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# OPTIMIZATION OF ETHANOL ISOLATION FROM MOLASSES FERMENTATION MESH USING BATCH DISTILLATION: SIMULATION WITH SECONDARY DATA VERIFICATION

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Ethanol isolation, Batch distillation, Process optimization

## ABSTRACT

This study focuses on the optimization of ethanol isolation from molasses fermentation mash through batch distillation, employing a simulation approach with secondary data verification. Molasses, a byproduct of sugar production, serves as an economical feedstock for ethanol production. The aim is to enhance the efficiency of the distillation process, maximizing ethanol yield while minimizing energy consumption. The research employs process simulation software to model and analyze the batch distillation of ethanol from molasses fermentation mash. The simulation incorporates secondary data verification, ensuring the accuracy and reliability of the model against experimental results from previous studies. This iterative process allows for the refinement of simulation parameters, ultimately improving the predictive capability of the model. Key factors such as reflux ratio, distillation time, and temperature profile are systematically varied to identify optimal conditions for ethanol isolation. The study also considers the impact of impurities present in the fermentation mash on the distillation process. Through sensitivity analysis, the influence of different variables on ethanol yield and purity is assessed, aiding in the identification of critical parameters for process optimization. Results obtained from the simulation and verified against experimental data reveal insights into the optimal operational conditions for ethanol isolation. The findings contribute to the development of more efficient and sustainable practices in ethanol production from molasses, offering potential economic and environmental benefits. In conclusion, this research bridges the gap between theoretical simulations and practical applications by optimizing the batch distillation process for ethanol isolation from molasses fermentation mash. The incorporation of secondary data verification enhances the reliability of the simulation, providing valuable insights for process engineers and researchers working towards the advancement of ethanol production technologies.

## INTRODUCTION

Currently, the use of alternative energy is being increased to reduce dependence on fuel oil (BBM), one of which is the use of ethanol. In the world of the oil and gas industry in Indonesia, ethanol has a high octane value and can be obtained through the fermentation process by distillation process. The process usually uses fungi, yeast, or bacteria that have a high enough selectivity to produce ethanol (Dhaniswara et al., 2016).

The fermentation process of materials containing glucose to produce ethanol is widely applied in the industrial world. The resulting products can be classified into two, namely as alcoholic beverages such as wine (wine) with a relatively low ethanol concentration (about 7.0-8.5 percent by weight) or as fuel with an ethanol concentration of at least 92.5-93.8 percent by weight or food grade ethanol which in addition to its relatively high ethanol content also does not contain impurities such as fuel oil, vinegar acid, acetaldehyde, and others which are by-products of fermentation. To produce products with a high enough ethanol concentration, a separation process is needed. Generally, the separation process used is using a distillation process (Greetham et al., 2020).

The distillation process is a process of separating mixtures based on their boiling point and relative volatility. Substances with high relative volatility will rise upwards and will be condensed to obtain distillate, while those that fail to evaporate will be taken as residues. Distillation usually uses two stages, namely evaporating and condensing without reflux and the second stage is returning some of the condensed steam to maintain the temperature of the upper tray and increase the concentration of distillate (Sari, 2018).

Distillation is most commonly used for the separation of homogeneous liquid mixtures. Separation is done by taking advantage of the boiling point difference or volatility between the components in a mixture by boiling or evaporating more of the more volatile components (Marnoto et al., 2019).

When a liquid mixture of two components is heated, the steam that comes out will contain more volatile components that are greater than the liquid in the boiler. Conversely, when steam is cooled, materials with higher boiling points tend to condense more easily than components with lower boiling points (Parhi et al., 2019).

The distillation process can be divided into two types: batch distillation and continuous distillation. This batch distillation is widely used in pharmaceuticals, essential oils, and some petroleum products. In the batch distillation column, the feed is first poured into the boiler and no more ingredients are added until the end of the process. The difference that stands out from these two distillation processes is that the material for continuous distillation, the feed is flowed into the column continuously and thus makes the process in steady state condition. For batch processes, components with higher boiling points increase over time (Raytama et al., 2021).

