 'APV100 SOLIDS' &
  / 'APV100 INORGANIC' / 'APESV100 AP-EOS' / &
  'NISTV100 NIST-TRC' / 'APV100 POLYMER' / &
  'APV100 ASPENPCD' / 'APV100 POLYPCSF'

PROP-SOURCES 'APV100 PURE35' / 'APV100 AQUEOUS' / &
  'APV100 SOLIDS' / 'APV100 INORGANIC' / 'APESV100 AP-EOS' &
  / 'NISTV100 NIST-TRC' / 'APV100 POLYMER' / &
  'APV100 ASPENPCD' / 'APV100 POLYPCSF'

COMPONENTS
  DDDA C12H22O4-N3 /
  ETHYLACE C4H8O2-3 /
  ADIPI-01 C6H10O4-D1 /
  SUBER-01 C8H14O4-D1 /
  SEBAC-01 C10H18O4 /
  N2 N2 /
  O2 O2 /
  WATER H2O

CISOLID-COMPS DDDA ADIPI-01 SUBER-01 SEBAC-01

MOIST-COMPS ETHYLACE

SOLVE
```



```

RUN-MODE MODE=SIM

FLOWSHEET
  BLOCK B2 IN=3 10 12 OUT=4
  BLOCK B5 IN=7 OUT=9 8
  BLOCK B6 IN=9 OUT=10
  BLOCK B4 IN=6 OUT=7
  BLOCK B1 IN=1 OUT=3 S2
  BLOCK B3 IN=4 S2 OUT=5 6 S5
  BLOCK B7 IN=8 OUT=13 11
  BLOCK B8 IN=11 OUT=12
  BLOCK B9 IN=5 OUT=14 15
  BLOCK B13 IN=13 20 OUT=21 27
  BLOCK B10 IN=22 15 OUT=16 S1
  BLOCK B14 IN=21 OUT=23 22
  BLOCK B12 IN=19 26 OUT=20
  BLOCK B15 IN=23 OUT=24 25
  BLOCK B18 IN=27 35 OUT=28
  BLOCK B20 IN=29 OUT=31 30
  BLOCK B23 IN=34 OUT=35 36
  BLOCK B22 IN=33 OUT=34
  BLOCK B21 IN=30 OUT=32 33
  BLOCK B24 IN=36 OUT=37
  BLOCK B19 IN=28 OUT=29
  BLOCK B16 IN=S3 OUT=PURGE RECYCLE
  BLOCK B11 IN=S1 OUT=S3
  BLOCK B27 IN=25 OUT=26

PROPERTIES NRTL

PROP-DATA NRTL-1
  IN-UNITS MET VOLUME-FLOW='cum/hr' ENTHALPY-FLO='Gcal/hr' &
    HEAT-TRANS-C='kcal/hr-sqm-K' PRESSURE=bar TEMPERATURE=C &
    VOLUME=cum DELTA-T=C HEAD=meter MASS-DENSITY='kg/cum' &
    MOLE-ENTHALP='kcal/mol' MASS-ENTHALP='kcal/kg' &
    MOLE-VOLUME='cum/kmol' HEAT=Gcal MOLE-CONC='mol/l' &
    PDROP=bar SHORT-LENGTH=mm
  PROP-LIST NRTL
  BPVAL N2 O2 -.1967330000 2.275480000 .1000000000 0.0 0.0 &
    0.0 -208.3142000 -157.1450000
  BPVAL O2 N2 .3489860000 .1299710000 .1000000000 0.0 0.0 &
    0.0 -208.3142000 -157.1450000
  BPVAL ETHYLACE WATER -3.719800000 1286.138300 .2000000000 &
    0.0 0.0 0.0 0.0 70.40000000
  BPVAL WATER ETHYLACE 9.463200000 -1705.683000 .2000000000 &
    0.0 0.0 0.0 0.0 70.40000000
  BPVAL ADIPI-01 WATER -5.751810000 2005.930000 .3829340000 &
    0.0 0.0 0.0 4.999000000 143.1500000
  BPVAL WATER ADIPI-01 1.031130000 -32.23590000 .3829340000 &
    0.0 0.0 0.0 4.999000000 143.1500000

DEF-SUBS-ATTR PSD PSD
  IN-UNITS ENG SHORT-LENGTH=in
  INTERVALS 10
  SIZE-LIMITS 0 <mu> / 50 <mu> / 100 <mu> / 150 <mu> / &
    200 <mu> / 250 <mu> / 300 <mu> / 350 <mu> / 400 <mu> / &
    450 <mu> / 500 <mu>

STREAM 1
  SUBSTREAM MIXED TEMP=70. PRES=3.

```

```

MASS-FLOW DDDA 2131.84 / ETHYLACE 16624.5 / ADIPI-01  &
79.069 / SUBER-01 79.069 / SEBAC-01 79.069

STREAM 6
SUBSTREAM MIXED TEMP=86 PRES=1.34301335 MASS-FLOW=70775.9704
MASS-FRAC ETHYLACE 1
SUBSTREAM CISOLID TEMP=86 PRES=1.34301335  &
MASS-FLOW=23591.9901
MASS-FRAC DDDA 0.500250125 / ADIPI-01 0.166583292 /  &
SUBER-01 0.166583292 / SEBAC-01 0.166583292

STREAM 10
SUBSTREAM MIXED TEMP=106.933031 PRES=3.75617845  &
MASS-FLOW=60159.0274
MASS-FRAC ETHYLACE 1
SUBSTREAM CISOLID TEMP=106.933031 PRES=3.75617845  &
MASS-FLOW=20053.0091
MASS-FRAC DDDA 0.500250125 / ADIPI-01 0.166583292 /  &
SUBER-01 0.166583292 / SEBAC-01 0.166583292

STREAM 12
SUBSTREAM MIXED TEMP=86.1380435 PRES=3.42641505  &
MASS-FLOW=8257.12141
MASS-FRAC ETHYLACE 1

STREAM 19
SUBSTREAM MIXED TEMP=20. PRES=10. <psig>  &
VOLUME-FLOW=1. <cuft/min>
MASS-FRAC N2 1.

STREAM 20
SUBSTREAM MIXED TEMP=38.4196536 PRES=1.06227223  &
MASS-FLOW=47.5279059
MASS-FRAC ETHYLACE 0.407211118 / N2 0.592788882

STREAM 35
SUBSTREAM MIXED TEMP=135.22685 PRES=3.42641505  &
MASS-FLOW=758.596515
MASS-FRAC DDDA 1

DEF-STREAMS HEAT S2

DEF-STREAMS HEAT S5

BLOCK B2 MIXER
PARAM

BLOCK B12 MIXER
PARAM

BLOCK B5 FSPLIT
FRAC 8 0.05

BLOCK B15 FSPLIT
FRAC 24 0.1

BLOCK B16 FSPLIT
FRAC RECYCLE 0.99

BLOCK B23 FSPLIT

```

```

FRAC 35 0.5

BLOCK B6 HEATER
  PARAM PRES=0. <psia> DUTY=3586. <MBtu/hr> DPPARMOPT=NO

BLOCK B3 FLASH2
  PARAM TEMP=86. VFRAC=0.22

BLOCK B9 FLASH2
  PARAM PRES=0. <psi> VFRAC=0.0001

BLOCK B10 FLASH2
  PARAM PRES=0. <psi> DUTY=0. <MBtu/hr>

BLOCK B13 FLASH2
  PARAM TEMP=115. PRES=1.

BLOCK B14 FLASH2
  PARAM TEMP=35. PRES=0. <psi>

BLOCK B21 FLASH2
  PARAM PRES=0. <psi> DUTY=0. <Btu/hr>

BLOCK B1 RSTOIC
  PARAM TEMP=70. PRES=0. <psia> HEAT-OF-REAC=YES
  STOIC 1 MIXED DDDA -1. / CISOLID DDDA 1.
  STOIC 2 MIXED SUBER-01 -1. / CISOLID SUBER-01 1.
  STOIC 3 MIXED SEBAC-01 -1. / CISOLID SEBAC-01 1.
  STOIC 4 MIXED ADIPI-01 -1. / CISOLID ADIPI-01 1.
  CONV 1 MIXED DDDA 1.
  CONV 2 MIXED SUBER-01 1.
  CONV 3 MIXED SEBAC-01 1.
  CONV 4 MIXED ADIPI-01 1.
  HEAT-RXN REACNO=1 CID=DDDA H-REAC=-21755.7 <Btu/lbmol> / &
    REACNO=2 CID=SUBER-01 H-REAC=-13198. <Btu/lbmol> / &
    REACNO=3 CID=SEBAC-01 H-REAC=-17540.7 <Btu/lbmol> / &
    REACNO=4 CID=ADIPI-01 H-REAC=-14951. <Btu/lbmol>

BLOCK B18 RSTOIC
  PARAM TEMP=135. PRES=0. <psig> HEAT-OF-REAC=YES
  STOIC 1 CISOLID DDDA -1. / MIXED DDDA 1.
  CONV 1 CISOLID DDDA 1.
  HEAT-RXN REACNO=1 CID=DDDA H-REAC=21755.7

BLOCK B24 RSTOIC
  PARAM TEMP=60. PRES=0. <psig> HEAT-OF-REAC=YES
  STOIC 1 MIXED DDDA -1. / CISOLID DDDA 1.
  CONV 1 MIXED DDDA 1.
  HEAT-RXN REACNO=1 CID=DDDA H-REAC=-21755.7

BLOCK B4 PUMP
  PARAM DELP=35. <psi>

BLOCK B8 PUMP
  PARAM PRES=35. <psig>

BLOCK B11 PUMP
  PARAM PRES=3.

BLOCK B19 PUMP

```

```

PARAM PRES=25. <psig>

BLOCK B22 PUMP
PARAM PRES=35. <psig>

BLOCK B27 COMPR
PARAM TYPE=ISENTROPIC DELP=25. <in-water> SB-MAXIT=30 &
SB-TOL=0.0001

BLOCK B7 SSPLIT
FRAC MIXED 13 0.12
FRAC CISOLID 13 1.

BLOCK B20 SSPLIT
FRAC MIXED 31 0.4
FRAC CISOLID 31 1.

DESIGN-SPEC PRODREC
DEFINE DDDA MASS-FLOW STREAM=28 SUBSTREAM=MIXED &
COMPONENT=DDDA UOM="kg/hr"
DEFINE AA MASS-FLOW STREAM=28 SUBSTREAM=CISOLID &
COMPONENT=ADIPI-01 UOM="kg/hr"
DEFINE SUBRA MASS-FLOW STREAM=28 SUBSTREAM=CISOLID &
COMPONENT=SUBER-01 UOM="kg/hr"
DEFINE SEBCA MASS-FLOW STREAM=28 SUBSTREAM=CISOLID &
COMPONENT=SEBAC-01 UOM="kg/hr"
SPEC "(AA+SUBRA+SEBCA)/(DDDA+AA+SUBRA+SEBCA)" TO "0.25"
TOL-SPEC "0.001"
VARY BLOCK-VAR BLOCK=B23 SENTENCE=FRAC VARIABLE=FRAC ID1=35
LIMITS "0.5" "0.95"

EO-CONV-OPTI

CALCULATOR CFUGE1
DEFINE SOLIDSIN STREAM-VAR STREAM=8 SUBSTREAM=CISOLID &
VARIABLE=MASS-FLOW UOM="kg/hr"
DEFINE MOISTURE LOCAL-PARAM
DEFINE LIQUIDIN STREAM-VAR STREAM=8 SUBSTREAM=MIXED &
VARIABLE=MASS-FLOW UOM="kg/hr"
DEFINE FRAC BLOCK-VAR BLOCK=B7 SENTENCE=FRAC VARIABLE=FRAC &
ID1=MIXED ID2=13
DEFINE CAKELIQ LOCAL-PARAM

C
F MOISTURE = 0.4
F CAKELIQ = SOLIDSIN/(1-MOISTURE)*MOISTURE
F FRAC = CAKELIQ/LIQUIDIN
READ-VARS SOLIDSIN LIQUIDIN
WRITE-VARS MOISTURE FRAC CAKELIQ
EXECUTE BEFORE BLOCK B7

CALCULATOR CRYSTVAP
DEFINE DDDALIQ MASS-FLOW STREAM=4 SUBSTREAM=MIXED &
COMPONENT=DDDA UOM="kg/hr"
DEFINE DDDASLD MASS-FLOW STREAM=4 SUBSTREAM=CISOLID &
COMPONENT=DDDA UOM="kg/hr"
DEFINE ETACIN MASS-FLOW STREAM=4 SUBSTREAM=MIXED &
COMPONENT=ETHYLACE UOM="kg/hr"
DEFINE SLURRY LOCAL-PARAM
DEFINE TOTLIQ LOCAL-PARAM
DEFINE TEMP BLOCK-VAR BLOCK=B3 VARIABLE=TEMP SENTENCE=PARAM &

```

```

      UOM="C"
      DEFINE SOLETAC LOCAL-PARAM
      DEFINE SOLVVAP LOCAL-PARAM
      DEFINE ETACOUT LOCAL-PARAM
      DEFINE VFRAC BLOCK-VAR BLOCK=B3 VARIABLE=VFRAC &
        SENTENCE=PARAM
      DEFINE MWDDDA LOCAL-PARAM
      DEFINE MWETAC LOCAL-PARAM
      DEFINE AASLD MASS-FLOW STREAM=4 SUBSTREAM=CISOLID &
        COMPONENT=ADIPI-01 UOM="kg/hr"
      DEFINE SUBRASLD MASS-FLOW STREAM=4 SUBSTREAM=CISOLID &
        COMPONENT=SUBER-01 UOM="kg/hr"
      DEFINE SEBCASLD MASS-FLOW STREAM=4 SUBSTREAM=CISOLID &
        COMPONENT=SEBAC-01 UOM="kg/hr"
C      DDDALIQ = DDDA mass flow in Liquid phase, kg/hr
C      DDDASLD = DDDA mass flow in Solid phase, kg/hr
C      ETACIN = Ethyl Acetate mass flow in Liquid phase, kg/hr
C      ETACOUT = Ethyl Acetate mass flow in crystallizer Liquid phase,
kg/hr
C      SLURRY = Mass fraction of Solids in crystallizer liquid out, frac
C      TOTLIQ = Mass flow of liquid phase in crystallizer liquid out, frac
C      TEMP = Crystallization/Flash temperature, °C
C      SOLETAC = DDDA solubility in Ethyl Acetate, mass frac
C      SOLVVAP = required solvent flow to vaporize, kg/hr
C      TLIQIN = Total liquid feed to flash, kg/hr
c      VFRAC = Flash Vapor fraction, mole frac
C
F      MWDDDA = 203.304
F      MWETAC = 88.1063
F      MWAA = 146.143
F      MWSUBRA = 174.197
F      MWSEBCA = 202.251
F      SOLETAC = 0.0011*EXP(0.0653*TEMP)*0
F      SLURRY = 0.25
F      TOTLIQ = (DDASLD+SUBRASLD+SEBCASLD+AASLD)/SLURRY*(1-SLURRY)
F      ETACOUT = TOTLIQ*(1 - SOLETAC)
F      SOLVVAP = ETACIN - ETACOUT
F      VFRAC = (SOLVVAP/MWETAC)/(DDDALIQ/MWDDDA+ETACIN/MWETAC)
      READ-VARS DDDASLD ETACIN DDDALIQ AASLD SUBRASLD SEBCASLD
      WRITE-VARS TOTLIQ SLURRY SOLETAC SOLVVAP ETACOUT VFRAC &
        MWDDDA MWETAC TEMP
      EXECUTE BEFORE BLOCK B3

CALCULATOR ROTYFLTR
      DEFINE SOLIDSIN STREAM-VAR STREAM=29 SUBSTREAM=CISOLID &
        VARIABLE=MASS-FLOW UOM="kg/hr"
      DEFINE LIQUIDIN LOCAL-PARAM
      DEFINE LIQUIDIN STREAM-VAR STREAM=29 SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW UOM="kg/hr"
      DEFINE FRAC BLOCK-VAR BLOCK=B20 SENTENCE=FRAC VARIABLE=FRAC &
        ID1=MIXED ID2=31
      DEFINE CAKELIQ LOCAL-PARAM
C
F      MOISTURE = 0.4
F      CAKELIQ = SOLIDSIN/(1-MOISTURE)*MOISTURE
F      FRAC = CAKELIQ/LIQUIDIN
      READ-VARS SOLIDSIN LIQUIDIN
      WRITE-VARS MOISTURE FRAC CAKELIQ

```

```

CONVERGENCE CPRDREC SECANT
    SPEC PRODREC

CONVERGENCE C-MLREC BROYDEN
    TEAR 12

CONVERGENCE C-S5 BROYDEN
    TEAR 6 1E-005

CONVERGENCE CDDDAREC BROYDEN
    TEAR 35

CONVERGENCE CS23 BROYDEN
    TEAR 20

CONV-ORDER C-S5 C-MLREC

STREAM-REPOR MOLEFLOW MASSFLOW

PROPERTY-REP NOPARAM-PLUS

PROP-TABLE PURE-1 PROPS
    IN-UNITS MET VOLUME-FLOW='cum/hr' ENTHALPY-FLO='Gcal/hr' &
        HEAT-TRANS-C='kcal/hr-sqm-K' PRESSURE=bar TEMPERATURE=C &
        VOLUME=cum DELTA-T=C HEAD=meter MASS-DENSITY='kg/cum' &
        MOLE-ENTHALP='kcal/mol' MASS-ENTHALP='kcal/kg' &
        MOLE-VOLUME='cum/kmol' HEAT=Gcal MOLE-CONC='mol/l' &
        PDROP=bar SHORT-LENGTH=mm
    ANALYSIS ANAL-TYPE=PURE PURE-PROP='PL' UNITS='psia' &
        PURE-PHASES= L
    MOLE-FLOW DDDA 1 / ETHYLACE 1
    PROPERTIES NRTL FREE-WATER=STEAM-TA SOLU-WATER=3 &
        TRUE-COMPS=YES
    VARY TEMP
    RANGE VARVALUE=RANGE LOWER=0 UPPER=150. INCR=5.
    VARY PRES
    RANGE LIST=1.013250000
    PARAM
;
;
;
;
;

```

Crystallization Block Report

BLOCK: B1 MODEL: RSTOIC

```

-----
INLET STREAM:      1
OUTLET STREAM:     3
OUTLET HEAT STREAM: S2
PROPERTY OPTION SET: NRTL        RENON (NRTL) / IDEAL GAS
  
```

```

***  MASS AND ENERGY BALANCE  ***
              IN              OUT              GENERATION  RELATIVE
DIFF.
TOTAL BALANCE
MOLE (KMOL/HR )      199.329      199.329      -0.112215E-14  -
0.142587E-15
MASS (KG/HR )        18993.5      18993.5              -
0.191538E-15
ENTHALPY (GCAL/HR )  -24.0580     -23.9345              -
0.513393E-02
  
```

```

***  CO2 EQUIVALENT SUMMARY  ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION   0.00000      KG/HR
  
```

*** INPUT DATA ***

STOICHIOMETRY MATRIX:

```

REACTION #  1:
SUBSTREAM MIXED  :
DDDA      -1.00
SUBSTREAM CISOLID :
DDDA      1.00
  
```

```

REACTION #  2:
SUBSTREAM MIXED  :
SUBER-01  -1.00
SUBSTREAM CISOLID :
SUBER-01   1.00
  
```

```

REACTION #  3:
SUBSTREAM MIXED  :
SEBAC-01  -1.00
SUBSTREAM CISOLID :
SEBAC-01   1.00
  
```

```

REACTION #  4:
SUBSTREAM MIXED  :
ADIPI-01  -1.00
SUBSTREAM CISOLID :
ADIPI-01   1.00
  
```

```

REACTION CONVERSION SPECS: NUMBER= 4
REACTION #  1:
SUBSTREAM:MIXED    KEY COMP:DDDA        CONV FRAC: 1.000
REACTION #  2:
SUBSTREAM:MIXED    KEY COMP:SUBER-01    CONV FRAC: 1.000
REACTION #  3:
  
```

SUBSTREAM:MIXED KEY COMP:SEBAC-01 CONV FRAC: 1.000
 REACTION # 4:
 SUBSTREAM:MIXED KEY COMP:ADIPI-01 CONV FRAC: 1.000

HEAT OF REACTION SPECIFICATIONS:

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION KCAL/MOL |
|--------------------|------------------------|---------------------------------|
| 1 | DDDA | -12.087 |
| 2 | SUBER-01 | -7.3322 |
| 3 | SEBAC-01 | -9.7448 |
| 4 | ADIPI-01 | -8.3061 |

TWO PHASE TP FLASH
 SPECIFIED TEMPERATURE C 70.0000
 PRESSURE DROP BAR 0.0
 MAXIMUM NO. ITERATIONS 30
 CONVERGENCE TOLERANCE 0.000100000
 SIMULTANEOUS REACTIONS
 GENERATE COMBUSTION REACTIONS FOR FEED SPECIES NO

*** RESULTS ***
 OUTLET TEMPERATURE C 70.000
 OUTLET PRESSURE BAR 3.0000
 HEAT DUTY GCAL/HR -0.12351
 VAPOR FRACTION 0.0000

HEAT OF REACTIONS:

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION KCAL/MOL |
|--------------------|------------------------|---------------------------------|
| 1 | DDDA | -12.087 |
| 2 | SUBER-01 | -7.3322 |
| 3 | SEBAC-01 | -9.7448 |
| 4 | ADIPI-01 | -8.3061 |

REACTION EXTENTS:

| REACTION NUMBER | REACTION EXTENT KMOL/HR |
|--------------------|-------------------------------|
| 1 | 9.2566 |
| 2 | 0.45391 |
| 3 | 0.39095 |
| 4 | 0.54104 |

V-L PHASE EQUILIBRIUM :

| COMP | F(I) | X(I) | Y(I) | K(I) |
|----------|--------|--------|--------|------|
| ETHYLACE | 1.0000 | 1.0000 | 1.0000 | |
| 0.26467 | | | | |

BLOCK: B2 MODEL: MIXER

```

INLET STREAMS:      3          10          12
OUTLET STREAM:      4
PROPERTY OPTION SET: NRTL      RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
                        IN          OUT          RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )      1996.92      1996.92
0.227724E-15
  MASS (KG/HR )        204569.      204569.      0.00000
  ENTHALPY (GCAL/HR )  -254.467     -254.467
0.327769E-07

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E   0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION   0.00000      KG/HR

*** INPUT DATA ***
TWO PHASE FLASH
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000
OUTLET PRESSURE: MINIMUM OF INLET STREAM PRESSURES

BLOCK: B3      MODEL: FLASH2
-----
INLET STREAM:      4
INLET HEAT STREAM: S2
OUTLET VAPOR STREAM: 5
OUTLET LIQUID STREAM: 6
OUTLET HEAT STREAM: S5
PROPERTY OPTION SET: NRTL      RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
                        IN          OUT          RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )      1996.92      1996.92      -
0.545473E-08
  MASS (KG/HR )        204569.      204569.      -
0.306442E-08
  ENTHALPY (GCAL/HR )  -254.344     -254.344
0.619220E-08

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E   0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION   0.00000      KG/HR

*** INPUT DATA ***
TWO PHASE TV FLASH
SPECIFIED TEMPERATURE C 86.0000
VAPOR FRACTION          0.095714
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

```

```

*** RESULTS ***
OUTLET TEMPERATURE      C      86.000
OUTLET PRESSURE          BAR    1.3430
HEAT DUTY                GCAL/HR 0.52872
NET DUTY                 GCAL/HR 0.40521
VAPOR FRACTION           0.95714E-01

V-L PHASE EQUILIBRIUM :

      COMP      F(I)      X(I)      Y(I)      K(I)
      ETHYLACE   1.0000    1.0000    1.0000
1.0000

BLOCK:  B4      MODEL: PUMP
-----
INLET STREAM:      6
OUTLET STREAM:     7
PROPERTY OPTION SET:  NRTL      RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
                        IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )      1826.16    1826.16    0.00000
  MASS (KG/HR )        189524.    189524.    0.00000
  ENTHALPY (GCAL/HR )  -236.108   -236.095    -
0.566014E-04

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000    KG/HR
PRODUCT STREAMS CO2E    0.00000    KG/HR
NET STREAMS CO2E PRODUCTION 0.00000    KG/HR
UTILITIES CO2E PRODUCTION 0.00000    KG/HR
TOTAL CO2E PRODUCTION   0.00000    KG/HR

*** INPUT DATA ***
PRESSURE CHANGE BAR      2.41317
DRIVER EFFICIENCY        1.00000

FLASH SPECIFICATIONS:
2 PHASE FLASH
MAXIMUM NUMBER OF ITERATIONS 30
TOLERANCE                  0.000100000

*** RESULTS ***
VOLUMETRIC FLOW RATE CUM/HR 173.846
PRESSURE CHANGE BAR    2.41317
NPSH AVAILABLE METER    0.0
FLUID POWER KW         11.6533
BRAKE POWER KW         15.5424
ELECTRICITY KW         15.5424
PUMP EFFICIENCY USED    0.74977
NET WORK REQUIRED KW     15.5424
HEAD DEVELOPED METER    30.0957

BLOCK:  B5      MODEL: FSPLIT
-----

```

```

INLET STREAM:      7
OUTLET STREAMS:   9      8
PROPERTY OPTION SET:  NRTL      RENON (NRTL) / IDEAL GAS

***  MASS AND ENERGY BALANCE  ***
                        IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )      1826.16      1826.16      0.00000
  MASS (KG/HR )        189524.      189524.      0.00000
  ENTHALPY (GCAL/HR )  -236.095     -236.095     -
0.240765E-15

***  CO2 EQUIVALENT SUMMARY  ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION    0.00000      KG/HR

***  INPUT DATA  ***

FRACTION OF FLOW      STRM=8      FRAC=      0.050000

***  RESULTS  ***

STREAM= 9      SPLIT=      0.95000      KEY= 0      STREAM-
ORDER= 2
      8      0.050000      0
1

BLOCK:  B6      MODEL:  HEATER
-----
INLET STREAM:      9
OUTLET STREAM:     10
PROPERTY OPTION SET:  NRTL      RENON (NRTL) / IDEAL GAS

***  MASS AND ENERGY BALANCE  ***
                        IN      OUT      RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )      1734.85      1734.85      0.00000
  MASS (KG/HR )        180048.      180048.
0.161645E-15
  ENTHALPY (GCAL/HR )  -224.290     -223.387     -
0.402896E-02