Ethanol itself is the alcohol most often used in everyday life. Because of its non-toxic nature, this material is widely used as a solvent in the pharmaceutical world and the food and beverage industry. Ethanol is colorless and tasteless but has a distinctive odor. Ethanol can be used in pure form or as a mixture of gasoline (gasoline) and hydrogen fuel. The interaction of ethanol with hydrogen can be used as a fuel cell energy source or in conventional internal combustion engines (Soputra et al., 2015).

In this study, ethanol purification will be carried out using batch distillation directly from the fermentation mash and new process optimization will be carried out to get answers to how much purity is produced by batch distillation and how much energy efficiency can be done (Suharto et al., 2020).

## RESEARCH METHODS

### Operation data retrieval

Operation data retrieval is intended to input the data needed to perform the simulation. Data from the *Mash Fermenter* is taken from the ethanol plant. *The mash fermenter* is obtained from PT Indo Acidatama Tbk, in Kebakkramat District, Karanganyar Regency, Central Java. *The mass fermenter* obtained is used for testing in the laboratory using a GC *(gas chromatograph)* tool to obtain content composition data from the *mash fermenter*, which later the data obtained is later used to be tested on *ASPEN plus software* (Wibowo et al., 2018).

### Thermodynamic Model Selection

In research, in particular simulation, to approach simulation conditions with field conditions it is necessary to select the most accurate thermodynamic model. In modeling the ethanol purification system from the *fermenter mash*, the selection of thermodynamic models greatly affects the simulation results (Xia et al., 2023).

For the selection of a proper thermodynamic model in this simulation, it is considered that the distillation system operates at *absolute* pressure and is ideal in Peng-robinson's *thermodynamic model* (Sodeifian et al., 2021).

### Evaluating Energy Consumption

The next step is to evaluate the energy consumption *(operating cost)* used in the process from the configuration simulation *flowsheet*. Energy evaluation includes the use of plant utilities in each distillation including *steam* and *cooling water* (Wei et al., 2012).

## RESULTS AND DISCUSSION

### Process Simulation

In researching the distillation of batch mash fermenters, a predestinate distillate scenario model was made using Aspen Plus software. The model consists of a feed, a distillation batch tower, and a condenser. The purpose of predestinate distillate is to get the best ethanol results in the component separation process. Based on the results obtained, economic calculations were carried out in terms of energy consumption, distillation duration, and price for ethanol obtained (Asadollahzadeh et al., 2017).

This simulation uses the Peng-Robinson thermodynamic model because the feed used in the system in this study is the result of fermentation, which has a fairly diverse component content and is usually distinguished based on the boiling point of the components.

Determine the composition of the feed to be distilled by conducting laboratory testing of the content contained in the mash fermenter with a GC-MS (Gas Chromatoghrap-Mass spectrometry) device (Luyben, 2005).

In the simulation, a fermenter mash feed base of 1000 km/hr was taken. The content of fermented mash in the form of ethanol content is 11%, water is 64%, and isoamyl alcohol is 25%. This distillation is done in batches by evaporating ethanol which has the lowest boiling point among the other 2 components. The boiling point of ethanol is 78.8, water is 100, and °C°Cisoamyl alcohol is 131. TRepeateddistillation or °Credistilate distillate is to obtain a high ethanol content of 99%.

**Re- distillate distillate**

In this simulation, repeated distillation was carried out on the feed, by reconnecting the distillate results *that had been distilled* to achieve 99% ethanol content. Distillation is carried out 3 times with 20 *stages* (Al-hotmani et al., 2020). *A feed* of 1000 kmol enters the first tower and is set at a temperature of 89oC and a pressure of 1 atm with a *reflux of* 1.63, where the value is obtained based on the calculation of the mass balance for the distillation tower. The following *are-distillate distillate* system uses *Aspen Plus v11.*

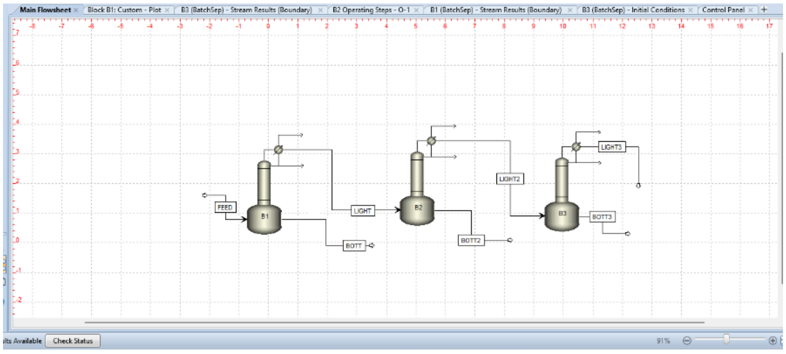



**Figure 1.**
**Flow diagram system *Distlate redistillations***

**B1 Distillation**

In this case, the results obtained are the result of the distillation of tower 1 from a *feed of* 1000 km, the goal of the first distillation is to reduce the isoamyl content *contained in the feed and focus on reducing the* isoamyl. The results of distillation on B1 can be seen in the graph below:

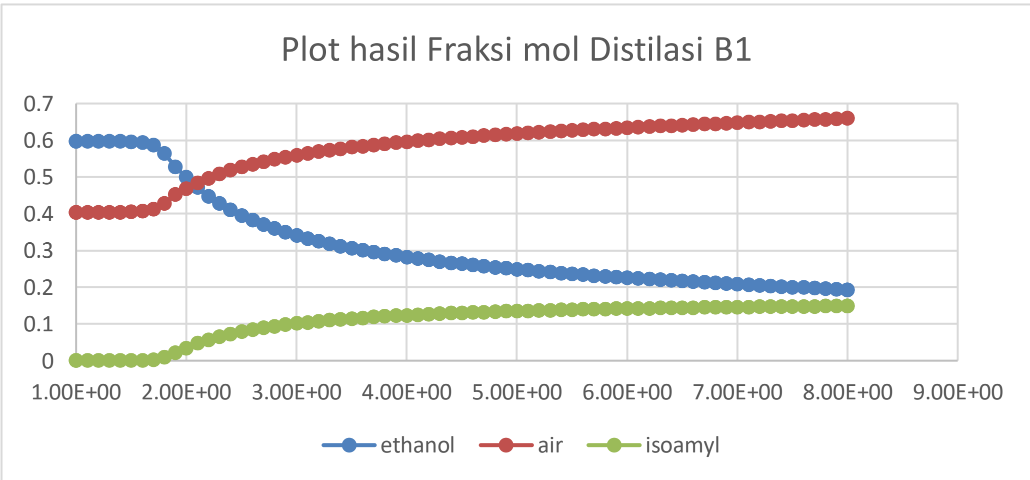



**Figure 2.**
**Plot Graph at Distillation 1**

The results in the graph above show a decrease in ethanol mole levels but an increase in mole levels in *isoamyl* and water. The decrease in ethanol levels from the first 1 hour of distillation to the 8 hours of distillation was significant in ethanol, but compared to the initial mole fraction the ethanol increase increased by 0.7%, and, in the isoamyl mole fraction there was a decrease of 0.9%. the results of the mass fraction produced from *distillate* B1 are shown below:

| | Units | FEED | BOTT | LIGHT | |
|---|---|---|---|---|---|
| **+ Mole Flows** | **kmol/hr** | **1000** | **569,81** | **430,19** | |
| **− Mole Fractions** | | | | | |
| ETHANOL | | 0,11 | 0,0474315 | 0,192875 | |
| WATER | | 0,64 | 0,625754 | 0,658873 | |
| ISOAMYL | | 0,25 | 0,326815 | 0,148253 | |
| **− Mass Flows** | **kg/hr** | **38634,8** | **24084,1** | **14550,6** | |
| ETHANOL | kg/hr | 5067,59 | 1245,1 | 3822,47 | |
| WATER | kg/hr | 11529,8 | 6423,54 | 5106,26 | |
| ISOAMYL | kg/hr | 22037,4 | 16415,5 | 5621,9 | |

**Figure 3.**
**Hasil Stream Result**

In the picture above, it can be seen that there was a decrease in ethanol, in *the initial feed* of 5067.59 kg/hr, but the *distillate* results obtained by 3822.47 kg/hr decreased ethanol by 24.6%. In the water component, there was a decrease of 64%, and *isoamyl alcohol* by 74.45%. Based on the above results, a decrease in *isoamyl* and water levels in the *feed* is achieved, so that it can be continued for distillation to 2.