***  CO2 EQUIVALENT SUMMARY  ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION    0.00000      KG/HR

***  INPUT DATA  ***

TWO PHASE PQ FLASH
PRESSURE DROP      BAR      0.0
SPECIFIED HEAT DUTY      GCAL/HR      0.90366
MAXIMUM NO. ITERATIONS      30

```

CONVERGENCE TOLERANCE
0.000100000

*** RESULTS ***
OUTLET TEMPERATURE C 95.473
OUTLET PRESSURE BAR 3.7562
OUTLET VAPOR FRACTION 0.0000

V-L PHASE EQUILIBRIUM :

| COMP | F(I) | X(I) | Y(I) | K(I) |
|----------|--------|--------|--------|------|
| ETHYLACE | 1.0000 | 1.0000 | 1.0000 | |

0.47556

BLOCK: B7 MODEL: SSPLIT

INLET STREAM: 8
OUTLET STREAMS: 13 11
PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
IN OUT RELATIVE
DIFF.
TOTAL BALANCE
MOLE (KMOL/HR) 91.3080 91.3080 0.00000
MASS (KG/HR) 9476.19 9476.19 0.00000
ENTHALPY (GCAL/HR) -11.8047 -11.8047
0.150478E-15

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E 0.00000 KG/HR
PRODUCT STREAMS CO2E 0.00000 KG/HR
NET STREAMS CO2E PRODUCTION 0.00000 KG/HR
UTILITIES CO2E PRODUCTION 0.00000 KG/HR
TOTAL CO2E PRODUCTION 0.00000 KG/HR

*** INPUT DATA ***

FRACTION OF FLOW
SUBSTRM= STRM= FRAC=
MIXED 13 0.22222
CISOLID 13 1.00000

*** RESULTS ***
STRM= 13 SUBSTRM= MIXED SPLIT FRACT= 0.22222
CISOLID 1.00000
STRM= 11 SUBSTRM= MIXED SPLIT FRACT= 0.77778
CISOLID 0.0

BLOCK: B8 MODEL: PUMP

INLET STREAM: 11
OUTLET STREAM: 12
PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | *** MASS AND ENERGY BALANCE *** | | |
|---------------------|---------------------------------|----------|----------|
| | IN | OUT | RELATIVE |
| DIFF. | | | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 62.7398 | 62.7398 | 0.00000 |
| MASS (KG/HR) | 5527.78 | 5527.78 | 0.00000 |
| ENTHALPY (GCAL/HR) | -7.02260 | -7.02262 | |
| 0.275341E-05 | | | |

| *** CO2 EQUIVALENT SUMMARY *** | | |
|--------------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

| *** INPUT DATA *** | | |
|------------------------------|--|-------------|
| OUTLET PRESSURE BAR | | 3.42642 |
| DRIVER EFFICIENCY | | 1.00000 |
| FLASH SPECIFICATIONS: | | |
| 2 PHASE FLASH | | |
| MAXIMUM NUMBER OF ITERATIONS | | 30 |
| TOLERANCE | | 0.000100000 |

| *** RESULTS *** | | |
|-----------------------------|--|-----------|
| VOLUMETRIC FLOW RATE CUM/HR | | 6.76219 |
| PRESSURE CHANGE BAR | | -0.32976 |
| NPSH AVAILABLE METER | | 30.0333 |
| FLUID POWER KW | | -0.061942 |
| BRAKE POWER KW | | -0.022344 |
| ELECTRICITY KW | | -0.022344 |
| PUMP EFFICIENCY USED | | 0.36072 |
| NET WORK REQUIRED KW | | -0.022344 |
| HEAD DEVELOPED METER | | -4.11357 |

BLOCK: B9 MODEL: FLASH2

INLET STREAM: 5

OUTLET VAPOR STREAM: 14

OUTLET LIQUID STREAM: 15

PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | *** MASS AND ENERGY BALANCE *** | | |
|---------------------|---------------------------------|----------|----------|
| | IN | OUT | RELATIVE |
| DIFF. | | | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 170.761 | 170.761 | 0.00000 |
| MASS (KG/HR) | 15045.1 | 15045.1 | |
| 0.241804E-15 | | | |
| ENTHALPY (GCAL/HR) | -17.8301 | -19.1146 | |
| 0.671984E-01 | | | |

| *** CO2 EQUIVALENT SUMMARY *** | | |
|--------------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

```

*** INPUT DATA ***
TWO PHASE PV FLASH
PRESSURE DROP BAR 0.0
VAPOR FRACTION 0.000100000
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

*** RESULTS ***
OUTLET TEMPERATURE C 86.000
OUTLET PRESSURE BAR 1.3430
HEAT DUTY GCAL/HR -1.2845
VAPOR FRACTION 0.10000E-03

V-L PHASE EQUILIBRIUM :
COMP F(I) X(I) Y(I) K(I)
ETHYLACE 1.0000 1.0000 1.0000
1.0000

BLOCK: B10 MODEL: FLASH2
-----
INLET STREAMS: 22 15
OUTLET VAPOR STREAM: 16
OUTLET LIQUID STREAM: S1
PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
DIFF. IN OUT RELATIVE
TOTAL BALANCE
MOLE (KMOL/HR ) 188.657 188.657 0.00000
MASS (KG/HR ) 16621.1 16621.1 0.00000
ENTHALPY (GCAL/HR ) -21.1580 -21.1580
0.455045E-13

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E 0.00000 KG/HR
PRODUCT STREAMS CO2E 0.00000 KG/HR
NET STREAMS CO2E PRODUCTION 0.00000 KG/HR
UTILITIES CO2E PRODUCTION 0.00000 KG/HR
TOTAL CO2E PRODUCTION 0.00000 KG/HR

*** INPUT DATA ***
TWO PHASE PQ FLASH
PRESSURE DROP BAR 0.0
SPECIFIED HEAT DUTY GCAL/HR 0.0
MAXIMUM NO. ITERATIONS 30
CONVERGENCE TOLERANCE 0.000100000

*** RESULTS ***
OUTLET TEMPERATURE C 76.732
OUTLET PRESSURE BAR 1.0000
VAPOR FRACTION 0.28938E-01

V-L PHASE EQUILIBRIUM :

```

| | | | | |
|----------|-------------|-------------|-------------|------|
| COMP | F(I) | X(I) | Y(I) | K(I) |
| ETHYLACE | 0.99993 | 1.0000 | 0.99760 | |
| 0.99760 | | | | |
| N2 | 0.71176E-04 | 0.16892E-05 | 0.24029E-02 | |
| 1422.5 | | | | |

BLOCK: B11 MODEL: PUMP

 INLET STREAM: S1
 OUTLET STREAM: S3
 PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | | | | |
|---------------------|-----|-------------------------|----------|----------|
| | *** | MASS AND ENERGY BALANCE | *** | |
| | | IN | OUT | RELATIVE |
| DIFF. | | | | |
| TOTAL BALANCE | | | | |
| MOLE (KMOL/HR) | | 183.198 | 183.198 | 0.00000 |
| MASS (KG/HR) | | 16140.9 | 16140.9 | 0.00000 |
| ENTHALPY (GCAL/HR) | | -20.5878 | -20.5860 | - |
| 0.875778E-04 | | | | |

| | | | |
|-----------------------------|---------|------------------------|-----|
| | *** | CO2 EQUIVALENT SUMMARY | *** |
| FEED STREAMS CO2E | 0.00000 | KG/HR | |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR | |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR | |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR | |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR | |

| | | | |
|------------------------------|-----|------------|-------------|
| | *** | INPUT DATA | *** |
| OUTLET PRESSURE BAR | | | 3.00000 |
| DRIVER EFFICIENCY | | | 1.00000 |
| FLASH SPECIFICATIONS: | | | |
| 2 PHASE FLASH | | | |
| MAXIMUM NUMBER OF ITERATIONS | | | 30 |
| TOLERANCE | | | 0.000100000 |

| | | | |
|-----------------------------|-----|---------|---------|
| | *** | RESULTS | *** |
| VOLUMETRIC FLOW RATE CUM/HR | | | 19.4375 |
| PRESSURE CHANGE BAR | | | 2.00000 |
| NPSH AVAILABLE METER | | | 0.0 |
| FLUID POWER KW | | | 1.07986 |
| BRAKE POWER KW | | | 2.09693 |
| ELECTRICITY KW | | | 2.09693 |
| PUMP EFFICIENCY USED | | | 0.51497 |
| NET WORK REQUIRED KW | | | 2.09693 |
| HEAD DEVELOPED METER | | | 24.5597 |

BLOCK: B12 MODEL: MIXER

 INLET STREAMS: 19 26
 OUTLET STREAM: 20
 PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | | | | |
|---------------|-----|-------------------------|-----|----------|
| | *** | MASS AND ENERGY BALANCE | *** | |
| | | IN | OUT | RELATIVE |
| DIFF. | | | | |
| TOTAL BALANCE | | | | |

| | | | |
|---------------------|---------------|---------------|---|
| MOLE (KMOL/HR) | 1.30050 | 1.30048 | |
| 0.158544E-04 | | | |
| MASS (KG/HR) | 50.5276 | 50.5267 | |
| 0.162986E-04 | | | |
| ENTHALPY (GCAL/HR) | -0.247168E-01 | -0.247164E-01 | - |
| 0.171420E-04 | | | |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| | |
|--|-------------|
| TWO PHASE FLASH | |
| MAXIMUM NO. ITERATIONS | 30 |
| CONVERGENCE TOLERANCE | 0.000100000 |
| OUTLET PRESSURE: MINIMUM OF INLET STREAM PRESSURES | |

BLOCK: B13 MODEL: FLASH2

| | | |
|-----------------------|------|--------------------------|
| INLET STREAMS: | 13 | 20 |
| OUTLET VAPOR STREAM: | 21 | |
| OUTLET LIQUID STREAM: | 27 | |
| PROPERTY OPTION SET: | NRTL | RENON (NRTL) / IDEAL GAS |

*** MASS AND ENERGY BALANCE ***

| | IN | OUT | RELATIVE |
|---------------------|----------|----------|----------|
| DIFF. | | | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 29.8687 | 29.8687 | |
| 0.118945E-15 | | | |
| MASS (KG/HR) | 3998.94 | 3998.94 | |
| 0.227434E-15 | | | |
| ENTHALPY (GCAL/HR) | -4.80687 | -4.62073 | - |
| 0.387242E-01 | | | |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| | |
|-------------------------|-------------|
| TWO PHASE TP FLASH | |
| SPECIFIED TEMPERATURE C | 115.000 |
| SPECIFIED PRESSURE BAR | 1.00000 |
| MAXIMUM NO. ITERATIONS | 30 |
| CONVERGENCE TOLERANCE | 0.000100000 |

*** RESULTS ***

| | | |
|--------------------|---------|---------|
| OUTLET TEMPERATURE | C | 115.00 |
| OUTLET PRESSURE | BAR | 1.0000 |
| HEAT DUTY | GCAL/HR | 0.18614 |
| VAPOR FRACTION | | 1.0000 |


```

V-L PHASE EQUILIBRIUM :

      COMP      F(I)      X(I)      Y(I)      K(I)
      ETHYLACE   0.94456   0.99990   0.94456
3.0511
      N2          0.55441E-01  0.10225E-03  0.55441E-01
1751.2

BLOCK:  B14      MODEL: FLASH2
-----
      INLET STREAM:      21
      OUTLET VAPOR STREAM: 23
      OUTLET LIQUID STREAM: 22
      PROPERTY OPTION SET:  NRTL      RENON (NRTL) / IDEAL GAS

***  MASS AND ENERGY BALANCE  ***
      IN      OUT      RELATIVE
DIFF.
      TOTAL BALANCE
      MOLE (KMOL/HR )      19.2261      19.2261      0.00000
      MASS (KG/HR )      1629.89      1629.89      -
0.558009E-15
      ENTHALPY (GCAL/HR )      -1.87909      -2.07273
0.934230E-01

***  CO2 EQUIVALENT SUMMARY  ***
      FEED STREAMS CO2E      0.00000      KG/HR
      PRODUCT STREAMS CO2E      0.00000      KG/HR
      NET STREAMS CO2E PRODUCTION      0.00000      KG/HR
      UTILITIES CO2E PRODUCTION      0.00000      KG/HR
      TOTAL CO2E PRODUCTION      0.00000      KG/HR

***  INPUT DATA  ***
TWO PHASE TP FLASH
SPECIFIED TEMPERATURE C      35.0000
PRESSURE DROP BAR      0.0
MAXIMUM NO. ITERATIONS      30
CONVERGENCE TOLERANCE      0.000100000

***  RESULTS  ***
      OUTLET TEMPERATURE C      35.000
      OUTLET PRESSURE BAR      1.0000
      HEAT DUTY GCAL/HR      -0.19364
      VAPOR FRACTION      0.68298E-01

```

```

V-L PHASE EQUILIBRIUM :

      COMP      F(I)      X(I)      Y(I)      K(I)
      ETHYLACE   0.94456   0.99925   0.19849
0.19863
      N2          0.55441E-01  0.74962E-03  0.80151
1069.2

BLOCK:  B15      MODEL: FSPLIT
-----
      INLET STREAM:      23
      OUTLET STREAMS:      24      25
      PROPERTY OPTION SET:  NRTL      RENON (NRTL) / IDEAL GAS

```

```

*** MASS AND ENERGY BALANCE ***
                                IN                OUT                RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )              1.31312          1.31312          -
0.169097E-15
  MASS (KG/HR )                52.4473          52.4473          -
0.135477E-15
  ENTHALPY (GCAL/HR )         -0.275263E-01    -0.275263E-01    0.00000

```

```

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E              0.00000          KG/HR
PRODUCT STREAMS CO2E           0.00000          KG/HR
NET STREAMS CO2E PRODUCTION    0.00000          KG/HR
UTILITIES CO2E PRODUCTION      0.00000          KG/HR
TOTAL CO2E PRODUCTION          0.00000          KG/HR

```

```

*** INPUT DATA ***
FRACTION OF FLOW                STRM=24          FRAC=          0.100000

```

```

*** RESULTS ***
STREAM= 24                      SPLIT=          0.100000    KEY= 0    STREAM-
ORDER=  1                      0.90000          0
2

```

```

BLOCK: B16      MODEL: FSPLIT
-----
INLET STREAM:    S3
OUTLET STREAMS:  PURGE      RECYCLE
PROPERTY OPTION SET: NRTL    RENON (NRTL) / IDEAL GAS

```

```

*** MASS AND ENERGY BALANCE ***
                                IN                OUT                RELATIVE
DIFF.
TOTAL BALANCE
  MOLE (KMOL/HR )              183.198          183.198          0.00000
  MASS (KG/HR )                16140.9          16140.9          0.00000
  ENTHALPY (GCAL/HR )         -20.5860          -20.5860
0.345158E-15

```

```

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E              0.00000          KG/HR
PRODUCT STREAMS CO2E           0.00000          KG/HR
NET STREAMS CO2E PRODUCTION    0.00000          KG/HR
UTILITIES CO2E PRODUCTION      0.00000          KG/HR
TOTAL CO2E PRODUCTION          0.00000          KG/HR

```

```

*** INPUT DATA ***
FRACTION OF FLOW                STRM=RECYCLE  FRAC=          0.99000

```

```

*** RESULTS ***
STREAM= PURGE                  SPLIT=          0.0100000    KEY= 0    STREAM-
ORDER=  2

```

```

1          RECYCLE          0.99000          0

BLOCK:  B18          MODEL: RSTOIC
-----
INLET STREAMS:      27          35
OUTLET STREAM:      28
PROPERTY OPTION SET:  NRTL          RENON (NRTL) / IDEAL GAS

***  MASS AND ENERGY BALANCE  ***
          IN          OUT          GENERATION  RELATIVE
DIFF.
TOTAL BALANCE
MOLE (KMOL/HR )      19.2125      19.2125      0.00000
0.00000
MASS (KG/HR )        4342.74      4342.74          -
0.209429E-15
ENTHALPY (GCAL/HR )  -4.95055      -4.92607          -
0.494491E-02

***  CO2 EQUIVALENT SUMMARY  ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION    0.00000      KG/HR

***  INPUT DATA  ***
STOICHIOMETRY MATRIX:

REACTION #    1:
SUBSTREAM MIXED :
DDDA          1.00
SUBSTREAM CISOLID :
DDDA          -1.00

REACTION CONVERSION SPECS: NUMBER=    1
REACTION #    1:
SUBSTREAM:CISOLID  KEY COMP:DDDA      CONV FRAC:  1.000

HEAT OF REACTION SPECIFICATIONS:

REACTION      REFERENCE      HEAT OF
NUMBER        COMPONENT      REACTION
          1          DDDA          KCAL/MOL
          21756.

TWO  PHASE  TP  FLASH
SPECIFIED TEMPERATURE C          135.000
SPECIFIED PRESSURE  BAR          1.01325
MAXIMUM NO. ITERATIONS          30
CONVERGENCE TOLERANCE          0.000100000
SIMULTANEOUS REACTIONS
GENERATE COMBUSTION REACTIONS FOR FEED SPECIES          NO

***  RESULTS  ***
OUTLET TEMPERATURE  C          135.00

```

| | | |
|-----------------|---------|--------|
| OUTLET PRESSURE | BAR | 1.0132 |
| HEAT DUTY | GCAL/HR | 201.41 |
| VAPOR FRACTION | | 0.0000 |

HEAT OF REACTIONS:

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION KCAL/MOL |
|--------------------|------------------------|---------------------------------|
| 1 | DDDA | 21756. |

REACTION EXTENTS:

| REACTION NUMBER | REACTION EXTENT KMOL/HR |
|--------------------|-------------------------------|
| 1 | 9.2566 |

BLOCK: B19 MODEL: PUMP

INLET STREAM: 28
OUTLET STREAM: 29
PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | *** MASS AND ENERGY BALANCE *** | |
|---------------------|---------------------------------|----------------------|
| | IN | OUT |
| DIFF. | | RELATIVE |
| TOTAL BALANCE | | |
| MOLE (KMOL/HR) | 19.2125 | 19.2125 0.00000 |
| MASS (KG/HR) | 4342.74 | 4342.74 0.00000 |
| ENTHALPY (GCAL/HR) | -4.92607 | -4.92557 - |

0.101173E-03

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| | |
|---------------------|---------|
| OUTLET PRESSURE BAR | 2.73694 |
| DRIVER EFFICIENCY | 1.00000 |

FLASH SPECIFICATIONS:
2 PHASE FLASH
MAXIMUM NUMBER OF ITERATIONS 30
TOLERANCE 0.000100000

*** RESULTS ***

| | |
|-----------------------------|---------|
| VOLUMETRIC FLOW RATE CUM/HR | 3.57912 |
| PRESSURE CHANGE BAR | 1.72369 |
| NPSH AVAILABLE METER | 0.0 |
| FLUID POWER KW | 0.17137 |
| BRAKE POWER KW | 0.57962 |
| ELECTRICITY KW | 0.57962 |
| PUMP EFFICIENCY USED | 0.29566 |
| NET WORK REQUIRED KW | 0.57962 |

HEAD DEVELOPED METER

15.3231

BLOCK: B20 MODEL: SSPLIT

 INLET STREAM: 29
 OUTLET STREAMS: 31 30
 PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
 IN OUT RELATIVE
 DIFF.
 TOTAL BALANCE
 MOLE (KMOL/HR) 19.2125 19.2125
 0.184917E-15
 MASS (KG/HR) 4342.74 4342.74
 0.209429E-15
 ENTHALPY (GCAL/HR) -4.92557 -4.92557
 0.180320E-15

*** CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E 0.00000 KG/HR
 PRODUCT STREAMS CO2E 0.00000 KG/HR
 NET STREAMS CO2E PRODUCTION 0.00000 KG/HR
 UTILITIES CO2E PRODUCTION 0.00000 KG/HR
 TOTAL CO2E PRODUCTION 0.00000 KG/HR

*** INPUT DATA ***

FRACTION OF FLOW
 SUBSTRM= STRM= FRAC=
 MIXED 31 0.038519
 CISOLID 31 1.00000

*** RESULTS ***

STRM= 31 SUBSTRM= MIXED SPLIT FRACT= 0.038519
 CISOLID 1.00000
 STRM= 30 SUBSTRM= MIXED SPLIT FRACT= 0.96148
 CISOLID 0.0

BLOCK: B21 MODEL: FLASH2

 INLET STREAM: 30
 OUTLET VAPOR STREAM: 32
 OUTLET LIQUID STREAM: 33
 PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***
 IN OUT RELATIVE
 DIFF.
 TOTAL BALANCE
 MOLE (KMOL/HR) 17.1399 17.1399 0.00000
 MASS (KG/HR) 3947.39 3947.39 0.00000
 ENTHALPY (GCAL/HR) -4.41802 -4.41802
 0.438226E-08

*** CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E 0.00000 KG/HR
 PRODUCT STREAMS CO2E 0.00000 KG/HR

| | | |
|-----------------------------|---------|-------|
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| | | |
|------------------------|---------|-------------|
| TWO PHASE PQ FLASH | | |
| PRESSURE DROP | BAR | 0.0 |
| SPECIFIED HEAT DUTY | GCAL/HR | 0.0 |
| MAXIMUM NO. ITERATIONS | | 30 |
| CONVERGENCE TOLERANCE | | 0.000100000 |

*** RESULTS ***

| | | |
|--------------------|-----|--------|
| OUTLET TEMPERATURE | C | 135.21 |
| OUTLET PRESSURE | BAR | 2.7369 |
| VAPOR FRACTION | | 0.0000 |

BLOCK: B22 MODEL: PUMP

| | |
|----------------------|-------------------------------|
| INLET STREAM: | 33 |
| OUTLET STREAM: | 34 |
| PROPERTY OPTION SET: | NRTL RENON (NRTL) / IDEAL GAS |

*** MASS AND ENERGY BALANCE ***

| | IN | OUT | RELATIVE |
|---------------------|----------|----------|----------|
| DIFF. | | | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 17.1399 | 17.1399 | 0.00000 |
| MASS (KG/HR) | 3947.39 | 3947.39 | 0.00000 |
| ENTHALPY (GCAL/HR) | -4.41802 | -4.41782 | - |

0.433873E-04

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| | | |
|-------------------|-----|---------|
| OUTLET PRESSURE | BAR | 3.42642 |
| DRIVER EFFICIENCY | | 1.00000 |

FLASH SPECIFICATIONS:

| | |
|------------------------------|-------------|
| 2 PHASE FLASH | |
| MAXIMUM NUMBER OF ITERATIONS | 30 |
| TOLERANCE | 0.000100000 |

*** RESULTS ***

| | | |
|----------------------|--------|----------|
| VOLUMETRIC FLOW RATE | CUM/HR | 3.44145 |
| PRESSURE CHANGE | BAR | 0.68948 |
| NPSH AVAILABLE | METER | 0.0 |
| FLUID POWER | KW | 0.065911 |
| BRAKE POWER | KW | 0.22293 |
| ELECTRICITY | KW | 0.22293 |
| PUMP EFFICIENCY USED | | 0.29566 |
| NET WORK REQUIRED | KW | 0.22293 |
| HEAD DEVELOPED | METER | 6.12957 |

BLOCK: B23 MODEL: FSPLIT

INLET STREAM: 34
OUTLET STREAMS: 35 36
PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | *** | MASS AND ENERGY BALANCE | *** | |
|---------------------|-----|-------------------------|----------|----------|
| | | IN | OUT | RELATIVE |
| DIFF. | | | | |
| TOTAL BALANCE | | | | |
| MOLE (KMOL/HR) | | 17.1399 | 17.1399 | |
| 0.509280E-12 | | | | |
| MASS (KG/HR) | | 3947.39 | 3947.39 | |
| 0.509423E-12 | | | | |
| ENTHALPY (GCAL/HR) | | -4.41782 | -4.41782 | - |
| 0.426314E-11 | | | | |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

FRACTION OF FLOW STRM=35 FRAC= 0.50000

*** RESULTS ***

STREAM= 35 SPLIT= 0.50000 KEY= 0 STREAM-
ORDER= 1
 36 0.50000 0
2

BLOCK: B24 MODEL: RSTOIC

INLET STREAM: 36
OUTLET STREAM: 37
PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

| | *** | MASS AND ENERGY BALANCE | *** | |
|---------------------|-----|-------------------------|----------|--------------------------|
| | | IN | OUT | GENERATION RELATIVE |
| DIFF. | | | | |
| TOTAL BALANCE | | | | |
| MOLE (KMOL/HR) | | 8.56995 | 8.56995 | 0.00000 |
| 0.00000 | | | | |
| MASS (KG/HR) | | 1973.70 | 1973.70 | |
| 0.00000 | | | | |
| ENTHALPY (GCAL/HR) | | -2.20891 | -2.28286 | |
| 0.323944E-01 | | | | |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

STOICHIOMETRY MATRIX:

REACTION # 1:
 SUBSTREAM MIXED :
 DDDA -1.00
 SUBSTREAM CISOLID :
 DDDA 1.00

REACTION CONVERSION SPECS: NUMBER= 1
 REACTION # 1:
 SUBSTREAM:MIXED KEY COMP:DDDA CONV FRAC: 1.000

HEAT OF REACTION SPECIFICATIONS:

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION KCAL/MOL |
|--------------------|------------------------|---------------------------------|
| 1 | DDDA | -21756. |

TWO PHASE TP FLASH
 SPECIFIED TEMPERATURE C 60.0000
 SPECIFIED PRESSURE BAR 1.01325
 MAXIMUM NO. ITERATIONS 30
 CONVERGENCE TOLERANCE 0.000100000
 SIMULTANEOUS REACTIONS
 GENERATE COMBUSTION REACTIONS FOR FEED SPECIES NO

*** RESULTS ***
 OUTLET TEMPERATURE C 60.000
 OUTLET PRESSURE BAR 1.0132
 HEAT DUTY GCAL/HR -186.52
 VAPOR FRACTION 0.0000

HEAT OF REACTIONS:

| REACTION NUMBER | REFERENCE COMPONENT | HEAT OF REACTION KCAL/MOL |
|--------------------|------------------------|---------------------------------|
| 1 | DDDA | -21756. |

REACTION EXTENTS:

| REACTION NUMBER | REACTION EXTENT KMOL/HR |
|--------------------|-------------------------------|
| 1 | 8.5700 |

BLOCK: B27 MODEL: COMPR

 INLET STREAM: 25
 OUTLET STREAM: 26
 PROPERTY OPTION SET: NRTL RENON (NRTL) / IDEAL GAS

*** MASS AND ENERGY BALANCE ***

| DIFF. | IN | OUT | RELATIVE |
|---------------------|---------------|---------------|----------|
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 1.18181 | 1.18181 | 0.00000 |
| MASS (KG/HR) | 47.2026 | 47.2026 | 0.00000 |
| ENTHALPY (GCAL/HR) | -0.247737E-01 | -0.247127E-01 | - |
| 0.246251E-02 | | | |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|-----------------------------|---------|-------|
| FEED STREAMS CO2E | 0.00000 | KG/HR |
| PRODUCT STREAMS CO2E | 0.00000 | KG/HR |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/HR |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/HR |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/HR |

*** INPUT DATA ***

| | |
|-----------------------------------|----------|
| ISENTROPIC CENTRIFUGAL COMPRESSOR | |
| PRESSURE CHANGE BAR | 0.062272 |
| ISENTROPIC EFFICIENCY | 0.72000 |
| MECHANICAL EFFICIENCY | 1.00000 |

*** RESULTS ***

| | | |
|-------------------------------------|----|----------|
| INDICATED HORSEPOWER REQUIREMENT | KW | 0.070949 |
| BRAKE HORSEPOWER REQUIREMENT | KW | 0.070949 |
| NET WORK REQUIRED | KW | 0.070949 |
| POWER LOSSES | KW | 0.0 |
| ISENTROPIC HORSEPOWER REQUIREMENT | KW | 0.051084 |
| CALCULATED OUTLET PRES BAR | | 1.06227 |
| CALCULATED OUTLET TEMP C | | 39.6578 |
| ISENTROPIC TEMPERATURE C | | 38.3556 |
| EFFICIENCY (POLYTR/ISENTR) USED | | 0.72000 |
| OUTLET VAPOR FRACTION | | 1.00000 |
| HEAD DEVELOPED, METER | | 397.281 |
| MECHANICAL EFFICIENCY USED | | 1.00000 |
| INLET HEAT CAPACITY RATIO | | 1.21913 |
| INLET VOLUMETRIC FLOW RATE , CUM/HR | | 30.2786 |
| OUTLET VOLUMETRIC FLOW RATE, CUM/HR | | 28.9344 |
| INLET COMPRESSIBILITY FACTOR | | 1.00000 |
| OUTLET COMPRESSIBILITY FACTOR | | 1.00000 |
| AV. ISENT. VOL. EXPONENT | | 1.21845 |
| AV. ISENT. TEMP EXPONENT | | 1.21845 |
| AV. ACTUAL VOL. EXPONENT | | 1.33039 |
| AV. ACTUAL TEMP EXPONENT | | 1.33039 |

BLOCK: EARECPMP MODEL: PUMP

| | |
|----------------------|-------------------------------|
| INLET STREAM: | 17 |
| OUTLET STREAM: | 18 |
| PROPERTY OPTION SET: | NRTL RENON (NRTL) / IDEAL GAS |

| DIFF. | IN | OUT | RELATIVE |
|---------------------------------|----------|----------|----------|
| *** MASS AND ENERGY BALANCE *** | | | |
| TOTAL BALANCE | | | |
| MOLE (KMOL/HR) | 212.151 | 212.151 | 0.00000 |
| MASS (KG/HR) | 18691.8 | 18691.8 | 0.00000 |
| ENTHALPY (GCAL/HR) | -23.8416 | -23.8392 | - |
| 0.102408E-03 | | | |