**Destilasi B2 (Re-distilate B1)**

The B2 distillation process (distillation of the results of distillate from B1) is to increase ethanol levels and reduce *isoamyl* and water levels that are still contained in *B1 distillate*. The graphic results of the mole fraction of ethanol, water, and *isoamyl* distillation B2 can be seen below. In the results of ethanol and water, there was a fairly drastic increase during the first 10 minutes, and there was a decrease in the next 2 hours. This decrease in the mole fraction of ethanol occurs due to the increase in water and *isoamyl* in small amounts but affects ethanol levels. Although there is a decrease in the mole fraction of ethanol, the ratio between *isoamyl* and water levels in B1 distillation results and after re-distillation (B2) can be a concern. *The flow rate* of ethanol can be seen in the *B2 stream result* below:

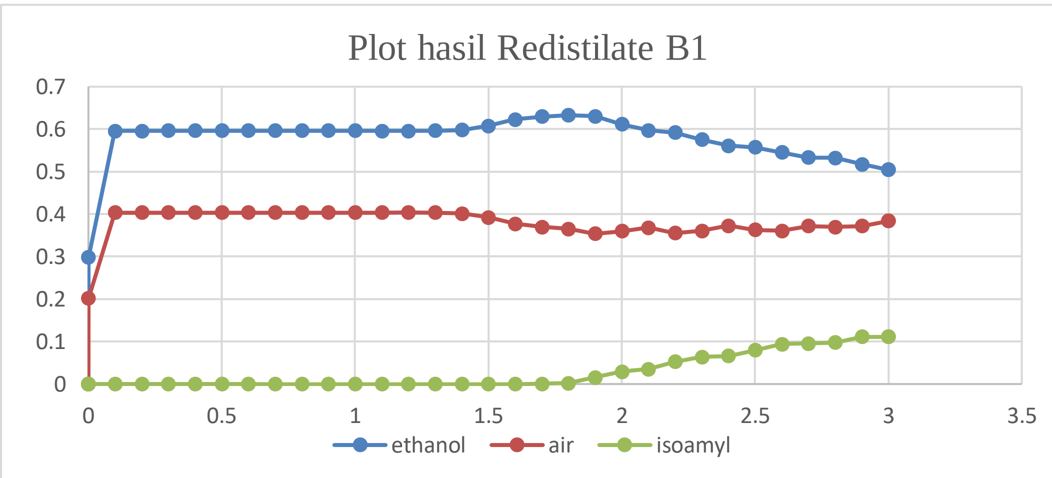



**Figure 4.**
**Hasil Destilat B2 (*Redistilled* B1)**

| | Units | LIGHT | BOTT2 | LIGHT2 |
|---|---|---|---|---|
| − Mole Fractions | | | | |
| ETHANOL | | 0,192875 | 0,0854064 | 0,504321 |
| WATER | | 0,658873 | 0,753675 | 0,384133 |
| ISOAMYL | | 0,148253 | 0,160918 | 0,111547 |
| **− Mass Flows** | **kg/hr** | **14550,6** | **10137,7** | **4412,95** |
| ETHANOL | kg/hr | 3822,47 | 1258,4 | 2564,07 |
| WATER | kg/hr | 5106,26 | 4342,53 | 763,724 |
| ISOAMYL | kg/hr | 5621,9 | 4536,74 | 1085,15 |
| − Mass Fractions | | | | |
| ETHANOL | | 0,262701 | 0,124131 | 0,581033 |
| WATER | | 0,35093 | 0,428356 | 0,173064 |
| ISOAMYL | | 0,386368 | 0,447513 | 0,245902 |
| Volume Flow | l/min | 575,213 | 202,673 | 93,7702 |

**Figure 5.**
***Stream Result* B2**

Based on the results above, the decrease in isoamyl mass *flow and water contained* in B2 distillate compared to the results of *B1 distillate* is quite high, *isoamyl* mass flow from 5621.9 kg/hr to 1085 kg/hr, decreased by 80.8%, water mass flow from 5106.26 kg/hr to 763,723 there was a decrease in mass flow by 85.05 % while in mass flow ethanol from 3822.47 kg/hr to 2564.07 kg/hr, decreased by 32.93%. However, because ethanol levels still have not reached the target of 99%, distillation is carried out again on the results of *distillate* B2.