```

*** CO2 EQUIVALENT SUMMARY ***
FEED STREAMS CO2E      0.00000      KG/HR
PRODUCT STREAMS CO2E    0.00000      KG/HR
NET STREAMS CO2E PRODUCTION 0.00000      KG/HR
UTILITIES CO2E PRODUCTION 0.00000      KG/HR
TOTAL CO2E PRODUCTION   0.00000      KG/HR

```

```

*** INPUT DATA ***
OUTLET PRESSURE BAR      3.42642
DRIVER EFFICIENCY        1.00000

FLASH SPECIFICATIONS:
2 PHASE FLASH
MAXIMUM NUMBER OF ITERATIONS 30
TOLERANCE                0.000100000

```

```

*** RESULTS ***
VOLUMETRIC FLOW RATE CUM/HR      22.5095
PRESSURE CHANGE BAR      2.42642
NPSH AVAILABLE METER      0.0
FLUID POWER KW      1.51715
BRAKE POWER KW      2.83954
ELECTRICITY KW      2.83954
PUMP EFFICIENCY USED      0.53429
NET WORK REQUIRED KW      2.83954
HEAD DEVELOPED METER      29.7960

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

1 10 11 12 13

| STREAM ID | 1 | 10 | 11 | 12 | 13 |
|----------------------|-----------|-----------|-----------|------------|-----|
| FROM : | ---- | B6 | B7 | B8 | B7 |
| TO : | B1 | B2 | B8 | B2 | B13 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| CONV. MAX. REL. ERR: | 0.0 | 0.0 | 0.0 | -7.7068-11 | 0.0 |
| TOTAL STREAM: | | | | | |
| KG/HR | 1.8994+04 | 1.8005+05 | 5527.7767 | 5527.7767 | |
| 3948.4119 | | | | | |
| GCAL/HR | -24.0580 | -223.3866 | -7.0226 | -7.0226 | - |
| 4.7822 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | MIXED | LIQUID | LIQUID | LIQUID | |
| LIQUID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 9.2566 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 188.6868 | 1532.6447 | 62.7398 | 62.7398 | |
| 17.9257 | | | | | |
| ADIPI-01 | 0.5410 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.4539 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.3909 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 2131.8400 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1.6625+04 | 1.3504+05 | 5527.7767 | 5527.7767 | |
| 1579.3648 | | | | | |
| ADIPI-01 | 79.0690 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 79.0690 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 79.0690 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 199.3293 | 1532.6447 | 62.7398 | 62.7398 | |
| 17.9257 | | | | | |
| KG/HR | 1.8994+04 | 1.3504+05 | 5527.7767 | 5527.7767 | |
| 1579.3648 | | | | | |

| | | | | | |
|---------------------|-------------------------|------------|------------|------------|-----|
| CUM/HR | 21.8184 | 167.8986 | 6.7622 | 6.7621 | |
| 1.9321 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 70.0000 | 95.4729 | 86.1327 | 86.1263 | |
| 86.1327 | | | | | |
| PRES BAR | 3.0000 | 3.7562 | 3.7562 | 3.4264 | |
| 3.7562 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 0.9466 | 1.0000 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| SFRAC | 5.3392-02 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -120.6947 | -111.4761 | -111.9320 | -111.9323 | - |
| 111.9320 | | | | | |
| KCAL/KG | -1266.6404 | -1265.2458 | -1270.4197 | -1270.4232 | - |
| 1270.4197 | | | | | |
| GCAL/HR | -24.0580 | -170.8533 | -7.0226 | -7.0226 | - |
| 2.0065 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -151.1162 | -108.2618 | -109.4806 | -109.4814 | - |
| 109.4806 | | | | | |
| CAL/GM-K | -1.5859 | -1.2288 | -1.2426 | -1.2426 | - |
| 1.2426 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 9.1358-03 | 9.1284-03 | 9.2780-03 | 9.2781-03 | |
| 9.2780-03 | | | | | |
| KG/CUM | 870.5280 | 804.2694 | 817.4534 | 817.4624 | |
| 817.4534 | | | | | |
| AVG MW | 95.2873 | 88.1063 | 88.1063 | 88.1063 | |
| 88.1063 | | | | | |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 175.8756 | 0.0 | 0.0 | |
| 9.2566 | | | | | |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 10.2799 | 0.0 | 0.0 | |
| 0.5410 | | | | | |
| SUBER-01 | 0.0 | 8.6243 | 0.0 | 0.0 | |
| 0.4539 | | | | | |
| SEBAC-01 | 0.0 | 7.4281 | 0.0 | 0.0 | |
| 0.3910 | | | | | |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 4.0505+04 | 0.0 | 0.0 | |
| 2131.8371 | | | | | |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 1502.3338 | 0.0 | 0.0 | |
| 79.0702 | | | | | |
| SUBER-01 | 0.0 | 1502.3288 | 0.0 | 0.0 | |
| 79.0699 | | | | | |
| SEBAC-01 | 0.0 | 1502.3288 | 0.0 | 0.0 | |
| 79.0699 | | | | | |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |

| | | | | | |
|---------------------|------------|------------|----------|-----------|------|
| KMOL/HR | 0.0 | 202.2079 | 0.0 | 0.0 | |
| 10.6425 | | | | | |
| KG/HR | 0.0 | 4.5012+04 | 0.0 | 0.0 | |
| 2369.0472 | | | | | |
| CUM/HR | 0.0 | 38.5360 | 0.0 | 0.0 | |
| 2.0234 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | MISSING | 95.4729 | MISSING | MISSING | |
| 86.1327 | | | | | |
| PRES BAR | 3.0000 | 3.7562 | MISSING | 3.4264 | |
| 3.7562 | | | | | |
| VFRAC | MISSING | 0.0 | MISSING | MISSING | 0.0 |
| LFRAC | MISSING | 0.0 | MISSING | MISSING | 0.0 |
| SFRAC | MISSING | 1.0000 | MISSING | MISSING | |
| 1.0000 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | MISSING | -259.7981 | MISSING | MISSING | - |
| 260.8119 | | | | | |
| KCAL/KG | MISSING | -1167.0964 | MISSING | MISSING | - |
| 1171.6506 | | | | | |
| GCAL/HR | MISSING | -52.5332 | MISSING | MISSING | - |
| 2.7757 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | MISSING | -843.9810 | MISSING | MISSING | - |
| 846.7665 | | | | | |
| CAL/GM-K | MISSING | -3.7914 | MISSING | MISSING | - |
| 3.8039 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | MISSING | 5.2472-03 | MISSING | MISSING | |
| 5.2597-03 | | | | | |
| KG/CUM | MISSING | 1168.0470 | MISSING | MISSING | |
| 1170.8279 | | | | | |
| AVG MW | MISSING | 222.6021 | MISSING | MISSING | |
| 222.6021 | | | | | |
| 14 15 16 17 18 | | | | | |
| ----- | | | | | |
| STREAM ID | 14 | 15 | 16 | 17 | 18 |
| FROM : | B9 | B9 | B10 | ---- | |
| EARECPMP | | | | | |
| TO : | ---- | B10 | ---- | EARECPMP | ---- |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 1.5045 | 1.5044+04 | 480.2170 | 1.8692+04 | |
| 1.8692+04 | | | | | |
| GCAL/HR | -1.7830-03 | -19.1128 | -0.5702 | -23.8416 | - |
| 23.8392 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | VAPOR | LIQUID | VAPOR | LIQUID | |
| LIQUID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1.7076-02 | 170.7441 | 5.4463 | 212.1505 | |
| 212.1505 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|-------------------|------------|------------|------------|------------|-----|
| N2 | 0.0 | 0.0 | 1.3118-02 | 3.6023-04 | |
| 3.6023-04 | | | | | |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1.5045 | 1.5044+04 | 479.8495 | 1.8692+04 | |
| 1.8692+04 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.3675 | 1.0091-02 | |
| 1.0091-02 | | | | | |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 1.7076-02 | 170.7441 | 5.4594 | 212.1509 | |
| 212.1509 | | | | | |
| KG/HR | 1.5045 | 1.5044+04 | 480.2170 | 1.8692+04 | |
| 1.8692+04 | | | | | |
| CUM/HR | 0.3797 | 18.3989 | 158.8149 | 22.5095 | |
| 22.5185 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 86.0000 | 86.0000 | 76.7317 | 76.7313 | |
| 76.9752 | | | | | |
| PRES BAR | 1.3430 | 1.3430 | 1.0000 | 1.0000 | |
| 3.4264 | | | | | |
| VFRAC | 1.0000 | 0.0 | 1.0000 | 0.0 | 0.0 |
| LFRAC | 0.0 | 1.0000 | 0.0 | 1.0000 | |
| 1.0000 | | | | | |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -104.4156 | -111.9384 | -104.4424 | -112.3804 | - |
| 112.3689 | | | | | |
| KCAL/KG | -1185.1093 | -1270.4924 | -1187.3596 | -1275.5102 | - |
| 1275.3796 | | | | | |
| GCAL/HR | -1.7830-03 | -19.1128 | -0.5702 | -23.8416 | - |
| 23.8392 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -88.5519 | -109.4980 | -88.5044 | -110.7155 | - |
| 110.6834 | | | | | |
| CAL/GM-K | -1.0051 | -1.2428 | -1.0062 | -1.2566 | - |
| 1.2562 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 4.4976-05 | 9.2801-03 | 3.4376-05 | 9.4250-03 | |
| 9.4212-03 | | | | | |
| KG/CUM | 3.9626 | 817.6384 | 3.0238 | 830.3976 | |
| 830.0657 | | | | | |
| AVG MW | 88.1063 | 88.1063 | 87.9619 | 88.1062 | |
| 88.1062 | | | | | |
| 19 20 21 22 23 | | | | | |
| ----- | | | | | |
| STREAM ID | 19 | 20 | 21 | 22 | 23 |
| FROM : | ---- | B12 | B13 | B14 | B14 |
| TO : | B12 | B13 | B14 | B10 | B15 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |

| | | | | | |
|----------------------|------------|------------|------------|------------|-----|
| CONV. MAX. REL. ERR: | 0.0 | 1.7447-05 | 0.0 | 0.0 | 0.0 |
| TOTAL STREAM: | | | | | |
| KG/HR | 3.3250 | 50.5267 | 1629.8915 | 1577.4442 | |
| 52.4473 | | | | | |
| GCAL/HR | -4.1283-06 | -2.4716-02 | -1.8791 | -2.0452 | - |
| 2.7526-02 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | VAPOR | VAPOR | VAPOR | LIQUID | |
| VAPOR | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 0.0 | 0.2346 | 18.1602 | 17.8996 | |
| 0.2606 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.1187 | 1.0659 | 1.0659 | 1.3428-02 | |
| 1.0525 | | | | | |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 0.0 | 20.6669 | 1600.0317 | 1577.0680 | |
| 22.9636 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 3.3250 | 29.8598 | 29.8598 | 0.3762 | |
| 29.4837 | | | | | |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.1187 | 1.3005 | 19.2261 | 17.9130 | |
| 1.3131 | | | | | |
| KG/HR | 3.3250 | 50.5267 | 1629.8915 | 1577.4442 | |
| 52.4473 | | | | | |
| CUM/HR | 1.6990 | 31.7214 | 620.4676 | 1.7837 | |
| 33.6428 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 20.0000 | 38.4936 | 115.0000 | 35.0000 | |
| 35.0000 | | | | | |
| PRES BAR | 1.7027 | 1.0623 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| VFRAC | 1.0000 | 1.0000 | 1.0000 | 0.0 | |
| 1.0000 | | | | | |
| LFRAC | 0.0 | 0.0 | 0.0 | 1.0000 | 0.0 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -3.4782-02 | -19.0056 | -97.7359 | -114.1738 | - |
| 20.9626 | | | | | |
| KCAL/KG | -1.2416 | -489.1741 | -1152.8897 | -1296.5269 | - |
| 524.8374 | | | | | |
| GCAL/HR | -4.1283-06 | -2.4716-02 | -1.8791 | -2.0452 | - |
| 2.7526-02 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -1.1484 | -15.5185 | -80.2691 | -116.2492 | - |
| 17.1453 | | | | | |
| CAL/GM-K | -4.0996-02 | -0.3994 | -0.9469 | -1.3201 | - |
| 0.4293 | | | | | |
| DENSITY: | | | | | |

| | | | | | |
|---------------------|------------|------------|------------|-----------|-----|
| MOL/CC | 6.9860-05 | 4.0997-05 | 3.0987-05 | 1.0042-02 | |
| 3.9031-05 | | | | | |
| KG/CUM | 1.9570 | 1.5928 | 2.6269 | 884.3424 | |
| 1.5589 | | | | | |
| AVG MW | 28.0135 | 38.8525 | 84.7747 | 88.0613 | |
| 39.9411 | | | | | |
| 24 25 26 27 28 | | | | | |
| ----- | | | | | |
| STREAM ID | 24 | 25 | 26 | 27 | 28 |
| FROM : | B15 | B15 | B27 | B13 | B18 |
| TO : | ---- | B27 | B12 | B18 | B19 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 5.2447 | 47.2026 | 47.2026 | 2369.0472 | |
| 4342.7442 | | | | | |
| GCAL/HR | -2.7526-03 | -2.4774-02 | -2.4713-02 | -2.7416 | - |
| 4.9261 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | VAPOR | VAPOR | VAPOR | MISSING | |
| SOLID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | |
| 17.8266 | | | | | |
| ETHYLACE | 2.6064-02 | 0.2346 | 0.2346 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.1052 | 0.9472 | 0.9472 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | |
| 4105.5341 | | | | | |
| ETHYLACE | 2.2964 | 20.6673 | 20.6673 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 2.9484 | 26.5353 | 26.5353 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.1313 | 1.1818 | 1.1818 | 0.0 | |
| 17.8266 | | | | | |
| KG/HR | 5.2447 | 47.2026 | 47.2026 | 0.0 | |
| 4105.5341 | | | | | |
| CUM/HR | 3.3643 | 30.2786 | 28.9344 | 0.0 | |
| 3.5791 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 35.0000 | 35.0000 | 39.6578 | MISSING | |
| 135.0000 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 1.0623 | 1.0000 | |
| 1.0133 | | | | | |
| VFRAC | 1.0000 | 1.0000 | 1.0000 | MISSING | 0.0 |
| LFRAC | 0.0 | 0.0 | 0.0 | MISSING | 0.0 |
| SFRAC | 0.0 | 0.0 | 0.0 | MISSING | |
| 1.0000 | | | | | |
| ENTHALPY: | | | | | |

| | | | | | |
|---------------------|-------------------------|------------|------------|-----------|-----|
| KCAL/MOL | -20.9626 | -20.9626 | -20.9109 | MISSING | - |
| 257.7885 | | | | | |
| KCAL/KG | -524.8374 | -524.8374 | -523.5449 | MISSING | - |
| 1119.3385 | | | | | |
| GCAL/HR | -2.7526-03 | -2.4774-02 | -2.4713-02 | MISSING | - |
| 4.5955 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -17.1453 | -17.1453 | -17.0990 | MISSING | - |
| 870.8997 | | | | | |
| CAL/GM-K | -0.4293 | -0.4293 | -0.4281 | MISSING | - |
| 3.7815 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 3.9031-05 | 3.9031-05 | 4.0844-05 | MISSING | |
| 4.9807-03 | | | | | |
| KG/CUM | 1.5589 | 1.5589 | 1.6314 | MISSING | |
| 1147.0777 | | | | | |
| AVG MW | 39.9411 | 39.9411 | 39.9411 | MISSING | |
| 230.3043 | | | | | |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 9.2566 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.5410 | |
| 0.5410 | | | | | |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.4539 | |
| 0.4539 | | | | | |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.3910 | |
| 0.3910 | | | | | |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 2131.8371 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 79.0702 | |
| 79.0702 | | | | | |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 79.0699 | |
| 79.0699 | | | | | |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 79.0699 | |
| 79.0699 | | | | | |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.0 | 0.0 | 0.0 | 10.6425 | |
| 1.3859 | | | | | |
| KG/HR | 0.0 | 0.0 | 0.0 | 2369.0472 | |
| 237.2101 | | | | | |
| CUM/HR | 0.0 | 0.0 | 0.0 | 2.0384 | |
| 0.1904 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | MISSING | MISSING | MISSING | 115.0000 | |
| 135.0000 | | | | | |
| PRES BAR | 1.0000 | 1.0000 | 1.0623 | 1.0000 | |
| 1.0133 | | | | | |
| VFRAC | MISSING | MISSING | MISSING | 0.0 | 0.0 |
| LFRAC | MISSING | MISSING | MISSING | 0.0 | 0.0 |
| SFRAC | MISSING | MISSING | MISSING | 1.0000 | |
| 1.0000 | | | | | |

| | | | | | |
|---------------------|-----------|-----------|-----------|------------|------|
| ENTHALPY: | | | | | |
| KCAL/MOL | MISSING | MISSING | MISSING | -257.6120 | - |
| 238.5366 | | | | | |
| KCAL/KG | MISSING | MISSING | MISSING | -1157.2757 | - |
| 1393.6593 | | | | | |
| GCAL/HR | MISSING | MISSING | MISSING | -2.7416 | - |
| 0.3306 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | MISSING | MISSING | MISSING | -838.2033 | - |
| 574.8695 | | | | | |
| CAL/GM-K | MISSING | MISSING | MISSING | -3.7655 | - |
| 3.3587 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | MISSING | MISSING | MISSING | 5.2211-03 | |
| 7.2804-03 | | | | | |
| KG/CUM | MISSING | MISSING | MISSING | 1162.2332 | |
| 1246.1054 | | | | | |
| AVG MW | MISSING | MISSING | MISSING | 222.6021 | |
| 171.1585 | | | | | |
| 29 3 30 31 32 | | | | | |
| ----- | | | | | |
| STREAM ID | 29 | 3 | 30 | 31 | 32 |
| FROM : | B19 | B1 | B20 | B20 | B21 |
| TO : | B20 | B2 | B21 | ---- | ---- |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 4342.7442 | 1.8994+04 | 3947.3941 | 395.3501 | 0.0 |
| GCAL/HR | -4.9256 | -24.0580 | -4.4180 | -0.5076 | 0.0 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | SOLID | LIQUID | SOLID | SOLID | |
| MISSING | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 17.8266 | 0.0 | 17.1399 | 0.6867 | 0.0 |
| ETHYLACE | 0.0 | 188.6868 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 4105.5341 | 0.0 | 3947.3941 | 158.1400 | 0.0 |
| ETHYLACE | 0.0 | 1.6625+04 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 17.8266 | 188.6868 | 17.1399 | 0.6867 | 0.0 |
| KG/HR | 4105.5341 | 1.6625+04 | 3947.3941 | 158.1400 | 0.0 |
| CUM/HR | 3.5793 | 19.8033 | 3.4415 | 0.1379 | 0.0 |
| STATE VARIABLES: | | | | | |
| TEMP C | 135.2144 | 70.0000 | 135.2144 | 135.2144 | |
| MISSING | | | | | |

| | | | | | |
|-----------|-----|------------|------------|------------|------------|
| PRES | BAR | 2.7369 | 3.0000 | 2.7369 | 2.7369 |
| 2.7369 | | | | | |
| VFRAC | | 0.0 | 0.0 | 0.0 | 0.0 |
| MISSING | | | | | |
| LFRAC | | 0.0 | 1.0000 | 0.0 | 0.0 |
| MISSING | | | | | |
| SFRAC | | 1.0000 | 0.0 | 1.0000 | 1.0000 |
| MISSING | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | | -257.7619 | -112.6957 | -257.7619 | -257.7619 |
| MISSING | | | | | |
| KCAL/KG | | -1119.2234 | -1279.0876 | -1119.2234 | -1119.2234 |
| MISSING | | | | | |
| GCAL/HR | | -4.5950 | -21.2642 | -4.4180 | -0.1770 |
| MISSING | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | | -870.8347 | -111.6061 | -870.8347 | -870.8347 |
| MISSING | | | | | |
| CAL/GM-K | | -3.7812 | -1.2667 | -3.7812 | -3.7812 |
| MISSING | | | | | |
| DENSITY: | | | | | |
| MOL/CC | | 4.9804-03 | 9.5281-03 | 4.9804-03 | 4.9804-03 |
| MISSING | | | | | |
| KG/CUM | | 1147.0135 | 839.4815 | 1147.0135 | 1147.0135 |
| MISSING | | | | | |
| AVG MW | | 230.3043 | 88.1063 | 230.3043 | 230.3043 |
| MISSING | | | | | |

SUBSTREAM: CISOLID
COMPONENTS: KMOL/HR

STRUCTURE: CONVENTIONAL

| | | | | | |
|----------|--------|--------|-----|--------|-----|
| DDDA | 0.0 | 9.2566 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.5410 | 0.5410 | 0.0 | 0.5410 | 0.0 |
| SUBER-01 | 0.4539 | 0.4539 | 0.0 | 0.4539 | 0.0 |
| SEBAC-01 | 0.3910 | 0.3909 | 0.0 | 0.3910 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

COMPONENTS: KG/HR

| | | | | | |
|----------|---------|-----------|-----|---------|-----|
| DDDA | 0.0 | 2131.8400 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 79.0702 | 79.0690 | 0.0 | 79.0702 | 0.0 |
| SUBER-01 | 79.0699 | 79.0690 | 0.0 | 79.0699 | 0.0 |
| SEBAC-01 | 79.0699 | 79.0690 | 0.0 | 79.0699 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

TOTAL FLOW:

| | | | | | |
|---------|----------|-----------|-----|----------|-----|
| KMOL/HR | 1.3859 | 10.6425 | 0.0 | 1.3859 | 0.0 |
| KG/HR | 237.2101 | 2369.0470 | 0.0 | 237.2101 | 0.0 |
| CUM/HR | 0.1904 | 2.0151 | 0.0 | 0.1904 | 0.0 |

STATE VARIABLES:

| | | | | | |
|---------|-----|----------|---------|---------|----------|
| TEMP | C | 135.2144 | 70.0000 | MISSING | 135.2144 |
| MISSING | | | | | |
| PRES | BAR | 2.7369 | 3.0000 | MISSING | 2.7369 |
| 2.7369 | | | | | |
| VFRAC | | 0.0 | 0.0 | MISSING | 0.0 |
| MISSING | | | | | |
| LFRAC | | 0.0 | 0.0 | MISSING | 0.0 |
| MISSING | | | | | |

| | | | | |
|-----------|------------|------------|---------|------------|
| SFRAC | 1.0000 | 1.0000 | MISSING | 1.0000 |
| MISSING | | | | |
| ENTHALPY: | | | | |
| KCAL/MOL | -238.5181 | -262.5134 | MISSING | -238.5181 |
| MISSING | | | | |
| KCAL/KG | -1393.5513 | -1179.2937 | MISSING | -1393.5513 |
| MISSING | | | | |
| GCAL/HR | -0.3306 | -2.7938 | MISSING | -0.3306 |
| MISSING | | | | |
| ENTROPY: | | | | |
| CAL/MOL-K | -574.8242 | -851.6117 | MISSING | -574.8242 |
| MISSING | | | | |
| CAL/GM-K | -3.3584 | -3.8257 | MISSING | -3.3584 |
| MISSING | | | | |
| DENSITY: | | | | |
| MOL/CC | 7.2801-03 | 5.2813-03 | MISSING | 7.2801-03 |
| MISSING | | | | |
| KG/CUM | 1246.0458 | 1175.6308 | MISSING | 1246.0458 |
| MISSING | | | | |
| AVG MW | 171.1585 | 222.6022 | MISSING | 171.1585 |
| MISSING | | | | |

33 34 35 36 37

| STREAM ID | 33 | 34 | 35 | 36 | 37 |
|----------------------|-----------|-----------|------------|-----------|------|
| FROM : | B21 | B22 | B23 | B23 | B24 |
| TO : | B22 | B23 | B18 | B24 | ---- |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| CONV. MAX. REL. ERR: | 0.0 | 0.0 | -7.5074-12 | 0.0 | 0.0 |
| TOTAL STREAM: | | | | | |
| KG/HR | 3947.3941 | 3947.3941 | 1973.6970 | 1973.6970 | |
| 1973.6970 | | | | | |
| GCAL/HR | -4.4180 | -4.4178 | -2.2089 | -2.2089 | - |
| 2.2829 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | SOLID | SOLID | SOLID | SOLID | |
| MISSING | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 17.1399 | 17.1399 | 8.5700 | 8.5700 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 3947.3941 | 3947.3941 | 1973.6970 | 1973.6970 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 17.1399 | 17.1399 | 8.5700 | 8.5700 | 0.0 |

| | | | | | |
|-------------------------|------------|------------|------------|------------|-----|
| KG/HR | 3947.3941 | 3947.3941 | 1973.6970 | 1973.6970 | 0.0 |
| CUM/HR | 3.4415 | 3.4415 | 1.7208 | 1.7208 | 0.0 |
| STATE VARIABLES: | | | | | |
| TEMP C | 135.2144 | 135.3047 | 135.3047 | 135.3047 | |
| MISSING | | | | | |
| PRES BAR | 2.7369 | 3.4264 | 3.4264 | 3.4264 | |
| 1.0133 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | |
| MISSING | | | | | |
| LFRAC | 0.0 | 0.0 | 0.0 | 0.0 | |
| MISSING | | | | | |
| SFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | |
| MISSING | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | -257.7619 | -257.7508 | -257.7508 | -257.7508 | |
| MISSING | | | | | |
| KCAL/KG | -1119.2234 | -1119.1748 | -1119.1748 | -1119.1748 | |
| MISSING | | | | | |
| GCAL/HR | -4.4180 | -4.4178 | -2.2089 | -2.2089 | |
| MISSING | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -870.8347 | -870.8073 | -870.8073 | -870.8073 | |
| MISSING | | | | | |
| CAL/GM-K | -3.7812 | -3.7811 | -3.7811 | -3.7811 | |
| MISSING | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 4.9804-03 | 4.9803-03 | 4.9803-03 | 4.9803-03 | |
| MISSING | | | | | |
| KG/CUM | 1147.0135 | 1146.9864 | 1146.9864 | 1146.9864 | |
| MISSING | | | | | |
| AVG MW | 230.3043 | 230.3043 | 230.3043 | 230.3043 | |
| MISSING | | | | | |
| SUBSTREAM: CISOLID | | | | | |
| STRUCTURE: CONVENTIONAL | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | |
| 8.5700 | | | | | |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1973.6970 | | | | | |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 0.0 | 0.0 | 0.0 | 0.0 | |
| 8.5700 | | | | | |
| KG/HR | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1973.6970 | | | | | |

| | | | | | |
|----------------------|-----------|-----------|------------|-----------|-----|
| CUM/HR | 0.0 | 0.0 | 0.0 | 0.0 | |
| 1.6876 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | MISSING | MISSING | MISSING | MISSING | |
| 60.0000 | | | | | |
| PRES BAR | 2.7369 | 3.4264 | MISSING | 3.4264 | |
| 1.0133 | | | | | |
| VFRAC | MISSING | MISSING | MISSING | MISSING | 0.0 |
| LFRAC | MISSING | MISSING | MISSING | MISSING | 0.0 |
| SFRAC | MISSING | MISSING | MISSING | MISSING | |
| 1.0000 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | MISSING | MISSING | MISSING | MISSING | - |
| 266.3800 | | | | | |
| KCAL/KG | MISSING | MISSING | MISSING | MISSING | - |
| 1156.6436 | | | | | |
| GCAL/HR | MISSING | MISSING | MISSING | MISSING | - |
| 2.2829 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | MISSING | MISSING | MISSING | MISSING | - |
| 894.0951 | | | | | |
| CAL/GM-K | MISSING | MISSING | MISSING | MISSING | - |
| 3.8822 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | MISSING | MISSING | MISSING | MISSING | |
| 5.0782-03 | | | | | |
| KG/CUM | MISSING | MISSING | MISSING | MISSING | |
| 1169.5323 | | | | | |
| AVG MW | MISSING | MISSING | MISSING | MISSING | |
| 230.3043 | | | | | |
| 4 5 6 7 8 | | | | | |
| ----- | | | | | |
| STREAM ID | 4 | 5 | 6 | 7 | 8 |
| FROM : | B2 | B3 | B3 | B4 | B5 |
| TO : | B3 | B9 | B4 | B5 | B7 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| CONV. MAX. REL. ERR: | 0.0 | 0.0 | -7.6014-07 | 0.0 | 0.0 |
| TOTAL STREAM: | | | | | |
| KG/HR | 2.0457+05 | 1.5045+04 | 1.8952+05 | 1.8952+05 | |
| 9476.1886 | | | | | |
| GCAL/HR | -254.4672 | -17.8301 | -236.1083 | -236.0950 | - |
| 11.8047 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | VAPOR | LIQUID | LIQUID | |
| LIQUID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1784.0714 | 170.7611 | 1613.3103 | 1613.3103 | |
| 80.6655 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |

| | | | | | |
|---------------------|-------------------------|------------|------------|------------|-----|
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1.5719+05 | 1.5045+04 | 1.4214+05 | 1.4214+05 | |
| 7107.1415 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 1784.0714 | 170.7611 | 1613.3103 | 1613.3103 | |
| 80.6655 | | | | | |
| KG/HR | 1.5719+05 | 1.5045+04 | 1.4214+05 | 1.4214+05 | |
| 7107.1415 | | | | | |
| CUM/HR | 194.5494 | 3796.7486 | 173.8456 | 173.8849 | |
| 8.6942 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 92.8832 | 86.0000 | 86.0000 | 86.1327 | |
| 86.1327 | | | | | |
| PRES BAR | 3.0000 | 1.3430 | 1.3430 | 3.7562 | |
| 3.7562 | | | | | |
| VFRAC | 0.0 | 1.0000 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 0.0 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -111.6036 | -104.4156 | -111.9384 | -111.9320 | - |
| 111.9320 | | | | | |
| KCAL/KG | -1266.6922 | -1185.1093 | -1270.4924 | -1270.4197 | - |
| 1270.4197 | | | | | |
| GKAL/HR | -199.1088 | -17.8301 | -180.5914 | -180.5810 | - |
| 9.0291 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -108.5990 | -88.5519 | -109.4980 | -109.4806 | - |
| 109.4806 | | | | | |
| CAL/GM-K | -1.2326 | -1.0051 | -1.2428 | -1.2426 | - |
| 1.2426 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 9.1703-03 | 4.4976-05 | 9.2801-03 | 9.2780-03 | |
| 9.2780-03 | | | | | |
| KG/CUM | 807.9590 | 3.9626 | 817.6384 | 817.4534 | |
| 817.4534 | | | | | |
| AVG MW | 88.1063 | 88.1063 | 88.1063 | 88.1063 | |
| 88.1063 | | | | | |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 185.1322 | 0.0 | 185.1322 | 185.1322 | |
| 9.2566 | | | | | |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 10.8209 | 0.0 | 10.8209 | 10.8209 | |
| 0.5410 | | | | | |
| SUBER-01 | 9.0782 | 0.0 | 9.0782 | 9.0782 | |
| 0.4539 | | | | | |
| SEBAC-01 | 7.8190 | 0.0 | 7.8190 | 7.8190 | |
| 0.3910 | | | | | |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |

| | | | | | |
|-----------------------|------------|----------|------------|------------|-----|
| DDDA | 4.2637+04 | 0.0 | 4.2637+04 | 4.2637+04 | |
| 2131.8371 | | | | | |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 1581.4028 | 0.0 | 1581.4040 | 1581.4040 | |
| 79.0702 | | | | | |
| SUBER-01 | 1581.3978 | 0.0 | 1581.3987 | 1581.3987 | |
| 79.0699 | | | | | |
| SEBAC-01 | 1581.3978 | 0.0 | 1581.3987 | 1581.3987 | |
| 79.0699 | | | | | |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 212.8504 | 0.0 | 212.8504 | 212.8504 | |
| 10.6425 | | | | | |
| KG/HR | 4.7381+04 | 0.0 | 4.7381+04 | 4.7381+04 | |
| 2369.0472 | | | | | |
| CUM/HR | 40.5375 | 0.0 | 40.4665 | 40.4679 | |
| 2.0234 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 92.8832 | MISSING | 86.0000 | 86.1327 | |
| 86.1327 | | | | | |
| PRES BAR | 3.0000 | 1.3430 | 1.3430 | 3.7562 | |
| 3.7562 | | | | | |
| VFRAC | 0.0 | MISSING | 0.0 | 0.0 | 0.0 |
| LFRAC | 0.0 | MISSING | 0.0 | 0.0 | 0.0 |
| SFRAC | 1.0000 | MISSING | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| ENTHALPY: | | | | | |
| KCAL/MOL | -260.0813 | MISSING | -260.8261 | -260.8119 | - |
| 260.8119 | | | | | |
| KCAL/KG | -1168.3685 | MISSING | -1171.7146 | -1171.6506 | - |
| 1171.6506 | | | | | |
| GCAL/HR | -55.3584 | MISSING | -55.5169 | -55.5139 | - |
| 2.7757 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -844.7519 | MISSING | -846.8062 | -846.7665 | - |
| 846.7665 | | | | | |
| CAL/GM-K | -3.7949 | MISSING | -3.8041 | -3.8039 | - |
| 3.8039 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 5.2507-03 | MISSING | 5.2599-03 | 5.2597-03 | |
| 5.2597-03 | | | | | |
| KG/CUM | 1168.8181 | MISSING | 1170.8674 | 1170.8279 | |
| 1170.8279 | | | | | |
| AVG MW | 222.6021 | MISSING | 222.6021 | 222.6021 | |
| 222.6021 | | | | | |
| 9 PURGE RECYCLE S1 S3 | | | | | |
| ----- | | | | | |
| STREAM ID | 9 | PURGE | RECYCLE | S1 | S3 |
| FROM : | B5 | B16 | B16 | B10 | B11 |
| TO : | B6 | ---- | ---- | B11 | B16 |
| CLASS: | MIXCISLD | MIXCISLD | MIXCISLD | MIXCISLD | |
| MIXCISLD | | | | | |
| TOTAL STREAM: | | | | | |
| KG/HR | 1.8005+05 | 161.4086 | 1.5979+04 | 1.6141+04 | |
| 1.6141+04 | | | | | |

| | | | | | |
|---------------------|------------|------------|------------|------------|-----|
| GCAL/HR | -224.2902 | -0.2059 | -20.3802 | -20.5878 | - |
| 20.5860 | | | | | |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | |
| LIQUID | | | | | |
| COMPONENTS: KMOL/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1532.6447 | 1.8320 | 181.3654 | 183.1974 | |
| 183.1974 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 3.0946-06 | 3.0636-04 | 3.0946-04 | |
| 3.0946-04 | | | | | |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | | |
| DDDA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 1.3504+05 | 161.4085 | 1.5979+04 | 1.6141+04 | |
| 1.6141+04 | | | | | |
| ADIPI-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 8.6689-05 | 8.5823-03 | 8.6689-03 | |
| 8.6689-03 | | | | | |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| KMOL/HR | 1532.6447 | 1.8320 | 181.3657 | 183.1977 | |
| 183.1977 | | | | | |
| KG/HR | 1.3504+05 | 161.4086 | 1.5979+04 | 1.6141+04 | |
| 1.6141+04 | | | | | |
| CUM/HR | 165.1907 | 0.1944 | 19.2497 | 19.4375 | |
| 19.4442 | | | | | |
| STATE VARIABLES: | | | | | |
| TEMP C | 86.1327 | 76.9403 | 76.9403 | 76.7317 | |
| 76.9403 | | | | | |
| PRES BAR | 3.7562 | 3.0000 | 3.0000 | 1.0000 | |
| 3.0000 | | | | | |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | |
| 1.0000 | | | | | |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KCAL/MOL | -111.9320 | -112.3705 | -112.3705 | -112.3804 | - |
| 112.3705 | | | | | |
| KCAL/KG | -1270.4197 | -1275.3983 | -1275.3983 | -1275.5100 | - |
| 1275.3983 | | | | | |
| GCAL/HR | -171.5520 | -0.2059 | -20.3802 | -20.5878 | - |
| 20.5860 | | | | | |
| ENTROPY: | | | | | |
| CAL/MOL-K | -109.4806 | -110.6880 | -110.6880 | -110.7155 | - |
| 110.6880 | | | | | |
| CAL/GM-K | -1.2426 | -1.2563 | -1.2563 | -1.2566 | - |
| 1.2563 | | | | | |
| DENSITY: | | | | | |
| MOL/CC | 9.2780-03 | 9.4217-03 | 9.4217-03 | 9.4250-03 | |
| 9.4217-03 | | | | | |
| KG/CUM | 817.4534 | 830.1133 | 830.1133 | 830.3971 | |
| 830.1133 | | | | | |

| | | | | |
|---------------------|------------|-------------------------|---------|---------|
| AVG MW | 88.1063 | 88.1062 | 88.1062 | 88.1062 |
| 88.1062 | | | | |
| SUBSTREAM: CISOLID | | STRUCTURE: CONVENTIONAL | | |
| COMPONENTS: KMOL/HR | | | | |
| DDDA | 175.8756 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 10.2799 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 8.6243 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 7.4281 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 |
| COMPONENTS: KG/HR | | | | |
| DDDA | 4.0505+04 | 0.0 | 0.0 | 0.0 |
| ETHYLACE | 0.0 | 0.0 | 0.0 | 0.0 |
| ADIPI-01 | 1502.3338 | 0.0 | 0.0 | 0.0 |
| SUBER-01 | 1502.3288 | 0.0 | 0.0 | 0.0 |
| SEBAC-01 | 1502.3288 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 |
| O2 | 0.0 | 0.0 | 0.0 | 0.0 |
| WATER | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | |
| KMOL/HR | 202.2079 | 0.0 | 0.0 | 0.0 |
| KG/HR | 4.5012+04 | 0.0 | 0.0 | 0.0 |
| CUM/HR | 38.4445 | 0.0 | 0.0 | 0.0 |
| STATE VARIABLES: | | | | |
| TEMP C | 86.1327 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| PRES BAR | 3.7562 | 3.0000 | 3.0000 | 1.0000 |
| 3.0000 | | | | |
| VFRAC | 0.0 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| LFRAC | 0.0 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| SFRAC | 1.0000 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| ENTHALPY: | | | | |
| KCAL/MOL | -260.8119 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| KCAL/KG | -1171.6506 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| GCAL/HR | -52.7382 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| ENTROPY: | | | | |
| CAL/MOL-K | -846.7665 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| CAL/GM-K | -3.8039 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| DENSITY: | | | | |
| MOL/CC | 5.2597-03 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| KG/CUM | 1170.8279 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| AVG MW | 222.6021 | MISSING | MISSING | MISSING |
| MISSING | | | | |
| S2 S5 | | | | |
| ----- | | | | |

| | | |
|-----------|------|------|
| STREAM ID | S2 | S5 |
| FROM : | B1 | B3 |
| TO : | B3 | ---- |
| CLASS: | HEAT | HEAT |

STREAM ATTRIBUTES:

| | | | |
|------|---------|---------|---------|
| HEAT | | | |
| Q | GCAL/HR | 0.1235 | -0.4052 |
| TBEG | C | 70.0000 | 86.0000 |
| TEND | C | 70.0000 | 92.8832 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

1

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| | |
|-----------|----------|
| STREAM ID | 1 |
| FROM : | ---- |
| TO : | B1 |
| CLASS: | MIXCISLD |

TOTAL STREAM:

| | |
|---------|-----------|
| KG/HR | 1.8994+04 |
| GCAL/HR | -24.0580 |

SUBSTREAM: MIXED

| | |
|--------|-------|
| PHASE: | MIXED |
|--------|-------|

COMPONENTS: KMOL/HR

| | |
|----------|----------|
| DDDA | 9.2566 |
| ETHYLACE | 188.6868 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3909 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 2131.8400 |
| ETHYLACE | 1.6625+04 |
| ADIPI-01 | 79.0690 |
| SUBER-01 | 79.0690 |
| SEBAC-01 | 79.0690 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 199.3293 |
| KG/HR | 1.8994+04 |

CUM/HR 21.8184
 STATE VARIABLES:
 TEMP C 70.0000
 PRES BAR 3.0000
 VFRAC 0.0
 LFRAC 0.9466
 SFRAC 5.3392-02
 ENTHALPY:
 KCAL/MOL -120.6947
 KCAL/KG -1266.6404
 GCAL/HR -24.0580
 ENTROPY:
 CAL/MOL-K -151.1162
 CAL/GM-K -1.5859
 DENSITY:
 MOL/CC 9.1358-03
 KG/CUM 870.5280
 AVG MW 95.2873

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

3

-

STREAM ID 3
 FROM : B1
 TO : B2
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 1.8994+04
 GCAL/HR -24.0580
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 188.6868
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 ETHYLACE 1.6625+04
 ADIPI-01 0.0

| | |
|-------------------------|------------|
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 188.6868 |
| KG/HR | 1.6625+04 |
| CUM/HR | 19.8033 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 3.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -112.6957 |
| KCAL/KG | -1279.0876 |
| GCAL/HR | -21.2642 |
| ENTROPY: | |
| CAL/MOL-K | -111.6061 |
| CAL/GM-K | -1.2667 |
| DENSITY: | |
| MOL/CC | 9.5281-03 |
| KG/CUM | 839.4815 |
| AVG MW | 88.1063 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.2566 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3909 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2131.8400 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0690 |
| SUBER-01 | 79.0690 |
| SEBAC-01 | 79.0690 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 10.6425 |
| KG/HR | 2369.0470 |
| CUM/HR | 2.0151 |
| STATE VARIABLES: | |
| TEMP C | 70.0000 |
| PRES BAR | 3.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -262.5134 |
| KCAL/KG | -1179.2937 |
| GCAL/HR | -2.7938 |

ENTROPY:
 CAL/MOL-K -851.6117
 CAL/GM-K -3.8257
 DENSITY:
 MOL/CC 5.2813-03
 KG/CUM 1175.6308
 AVG MW 222.6022

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

4
 -

STREAM ID 4
 FROM : B2
 TO : B3
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 2.0457+05
 GCAL/HR -254.4672
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 1784.0714
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 ETHYLACE 1.5719+05
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 1784.0714
 KG/HR 1.5719+05
 CUM/HR 194.5494
 STATE VARIABLES:
 TEMP C 92.8832

| | | |
|---|-----|------------|
| PRES | BAR | 3.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 1.0000 |
| SFRAC | | 0.0 |
| ENTHALPY: | | |
| KCAL/MOL | | -111.6036 |
| KCAL/KG | | -1266.6922 |
| GCAL/HR | | -199.1088 |
| ENTROPY: | | |
| CAL/MOL-K | | -108.5990 |
| CAL/GM-K | | -1.2326 |
| DENSITY: | | |
| MOL/CC | | 9.1703-03 |
| KG/CUM | | 807.9590 |
| AVG MW | | 88.1063 |
| SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL | | |
| COMPONENTS: KMOL/HR | | |
| DDDA | | 185.1322 |
| ETHYLACE | | 0.0 |
| ADIPI-01 | | 10.8209 |
| SUBER-01 | | 9.0782 |
| SEBAC-01 | | 7.8190 |
| N2 | | 0.0 |
| O2 | | 0.0 |
| WATER | | 0.0 |
| COMPONENTS: KG/HR | | |
| DDDA | | 4.2637+04 |
| ETHYLACE | | 0.0 |
| ADIPI-01 | | 1581.4028 |
| SUBER-01 | | 1581.3978 |
| SEBAC-01 | | 1581.3978 |
| N2 | | 0.0 |
| O2 | | 0.0 |
| WATER | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 212.8504 |
| KG/HR | | 4.7381+04 |
| CUM/HR | | 40.5375 |
| STATE VARIABLES: | | |
| TEMP | C | 92.8832 |
| PRES | BAR | 3.0000 |
| VFRAC | | 0.0 |
| LFRAC | | 0.0 |
| SFRAC | | 1.0000 |
| ENTHALPY: | | |
| KCAL/MOL | | -260.0813 |
| KCAL/KG | | -1168.3685 |
| GCAL/HR | | -55.3584 |
| ENTROPY: | | |
| CAL/MOL-K | | -844.7519 |
| CAL/GM-K | | -3.7949 |
| DENSITY: | | |
| MOL/CC | | 5.2507-03 |
| KG/CUM | | 1168.8181 |
| AVG MW | | 222.6021 |
| SUBSTREAM ATTR PSD TYPE: PSD | | |
| ----- | | |

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

5

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```

STREAM ID          5
FROM :            B3
TO :              B9
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR            1.5045+04
  GCAL/HR          -17.8301
SUBSTREAM: MIXED
PHASE:             VAPOR
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          170.7611
  ADIPI-01           0.0
  SUBER-01           0.0
  SEBAC-01           0.0
  N2                 0.0
  O2                  0.0
  WATER              0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          1.5045+04
  ADIPI-01           0.0
  SUBER-01           0.0
  SEBAC-01           0.0
  N2                 0.0
  O2                  0.0
  WATER              0.0
TOTAL FLOW:
  KMOL/HR            170.7611
  KG/HR              1.5045+04
  CUM/HR             3796.7486
STATE VARIABLES:
  TEMP   C           86.0000
  PRES   BAR          1.3430
  VFRAC              1.0000
  LFRAC              0.0
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL           -104.4156
  KCAL/KG            -1185.1093
  GCAL/HR            -17.8301
ENTROPY:
  CAL/MOL-K          -88.5519
  CAL/GM-K           -1.0051

```


DENSITY:
 MOL/CC 4.4976-05
 KG/CUM 3.9626
 AVG MW 88.1063

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

6

-

STREAM ID 6
 FROM : B3
 TO : B4
 CLASS: MIXCISLD

CONV. MAX. REL. ERR: -7.6014-07

TOTAL STREAM:

KG/HR 1.8952+05
 GCAL/HR -236.1083

SUBSTREAM: MIXED

PHASE: LIQUID

COMPONENTS: KMOL/HR

DDDA 0.0
 ETHYLACE 1613.3103
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0

COMPONENTS: KG/HR

DDDA 0.0
 ETHYLACE 1.4214+05
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0

TOTAL FLOW:

KMOL/HR 1613.3103
 KG/HR 1.4214+05
 CUM/HR 173.8456

STATE VARIABLES:

TEMP C 86.0000
 PRES BAR 1.3430

| | |
|-------------------------|------------|
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -111.9384 |
| KCAL/KG | -1270.4924 |
| GCAL/HR | -180.5914 |
| ENTROPY: | |
| CAL/MOL-K | -109.4980 |
| CAL/GM-K | -1.2428 |
| DENSITY: | |
| MOL/CC | 9.2801-03 |
| KG/CUM | 817.6384 |
| AVG MW | 88.1063 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 185.1322 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 10.8209 |
| SUBER-01 | 9.0782 |
| SEBAC-01 | 7.8190 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 4.2637+04 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 1581.4040 |
| SUBER-01 | 1581.3987 |
| SEBAC-01 | 1581.3987 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 212.8504 |
| KG/HR | 4.7381+04 |
| CUM/HR | 40.4665 |
| STATE VARIABLES: | |
| TEMP C | 86.0000 |
| PRES BAR | 1.3430 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -260.8261 |
| KCAL/KG | -1171.7146 |
| GCAL/HR | -55.5169 |
| ENTROPY: | |
| CAL/MOL-K | -846.8062 |
| CAL/GM-K | -3.8041 |
| DENSITY: | |
| MOL/CC | 5.2599-03 |
| KG/CUM | 1170.8674 |
| AVG MW | 222.6021 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-------------|-------------|
|----------|-------------|-------------|

| | | | | |
|----|-----------|-------|-----------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

7

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```

STREAM ID          7
FROM :             B4
TO :               B5
CLASS:             MIXCISLD
TOTAL STREAM:
  KG/HR             1.8952+05
  GCAL/HR           -236.0950
SUBSTREAM: MIXED
PHASE:              LIQUID
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          1613.3103
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                0.0
  O2                0.0
  WATER             0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          1.4214+05
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                0.0
  O2                0.0
  WATER             0.0
TOTAL FLOW:
  KMOL/HR           1613.3103
  KG/HR             1.4214+05
  CUM/HR            173.8849
STATE VARIABLES:
  TEMP  C           86.1327
  PRES  BAR          3.7562
  VFRAC              0.0
  LFRAC              1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL          -111.9320
  KCAL/KG           -1270.4197
  GCAL/HR           -180.5810
ENTROPY:
  CAL/MOL-K         -109.4806
  CAL/GM-K          -1.2426
DENSITY:

```

| | |
|--------|-----------|
| MOL/CC | 9.2780-03 |
| KG/CUM | 817.4534 |
| AVG MW | 88.1063 |

| | |
|---------------------|-------------------------|
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |

| | |
|----------|----------|
| DDDA | 185.1322 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 10.8209 |
| SUBER-01 | 9.0782 |
| SEBAC-01 | 7.8190 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

| | |
|-------------------|-----------|
| COMPONENTS: KG/HR | |
| DDDA | 4.2637+04 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 1581.4040 |
| SUBER-01 | 1581.3987 |
| SEBAC-01 | 1581.3987 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

| | |
|-------------|-----------|
| TOTAL FLOW: | |
| KMOL/HR | 212.8504 |
| KG/HR | 4.7381+04 |
| CUM/HR | 40.4679 |

| | |
|------------------|---------|
| STATE VARIABLES: | |
| TEMP C | 86.1327 |
| PRES BAR | 3.7562 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |

| | |
|-----------|------------|
| ENTHALPY: | |
| KCAL/MOL | -260.8119 |
| KCAL/KG | -1171.6506 |
| GCAL/HR | -55.5139 |

| | |
|-----------|-----------|
| ENTROPY: | |
| CAL/MOL-K | -846.7665 |
| CAL/GM-K | -3.8039 |

| | |
|----------|-----------|
| DENSITY: | |
| MOL/CC | 5.2597-03 |
| KG/CUM | 1170.8279 |
| AVG MW | 222.6021 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

8

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| | |
|---------------------|-------------------------|
| STREAM ID | 8 |
| FROM : | B5 |
| TO : | B7 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 9476.1886 |
| GCAL/HR | -11.8047 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| ETHYLACE | 80.6655 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 7107.1415 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 80.6655 |
| KG/HR | 7107.1415 |
| CUM/HR | 8.6942 |
| STATE VARIABLES: | |
| TEMP C | 86.1327 |
| PRES BAR | 3.7562 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -111.9320 |
| KCAL/KG | -1270.4197 |
| GCAL/HR | -9.0291 |
| ENTROPY: | |
| CAL/MOL-K | -109.4806 |
| CAL/GM-K | -1.2426 |
| DENSITY: | |
| MOL/CC | 9.2780-03 |
| KG/CUM | 817.4534 |
| AVG MW | 88.1063 |
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |
| DDDA | 9.2566 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3910 |

| | |
|-------------------|------------|
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 2131.8371 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0702 |
| SUBER-01 | 79.0699 |
| SEBAC-01 | 79.0699 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 10.6425 |
| KG/HR | 2369.0472 |
| CUM/HR | 2.0234 |
| STATE VARIABLES: | |
| TEMP C | 86.1327 |
| PRES BAR | 3.7562 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -260.8119 |
| KCAL/KG | -1171.6506 |
| GCAL/HR | -2.7757 |
| ENTROPY: | |
| CAL/MOL-K | -846.7665 |
| CAL/GM-K | -3.8039 |
| DENSITY: | |
| MOL/CC | 5.2597-03 |
| KG/CUM | 1170.8279 |
| AVG MW | 222.6021 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