**Destilase B3 (Re-distilate B2)**

The results of the B3 distillation mole fraction (B2 re-distillate) showed a significant increase in the graph below, especially in the ethanol component that rose and did not decrease for 3 hours of distillation duration. While the water component has increased but decreased levels at distillation time for 2.5 hours, and for the *isoamyl component* there was no increase in levels during the distillation process. Here is a plot of the yield of the B2 mole fraction:

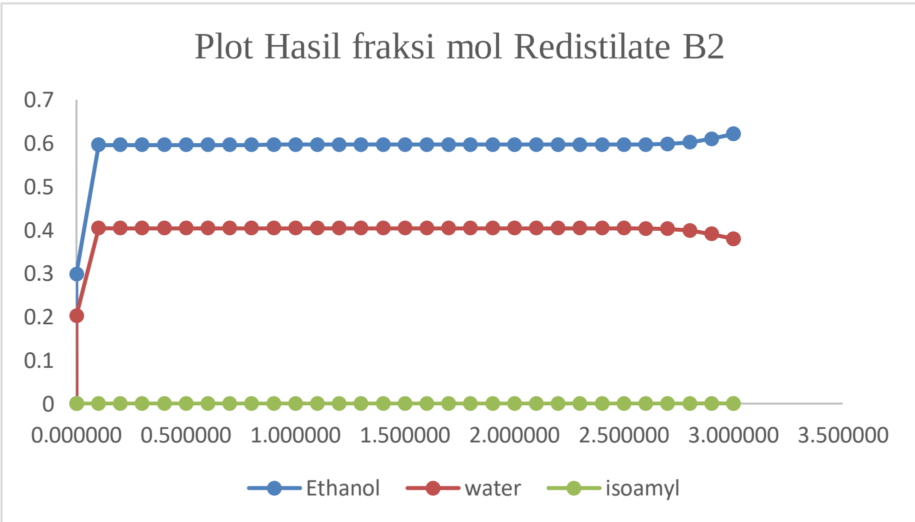



**Figure 6.**

**Re-distillation of distillate B2**

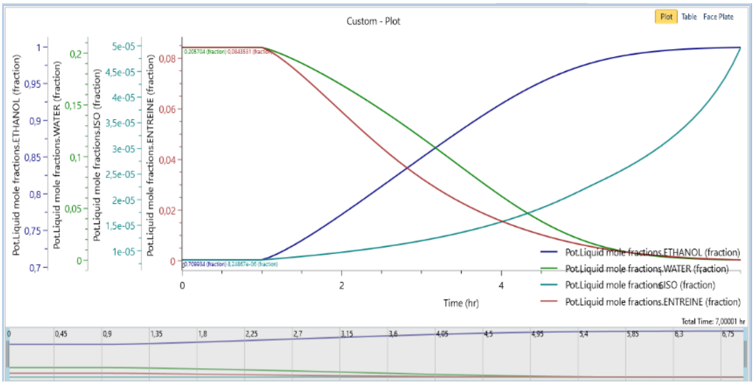
| | Units | LIGHT2 | BOTT3 | LIGHT3 |
|---|---|---|---|---|
| **− Mole Fractions** | | | | |
| ETHANOL | | 0,504321 | 0,27037 | 0,596036 |
| WATER | | 0,384133 | 0,333559 | 0,403959 |
| ISOAMYL | | 0,111547 | 0,396071 | 5,3148e-06 |
| **− Mass Flows** | **kg/hr** | **4412,95** | **1659,01** | **2753,94** |
| ETHANOL | kg/hr | 2564,07 | 387,124 | 2176,95 |
| WATER | kg/hr | 763,724 | 186,765 | 576,959 |
| ISOAMYL | kg/hr | 1085,15 | 1085,12 | 0,0371427 |
| **− Mass Fractions** | | | | |
| ETHANOL | | 0,581033 | 0,233347 | 0,790484 |
| WATER | | 0,173064 | 0,112577 | 0,209503 |
| ISOAMYL | | 0,245902 | 0,654077 | 1,34871e-05 |

**Figure 7.**
***Stream Result* B3**

*The mass rate* of the B3 distillation results can be seen in the picture above. For ethanol decreased by 15.1%, from 2564.07 kg/hr to 2176.95 kg/hr. While water decreased by 24.5%, from 763,724 kg/hr to 576,959 kg/hr and *isoamyl* can be said to have no increase in *flow rate* at the top *(distillate)*. So that the content contained in B3 distillate is only water and ethanol. In the results obtained distillate it is very difficult to obtain ethanol content up to 99% because there is *an azeotrope* between water and ethanol at the point of ethanol at 79% and water at 21%. Therefore, *an entrainer* or the addition of a third component is needed to overcome the *azeotrope* of water and ethanol so that it can be continued for further distillation.