9

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| | |
|---------------|-----------|
| STREAM ID | 9 |
| FROM : | B5 |
| TO : | B6 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.8005+05 |
| GCAL/HR | -224.2902 |

| | |
|-------------------------|------------|
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| ETHYLACE | 1532.6447 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 1.3504+05 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 1532.6447 |
| KG/HR | 1.3504+05 |
| CUM/HR | 165.1907 |
| STATE VARIABLES: | |
| TEMP C | 86.1327 |
| PRES BAR | 3.7562 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -111.9320 |
| KCAL/KG | -1270.4197 |
| GCAL/HR | -171.5520 |
| ENTROPY: | |
| CAL/MOL-K | -109.4806 |
| CAL/GM-K | -1.2426 |
| DENSITY: | |
| MOL/CC | 9.2780-03 |
| KG/CUM | 817.4534 |
| AVG MW | 88.1063 |
| SUBSTREAM: CISOLID | |
| STRUCTURE: CONVENTIONAL | |
| COMPONENTS: KMOL/HR | |
| DDDA | 175.8756 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 10.2799 |
| SUBER-01 | 8.6243 |
| SEBAC-01 | 7.4281 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 4.0505+04 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 1502.3338 |
| SUBER-01 | 1502.3288 |
| SEBAC-01 | 1502.3288 |
| N2 | 0.0 |
| O2 | 0.0 |

WATER 0.0
 TOTAL FLOW:
 KMOL/HR 202.2079
 KG/HR 4.5012+04
 CUM/HR 38.4445
 STATE VARIABLES:
 TEMP C 86.1327
 PRES BAR 3.7562
 VFRAC 0.0
 LFRAC 0.0
 SFRAC 1.0000
 ENTHALPY:
 KCAL/MOL -260.8119
 KCAL/KG -1171.6506
 GCAL/HR -52.7382
 ENTROPY:
 CAL/MOL-K -846.7665
 CAL/GM-K -3.8039
 DENSITY:
 MOL/CC 5.2597-03
 KG/CUM 1170.8279
 AVG MW 222.6021

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

10

--

STREAM ID 10
 FROM : B6
 TO : B2
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 1.8005+05
 GCAL/HR -223.3866
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 1532.6447
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0

| | | |
|---|-----|------------|
| COMPONENTS: KG/HR | | |
| DDDA | | 0.0 |
| ETHYLACE | | 1.3504+05 |
| ADIPI-01 | | 0.0 |
| SUBER-01 | | 0.0 |
| SEBAC-01 | | 0.0 |
| N2 | | 0.0 |
| O2 | | 0.0 |
| WATER | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 1532.6447 |
| KG/HR | | 1.3504+05 |
| CUM/HR | | 167.8986 |
| STATE VARIABLES: | | |
| TEMP | C | 95.4729 |
| PRES | BAR | 3.7562 |
| VFRAC | | 0.0 |
| LFRAC | | 1.0000 |
| SFRAC | | 0.0 |
| ENTHALPY: | | |
| KCAL/MOL | | -111.4761 |
| KCAL/KG | | -1265.2458 |
| GCAL/HR | | -170.8533 |
| ENTROPY: | | |
| CAL/MOL-K | | -108.2618 |
| CAL/GM-K | | -1.2288 |
| DENSITY: | | |
| MOL/CC | | 9.1284-03 |
| KG/CUM | | 804.2694 |
| AVG MW | | 88.1063 |
| SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL | | |
| COMPONENTS: KMOL/HR | | |
| DDDA | | 175.8756 |
| ETHYLACE | | 0.0 |
| ADIPI-01 | | 10.2799 |
| SUBER-01 | | 8.6243 |
| SEBAC-01 | | 7.4281 |
| N2 | | 0.0 |
| O2 | | 0.0 |
| WATER | | 0.0 |
| COMPONENTS: KG/HR | | |
| DDDA | | 4.0505+04 |
| ETHYLACE | | 0.0 |
| ADIPI-01 | | 1502.3338 |
| SUBER-01 | | 1502.3288 |
| SEBAC-01 | | 1502.3288 |
| N2 | | 0.0 |
| O2 | | 0.0 |
| WATER | | 0.0 |
| TOTAL FLOW: | | |
| KMOL/HR | | 202.2079 |
| KG/HR | | 4.5012+04 |
| CUM/HR | | 38.5360 |
| STATE VARIABLES: | | |
| TEMP | C | 95.4729 |
| PRES | BAR | 3.7562 |
| VFRAC | | 0.0 |
| LFRAC | | 0.0 |
| SFRAC | | 1.0000 |

ENTHALPY:
 KCAL/MOL -259.7981
 KCAL/KG -1167.0964
 GCAL/HR -52.5332
 ENTROPY:
 CAL/MOL-K -843.9810
 CAL/GM-K -3.7914
 DENSITY:
 MOL/CC 5.2472-03
 KG/CUM 1168.0470
 AVG MW 222.6021

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

11

--

STREAM ID 11
 FROM : B7
 TO : B8
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 5527.7767
 GCAL/HR -7.0226
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 62.7398
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 ETHYLACE 5527.7767
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 62.7398

KG/HR 5527.7767
 CUM/HR 6.7622
 STATE VARIABLES:
 TEMP C 86.1327
 PRES BAR 3.7562
 VFRAC 0.0
 LFRAC 1.0000
 SFRAC 0.0
 ENTHALPY:
 KCAL/MOL -111.9320
 KCAL/KG -1270.4197
 GCAL/HR -7.0226
 ENTROPY:
 CAL/MOL-K -109.4806
 CAL/GM-K -1.2426
 DENSITY:
 MOL/CC 9.2780-03
 KG/CUM 817.4534
 AVG MW 88.1063

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

12
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STREAM ID 12
 FROM : B8
 TO : B2
 CLASS: MIXCISLD

CONV. MAX. REL. ERR: -7.7068-11

TOTAL STREAM:

KG/HR 5527.7767
 GCAL/HR -7.0226

SUBSTREAM: MIXED

PHASE: LIQUID

COMPONENTS: KMOL/HR

DDDA 0.0
 ETHYLACE 62.7398
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0

COMPONENTS: KG/HR

```

DDDA                0.0
ETHYLACE            5527.7767
ADIPI-01            0.0
SUBER-01            0.0
SEBAC-01            0.0
N2                  0.0
O2                  0.0
WATER                0.0
TOTAL FLOW:
  KMOL/HR            62.7398
  KG/HR              5527.7767
  CUM/HR             6.7621
STATE VARIABLES:
  TEMP   C           86.1263
  PRES   BAR          3.4264
  VFRAC              0.0
  LFRAC              1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL           -111.9323
  KCAL/KG            -1270.4232
  GCAL/HR            -7.0226
ENTROPY:
  CAL/MOL-K          -109.4814
  CAL/GM-K           -1.2426
DENSITY:
  MOL/CC             9.2781-03
  KG/CUM             817.4624
AVG MW              88.1063

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

13

--

```

STREAM ID           13
FROM :              B7
TO   :              B13
CLASS:              MIXCISLD
TOTAL STREAM:
  KG/HR              3948.4119
  GCAL/HR            -4.7822
SUBSTREAM: MIXED
PHASE:              LIQUID
COMPONENTS: KMOL/HR
  DDDA                0.0

```

| | |
|----------|---------|
| ETHYLACE | 17.9257 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 0.0 |
| ETHYLACE | 1579.3648 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 17.9257 |
| KG/HR | 1579.3648 |
| CUM/HR | 1.9321 |

STATE VARIABLES:

| | |
|----------|---------|
| TEMP C | 86.1327 |
| PRES BAR | 3.7562 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -111.9320 |
| KCAL/KG | -1270.4197 |
| GCAL/HR | -2.0065 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -109.4806 |
| CAL/GM-K | -1.2426 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 9.2780-03 |
| KG/CUM | 817.4534 |

| | |
|--------|---------|
| AVG MW | 88.1063 |
|--------|---------|

SUBSTREAM: CISOLID

STRUCTURE: CONVENTIONAL

COMPONENTS: KMOL/HR

| | |
|----------|--------|
| DDDA | 9.2566 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3910 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 2131.8371 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0702 |
| SUBER-01 | 79.0699 |
| SEBAC-01 | 79.0699 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 10.6425 |
| KG/HR | 2369.0472 |

```

CUM/HR                2.0234
STATE VARIABLES:
  TEMP    C            86.1327
  PRES    BAR           3.7562
  VFRAC                    0.0
  LFRAC                    0.0
  SFRAC                    1.0000
ENTHALPY:
  KCAL/MOL          -260.8119
  KCAL/KG           -1171.6506
  GCAL/HR           -2.7757
ENTROPY:
  CAL/MOL-K          -846.7665
  CAL/GM-K           -3.8039
DENSITY:
  MOL/CC             5.2597-03
  KG/CUM             1170.8279
AVG MW               222.6021

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

14

--

```

STREAM ID              14
FROM :                 B9
TO :                   ----
CLASS:                 MIXCISLD
TOTAL STREAM:
  KG/HR                 1.5045
  GCAL/HR              -1.7830-03
SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: KMOL/HR
  DDDA                  0.0
  ETHYLACE              1.7076-02
  ADIPI-01              0.0
  SUBER-01              0.0
  SEBAC-01              0.0
  N2                    0.0
  O2                    0.0
  WATER                 0.0
COMPONENTS: KG/HR
  DDDA                  0.0
  ETHYLACE              1.5045
  ADIPI-01              0.0

```

SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 1.7076-02
 KG/HR 1.5045
 CUM/HR 0.3797
 STATE VARIABLES:
 TEMP C 86.0000
 PRES BAR 1.3430
 VFRAC 1.0000
 LFRAC 0.0
 SFRAC 0.0
 ENTHALPY:
 KCAL/MOL -104.4156
 KCAL/KG -1185.1093
 GCAL/HR -1.7830-03
 ENTROPY:
 CAL/MOL-K -88.5519
 CAL/GM-K -1.0051
 DENSITY:
 MOL/CC 4.4976-05
 KG/CUM 3.9626
 AVG MW 88.1063

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

15

--

STREAM ID 15
 FROM : B9
 TO : B10
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 1.5044+04
 GCAL/HR -19.1128
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 170.7441
 ADIPI-01 0.0
 SUBER-01 0.0

| | |
|-------------------|------------|
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 1.5044+04 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 170.7441 |
| KG/HR | 1.5044+04 |
| CUM/HR | 18.3989 |
| STATE VARIABLES: | |
| TEMP C | 86.0000 |
| PRES BAR | 1.3430 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KCAL/MOL | -111.9384 |
| KCAL/KG | -1270.4924 |
| GCAL/HR | -19.1128 |
| ENTROPY: | |
| CAL/MOL-K | -109.4980 |
| CAL/GM-K | -1.2428 |
| DENSITY: | |
| MOL/CC | 9.2801-03 |
| KG/CUM | 817.6384 |
| AVG MW | 88.1063 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

16

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| | |
|---------------|----------|
| STREAM ID | 16 |
| FROM : | B10 |
| TO : | ---- |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 480.2170 |

GCAL/HR -0.5702
 SUBSTREAM: MIXED
 PHASE: VAPOR
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 5.4463
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 1.3118-02
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 ETHYLACE 479.8495
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.3675
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 5.4594
 KG/HR 480.2170
 CUM/HR 158.8149
 STATE VARIABLES:
 TEMP C 76.7317
 PRES BAR 1.0000
 VFRAC 1.0000
 LFRAC 0.0
 SFRAC 0.0
 ENTHALPY:
 KCAL/MOL -104.4424
 KCAL/KG -1187.3596
 GCAL/HR -0.5702
 ENTROPY:
 CAL/MOL-K -88.5044
 CAL/GM-K -1.0062
 DENSITY:
 MOL/CC 3.4376-05
 KG/CUM 3.0238
 AVG MW 87.9619

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

--

STREAM ID 17
FROM : ----
TO : EARECPMP
CLASS: MIXCISLD
TOTAL STREAM:
KG/HR 1.8692+04
GCAL/HR -23.8416
SUBSTREAM: MIXED
PHASE: LIQUID
COMPONENTS: KMOL/HR
DDDA 0.0
ETHYLACE 212.1505
ADIPI-01 0.0
SUBER-01 0.0
SEBAC-01 0.0
N2 3.6023-04
O2 0.0
WATER 0.0
COMPONENTS: KG/HR
DDDA 0.0
ETHYLACE 1.8692+04
ADIPI-01 0.0
SUBER-01 0.0
SEBAC-01 0.0
N2 1.0091-02
O2 0.0
WATER 0.0
TOTAL FLOW:
KMOL/HR 212.1509
KG/HR 1.8692+04
CUM/HR 22.5095
STATE VARIABLES:
TEMP C 76.7313
PRES BAR 1.0000
VFRAC 0.0
LFRAC 1.0000
SFRAC 0.0
ENTHALPY:
KCAL/MOL -112.3804
KCAL/KG -1275.5102
GCAL/HR -23.8416
ENTROPY:
CAL/MOL-K -110.7155
CAL/GM-K -1.2566
DENSITY:
MOL/CC 9.4250-03
KG/CUM 830.3976
AVG MW 88.1062

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |

| | | | | |
|----|-----------|-------|-----------|-------|
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

18

--

```

STREAM ID          18
FROM :            EARECPMP
TO :              ----
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR            1.8692+04
  GCAL/HR          -23.8392
SUBSTREAM: MIXED
PHASE:            LIQUID
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          212.1505
  ADIPI-01           0.0
  SUBER-01           0.0
  SEBAC-01           0.0
  N2                 3.6023-04
  O2                  0.0
  WATER              0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          1.8692+04
  ADIPI-01           0.0
  SUBER-01           0.0
  SEBAC-01           0.0
  N2                 1.0091-02
  O2                  0.0
  WATER              0.0
TOTAL FLOW:
  KMOL/HR            212.1509
  KG/HR              1.8692+04
  CUM/HR              22.5185
STATE VARIABLES:
  TEMP   C           76.9752
  PRES   BAR          3.4264
  VFRAC              0.0
  LFRAC              1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL           -112.3689
  KCAL/KG            -1275.3796
  GCAL/HR            -23.8392
ENTROPY:
  CAL/MOL-K          -110.6834
  CAL/GM-K           -1.2562
DENSITY:
  MOL/CC              9.4212-03
  KG/CUM              830.0657
AVG MW                88.1062

```

SUBSTREAM ATTR PSD TYPE: PSD

| ----- | | | | |
|----------|-------------|-------|-------------|-------|
| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

19

--

```

STREAM ID          19
FROM :            ----
TO   :            B12
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR              3.3250
  GCAL/HR            -4.1283-06
SUBSTREAM: MIXED
PHASE:              VAPOR
COMPONENTS: KMOL/HR
  DDDA                0.0
  ETHYLACE             0.0
  ADIPI-01             0.0
  SUBER-01             0.0
  SEBAC-01             0.0
  N2                   0.1187
  O2                   0.0
  WATER                0.0
COMPONENTS: KG/HR
  DDDA                0.0
  ETHYLACE             0.0
  ADIPI-01             0.0
  SUBER-01             0.0
  SEBAC-01             0.0
  N2                   3.3250
  O2                   0.0
  WATER                0.0
TOTAL FLOW:
  KMOL/HR              0.1187
  KG/HR                 3.3250
  CUM/HR                1.6990
STATE VARIABLES:
  TEMP   C              20.0000
  PRES   BAR            1.7027
  VFRAC              1.0000
  LFRAC              0.0
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL            -3.4782-02
  KCAL/KG              -1.2416
  GCAL/HR             -4.1283-06
ENTROPY:

```

CAL/MOL-K -1.1484
 CAL/GM-K -4.0996-02
 DENSITY:
 MOL/CC 6.9860-05
 KG/CUM 1.9570
 AVG MW 28.0135

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

20

--

STREAM ID 20
 FROM : B12
 TO : B13
 CLASS: MIXCISLD

CONV. MAX. REL. ERR: 1.7447-05

TOTAL STREAM:

KG/HR 50.5267

GCAL/HR -2.4716-02

SUBSTREAM: MIXED

PHASE: VAPOR

COMPONENTS: KMOL/HR

DDDA 0.0

ETHYLACE 0.2346

ADIP-01 0.0

SUBER-01 0.0

SEBAC-01 0.0

N2 1.0659

O2 0.0

WATER 0.0

COMPONENTS: KG/HR

DDDA 0.0

ETHYLACE 20.6669

ADIP-01 0.0

SUBER-01 0.0

SEBAC-01 0.0

N2 29.8598

O2 0.0

WATER 0.0

TOTAL FLOW:

KMOL/HR 1.3005

KG/HR 50.5267

CUM/HR 31.7214

STATE VARIABLES:

| | | |
|-----------|-----|------------|
| TEMP | C | 38.4936 |
| PRES | BAR | 1.0623 |
| VFRAC | | 1.0000 |
| LFRAC | | 0.0 |
| SFRAC | | 0.0 |
| ENTHALPY: | | |
| KCAL/MOL | | -19.0056 |
| KCAL/KG | | -489.1741 |
| GCAL/HR | | -2.4716-02 |
| ENTROPY: | | |
| CAL/MOL-K | | -15.5185 |
| CAL/GM-K | | -0.3994 |
| DENSITY: | | |
| MOL/CC | | 4.0997-05 |
| KG/CUM | | 1.5928 |
| AVG MW | | 38.8525 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

21

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| | |
|---------------------|-----------|
| STREAM ID | 21 |
| FROM : | B13 |
| TO : | B14 |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1629.8915 |
| GCAL/HR | -1.8791 |
| SUBSTREAM: MIXED | |
| PHASE: | VAPOR |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| ETHYLACE | 18.1602 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 1.0659 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 1600.0317 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |

N2 29.8598
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 19.2261
 KG/HR 1629.8915
 CUM/HR 620.4676
 STATE VARIABLES:
 TEMP C 115.0000
 PRES BAR 1.0000
 VFRAC 1.0000
 LFRAC 0.0
 SFRAC 0.0
 ENTHALPY:
 KCAL/MOL -97.7359
 KCAL/KG -1152.8897
 GCAL/HR -1.8791
 ENTROPY:
 CAL/MOL-K -80.2691
 CAL/GM-K -0.9469
 DENSITY:
 MOL/CC 3.0987-05
 KG/CUM 2.6269
 AVG MW 84.7747

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

22

--

STREAM ID 22
 FROM : B14
 TO : B10
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 1577.4442
 GCAL/HR -2.0452
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 17.8996
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 1.3428-02

```

O2                0.0
WATER             0.0
COMPONENTS: KG/HR
  DDDA            0.0
  ETHYLACE        1577.0680
  ADIPI-01        0.0
  SUBER-01        0.0
  SEBAC-01        0.0
  N2              0.3762
  O2              0.0
  WATER          0.0
TOTAL FLOW:
  KMOL/HR         17.9130
  KG/HR           1577.4442
  CUM/HR          1.7837
STATE VARIABLES:
  TEMP   C        35.0000
  PRES   BAR      1.0000
  VFRAC              0.0
  LFRAC             1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL         -114.1738
  KCAL/KG          -1296.5269
  GCAL/HR          -2.0452
ENTROPY:
  CAL/MOL-K        -116.2492
  CAL/GM-K         -1.3201
DENSITY:
  MOL/CC           1.0042-02
  KG/CUM           884.3424
AVG MW             88.0613

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

23

--

```

STREAM ID        23
FROM :          B14
TO :            B15
CLASS:          MIXCISLD
TOTAL STREAM:
  KG/HR          52.4473
  GCAL/HR        -2.7526-02
SUBSTREAM: MIXED

```


PHASE:
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 0.2606
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 1.0525
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 ETHYLACE 22.9636
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 29.4837
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 1.3131
 KG/HR 52.4473
 CUM/HR 33.6428
 STATE VARIABLES:
 TEMP C 35.0000
 PRES BAR 1.0000
 VFRAC 1.0000
 LFRAC 0.0
 SFRAC 0.0
 ENTHALPY:
 KCAL/MOL -20.9626
 KCAL/KG -524.8374
 GCAL/HR -2.7526-02
 ENTROPY:
 CAL/MOL-K -17.1453
 CAL/GM-K -0.4293
 DENSITY:
 MOL/CC 3.9031-05
 KG/CUM 1.5589
 AVG MW 39.9411

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

24

--

```

STREAM ID          24
FROM :             B15
TO :               ----
CLASS:             MIXCISLD
TOTAL STREAM:
  KG/HR             5.2447
  GCAL/HR           -2.7526-03
SUBSTREAM: MIXED
PHASE:              VAPOR
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          2.6064-02
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                 0.1052
  O2                 0.0
  WATER             0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          2.2964
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                 2.9484
  O2                 0.0
  WATER             0.0
TOTAL FLOW:
  KMOL/HR           0.1313
  KG/HR             5.2447
  CUM/HR            3.3643
STATE VARIABLES:
  TEMP   C          35.0000
  PRES   BAR         1.0000
  VFRAC              1.0000
  LFRAC              0.0
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL          -20.9626
  KCAL/KG           -524.8374
  GCAL/HR           -2.7526-03
ENTROPY:
  CAL/MOL-K         -17.1453
  CAL/GM-K          -0.4293
DENSITY:
  MOL/CC            3.9031-05
  KG/CUM            1.5589
AVG MW              39.9411

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |

| | | | | |
|----|-----------|-------|-----------|-------|
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

25
--

STREAM ID 25
FROM : B15
TO : B27
CLASS: MIXCISLD
TOTAL STREAM:
KG/HR 47.2026
GCAL/HR -2.4774-02
SUBSTREAM: MIXED
PHASE: VAPOR
COMPONENTS: KMOL/HR
DDDA 0.0
ETHYLACE 0.2346
ADIPI-01 0.0
SUBER-01 0.0
SEBAC-01 0.0
N2 0.9472
O2 0.0
WATER 0.0
COMPONENTS: KG/HR
DDDA 0.0
ETHYLACE 20.6673
ADIPI-01 0.0
SUBER-01 0.0
SEBAC-01 0.0
N2 26.5353
O2 0.0
WATER 0.0
TOTAL FLOW:
KMOL/HR 1.1818
KG/HR 47.2026
CUM/HR 30.2786
STATE VARIABLES:
TEMP C 35.0000
PRES BAR 1.0000
VFRAC 1.0000
LFRAC 0.0
SFRAC 0.0
ENTHALPY:
KCAL/MOL -20.9626
KCAL/KG -524.8374
GCAL/HR -2.4774-02
ENTROPY:
CAL/MOL-K -17.1453
CAL/GM-K -0.4293
DENSITY:
MOL/CC 3.9031-05
KG/CUM 1.5589
AVG MW 39.9411

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

26

--

```

STREAM ID          26
FROM :            B27
TO   :            B12
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR            47.2026
  GCAL/HR          -2.4713-02
SUBSTREAM: MIXED
PHASE:             VAPOR
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          0.2346
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                 0.9472
  O2                 0.0
  WATER             0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          20.6673
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                 26.5353
  O2                 0.0
  WATER             0.0
TOTAL FLOW:
  KMOL/HR            1.1818
  KG/HR              47.2026
  CUM/HR             28.9344
STATE VARIABLES:
  TEMP   C           39.6578
  PRES   BAR          1.0623
  VFRAC              1.0000
  LFRAC              0.0
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL           -20.9109
  KCAL/KG            -523.5449
  GCAL/HR            -2.4713-02
ENTROPY:
  CAL/MOL-K          -17.0990
  CAL/GM-K           -0.4281

```

DENSITY:
 MOL/CC 4.0844-05
 KG/CUM 1.6314
 AVG MW 39.9411

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

27

--

STREAM ID 27
 FROM : B13
 TO : B18
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 2369.0472
 GCAL/HR -2.7416

SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL
 COMPONENTS: KMOL/HR

| | |
|----------|--------|
| DDDA | 9.2566 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3910 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 2131.8371 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0702 |
| SUBER-01 | 79.0699 |
| SEBAC-01 | 79.0699 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 10.6425 |
| KG/HR | 2369.0472 |
| CUM/HR | 2.0384 |

STATE VARIABLES:

| | |
|----------|----------|
| TEMP C | 115.0000 |
| PRES BAR | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |

```

SFRAC                      1.0000
ENTHALPY:
  KCAL/MOL                 -257.6120
  KCAL/KG                  -1157.2757
  GCAL/HR                  -2.7416
ENTROPY:
  CAL/MOL-K                -838.2033
  CAL/GM-K                 -3.7655
DENSITY:
  MOL/CC                   5.2211-03
  KG/CUM                   1162.2332
AVG MW                     222.6021

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

28

--

```

STREAM ID                  28
FROM :                    B18
TO   :                    B19
CLASS:                    MIXCISLD
TOTAL STREAM:
  KG/HR                   4342.7442
  GCAL/HR                 -4.9261
SUBSTREAM: MIXED
PHASE:                    SOLID
COMPONENTS: KMOL/HR
  DDDA                    17.8266
  ETHYLACE                 0.0
  ADIPI-01                 0.0
  SUBER-01                 0.0
  SEBAC-01                 0.0
  N2                       0.0
  O2                       0.0
  WATER                    0.0
COMPONENTS: KG/HR
  DDDA                     4105.5341
  ETHYLACE                 0.0
  ADIPI-01                 0.0
  SUBER-01                 0.0
  SEBAC-01                 0.0
  N2                       0.0
  O2                       0.0
  WATER                    0.0
TOTAL FLOW:

```

| | |
|------------------|------------|
| KMOL/HR | 17.8266 |
| KG/HR | 4105.5341 |
| CUM/HR | 3.5791 |
| STATE VARIABLES: | |
| TEMP C | 135.0000 |
| PRES BAR | 1.0133 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -257.7885 |
| KCAL/KG | -1119.3385 |
| GCAL/HR | -4.5955 |
| ENTROPY: | |
| CAL/MOL-K | -870.8997 |
| CAL/GM-K | -3.7815 |
| DENSITY: | |
| MOL/CC | 4.9807-03 |
| KG/CUM | 1147.0777 |
| AVG MW | 230.3043 |

| | |
|---------------------|-------------------------|
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |

| | |
|----------|--------|
| DDDA | 0.0 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3910 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

| | |
|-------------------|---------|
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0702 |
| SUBER-01 | 79.0699 |
| SEBAC-01 | 79.0699 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

| | |
|-------------|----------|
| TOTAL FLOW: | |
| KMOL/HR | 1.3859 |
| KG/HR | 237.2101 |
| CUM/HR | 0.1904 |

| | |
|------------------|------------|
| STATE VARIABLES: | |
| TEMP C | 135.0000 |
| PRES BAR | 1.0133 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |
| ENTHALPY: | |
| KCAL/MOL | -238.5366 |
| KCAL/KG | -1393.6593 |
| GCAL/HR | -0.3306 |
| ENTROPY: | |
| CAL/MOL-K | -574.8695 |
| CAL/GM-K | -3.3587 |
| DENSITY: | |
| MOL/CC | 7.2804-03 |
| KG/CUM | 1246.1054 |

AVG MW 171.1585

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

29

--

STREAM ID 29
FROM : B19
TO : B20
CLASS: MIXCISLD
TOTAL STREAM:
KG/HR 4342.7442
GCAL/HR -4.9256
SUBSTREAM: MIXED
PHASE: SOLID
COMPONENTS: KMOL/HR
DDDA 17.8266
ETHYLACE 0.0
ADIPI-01 0.0
SUBER-01 0.0
SEBAC-01 0.0
N2 0.0
O2 0.0
WATER 0.0
COMPONENTS: KG/HR
DDDA 4105.5341
ETHYLACE 0.0
ADIPI-01 0.0
SUBER-01 0.0
SEBAC-01 0.0
N2 0.0
O2 0.0
WATER 0.0
TOTAL FLOW:
KMOL/HR 17.8266
KG/HR 4105.5341
CUM/HR 3.5793
STATE VARIABLES:
TEMP C 135.2144
PRES BAR 2.7369
VFRAC 0.0
LFRAC 0.0
SFRAC 1.0000
ENTHALPY:
KCAL/MOL -257.7619

| | |
|-----------|------------|
| KCAL/KG | -1119.2234 |
| GCAL/HR | -4.5950 |
| ENTROPY: | |
| CAL/MOL-K | -870.8347 |
| CAL/GM-K | -3.7812 |
| DENSITY: | |
| MOL/CC | 4.9804-03 |
| KG/CUM | 1147.0135 |
| AVG MW | 230.3043 |

SUBSTREAM: CISOLID STRUCTURE: CONVENTIONAL

COMPONENTS: KMOL/HR

| | |
|----------|--------|
| DDDA | 0.0 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3910 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|---------|
| DDDA | 0.0 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0702 |
| SUBER-01 | 79.0699 |
| SEBAC-01 | 79.0699 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|----------|
| KMOL/HR | 1.3859 |
| KG/HR | 237.2101 |
| CUM/HR | 0.1904 |

STATE VARIABLES:

| | | |
|-------|-----|----------|
| TEMP | C | 135.2144 |
| PRES | BAR | 2.7369 |
| VFRAC | | 0.0 |
| LFRAC | | 0.0 |
| SFRAC | | 1.0000 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -238.5181 |
| KCAL/KG | -1393.5513 |
| GCAL/HR | -0.3306 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -574.8242 |
| CAL/GM-K | -3.3584 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 7.2801-03 |
| KG/CUM | 1246.0458 |
| AVG MW | 171.1585 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |

| | | | | |
|----|-----------|-------|-----------|-------|
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

30

--

```

STREAM ID          30
FROM :            B20
TO :             B21
CLASS:           MIXCISLD
TOTAL STREAM:
  KG/HR          3947.3941
  GCAL/HR        -4.4180
SUBSTREAM: MIXED
PHASE:           SOLID
COMPONENTS: KMOL/HR
  DDDA           17.1399
  ETHYLACE        0.0
  ADIPI-01        0.0
  SUBER-01        0.0
  SEBAC-01        0.0
  N2              0.0
  O2              0.0
  WATER           0.0
COMPONENTS: KG/HR
  DDDA           3947.3941
  ETHYLACE        0.0
  ADIPI-01        0.0
  SUBER-01        0.0
  SEBAC-01        0.0
  N2              0.0
  O2              0.0
  WATER           0.0
TOTAL FLOW:
  KMOL/HR         17.1399
  KG/HR           3947.3941
  CUM/HR           3.4415
STATE VARIABLES:
  TEMP  C         135.2144
  PRES  BAR        2.7369
  VFRAC         0.0
  LFRAC         0.0
  SFRAC         1.0000
ENTHALPY:
  KCAL/MOL       -257.7619
  KCAL/KG        -1119.2234
  GCAL/HR        -4.4180
ENTROPY:
  CAL/MOL-K       -870.8347
  CAL/GM-K        -3.7812
DENSITY:
  MOL/CC          4.9804-03
  KG/CUM          1147.0135
AVG MW           230.3043

```

SUBSTREAM ATTR PSD TYPE: PSD

```

-----
INTERVAL      LOWER LIMIT      UPPER LIMIT
  1           0.0      METER      5.0000-05  METER
  2       5.0000-05  METER      1.0000-04  METER
  3       1.0000-04  METER      1.5000-04  METER
  4       1.5000-04  METER      2.0000-04  METER
  5       2.0000-04  METER      2.5000-04  METER
  6       2.5000-04  METER      3.0000-04  METER
  7       3.0000-04  METER      3.5000-04  METER
  8       3.5000-04  METER      4.0000-04  METER
  9       4.0000-04  METER      4.5000-04  METER
 10       4.5000-04  METER      5.0000-04  METER

```

```

31
--

```

```

STREAM ID      31
FROM :         B20
TO :          ----
CLASS:         MIXCISLD
TOTAL STREAM:
  KG/HR        395.3501
  GCAL/HR      -0.5076
SUBSTREAM: MIXED
PHASE:         SOLID
COMPONENTS: KMOL/HR
  DDDA         0.6867
  ETHYLACE     0.0
  ADIPI-01     0.0
  SUBER-01     0.0
  SEBAC-01     0.0
  N2           0.0
  O2           0.0
  WATER        0.0
COMPONENTS: KG/HR
  DDDA         158.1400
  ETHYLACE     0.0
  ADIPI-01     0.0
  SUBER-01     0.0
  SEBAC-01     0.0
  N2           0.0
  O2           0.0
  WATER        0.0
TOTAL FLOW:
  KMOL/HR      0.6867
  KG/HR        158.1400
  CUM/HR       0.1379
STATE VARIABLES:
  TEMP  C      135.2144
  PRES  BAR     2.7369
  VFRAC      0.0
  LFRAC      0.0
  SFRAC      1.0000
ENTHALPY:
  KCAL/MOL    -257.7619
  KCAL/KG     -1119.2234
  GCAL/HR     -0.1770
ENTROPY:

```

| | |
|-----------|-----------|
| CAL/MOL-K | -870.8347 |
| CAL/GM-K | -3.7812 |
| DENSITY: | |
| MOL/CC | 4.9804-03 |
| KG/CUM | 1147.0135 |
| AVG MW | 230.3043 |

| | |
|---------------------|-------------------------|
| SUBSTREAM: CISOLID | STRUCTURE: CONVENTIONAL |
| COMPONENTS: KMOL/HR | |

| | |
|----------|--------|
| DDDA | 0.0 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.5410 |
| SUBER-01 | 0.4539 |
| SEBAC-01 | 0.3910 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

| | |
|-------------------|---------|
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 79.0702 |
| SUBER-01 | 79.0699 |
| SEBAC-01 | 79.0699 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

| | |
|-------------|----------|
| TOTAL FLOW: | |
| KMOL/HR | 1.3859 |
| KG/HR | 237.2101 |
| CUM/HR | 0.1904 |

| | |
|------------------|----------|
| STATE VARIABLES: | |
| TEMP C | 135.2144 |
| PRES BAR | 2.7369 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |

| | |
|-----------|------------|
| ENTHALPY: | |
| KCAL/MOL | -238.5181 |
| KCAL/KG | -1393.5513 |
| GKAL/HR | -0.3306 |

| | |
|-----------|-----------|
| ENTROPY: | |
| CAL/MOL-K | -574.8242 |
| CAL/GM-K | -3.3584 |

| | |
|----------|-----------|
| DENSITY: | |
| MOL/CC | 7.2801-03 |
| KG/CUM | 1246.0458 |
| AVG MW | 171.1585 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |

| | | | | |
|----|-----------|-------|-----------|-------|
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

32
--

```

STREAM ID          32
FROM :            B21
TO   :            ----
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR          0.0

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

33
--

```

STREAM ID          33
FROM :            B21
TO   :            B22
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR          3947.3941
  GCAL/HR        -4.4180
SUBSTREAM: MIXED
PHASE:            SOLID
COMPONENTS: KMOL/HR
  DDDA           17.1399
  ETHYLACE        0.0
  ADIPI-01        0.0
  SUBER-01        0.0
  SEBAC-01        0.0
  N2              0.0
  O2              0.0
  WATER          0.0
COMPONENTS: KG/HR
  DDDA           3947.3941
  ETHYLACE        0.0
  ADIPI-01        0.0
  SUBER-01        0.0
  SEBAC-01        0.0
  N2              0.0
  O2              0.0
  WATER          0.0

```

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 17.1399 |
| KG/HR | 3947.3941 |
| CUM/HR | 3.4415 |

STATE VARIABLES:

| | |
|----------|----------|
| TEMP C | 135.2144 |
| PRES BAR | 2.7369 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -257.7619 |
| KCAL/KG | -1119.2234 |
| GCAL/HR | -4.4180 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -870.8347 |
| CAL/GM-K | -3.7812 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 4.9804-03 |
| KG/CUM | 1147.0135 |
| AVG MW | 230.3043 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

34

--

STREAM ID 34

FROM : B22

TO : B23

CLASS: MIXCISLD

TOTAL STREAM:

| | |
|---------|-----------|
| KG/HR | 3947.3941 |
| GCAL/HR | -4.4178 |

SUBSTREAM: MIXED

PHASE: SOLID

COMPONENTS: KMOL/HR

| | |
|----------|---------|
| DDA | 17.1399 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

```

DDDA                3947.3941
ETHYLACE             0.0
ADIPI-01             0.0
SUBER-01             0.0
SEBAC-01             0.0
N2                   0.0
O2                   0.0
WATER                0.0
TOTAL FLOW:
  KMOL/HR             17.1399
  KG/HR               3947.3941
  CUM/HR              3.4415
STATE VARIABLES:
  TEMP    C           135.3047
  PRES    BAR          3.4264
  VFRAC                     0.0
  LFRAC                     0.0
  SFRAC                    1.0000
ENTHALPY:
  KCAL/MOL             -257.7508
  KCAL/KG              -1119.1748
  GCAL/HR              -4.4178
ENTROPY:
  CAL/MOL-K            -870.8073
  CAL/GM-K             -3.7811
DENSITY:
  MOL/CC               4.9803-03
  KG/CUM               1146.9864
AVG MW                230.3043

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

35

--

```

STREAM ID           35
FROM :              B23
TO :                B18
CLASS:              MIXCISLD

```

CONV. MAX. REL. ERR: -7.5074-12

TOTAL STREAM:

```

  KG/HR              1973.6970
  GCAL/HR            -2.2089

```

SUBSTREAM: MIXED

PHASE: SOLID

COMPONENTS: KMOL/HR

| | |
|----------|--------|
| DDDA | 8.5700 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 1973.6970 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 8.5700 |
| KG/HR | 1973.6970 |
| CUM/HR | 1.7208 |

STATE VARIABLES:

| | |
|----------|----------|
| TEMP C | 135.3047 |
| PRES BAR | 3.4264 |
| VFRAC | 0.0 |
| LFRAC | 0.0 |
| SFRAC | 1.0000 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -257.7508 |
| KCAL/KG | -1119.1748 |
| GCAL/HR | -2.2089 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -870.8073 |
| CAL/GM-K | -3.7811 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 4.9803-03 |
| KG/CUM | 1146.9864 |
| AVG MW | 230.3043 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

36

--

STREAM ID

36

FROM : B23
 TO : B24
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 1973.6970
 GCAL/HR -2.2089
 SUBSTREAM: MIXED
 PHASE: SOLID
 COMPONENTS: KMOL/HR
 DDDA 8.5700
 ETHYLACE 0.0
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 1973.6970
 ETHYLACE 0.0
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 0.0
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 8.5700
 KG/HR 1973.6970
 CUM/HR 1.7208
 STATE VARIABLES:
 TEMP C 135.3047
 PRES BAR 3.4264
 VFRAC 0.0
 LFRAC 0.0
 SFRAC 1.0000
 ENTHALPY:
 KCAL/MOL -257.7508
 KCAL/KG -1119.1748
 GCAL/HR -2.2089
 ENTROPY:
 CAL/MOL-K -870.8073
 CAL/GM-K -3.7811
 DENSITY:
 MOL/CC 4.9803-03
 KG/CUM 1146.9864
 AVG MW 230.3043

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |

| | | | | |
|----|-----------|-------|-----------|-------|
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

37
--

```

STREAM ID          37
FROM :            B24
TO   :            ----
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR           1973.6970
  GCAL/HR         -2.2829

```

```

SUBSTREAM: CISOLID      STRUCTURE: CONVENTIONAL
COMPONENTS: KMOL/HR

```

| | |
|----------|--------|
| DDDA | 8.5700 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

COMPONENTS: KG/HR

| | |
|----------|-----------|
| DDDA | 1973.6970 |
| ETHYLACE | 0.0 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 0.0 |
| O2 | 0.0 |
| WATER | 0.0 |

TOTAL FLOW:

| | |
|---------|-----------|
| KMOL/HR | 8.5700 |
| KG/HR | 1973.6970 |
| CUM/HR | 1.6876 |

STATE VARIABLES:

| | | |
|-------|-----|---------|
| TEMP | C | 60.0000 |
| PRES | BAR | 1.0133 |
| VFRAC | | 0.0 |
| LFRAC | | 0.0 |
| SFRAC | | 1.0000 |

ENTHALPY:

| | |
|----------|------------|
| KCAL/MOL | -266.3800 |
| KCAL/KG | -1156.6436 |
| GCAL/HR | -2.2829 |

ENTROPY:

| | |
|-----------|-----------|
| CAL/MOL-K | -894.0951 |
| CAL/GM-K | -3.8822 |

DENSITY:

| | |
|--------|-----------|
| MOL/CC | 5.0782-03 |
| KG/CUM | 1169.5323 |
| AVG MW | 230.3043 |

SUBSTREAM ATTR PSD TYPE: PSD

| | | |
|----------|-------------|-------------|
| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-------------|-------------|

| | | | | |
|----|-----------|-------|-----------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

PURGE

```

STREAM ID          PURGE
FROM :            B16
TO   :            ----
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR            161.4086
  GCAL/HR          -0.2059
SUBSTREAM: MIXED
PHASE:            LIQUID
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          1.8320
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                3.0946-06
  O2                0.0
  WATER             0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          161.4085
  ADIPI-01          0.0
  SUBER-01          0.0
  SEBAC-01          0.0
  N2                8.6689-05
  O2                0.0
  WATER             0.0
TOTAL FLOW:
  KMOL/HR            1.8320
  KG/HR              161.4086
  CUM/HR              0.1944
STATE VARIABLES:
  TEMP   C           76.9403
  PRES   BAR          3.0000
  VFRAC              0.0
  LFRAC              1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL           -112.3705
  KCAL/KG            -1275.3983
  GCAL/HR            -0.2059
ENTROPY:
  CAL/MOL-K          -110.6880
  CAL/GM-K           -1.2563
DENSITY:

```

| | |
|--------|-----------|
| MOL/CC | 9.4217-03 |
| KG/CUM | 830.1133 |
| AVG MW | 88.1062 |

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

RECYCLE

| | |
|---------------------|-----------|
| STREAM ID | RECYCLE |
| FROM : | B16 |
| TO : | ---- |
| CLASS: | MIXCISLD |
| TOTAL STREAM: | |
| KG/HR | 1.5979+04 |
| GCAL/HR | -20.3802 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: KMOL/HR | |
| DDDA | 0.0 |
| ETHYLACE | 181.3654 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 3.0636-04 |
| O2 | 0.0 |
| WATER | 0.0 |
| COMPONENTS: KG/HR | |
| DDDA | 0.0 |
| ETHYLACE | 1.5979+04 |
| ADIPI-01 | 0.0 |
| SUBER-01 | 0.0 |
| SEBAC-01 | 0.0 |
| N2 | 8.5823-03 |
| O2 | 0.0 |
| WATER | 0.0 |
| TOTAL FLOW: | |
| KMOL/HR | 181.3657 |
| KG/HR | 1.5979+04 |
| CUM/HR | 19.2497 |
| STATE VARIABLES: | |
| TEMP C | 76.9403 |
| PRES BAR | 3.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |

ENTHALPY:
 KCAL/MOL -112.3705
 KCAL/KG -1275.3983
 GCAL/HR -20.3802
 ENTROPY:
 CAL/MOL-K -110.6880
 CAL/GM-K -1.2563
 DENSITY:
 MOL/CC 9.4217-03
 KG/CUM 830.1133
 AVG MW 88.1062

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

S1

--

STREAM ID S1
 FROM : B10
 TO : B11
 CLASS: MIXCISLD
 TOTAL STREAM:
 KG/HR 1.6141+04
 GCAL/HR -20.5878
 SUBSTREAM: MIXED
 PHASE: LIQUID
 COMPONENTS: KMOL/HR
 DDDA 0.0
 ETHYLACE 183.1974
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 3.0946-04
 O2 0.0
 WATER 0.0
 COMPONENTS: KG/HR
 DDDA 0.0
 ETHYLACE 1.6141+04
 ADIPI-01 0.0
 SUBER-01 0.0
 SEBAC-01 0.0
 N2 8.6689-03
 O2 0.0
 WATER 0.0
 TOTAL FLOW:
 KMOL/HR 183.1977

KG/HR 1.6141+04
 CUM/HR 19.4375
 STATE VARIABLES:
 TEMP C 76.7317
 PRES BAR 1.0000
 VFRAC 0.0
 LFRAC 1.0000
 SFRAC 0.0
 ENTHALPY:
 KCAL/MOL -112.3804
 KCAL/KG -1275.5100
 GCAL/HR -20.5878
 ENTROPY:
 CAL/MOL-K -110.7155
 CAL/GM-K -1.2566
 DENSITY:
 MOL/CC 9.4250-03
 KG/CUM 830.3971
 AVG MW 88.1062

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |
| 7 | 3.0000-04 METER | 3.5000-04 METER |
| 8 | 3.5000-04 METER | 4.0000-04 METER |
| 9 | 4.0000-04 METER | 4.5000-04 METER |
| 10 | 4.5000-04 METER | 5.0000-04 METER |

S2

--

STREAM ID S2
 FROM : B1
 TO : B3
 CLASS: HEAT

STREAM ATTRIBUTES:

HEAT
 Q GCAL/HR 0.1235
 TBEG C 70.0000
 TEND C 70.0000

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | UPPER LIMIT |
|----------|-----------------|-----------------|
| 1 | 0.0 METER | 5.0000-05 METER |
| 2 | 5.0000-05 METER | 1.0000-04 METER |
| 3 | 1.0000-04 METER | 1.5000-04 METER |
| 4 | 1.5000-04 METER | 2.0000-04 METER |
| 5 | 2.0000-04 METER | 2.5000-04 METER |
| 6 | 2.5000-04 METER | 3.0000-04 METER |

| | | | | |
|----|-----------|-------|-----------|-------|
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

S3
--