**Distillation B1.2 (Entrainer addition)**

To overcome the *azeotrope* found in water and ethanol, *an entrainer* is added as a third component. The component used as an entrainer is ethyl acetate. Ethyl acetate can bind the water content contained in ethanol so that the boiling point of a mixture of ethyl acetate and water drops to 70oC while ethanol is 78.9oC, and in the results to be obtained, ethanol will be the *bottom* result in distillation, while the top result *(distillate)* will contain rich water and ethyl acetate, then the distillation process can be carried out. The results obtained can be seen in the graph below:




**Gambar 8.**
**Grafik Plot Destilasi B1.2 (Penambahan Entreiner)**

Based on the graph of the component content in the POT *(bottom)* above during distillation of 7 hours, the moisture content and ethyl acetate decreased very significantly, which is because it has risen to distillate at 70oC, while ethanol remains at the bottom. The levels obtained in B1.2 distillation can be seen in the figure below:

| | Units | FEED | BOTT | LIGHT |
|---|---|---|---|---|
| **− Mole Fractions** | | | | |
| ETHANOL | | 0,509367 | 0,990408 | 0,206968 |
| WATER | | 0,31196 | 0,00875002 | 0,50257 |
| ISO | | 5,63e-06 | 1,45852e-05 | 1,55152e-10 |
| ENTREINE | | 0,178668 | 0,000827763 | 0,290463 |
| **− Mass Flows** | **kg/hr** | **4648,33** | **1835,48** | **2812,85** |
| ETHANOL | kg/hr | 2433,23 | 1826,2 | 607,056 |
| WATER | kg/hr | 582,752 | 6,3092 | 576,44 |
| ISO | kg/hr | 0,0514604 | 0,0514585 | 8,70753e-07 |
| ENTREINE | kg/hr | 1632,29 | 2,91902 | 1629,35 |
| **− Mass Fractions** | | | | |
| ETHANOL | | 0,523464 | 0,994944 | 0,215816 |

**Figure 9.**
**Stream Result B1.2**

Based on the picture above, ethanol levels in the mole fraction and mass have met the achievement, which is 99%, because ethyl acetate binds water so that the boiling point of the mixture becomes 70 so it is more *volatile* than ethanol. So the *ethanol mass flow* is 1826.2 Kg/hr.

## CONCLUSION

The conclusions that can be drawn are the content of the fermenter mash in the GC test there are: Water, Isoamyl, and Ethanol, Isoamyl Alcohol which can be optimized using the batch distillation process, The operating scheme of the batch distillation tower for purification of ethanol content from the fermenter mash is the best re-destilling distillate with cut-off at step-1, and obtained Product recovery 24.6% of the amount of feed. In the initial B1 feed of 5067.59 kg/hr, the distillate results obtained by 3822.47 kg/hr decreased ethanol by 24.6%. In the water component, there was a decrease of 64%, and isoamyl alcohol by 74.45%.

in B2 isoamyl mass flow from 5621.9 kg/hr to 1085 kg/hr, there was a decrease of 80.8%, Water mass flow from 5106.26 kg/hr to 763.723 there was a decrease in mass flow by 85.05% while in ethanol mass flow from 3822.47 kg/hr to 2564.07 kg/hr, there was a decrease of 32.93 %. However, because ethanol levels still have not reached the target of 99%, the B3 Mass rate on the results of B3 distillation can be seen in the picture above. For ethanol decreased by 15.1%, from 2564.07 kg/hr to 2176.95 kg/hr. While water decreased by 24.5%, from 763,724 kg/hr to 576,959 kg/hr and isoamyl can be said to have no increase in flowrate at the top (distillate). So that the content contained in B3 distillate is only water and ethanol, in B4 the addition of an entrainer is carried out to achieve the target of 99% because this is very difficult to do because there is azeotrope. After adding the entrainer, the mole fraction and mass were 99% and the ethanol mass flow was 1826.2 Kg/hr.

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