```

STREAM ID          S3
FROM :            B11
TO   :            B16
CLASS:            MIXCISLD
TOTAL STREAM:
  KG/HR            1.6141+04
  GCAL/HR          -20.5860
SUBSTREAM: MIXED
PHASE:             LIQUID
COMPONENTS: KMOL/HR
  DDDA              0.0
  ETHYLACE          183.1974
  ADIPI-01           0.0
  SUBER-01           0.0
  SEBAC-01           0.0
  N2                 3.0946-04
  O2                  0.0
  WATER              0.0
COMPONENTS: KG/HR
  DDDA              0.0
  ETHYLACE          1.6141+04
  ADIPI-01           0.0
  SUBER-01           0.0
  SEBAC-01           0.0
  N2                 8.6689-03
  O2                  0.0
  WATER              0.0
TOTAL FLOW:
  KMOL/HR            183.1977
  KG/HR              1.6141+04
  CUM/HR             19.4442
STATE VARIABLES:
  TEMP   C           76.9403
  PRES   BAR          3.0000
  VFRAC              0.0
  LFRAC              1.0000
  SFRAC              0.0
ENTHALPY:
  KCAL/MOL           -112.3705
  KCAL/KG            -1275.3983
  GCAL/HR            -20.5860
ENTROPY:
  CAL/MOL-K           -110.6880
  CAL/GM-K            -1.2563
DENSITY:
  MOL/CC              9.4217-03
  KG/CUM              830.1133
AVG MW                88.1062

```

SUBSTREAM ATTR PSD TYPE: PSD

| INTERVAL | LOWER LIMIT | | UPPER LIMIT | |
|----------|-------------|-------|-------------|-------|
| 1 | 0.0 | METER | 5.0000-05 | METER |
| 2 | 5.0000-05 | METER | 1.0000-04 | METER |
| 3 | 1.0000-04 | METER | 1.5000-04 | METER |
| 4 | 1.5000-04 | METER | 2.0000-04 | METER |
| 5 | 2.0000-04 | METER | 2.5000-04 | METER |
| 6 | 2.5000-04 | METER | 3.0000-04 | METER |
| 7 | 3.0000-04 | METER | 3.5000-04 | METER |
| 8 | 3.5000-04 | METER | 4.0000-04 | METER |
| 9 | 4.0000-04 | METER | 4.5000-04 | METER |
| 10 | 4.5000-04 | METER | 5.0000-04 | METER |

S5
--

| | |
|-----------|------|
| STREAM ID | S5 |
| FROM : | B3 |
| TO : | ---- |
| CLASS: | HEAT |

STREAM ATTRIBUTES:

| | | |
|------|---------|---------|
| HEAT | | |
| Q | GCAL/HR | -0.4052 |
| TBEG | C | 86.0000 |
| TEND | C | 92.8832 |

Appendix C: Material Safety Data Sheets

This appendix contains MSDS forms for all major materials in our process. They are in the following order:

- Palm Oil
- Glucose
- DDDA
- Sebacic Acid
- Suberic Acid
- Adipic Acid
- Ethyl Acetate



MATERIAL SAFETY DATA SHEET

Weich, Holme & Clark Co., Inc., 7 Avenue L, Newark, NJ 07105
Tel: 973-465-1200 • Fax 973-465-7332 • www.weich-holme-clark.com

MSDS NO.: 02-026
REVISION DATE: 1-03-00

PRODUCT INFORMATION

TRADE NAME: CRUDE PALM OIL CAS NO.: 8002-75-3
CHEMICAL NAME: TRIGLYCERIDE OF FATTY ACIDS
CHEMICAL FAMILY: VEGETABLE OIL H M I S: 0, 1, 0, A

HAZARDOUS COMPONENT

DOES NOT CONTAIN ANY KNOWN HAZARDOUS INGREDIENTS

PHYSICAL CHARACTERISTICS

BOILING POINT N/D
VAPOR PRESSURE N/A
VAPOR DENSITY (AIR=1) EXCEEDS 1.0
SPECIFIC GRAVITY (H₂O=1) 0.9
MELTING POINT APPROX. 30°C
EVAPORATION RATE N/A
(BUILTUP ACETATE = 1)
SOLUBILITY IN WATER INSOLUBLE
APPEARANCE REDDISH-YELLOW FAT
WEIGHT PER GALLON APPROX 7.6 LBS/GAL

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT >300°F (CC)
FLAMMABLE LIMITS N/D
EXTINGUISHING MEDIA FOAM, DRY CHEMICAL, CO₂
FIRE FIGHTING: DO NOT USE WATER - may spread fire by dispersing oil. Water may be used to keep containers cool.

REACTIVITY DATA

STABILITY: STABLE
CONDITIONS TO AVOID: NONE
INCOMPATIBILITY: CAN REACT WITH OXIDIZERS
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR
HAZARDOUS DECOMPOSITION PRODUCTS: CO, CO₂ ON BURNING

HEALTH HAZARD DATA

TRESHHOLD LIMIT VALUE: Liquid-none; oil mist 10 mg/m³ total particulate.

EFFECTS OF OVEREXPOSURE: Excessive inhalation of oil mist may affect respiratory system. Oil mist is classified as a nuisance particulate by ACGIH. Sensitive individuals may experience dermatitis after long exposure of oil on skin.

EMERGENCY FIRST AID PROCEDURES: Wash skin with soap and water. Flush eyes with water and seek medical attention if irritation occurs. If ingested in large quantities, contact a physician if discomfort is encountered.

CARCINOGENICITY LISTING: None

SAFE HANDLING AND USE

SPILL OR LEAK PROCEDURES: Spills of this material are very slippery. Cover spills with some inert absorbent material and scoop into a container. Wash floors with detergent or soap and hot water and rinse with hot water.

SPECIAL PRECAUTIONS: As with all unsaturated fats and oils, some porous materials such as rags, paper, insulation or clay when wetted with this product may undergo spontaneous combustion. Keep such wetted materials well ventilated to prevent possible heat build-up.

WASTE DISPOSAL: Disposal must be made in accordance with all local, state, and federal regulations.

CONTROL MEASURES

EXPOSURE CONTROL: Engineering controls are usually not necessary if good hygiene practices are strictly followed. Respiratory protection is generally not required during normal operations. Wear the following to prevent skin contact: work pants, long sleeve work shirt and work gloves. Where there is the danger of eye contact, wear splash-proof goggles.

*The information contained in this material safety data sheet is based on the best data of which we are aware and is believed correct as of the date prepared. Since the use of this data sheet is not intended to constitute a contract, we make no warranty, express or implied, that the information herein will meet the requirements of any particular application. It is the user's responsibility to determine the conditions for safe use of this product. NO WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE IS MADE.

Material Safety Data Sheet



Glucose

1. Product and company identification

Product name : Glucose
 Product code : 10117
 Supplier : EMD Chemicals Inc.
 1000 Glenview Road
 Gibbstown, NJ 08027
 856-423-6300 Technical Service
 Monday-Friday: 9:00 - 5:00 PM
 Synonym : Glucose
 Material uses : Other non-specified industry, Analytical reagent.
 Validation date : 3/27/2009
 In case of emergency : 800-624-6300 CHEMTREC (USA)
 613-566-6666 CANUTEC (Canada)
 24 Hours/Day, 7 Days/Week

2. Hazards identification

Emergency overview : CAUTION
 Handling care generally in keeping with safe laboratory practices is recommended.
 No known significant effects or critical hazards. Avoid prolonged contact with eyes, skin and clothing.
 Physical state : Solid. [Powder, Granular solid.]
 OSHA/HC status : While this material is not considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200), this MSDS contains valuable information critical to the safe handling and proper use of the product. This MSDS should be retained and available for employees and other users of this product.
 Routes of entry : Inhalation, Ingestion.
 Potential acute health effects :
 Inhalation : No known significant effects or critical hazards.
 Ingestion : No known significant effects or critical hazards.
 Skin : No known significant effects or critical hazards.
 Eyes : No known significant effects or critical hazards.
 Potential chronic health effects :
 Carcinogenicity : No known significant effects or critical hazards.
 Mutagenicity : No known significant effects or critical hazards.
 Teratogenicity : No known significant effects or critical hazards.
 Developmental effects : No known significant effects or critical hazards.
 Fertility effects : No known significant effects or critical hazards.
 Medical conditions aggravated by over-exposure : None known.
 See toxicological information (section 11)

3. Composition/information on ingredients

Name : Dextrose
 CAS number : 50-99-7
 % by weight : 100

Continued on next page

Glucose 10117 2/5

4. First aid measures

Eye contact : Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention if symptoms occur.
 Skin contact : In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention if symptoms occur.
 Inhalation : Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms occur.
 Ingestion : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention if symptoms occur.

5. Fire-fighting measures

Flammability of the product : No specific fire or explosion hazard.
 Extinguishing media : Use an extinguishing agent suitable for the surrounding fire.
 Not suitable : None known.
 Special exposure hazards : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training.
 Hazardous thermal decomposition products may include the following materials:
 carbon monoxide
 carbon dioxide
 Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

6. Accidental release measures

Personal precautions : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Put on appropriate personal protective equipment (see section 8).
 Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).
 Methods for cleaning up :
 Spill : Move containers from spill area. Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see section 1 for emergency contact information and section 13 for waste disposal.

7. Handling and storage

Storage : Store in accordance with local regulations. Store in original container, protected from direct sunlight. Keep container tightly closed and sealed until ready for use.

8. Exposure controls/personal protection

Consult local authorities for acceptable exposure limits.
 Engineering measures : No special ventilation requirements. Good general ventilation should be sufficient to control worker exposure to airborne contaminants. If this product contains ingredients with exposure limits, use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure below any recommended or statutory limits.

Continued on next page

| | | |
|---|---|-----|
| Glucose | 10117 | 3/5 |
| 8. Exposure controls/personal protection | | |
| Hygiene measures | <ul style="list-style-type: none">Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location. | |
| Personal protection | | |
| Respiratory | <ul style="list-style-type: none">Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. | |
| Hands | <ul style="list-style-type: none">Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. | |
| Eyes | <ul style="list-style-type: none">Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or aerosols. Recommended: safety glasses with side-shields | |
| Skin | <ul style="list-style-type: none">Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product. | |
| Environmental exposure controls | <p>Recommended: lab coat</p> <ul style="list-style-type: none">Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels. | |
| 9. Physical and chemical properties | | |
| Physical state | <ul style="list-style-type: none">Solid [Powder, Granular solid.] | |
| Color | <ul style="list-style-type: none">White. | |
| Odor | <ul style="list-style-type: none">Odorless. | |
| Molecular weight | <ul style="list-style-type: none">180.18 g/mole | |
| Molecular formula | <ul style="list-style-type: none">C6-H12-O6 | |
| pH | <ul style="list-style-type: none">Not available. | |
| Boiling/condensation point | <ul style="list-style-type: none">Not available. | |
| Melting/freezing point | <ul style="list-style-type: none">Not available. | |
| Relative density | <ul style="list-style-type: none">Not available. | |
| Vapor pressure | <ul style="list-style-type: none">Not available. | |
| Vapor density | <ul style="list-style-type: none">Not available. | |
| Odor threshold | <ul style="list-style-type: none">Not available. | |
| Evaporation rate | <ul style="list-style-type: none">Not available. | |
| Solubility | <ul style="list-style-type: none">Soluble in the following materials: water | |
| 10. Stability and reactivity | | |
| Chemical stability | <ul style="list-style-type: none">The product is stable | |
| Possibility of hazardous reactions | <ul style="list-style-type: none">Under normal conditions of storage and use, hazardous reactions will not occur. | |
| Hazardous polymerization | <ul style="list-style-type: none">Under normal conditions of storage and use, hazardous polymerization will not occur. | |
| Conditions to avoid | <ul style="list-style-type: none">No specific data. | |
| Materials to avoid | <ul style="list-style-type: none">Reactive or incompatible with the following materials: oxidizing materials. | |
| Hazardous decomposition products | <ul style="list-style-type: none">Under normal conditions of storage and use, hazardous decomposition products should not be produced. | |
| Continued on next page | | |

Glucose

10117

4/5

11. Toxicological information

Acute toxicity

| Producing/ingredient name | Test Route | Species | Result |
|---------------------------|---------------------|---------|-------------|
| Dextrose | LD50 Oral | Rat | 25800 mg/kg |
| | TDLo Intrapertoneal | Rat | 2000 mg/kg |

Carcinogenicity

No known significant effects or critical hazards.

Mutagenicity

No known significant effects or critical hazards.

Teratogenicity

No known significant effects or critical hazards.

12. Ecological information

Environmental effects : No known significant effects or critical hazards.

Other adverse effects : No known significant effects or critical hazards.

13. Disposal considerations

The information presented only applies to the material as supplied. The identification based on characteristic(s) or listing may not apply if the material has been used or otherwise contaminated. It is the responsibility of the waste generator to determine the toxicity and physical properties of the material generated to determine the proper waste identification and disposal in accordance with applicable regulations. Disposal should be in accordance with applicable regional, national and local laws and regulations.

14. Transport information

| Regulatory information | UN number | Proper shipping name | Classes | PG* | Label | Additional information |
|------------------------|-----------|----------------------|---------|-----|-------|------------------------|
| DOT Classification | - | CHEMICALS, N.O.S. | - | - | - | - |

PG* : Packing group

15. Regulatory information

United States

HCS Classification

U.S. Federal regulations

: Not regulated.

: United States Inventory (TSCA 8b): This material is listed or exempted.

TSCA (Toxic Substance Control Act): This product is listed on the TSCA inventory.

SARA 302/304/311/312 extremely hazardous substances: No products were found.

SARA 302/304/311/312 hazardous materials: No products were found.

SARA 302/304/311/312 hazardous chemicals: No products were found.

SARA 311/312 MSDS distribution - chemical inventory - hazard identification: No products were found.

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 accidental release prevention: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

: Not listed

DEA List I Chemicals

(Precursor Chemicals)

DEA List II Chemicals

(Essential Chemicals)

: Not listed

Canada

Continued on next page

Dodecanedioic Acid

1. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

1.1. Product identifier
1.1.1. Name of the substance
DODECANEDIOIC ACID
1.1.2. Registration number
01-2115943732-40-0003
1.2. Relevant identified uses of the substance or mixture and uses advised against identified uses
1.2.1. Uses
None known.
1.2.2. Uses advised against
None known.
1.3. Details of the supplier of the safety data sheet
1.3.1. Company name
LEMRO Chemieprodukte Michael Mrozyk KG
1.3.2. Address
Luisenweg
Ortenau Str. 33
74639 Gernsheim
1.3.3. Telephone
+49-(0)181-2392-00
1.3.4. Telefax
+49-(0)181-2392-33
1.3.5. E-mail
info@lemro.de
1.3.6. Web
www.lemro.de
1.3.7. Emergency telephone number
+44-1235-239-670 (24 hr)
+49-(0)181-2392-00 weekdays 8-17h LEMRO
or the emergency call numbers for cases of poisoning

2. HAZARDS IDENTIFICATION

2.1. Classification of the substance or mixture
The substance has been assessed and/or tested for its physical, health and environmental hazards and the following classification applies.
Classification according to Directive 67/548/EEC or 1999/45/EC as amended
Xn;R36
Classification according to Regulation (EC) No 1272/2008 as amended
Health hazards Category 2 H319 - Causes serious eye irritation.
2.2. Label elements
Label according to Regulation (EC) No. 1272/2008 as amended
Contains DODECANEDIOIC ACID
Hazard pictograms



Signal word
Warning
Precautionary statements
P264 Wash thoroughly after handling.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P303 + P361 + P353 If exposed to skin, wash with plenty of water for several minutes. Remove contaminated clothing and shoes.
P337 + P313 If eye irritation persists: Get medical advice/attention.
Storage
Store container tightly closed in well-ventilated place.
Disposal
P301 Dispose of contents/container in accordance with local/regional/national/international regulations.
Supplemental label information
Not applicable.
2.3. Other hazards
Dust can form an explosive mixture in air.

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1. Substances
General information
Name of the substance
DODECANEDIOIC ACID
CAS-No./EC No.
693-23-2/211-746-3
%>96,5%
Classification
DSD: Eye Irrit. 2;H319
CLP: Eye Irrit. 2;H319
DSD: Directive 67/540/EEC.

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Dodecanedioic Acid

CLP: Regulation No. 1272/2008.
Composition comments
The full text for all R- and H-phrases is displayed in section 16.

4. FIRST AID MEASURES

General information
Persons responsible are aware of the material(s) involved, and take precautions to protect themselves. Take off contaminated clothing and shoes immediately. Keep victim warm. In case of shortness of breath, give oxygen. In the case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

4.1. Description of first aid measures

Inhalation
If inhaled, move to fresh air. If breathing is difficult, give oxygen. If the affected person is not breathing, apply artificial respiration. Induce artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device. Get medical attention, if needed.

Skin contact

Get medical attention if symptoms occur.
Hold eyelids apart and flush eyes with plenty of water for at least 15 minutes. Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists, get medical advice/attention.

Ingestion

If swallowed, do not induce vomiting. If symptoms of skin irritation appear, consult a physician.

4.2. Most important symptoms and effects, both acute and delayed

Skin:
Symptoms may include redness, drying of skin, itching and pain.
Eyes:
Symptoms may include discomfort or pain, excess blinking and tear production, with marked redness and swelling of the conjunctiva.
Inhalation:
Inhalation of dust may cause shortness of breath, tightness of the chest, a sore throat and cough.

4.3. Indication of any immediate medical attention and special treatment needed

Treat symptomatically.

5. FIRE-FIGHTING MEASURES

General fire hazards

Flammable liquids or fumes may be released during a fire.

5.1. Extinguishing media Suitable extinguishing media

Dry chemical, CO2, water spray or regular foam.

Unsuitable extinguishing media

Do not use a solid water stream as it may scatter and spread fire.

Flammable liquids or fumes may be released during a fire. Upon decomposition, this product emits carbon monoxide, carbon dioxide and/or low molecular weight hydrocarbons.
Injuring and toxic gases or fumes may be released during a fire. Upon decomposition, this product emits carbon monoxide, carbon dioxide and/or low molecular weight hydrocarbons.

Explosion hazard: Avoid generating dust: fine dust dispersed in air in sufficient concentrations and in the presence of an ignition source is a potential dust explosion hazard.

Special protective equipment for firefighters

Wear full protective clothing, including helmet, self-contained positive pressure or pressure demand breathing apparatus, protective clothing and face mask.

Special fire fighting procedures

In the event of fire, cool tanks with water spray.

6. ACCIDENTAL RELEASE MEASURES

6.1. Personal precautions, protective equipment and emergency procedures

For non-emergency personnel

Dust deposits should not be allowed to accumulate on surfaces, as these may form an explosive mixture if they are ignited. Do not breathe dust. Do not get dust in eyes. Do not get dust on skin or clothing. Do not get dust in compressed air. Use non-sparking tools and explosion-proof equipment. Ventilate closed spaces before entering. Remove all sources of ignition.

For emergency responders

Local authorities should be advised if significant spillages cannot be contained. Wear appropriate protective equipment and clothing during clean-up. Ventilate closed spaces before entering.

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Safety Data Sheet

According to Regulation (EC) No 1907/2006
revision date: 09.12.2014/Mr replaced edition: 03.06.2011/AM Page 3/8



Dodecanedioic Acid

Do not touch damaged containers or spilled material unless wearing appropriate protective clothing.
Avoid dust formation. Remove all sources of ignition.

6.2. Environmental precautions
Dust deposits should not be allowed to accumulate on surfaces, as these may form an explosive mixture if they are released into the atmosphere in sufficient concentration. Use only non-sparking tools.

6.3. Disposal considerations
Cover with plastic sheet to prevent spreading. Sweep up or gather material and place in appropriate container for disposal. If sweeping of a contaminated area is necessary use a dust suppressant agent which does not react with the product. Following product recovery, flush area with water.

Small Dry Spills: With clean shovel place material into clean, dry container and cover loosely;

Large Spills: Use mechanical handling equipment. Put material in suitable, covered, labeled containers.

Never return spills to original containers for re-use.

6.4. Reference to other sections
See Section 8 for personal protective equipment. For waste disposal, see section 13.

7. HANDLING AND STORAGE

7.1. Precautions for safe handling

Use care in handling/storage. Take precautionary measures against static discharges. Minimise dust generation and accumulation. Avoid contact with skin and eyes. Avoid prolonged exposure. Wash thoroughly after handling.

7.2. Conditions for safe storage, including any incompatibilities
Store in a cool, dry, well-ventilated area. Keep away from heat, sparks, and flame. Routine housekeeping should be instituted to ensure that dusts do not accumulate on surfaces. Dry powders can build static electricity charges when subjected to the friction of transfer and mixing operations. Provide adequate precautions, such as electrical grounding and bonding, or inert atmospheres.

7.3. Specific end use(s)
Not available.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1. Control parameters

Occupational exposure limits

Not available. No biological exposure limits noted for the ingredient(s).

Biological limit values

Not available. No biological exposure limits noted for the ingredient(s).

Recommended monitoring procedures

Not available.

Material

Material

Material

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Safety Data Sheet

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revision date: 09.12.2014/Mr replaced edition: 03.06.2011/AM Page 4/8



Dodecanedioic Acid

Do not touch damaged containers or spilled material unless wearing appropriate protective clothing.
Avoid dust formation. Remove all sources of ignition.

6.2. Environmental precautions
Dust deposits should not be allowed to accumulate on surfaces, as these may form an explosive mixture if they are released into the atmosphere in sufficient concentration. Use only non-sparking tools.

6.3. Disposal considerations
Cover with plastic sheet to prevent spreading. Sweep up or gather material and place in appropriate container for disposal. If sweeping of a contaminated area is necessary use a dust suppressant agent which does not react with the product. Following product recovery, flush area with water.

Small Dry Spills: With clean shovel place material into clean, dry container and cover loosely;

Large Spills: Use mechanical handling equipment. Put material in suitable, covered, labeled containers.

Never return spills to original containers for re-use.

6.4. Reference to other sections
See Section 8 for personal protective equipment. For waste disposal, see section 13.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1. Information on basic physical and chemical properties

Appearance

Physical state

Form

Color

Odour

Odour threshold

pH

Melting point/freezing point

Boiling point and boiling range

Flash point

Evaporation rate

Flammability (solid, gas)

Upper/lower flammability or explosive limits

Flammability limit - upper (%)

Vapour pressure

Vapour density

Relative density (liquid)

Partition coefficient (n-octanol/water)

Auto-ignition temperature

Decomposition temperature

Viscosity

Dynamic viscosity

Oxidizing properties

9.2. Other information

Dust explosion properties

Kst

Minimum explosible concentration (MEC)

Minimum ignition Energy (MIE) - dust cloud

Molecular formula

Molecular weight

VOC (Weight %)

262 bar/m/s

10. STABILITY AND REACTIVITY

10.1. Reactivity

The product is stable and non-reactive under normal conditions of use, storage and transport.

10.2. Chemical stability

Stable under normal conditions.

10.3. Reactivity with water

Not expected to occur.

10.4. Conditions to avoid

Do not expose to temperatures above 200°C.

10.5. Incompatible materials

None known.

10.6. Hazardous decomposition products

At thermal decomposition temperatures, carbon monoxide and carbon dioxide.

11. TOXICOLOGICAL INFORMATION

General Information

Dodecanedioic Acid

Not available.

Information on likely routes of exposure

Ingestion
Ingestion of this product may cause nausea, vomiting and diarrhoea.

Inhalation
Inhalation of vapours/fumes generated by heating this product may cause respiratory irritation with throat discomfort, coughing or difficulty breathing. Prolonged inhalation may be harmful. Inhalation of dust may cause shortness of breath, tightness of the chest, a sore throat and cough.

Skin contact
Skin contact may include redness, itching, drying of skin. Not expected to be a primary skin irritant.

Eye contact
Prolonged and/or repeated skin contact may result in mild irritation or redness.

Eye contact
Causes serious eye irritation. Symptoms may include stinging, tearing, redness, swelling, and blurred vision. Avoid contact with eyes. Symptoms may include discomfort or pain, excess blinking and tear production, with marked redness and swelling of the conjunctiva.

Skin contact
Not available.

11.1. Information on toxicological effects

Product Species Test results

DODECANEDIOIC ACID

Acute toxicity

LD50

Oral

Rabbit

> 6000 mg/kg

ALD

Rat

> 17000 mg/kg

Rat

3038 mg/kg

Skin corrosion/irritation

Based on available data, the classification criteria are not met.

Serious eye damage/eye irritation

Causes serious eye irritation.

Respiratory sensitization

Based on available data, the classification criteria are not met.

Reproductive toxicity

Based on available data, the classification criteria are not met.

Germ cell mutagenicity

Tests on bacterial or mammalian cell cultures did not show mutagenic effects.

Cardiogenicity

Based on available data, the classification criteria are not met.

Specific target organ toxicity - single exposure

Based on available data, the classification criteria are not met.

Specific target organ toxicity - repeated exposure

Based on available data, the classification criteria are not met.

Mixture versus substance

Information

Not applicable.

Other information

None known

12. ECOLOGICAL INFORMATION

12.1. Toxicity

Product Species Test results

DODECANEDIOIC ACID

Algae

NOEC

> 5.8 mg/l, 72 Hours

Daphnia

EC50

> 27.6 mg/l, 24 Hours

Fish

LC50

> 1000 mg/l, 48 Hours

12.2. Persistence and degradability

Inherent biodegradability = 71 % after 28 Days

12.3. Bioaccumulative potential

Based on available data, the classification criteria are not met.

12.4. Mobility in soil

Not available.

Other information

None known

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Dodecanedioic Acid

Not available.

12.5. Results of PBT and vPvB assessment

Not available.

12.6. Other adverse effects

None known.

13. DISPOSAL CONSIDERATIONS

13.1. Waste treatment methods

Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe manner (see Disposal instructions).

Contaminated packaging

Since emptied containers may retain product residue, follow label warnings even after container is emptied. Do not re-use empty containers.

Waste codes should be assigned by the user based on the application for which the product was used.

Dispose of contents/container in accordance with local/regional/national/international regulations.

Do not dispose of waste into sewer.

14. TRANSPORT INFORMATION

ADR

Not regulated as dangerous goods.

RID

Not regulated as dangerous goods.

ADN

Not regulated as dangerous goods.

IATA

Not regulated as dangerous goods.

IMDG

Not regulated as dangerous goods.

15. REGULATORY INFORMATION

15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture

EU regulations

Regulation (EC) No. 2037/2000 on substances that deplete the ozone layer, Annex II

Not listed.

Regulation (EC) No. 850/2004 on persistent organic pollutants, Annex I

Not listed.

Regulation (EC) No. 689/2008 concerning the export and import of dangerous chemicals, Annex I, part 1

Not listed.

Regulation (EC) No. 689/2008 concerning the export and import of dangerous chemicals, Annex I, part 2

Not listed.

Regulation (EC) No. 689/2008 concerning the export and import of dangerous chemicals, Annex I, part 3

Not listed.

Regulation (EC) No. 689/2008 concerning the export and import of dangerous chemicals, Annex V

Not listed.

Regulation (EC) No. 166/2006 Annex II Pollutant Release and Transfer Registry

Not listed.

Regulation (EC) No. 1907/2006, Article 59(1), Candidate List

Not listed.

Authorisations

Regulation (EC) No. 1907/2006, REACH Annex XIV Substances subject to authorization, as amended

Not listed.

Restrictions on use

Regulation (EC) No. 1907/2006 Annex XVII Substances subject to restriction on marketing and use

Not regulated.

Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens and

mutagens at work

Not regulated.

Directive 92/85/EEC on the safety and health of pregnant workers and workers who have recently given birth or are breastfeeding

Not listed.

Other EU regulations

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Product: **SEBACIC ACID** Page: 1 / 7
SDS No.: 005695-001 (Version 1.1) Date 21.10.2014 (cancel and replace : 26.09.2013)

1. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

Generic Safety Data Sheet

1.1. Identification of the product

Substance name:
REACH Registration Name: Sebacic acid
REACH Registration Number: 01-2119519215-52-0005, 01-2119519215-52-0016
EC No.: 203-345-5
CAS-No.: 111-20-6

Grade : SEBACIC ACID STANDARD PELLETS, SEBACIC ACID REFINED PELLETS

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the Substance/Mixture : Monomer, Synthesis intermediate.

1.3. Details of the supplier of the safety data sheet

Supplier
ARKEMA
POLYMERES DE SPECIALITES
Arkema France or Arkema Only Representative
420 rue d'Estienne d'Orves
F-93100 La Courneuve
Telephone : +33 (0)1 49 00 80 80
Telecopie : +33 (0)1 49 00 83 96
http://www.arkema.com
par-sdp-rdg@arkema.com

E-mail address

Manufacturer

CASDA BIOMATERIALS CO., LTD
NO.36 DONGFENG ROAD, NORTH INDUSTRIAL ZONE, HENGSHUI CITY, HEBEI
PROVINCE, CHINA
Telephone: 0086-318-2124268
Fax: 0086-318-2101356
CASDA BIOMATERIALS CO., LTD
NO.36 DONGFENG ROAD, NORTH INDUSTRIAL ZONE, HENGSHUI CITY, HEBEI
PROVINCE, CHINA
Telephone: 0086-318-2124268
Fax: 0086-318-2101356

1.4. Emergency telephone number

+33 1 49 00 77 77
European emergency phone number : 112
National Chemical Emergency Centre Tel: 01695 407 333

2. HAZARDS IDENTIFICATION

2.1. Classification of the substance or mixture

Classification (REGULATION (EC) No 1272/2008):
This substance is not classified as dangerous according to Regulation (EC) No 1272/2008.
Classification (Directive 67/548/EEC):

This substance is not classified as dangerous according to Directive 67/548/EEC.

2.2. Label elements

Label elements (REGULATION (EC) No 1272/2008):

This substance does not require a label.

2.3. Other hazards

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Environmental Effects:
harmful to aquatic life by bioaccumulation.

Physical and chemical hazards:
Decomposition products: See chapter 10.

Other:
Results of PBT and vPvB assessment : According to REACH regulation, annex XIII, the substance does not meet PBT and vPvB criteria.

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1. Substances

| Chemical Name ¹ | EC No. | CAS-No. | Concentration | Classification Directive 67/548/EEC | Classification REGULATION (EC) No 1272/2008 |
|----------------------------|-----------|----------|---------------|-------------------------------------|---|
| Sebacic acid | 203-345-5 | 111-20-6 | > 99,5 % | — | — |

¹: See chapter 14 for Proper Shipping Name

4. FIRST AID MEASURES

4.1. & 4.2. Description of necessary first-aid measures & Most important symptoms/effects, acute and delayed.

Inhalation:
Move to fresh air. Oxygen or artificial respiration if needed. In case of persistent problems : Consult a physician.

Skin contact:
Wash immediately, abundantly and thoroughly with water.

Eye contact:
Wash well-open eyes immediately, abundantly and thoroughly with water. If irritation persists, consult an ophthalmologist.

Ingestion:
In case of problems : Consult a doctor.

4.3 Indication of immediate medical attention and special treatment needed, if necessary : No data available.

5. FIREFIGHTING MEASURES

5.1. Extinguishing media

Suitable extinguishing media:
Water spray, carbon dioxide, Dry powder

5.2. Special hazards arising from the substance or mixture.

Thermal decomposition giving toxic products:
Organic vapours, Carbon oxides (by combustion)

5.3. Advice for firefighters.

Specific methods:
In case of fire nearby, remove the bags. Ensure a system for the rapid emptying of containers.

Special protective actions for fire-fighters:
Wear self-contained breathing apparatus and protective suit

6. ACCIDENTAL RELEASE MEASURES

6.1. Personal precautions, protective equipment and emergency procedures.

Avoid contact with the skin and the eyes.

6.2. Environmental precautions:

Do not release into the environment. Do not let product enter drains.

6.3. Methods and materials for containment and cleaning up:

Recovery:

Shovel into suitable container for disposal. Sweep up to prevent slipping hazard.
After cleaning, flush away traces with water. Recover waste water for processing later.

Elimination: See chapter 13

6.4. Reference to other sections: None.

7. HANDLING AND STORAGE

7.1. Precautions for safe handling:

Technical measures/Precautions:

Use only approved equipment for handling of products. Solid.

Provide sufficient air exchange and/or exhaust in work rooms. Provide showers, eye-baths.

Safe handling advice: Protect at sources of sparks and ignition. Do not smoke. Avoid accumulation of static charges during transfers in metallic systems.

Hygiene measures: Avoid contact with the skin and the eyes. When using do not eat, drink or smoke.

Wash hands after handling. Remove contaminated clothing and protective equipment before entering eating areas.

7.2. Conditions for safe storage, including any incompatibilities:

Store in a cool, dry, well-ventilated place. Keep away from heat and sources of ignition. Do not smoke. Provide eating and safe electrical equipment. Provide impermeable floor.

Packaging material:

Recommended: woven bag, Paper bag with inner plastic film

7.3. Specific and usual: None.

8. EXPOSURE CONTROL/PERSONAL PROTECTION

8.1. Control parameters:

Exposure Limit Values: Not relevant

Derived No Effect Level (DNEL): No adverse effects have been observed at the highest recommended concentrations (tested), thus no DNELs were derived

Predicted No Effect Concentration:

| Compartment: | Value: |
|---|-----------------|
| Fresh water | 0.018 mg/l |
| Marine water | 0.0018 mg/l |
| Water (intermittent release) | 0.18 mg/l |
| Effects on waste water treatment plants | 10 mg/l |
| Fresh water sediment | 0.347 mg/kg dw |
| Marine sediment | 0.0347 mg/kg dw |
| Soil | 0.0369 mg/kg on |

8.2. Exposure controls:

General protective measures: Provide sufficient air exchange and/or exhaust in work rooms.

Personal protective equipment:

Respiratory protection: In the case of hazardous fumes, wear self contained breathing apparatus.

Eye/face protection: Protective gloves

Hand protection: Safety glasses

Skin and body protection: Protective suit

Environmental exposure controls: See chapter 6

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1. Information on basic physical and chemical properties

Appearance:

Physical state (20°C): solid

Form: granules

Colour: white

Granulometry:

Not applicable

Odour:

Slightly acidic, slight

Odour threshold:

No data available.

pH:

Not applicable

Melting point/range:

131 - 134.5 °C (Pressure: 1.013 kPa)

Boiling point/boiling range:

294.5 °C (Pressure: 13.3 kPa)

Flash point:

Not applicable

Evaporation rate:

No data available.

Flammability (solid, gas):

Not flammable product

Flammability:

Not flammable product

Vapour pressure:

~ 0.001 Pa at 25 °C

Vapour density:

No data available.

Relative density (Water=1):

1.207 at 0 °C

Water solubility:

250 mg/l at 20 °C

Partition coefficient: n-octanol/water:

log K_{ow} = 1.5, at 23 °C (OECD Test Guideline 117)

Auto-ignition temperature:

Not relevant

Decomposition temperature:

No data available.

Viscosity, dynamic:

Not applicable

Explosive properties:

Not applicable

Lower explosion limit:

50 - 60 g/m3

Minimum grain energy:

100 - 300 mJ

Explosivity:

Not relevant (due to the chemical structure)

Oxidizing properties:

According to its structure, Not fire-propagating

9.2. Other data:

Solubility in other solvents:

Soluble in: Alcohols, Esters, Ketones

pKa:

5 at 24 °C

10. STABILITY AND REACTIVITY

10.1. & 10.2. Reactivity & Chemical stability:

The product is stable under normal handling and storage conditions.

10.3. Reactivity of hazardous reactions:

None known

10.4. Conditions to avoid:

Heat, flames and sparks. Store protected from moisture and heat (to maintain the technical properties of the product).

10.5. Incompatible materials to avoid:

None known.

10.6. Hazardous decomposition products:

Thermal decomposition giving toxic products:

Organic vapours, Carbon oxides (by combustion)

11. TOXICOLOGICAL INFORMATION

11.1. Information on toxicological effects:

Acute toxicity:

Ingestion: Slightly harmful by ingestion

LD50/Rat: ~ 5.000 mg/kg

• In animals:

Slightly harmful in contact with skin

Dermal:

LD50/Rat: ~ 2.000 mg/kg (Method: OECD Test Guideline 402)

• In animals:

Local effects (Corrosion / Irritation / Serious eye damage):

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|--|--|--|-----------|
| Skin contact: | Slightly or not irritating to skin (OECD Test Guideline 404, Rabbit) | | |
| Eye contact: | Slightly or not irritating to eyes (OECD Test Guideline 405, Rabbit) | | |
| Respiratory or skin sensitisation: | | | |
| Inhalation: | No data available. | | |
| Skin contact: | Not a skin sensitizer (Method: OECD Test Guideline 405 : Guinea pig) | | |
| CMR effects : Mutagenicity: In vitro | May be considered as comparable to a similar product for which experimental results are: In vitro gene mutations test on mammalian cells: negative (Method: OECD Test Guideline 476) Ames test: negative (Method: OECD Test Guideline 471) | | |
| Carcinogenicity: | No data available. | | |
| Reproductive toxicity: | | | |
| Fertility: | No data available. | | |
| Fetal development: | Based on the available data, the substance is not suspected of having developmental toxicity potential. NOAEL (Developmental Toxicity) : > 1.000 mg/kg bw/day (Method: OECD Test Guideline 414, Rabbit, oral) NOAEL (Developmental Toxicity) : > 500 mg/kg bw/day (Rat, by gavage) NOAEL (Maternal Toxicity) : > 500 mg/kg bw/day (Rat, by gavage) | | |
| Specific target organ toxicity: | | | |
| Single exposure: | No data available. | | |
| Repeated exposures: | The substance or mixture is not classified as specific target organ toxicant, repeated exposure. Oral NOAEL = >1000mg/kg (Rat, 6 months) | | |
| Aspiration hazard: | Not relevant | | |
| 12. ECOLOGICAL INFORMATION Ecotoxicology / Assessment: | All available data on this product and/or the components quoted in section 3 and/or the analogue substances/metabolites have been taken into account for the hazard assessment. | | |
| 12.1. Toxicity: | | | |
| Fish: | Slightly harmful to fish LC50, 96 h (Brachydanio rerio) : > 100 mg/l (Method: OECD Test Guideline 203) | | |
| Aquatic invertebrates: | Slightly harmful to daphnia EC50, 48 h (Daphnia magna (Water flea)) : > 100 mg/l (Method: OECD Test Guideline 202) | | |
| Aquatic plants: | Harmful to algae EC50, 72 h (Skeletonema costatum) : > 38,7 mg/l (Method: ISO 10253, Growth inhibition) Water accommodated fraction was tested. | | |
| Microorganisms: | EC20, 3 h : > 1.000 mg/l (Method: Standard : ISO 8152, Respiration inhibition of activated sludge) | | |
| ARKEMA Quiber-P02 (17244-2053-01)S-015009 - 2015-03-18 - 08:17:34 | 420 rue d'Estienne d'Orves - 92760 Colombes - FRANCE | | |

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|--|--|--|-----------|
| Aquatic toxicity: Long term toxicity: Aquatic plants: | NOEC, 72 h (Skeletonema costatum) : > 3 mg/l (Growth inhibition) | | |
| 12.2. Persistence and biodegradability: | | | |
| Biodegradation (in water): | Readily biodegradable 98 % after 7 d (Method: Standard : ISO 7827) 89 % after 28 d (Method: OECD Test Guideline 306) | | |
| 12.3. Bioaccumulative potential: | | | |
| Bioaccumulation: | Not bioaccumulable Partition coefficient n-octanol/water log Kow : > 1,5 , at 23 °C (Method: OECD Test Guideline 117) | | |
| 12.4. Mobility in soil: Distribution among environmental compartments: | | | |
| Absorption / desorption: | Slight adsorption log Koc : > 2,439 (Method: calculated) | | |
| 12.5. Results of PBT and vPvB assessment: | | | |
| According to REACH regulation, annex XIII, the substance does not meet PBT and vPvB criteria. | | | |
| 12.6. Other adverse effects: None known. | | | |
| 13. DISPOSAL CONSIDERATIONS | | | |
| 13.1. Waste treatment: | | | |
| Disposal of product: | Do not dispose of waste into sewer. If recycling is not practicable, dispose of in compliance with local regulations. | | |
| Disposal of packaging: | Do not release into the environment. Destroy packaging by incineration at an approved waste disposal site (in accordance with local and national regulations). | | |
| 14. TRANSPORT INFORMATION | | | |
| | Not classified as dangerous in the meaning of transport regulations. | | |
| 15. REGULATORY INFORMATION | | | |
| Safety data sheets: according to Regulation (EC) No. 1907/2006 (as amendment (453/2010)) | | | |
| 15.1. Safety, health and environmental regulation/legislation specific for the substance or mixture: | | | |
| UK REGULATION | Chp3: Chemical (hazard information and Packaging for Supply) Regulations 2002 | | |
| 15.2. Chemical Safety Assessment: | | | |
| At the substance doesn't meet the criteria for classification and is neither PBT nor vPvB, according to REACH regulation, article 14(4), development of specific exposure scenarios is not required. | | | |
| ARKEMA Quiber-P02 (17244-2053-01)S-015009 - 2015-03-18 - 08:17:34 | 420 rue d'Estienne d'Orves - 92760 Colombes - FRANCE | | |

| | | | |
|--|--------------|--|-----------|
| Product: | SEBACIC ACID | Date: 21.10.2014 (Cancel and replace: 26.06.2013). | Page: 7/7 |
| SDS No.: 005695-001 (Version 1.1.) | | | |
| INFORMATIONS: | | | |
| ENCS: | Conforms to | | |
| ALCO: | Conforms to | | |
| TRCA: | Conforms to | | |
| ENCS (JP): | Conforms to | | |
| KECO (FR): | Conforms to | | |
| ENCS (CN): | Conforms to | | |
| ENCS (CN): | Conforms to | | |
| 16. OTHER INFORMATION | | | |
| THREATS: | | | |
| NOAEL: No Observed Adverse Effect Level (NOAEL) | | | |
| LOAEL: Lowest Observed Adverse Effect Level (LOAEL) | | | |
| bw: Body weight | | | |
| bw: Body weight | | | |
| bw: Dry weight | | | |
| bw: Dry weight | | | |
| bw: Very Persistent and very Bioaccumulative | | | |
| PBT: Persistent, Bioaccumulative and Toxic | | | |
| <p>This information applies to the PRODUCT AS SUPPLIED and conforming to specifications of ARKEMA. In case of formulations or mixtures, it is necessary to ascertain that a new danger will not appear. The information contained is based on our knowledge of the product, at the date of publishing and it is given quite sincerely. Users are advised of possible additional hazards when the product is used in applications for which it was not intended. This sheet shall only be used and reproduced for prevention and security purposes. The references to legislative, regulatory and technical documents are for information only and do not constitute a commitment. It is the responsibility of the user to ensure that the product is used in accordance with the official documents concerning the use, the possession and the handling of the product. It is also the responsibility of the handler of the product to pass on to any subsequent persons who will come into contact with the product (usage, storage, cleaning of containers, other processes) the information contained within this safety data sheet and necessary for safety at work, the protection of health and the protection of the environment.</p> | | | |
| <p>NB: In this document the numerical separator of the thousands is the " " (point), the decimal separator is " ." (comma).</p> | | | |

M A T E R I A L S A F E T Y D A T A S H E E T

SECTION 1 - PRODUCT AND COMPANY IDENTIFICATION

| | |
|----------------------------------|--|
| Manufacturer: AccuStandard, Inc. | Date MSDS Printed: 12/30/2005 |
| 125 Market Street | Preparation Date: 12/30/2005 |
| New Haven, CT 06513 | Information Phone Number: 203-786-5290 |
| | Emergency Phone Number: 203-786-5290 |
| | Hours: Mon to Fri 8am-5pm EDT |

| |
|--|
| MSDS Number: PS-670CX-09 |
| Product Name: Suberic acid |
| Synonyms: Suberic acid, Octanedioic acid |
| Formula: C ₈ H ₁₄ O ₄ |
| Molecular Weight: 174.19 |

SECTION 2 - COMPOSITION INFORMATION ON INGREDIENTS

| Component(s) | (1) | CAS # | ACGIH-TLV (mg/m ³) | OSHA-PEL (mg/m ³) |
|--------------|-------|----------|--------------------------------|-------------------------------|
| Suberic acid | | 500-48-6 | Appt % TWA STE 8hr TWA STE 8hr | 100 |

SECTION 3 - HAZARDS IDENTIFICATION

| |
|------------------------------|
| Symptoms of Exposure: |
| Irritating to eyes. |

May be irritating to skin, mucous membranes and upper respiratory system.

To the best of our knowledge the chemical, physical and toxicological properties of the component ingredients have not been thoroughly investigated.

Potential Health Effects:

May be harmful if inhaled, absorbed through the skin, or swallowed.

Routes of Entry:

Inhalation, ingestion or skin contact.

Carcinogenicity:

This product is or contains a component that is not listed (ACGIH, IARC, NTP, OSHA) as a cancer causing agent.

SECTION 4 - FIRST AID MEASURES

| | | | |
|--|--|--|------------------------------|
| Emergency First Aid: | | | Page 1 |
| Get medical assistance for all cases of overexposure. | | | Preparation Date: 12/30/2005 |
| Skin contact: Immediately wash skin with soap and plenty of water. Remove contaminated clothing. Get medical attention if symptoms occur. Wash clothing before reuse. | | | |
| Eye contact: Immediately flush with plenty of water. After initial flushing, remove and contact lenses and continue flushing for at least 15 minutes. Assume adequate flushing by separating the eyelids with fingers. | | | |
| Inhalation: Remove to fresh air. If not breathing, give artificial respiration or give oxygen by trained personnel. Seek immediate medical attention. | | | |
| MSDS Number: PS-670CX-09 | Alteration of any information contained herein without written permission from AccuStandard strictly prohibited. | | |

Ingestion: Drink water and induce vomiting immediately as directed by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention immediately.

SECTION 5 - FIRE FIGHTING MEASURES

| |
|---|
| Flammable Properties: |
| Flash Point: 410 °F (210 °C) (CC) |
| Flammable Limits LEL (%) : N/A |
| Flammable Limits UEL (%) : N/A |
| Autoignition Temperature: N/A |
| Dusts at sufficient concentrations can form explosive mixtures with air. |
| During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. |

Extinguishing Media:

Use alcohol foam, carbon dioxide, dry chemical, or water spray when fighting fire involving this material.

Fire Fighting Procedures:

As in any fire, wear self-contained breathing apparatus pressure demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

| |
|---|
| Spill Response: |
| Wear self-contained breathing apparatus and full protective clothing. Avoid rising dust. Prevent contact with skin or eyes. Take up and containize for proper disposal. Ventilate area. Flush spill area with water. Comply with Federal, State, and local regulations. |

SECTION 7 - HANDLING AND STORAGE

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|--|
| Store in a tightly closed container. |
| Store in a cool area away from ignition sources and oxidizers. |
| Do not breathe dust. |
| Do not get in eyes, on skin, or on clothing. |
| Avoid prolonged or repeated exposure. |
| This product should only be used by persons trained in the safe handling of hazardous chemicals. |

SECTION 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION

| |
|---|
| Engineering Controls and Personal Protection Equipment (PPE): |
| Respiratory Protection: If workplace exposure limit(s) of product or any component is exceeded (see TLV/PEL), a NIOSH/MSHA approved air supplied respirator is advised in absence of proper environmental control. OSHA regulations also permit other NIOSH/MSHA respirators (negative pressure type) under specified conditions (see your safety equipment supplier). Engineering and/or administrative controls should be implemented to reduce exposure. |

Material should be handled or transferred in an approved fume hood or with adequate ventilation.

Compatible chemical-resistant protective gloves must be worn to prevent skin contact.

Safety glasses with side shields must be worn at all times.

| | | | |
|--------------------------|--|---------|------------------------------|
| MSDS Number: PS-670CX-09 | Alteration of any information contained herein without written permission from AccuStandard strictly prohibited. | Page: 2 | Preparation Date: 12/30/2005 |
|--------------------------|--|---------|------------------------------|

General Hygiene Considerations:

Wash thoroughly after handling. Do not take internally. Eye wash and safety equipment should be readily available.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Fine beige, crystalline solid

Odor: N/A

pH: N/A

Vapor Pressure: N/A

Vapor Density (Air = 1): N/A

Boiling Point: 230 °C (15 mmHg)

Melting Point: 140 °C

Solubility in Water (%): N/A

Specific Gravity (H₂O = 1): N/A

Flash Point: 410 °F (210 °C) (G)

Explosion Limits (%): N/A to N/A

Autoignition Temperature: N/A

Percent Volatile: N/A

Evaporation Rate (BuAc = 1): N/A

Molecular Weight: 174.19

Molecular Formula: C₈H₈H₀₄

SECTION 10 - STABILITY AND REACTIVITY

Stability: Stable

Conditions To Avoid: None indicated

Materials To Avoid: Oxidizers

Hazardous Decomposition: Oxides of carbon

Hazardous Polymerization: Does not occur

SECTION 11 - TOXICOLOGICAL INFORMATION

See section 3 for specific toxicological information for the ingredients of this product.

SECTION 12 - ECOLOGICAL INFORMATION

By complying with sections 6 and 7 there will be no release to the environment.

SECTION 13 - DISPOSAL CONSIDERATIONS

Recycle or incinerate at any EPA approved facility or dispose in compliance with Federal, State and local regulations. Empty containers must be triple-rinsed prior to disposal.

SECTION 14 - TRANSPORT INFORMATION

DOT UN Number: NR Shipping Class: NR Packing Group: NR

SECTION 15 - REGULATORY INFORMATION

In addition to Federal and state regulations, local regulations may apply. Check with your local regulatory authorities.

The following regulations apply:

None

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Preparation Date: 12/30/2005

SECTION 16 - OTHER INFORMATION

This document has been designed to meet the requirements of OSHA, ANSI and CHIP's regulations.

The statements contained herein are offered for informational purposes only and are based on technical data that we believe to be accurate. It is intended for use only by persons having the necessary technical skill and at their own discretion and risk. Since conditions and manner of use are outside our control, we make

NO WARRANTY, EXPRESSED OR IMPLIED, OF MERCHANTABILITY, FITNESS OR OTHERWISE

Legend : N/A = Not Available ND = Not Determined NR = Not regulated

*** End of Document ***

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Preparation Date: 12/30/2005



| | |
|---------------------|---|
| Health | 2 |
| Fire | 3 |
| Reactivity | 0 |
| Personal Protection | G |

Material Safety Data Sheet

Ethyl acetate MSDS

| Section 1: Chemical Product and Company Identification | |
|--|---|
| Product Name: Ethyl acetate | Contact Information: |
| Catalog Codes: SLE2452, SLE2317 | ScienceLab.com, Inc. |
| CAS#: 141-78-6 | 14025 Smith Rd. |
| RTECS: AH5425000 | Houston, Texas 77396 |
| TSCA: TSCA 8(b) Inventory: Ethyl acetate | US Sales: 1-800-901-7247 |
| CIF: Not available. | International Sales: 1-281-441-4400 |
| Synonym: Acetic Acid, Ethyl Ester Acetic Ether | Order Online: ScienceLab.com |
| Chemical Name: Ethyl Acetate | CHEMTREC (24HR Emergency Telephone), call: |
| Chemical Formula: C4-H8-O2 | 1-800-424-9300 |
| | International CHEMTREC, call: 1-703-527-3887 |
| | For non-emergency assistance, call: 1-281-441-4400 |

| Section 2: Composition and Information on Ingredients | | |
|--|----------|-------------|
| Composition: | | |
| Name | CAS # | % by Weight |
| Ethyl acetate | 141-78-6 | 100 |
| Toxicological Data on Ingredients: Ethyl acetate: ORAL (LD50): Acute: 5620 mg/kg [Rat], 4100 mg/kg [Mouse], 4935 mg/kg [Rabbit], VAPOR (LC50): Acute: 45000 mg/m ³ 3 hours [Mouse], 16000 ppm 6 hours [Rat]. | | |

| Section 3: Hazards Identification | |
|--|--|
| Potential Acute Health Effects: Hazardous in case of ingestion, or inhalation. Slightly hazardous in case of skin contact (irritant, permeator), or eye contact (irritant). | |
| Potential Chronic Health Effects: POTENTIAL EFFECTS: A4 (Not classifiable for human or animal) by ACGIH. MUTAGENIC EFFECTS: Not available. TUMORIGENIC EFFECTS: Not available. Dermal: Not available. The substance is toxic to aquatic life with long-term effects. The substance may be toxic to blood, kidneys, liver, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organ damage. | |

| Section 4: First Aid Measures |
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| Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention. | |
| Skin Contact: Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops. Cold water may be used. | |
| Serious Skin Contact: Not available. | |
| Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention if symptoms appear. | |
| Serious Inhalation: Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention. | |
| Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear. | |
| Serious Ingestion: Not available. | |

| Section 5: Fire and Explosion Data | |
|---|--|
| Flammability of the Product: Flammable. | |
| Auto-Ignition Temperature: 426.67°C (800°F) | |
| Flash Points: CLOSED CUP: -4.4°C (24.1°F), (TAG) OPEN CUP: 7.2°C (45°F) (Cleveland). | |
| Flammable Limits: LOWER: 2.2% UPPER: 9% | |
| Products of Combustion: These products are carbon oxides (CO, CO2). | |
| Fire Hazards in Presence of Various Substances: Highly flammable in presence of open flames and sparks, of heat. Slightly flammable to flammable in presence of oxidizing materials, of acids, of alkalis. Non-flammable in presence of shocks. | |
| Explosion Hazards in Presence of Various Substances: Risks of explosion of the product in presence of static discharge: Not available. Slightly explosive in presence of heat. Non-explosive in presence of shocks. | |
| Fire Fighting Media and Instructions: Flammable liquid, soluble or dispersed in water. SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use alcohol foam, water spray or fog. | |
| Special Remarks on Fire Hazards: Vapor may travel considerable distance to source of ignition and flash back. When heated to decomposition it emits acid smoke and irritating fumes. | |
| Special Remarks on Explosion Hazards: The liquid produces a vapor that forms explosive mixtures with air at normal temperatures. Explosive reaction with lithium tetrahydroaluminate. | |

| Section 6: Accidental Release Measures |
|---|
| Small Spill: Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container. |

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| <p>Large Spill: Liquid. Keep away from heat. Keep away from sources of ignition. Stop leak if without risk. Absorb with DRY earth, sand or other non-combustible material. Do not touch spilled material. Prevent entry into sewers, basements or confined areas; dike if needed. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.</p> | <p>Section 7: Handling and Storage</p> <p>Precautions: Keep away from heat. Keep away from sources of ignition. Ground all equipment containing material. Do not ingest. Do not breathe gas/fumes/vapor/spray. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents, acids, alkalis.</p> <p>Storage: Store in a segregated and approved area. Keep container in a cool, well-ventilated area. Keep container tightly closed and sealed until ready for use. Avoid all possible sources of ignition (spark or flame). Moisture sensitive.</p> |
| <p>Engineering Controls: Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below their respective threshold limit value. Ensure that eyewash stations and safety showers are proximal to the work-station location.</p> <p>Personal Protection: Safety glasses. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.</p> <p>Personal Protection in Case of a Large Spill: Spare respiratory protection. Vapor respirator. Goggles. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.</p> <p>Exposure Limits: TWA: 400 (ppm) from OSHA (PEL) [United States] TWA: 400 from ACGIH (TLV) [United States] TWA: 1400 (mg/m3) from NIOSH (TLV) [United States] TWA: 1400 (ppm) from NIOSH (TLV) [United States] TWA: 1400 (mg/m3) [Canada] TWA: 1400 (mg/m3) from OSHA (PEL) [United States] Consult local authorities for acceptable exposure limits.</p> | <p>Section 8: Exposure Controls/Personal Protection</p> |
| <p>Physical state and appearance: Liquid.</p> <p>Odor: Ethereal. Fruity. (Slight.)</p> <p>Taste: Bittersweet, wine-like burning taste</p> <p>Molecular Weight: 88.11 g/mole</p> <p>Color: Colorless.</p> <p>pH (1% soln/water): Not available.</p> <p>Boiling Point: 77°C (170.6°F)</p> <p>Melting Point: -83°C (-117.4°F)</p> <p>Critical Temperature: 250°C (482°F)</p> <p>Specific Gravity: 0.902 (Water = 1)</p> <p>Vapor Pressure: 12.4 kPa (@ 20°C)</p> | <p>Section 9: Physical and Chemical Properties</p> |

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| <p>Vapor Density: 3.04 (Air = 1)</p> <p>Volatility: Not available.</p> <p>Odor Threshold: 3.9 ppm</p> <p>Water/Oil Dist. Coeff.: The product is more soluble in oil: log(oil/water) = 0.7</p> <p>Ioniscty (in Water): Not available.</p> <p>Dispersion Properties: See solubility in water, diethyl ether, acetone.</p> <p>Solubility: Soluble in cold water, hot water, diethyl ether, acetone, alcohol, benzene.</p> | <p>Section 10: Stability and Reactivity Data</p> <p>Stability: The product is stable.</p> <p>Instability Temperature: Not available.</p> <p>Conditions of Instability: Heat. Ignition sources (flames, sparks, static), incompatible materials</p> <p>Incompatibility with various substances: Reactive with oxidizing agents, acids, alkalis.</p> <p>Corrosivity: Non-corrosive in presence of glass.</p> <p>Special Remarks on Reactivity: Also incompatible with nitrates, chlorosulfonic acid, oleum, potassium-tert-butoxide, and lithium tetrahydroaluminate. Moisture sensitive. On storage, it is slowly decomposed by water.</p> <p>Special Remarks on Corrosivity: Not available.</p> <p>Polymerization: Will not occur.</p> |
| <p>Routes of Entry: Absorbed through skin. Eye contact. Inhalation. Ingestion.</p> <p>Toxicity to Animals: WARNING: THE LD50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 4100 mg/kg [Mouse]. Acute toxicity of the vapor (LC50): 45000 mg/m3 3 hours [Mouse].</p> <p>Chronic Effects on Humans: CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH. Causes damage to the following organs: mucous membranes, upper respiratory tract. May cause damage to the following organs: blood, kidneys, liver, central nervous system (CNS).</p> <p>Other Toxic Effects on Humans: Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, permeator).</p> <p>Special Remarks on Toxicity to Animals: LD50 [Rabbit] - Route: skin; Dose >20,000 ml/kg</p> <p>Special Remarks on Chronic Effects on Humans: May affect genetic material (mutagenic). May cause adverse reproductive effects, based on animal test data. No human data found at this time.</p> <p>Special Remarks on other Toxic Effects on Humans: Acute Potential Health Effects: Skin: May cause skin irritation. Eyes: Causes eye irritation. May cause irritation of the conjunctiva. Inhalation: May cause respiratory tract and mucous membrane irritation. May affect respiration and may cause acute pulmonary edema. May affect gastrointestinal tract (nausea, vomiting). May affect behavior/central nervous system (mild central nervous system depression - exhilaration, talkativeness, boastfulness, belligerency, vertigo, dizziness, drowsiness, slurred speech, slowed reaction time, dizziness, lightheadedness, somnolence, ataxia, unconsciousness, irritability, fatigue, loss of appetite, reduced memory and concentration, euphoria, cardiovascular system (peripheral vascular collapse (shock) - rapid pulse, hypotension, cold pale skin, hypothermia). Other symptoms may include: flushing of face and sweating.</p> | <p>Section 11: Toxicological Information</p> |

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| <p>Ingestion: May cause gastrointestinal tract irritation with nausea and vomiting. May affect blood, behavior/central nervous system (CNS depression - effects may be similar to that of inhalation). Chronic Potential Health Effects: Skin: Repeated or prolonged skin contact may cause drying and cracking of the skin. Ingestion: Prolonged or repeated ingestion may affect the liver. Inhalation: Prolonged inhalation may affect behavior/central nervous system (symptoms similar to those of acute inhalation), and cause liver, kidney, lung, and heart damage. It may also affect metabolism, and blood (anemia, leukocytosis).</p> | |
| <p>Section 12: Ecological Information</p> <p>Ecotoxicity: Ecotoxicity in water (LC50): 220 mg/l 96 hours [Fish (Fathead minnow)], 212.5 ppm 96 hours [Fish (Indian catfish)].</p> <p>BO05 and COD: Not available.</p> <p>Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.</p> <p>Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.</p> <p>Special Remarks on the Products of Biodegradation: Not available.</p> | |
| <p>Section 13: Disposal Considerations</p> <p>Waste Disposal: Waste must be disposed of in accordance with federal, state and local environmental control regulations.</p> | |
| <p>Section 14: Transport Information</p> <p>DOT Classification: CLASS 3: Flammable liquid.</p> <p>Identification: : Ethyl Acetate UNNA: 1173 PG: II</p> <p>Special Provisions for Transport: Not available.</p> | |
| <p>Section 15: Other Regulatory Information</p> <p>Federal and State Regulations: Connecticut hazardous material survey.: Ethyl acetate Illinois toxic substances disclosure to employee act: Ethyl acetate Illinois chemical safety act: Ethyl acetate New York release reporting list: Ethyl acetate Rhode Island RTK hazardous substances: Ethyl acetate Pennsylvania RTK: Ethyl acetate Florida: Ethyl acetate Minnesota: Ethyl acetate Massachusetts RTK: Ethyl acetate Massachusetts spill list: Ethyl acetate New Jersey: Ethyl acetate New Jersey spill list: Ethyl acetate Louisiana spill reporting: Ethyl acetate California Director's list of Hazardous Substances: Ethyl acetate TSCA 8(b) inventory: Ethyl acetate TSCA 4(a) final test rules: Ethyl acetate TSCA 8(a) IUR: Ethyl acetate TSCA 12(b) annual export notification: Ethyl acetate CERCLA: Hazardous substances.: Ethyl acetate: 5000 lbs. (2268 kg)</p> <p>Other Regulations: OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200). EINECS: This product is on the European Inventory of Existing Commercial Substances.</p> <p>Other Classifications: WHMIS (Canada): CLASS B-2: Flammable liquid with a flash point lower than 37.8°C (100°F).</p> <p>DSCL (IEEC): R11: Highly flammable, R06: Irritating to eyes, S2: Keep out of the reach of children, S16: Keep away from sources of ignition. No smoking, S26: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice, S33: Take special precautions against static discharges, S46: If swallowed, seek medical advice immediately and show this container or label.</p> | |

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| <p>HMIS (U.S.A.):</p> <p>Health Hazard: 2</p> <p>Fire Hazard: 3</p> <p>Reactivity: 0</p> <p>Personal Protection: g</p> <p>National Fire Protection Association (U.S.A.):</p> <p>Health: 1</p> <p>Flammability: 3</p> <p>Reactivity: 0</p> <p>Specific hazard:</p> <p>Protective Equipment: Gloves, Lab coat, Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Safety glasses.</p> | |
| <p>Section 16: Other Information</p> <p>References: Not available.</p> <p>Other Special Considerations: Not available.</p> <p>Created: 10/10/2005 08:18 PM</p> <p>Last Updated: 05/21/2013 12:00 PM</p> <p><i>The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Sciencelab.com be liable for any claims, losses, or damages of any third party or for lost profits or any special, incidental, or consequential damages, howsoever arising, even if Sciencelab.com has been advised of the possibility of such damages.</i></p> | |

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