

# **SAMPLE ASSESSMENT REPORT**

**ROY G. PERRY COLLEGE OF ENGINEERING  
MECHANICAL ENGINEERING DEPARTMENT  
PRAIRIE VIEW A&M UNIVERSITY**

**ASSESSMENT REPORT COVER PAGE**

**CHEG 4248 SENIOR DESIGN AND PROFESSIONALISM II**

**SPRING 2022 SEMESTER**

**NAME OF INSTRUCTOR: Dr. Emmanuel A. Dada**

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**Detailed Course Syllabus**  
**(Distributed to Students at the beginning of the Semester)**  
**ABET Outcomes measured using course should be**  
**explicitly listed in the syllabus**

# Course Description in ABET Format

## CHEG 4248: SENIOR DESIGN AND PROFESSIONALISM II

- |                                               |                                                   |
|-----------------------------------------------|---------------------------------------------------|
| 1. Course number and name:                    | CHEG 4248: Senior Design and Professionalism II   |
| 2. Credits, contact hours, categorization:    | 2-Credit Hour, 4-Contact Hours, Engineering Topic |
| 3. Instructor's or course coordinator's name: | Dr. Emmanuel Dada                                 |
| 4. Textbook: Title:                           | Not Required                                      |
- Author:
- Publisher, Year & Edition:
- a. Other Supplemental material
1. "Chemical Process Engineering: Design & Economics," by Harry Silla, 2003, Marcel Dekker, ISBN 0-8247-4274-5.
  2. "Analysis, synthesis and Design of Chemical Processes" by Richard Turton, Richard C. Bailie, Wallace B. Whitting, Joseph A. Schaeiwitz and Debangsu Bhattacharrya, 4th Edition, 2012, Prentice Hall, ISBN-13: 9780132618120
  3. "Plant Design and Economics for Chemical Engineers" by Peters, M.S., K.D. Timmerhaus and R.E. West, 5th edition, 2003, McGraw-Hill, ISBN 0—07-2392665.
  4. "Fundamentals of Engineering Design", by Barry Hyman, 2nd edition, 2003, Pearson Education, Inc. (Prentice Hall), ISBN 0-13-046712-X
  5. "Chemical Engineering Process Design and Economics: A Practical Guide" by Gael D. Ulrich and Palligarnai T. Vasudevan, 2nd Edition, 2004, Process (Ulrich) Publishing, ISBN0-9708768-2-3
  6. "Senior Project Manual" by Prairie View A & M University College of Engineering
5. Specific course information
- a. Brief description of the content of the course (catalog description)
- CHEG 4248 (2:0) Credit 2 semester hours. This is the second course of a two-semester capstone experience (CHEG 4248 must immediately follow CHEG 4247 or the sequence must restart with CHEG 4247) involving the engineering design of an industrial or advanced team project. Elements of ethics and professionalism in engineering practice are integrated into the project experience. The project will include the application of relevant engineering codes and standards, as well as realistic constraints. Design achievements are demonstrated with written reports, oral presentations, professional standards, and ethics examinations.
- b. Prerequisites
- CHEG 3301, CHEG 3302, CHEG 3305, CHEG 3306, and CHEG 4247.
- c. \*Indicate whether a required, elective, or selected elective (as per
- Required

definition provided) course in the program

6. Specific goals for the course

a. specific outcomes of instruction

Students will be able to :

1. Be able to design a system, component, or process to meet desired needs.
2. Demonstrate an understanding of professional and ethical responsibility.
3. Be able to demonstrate the broad education necessary to understand the impact of engineering solutions in a global and societal context.
4. Be able to recognize the need for and ability to engage in life-long learning.
5. Demonstrate knowledge of contemporary issues.

b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.

This course addresses the following student learning outcome determined by the department:

Outcome 2:

Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

Outcome 3:

An ability to communicate effectively with a range of audiences.

Outcome 5:

Ability to (i) function effectively on a team whose members together (ii) provide leadership, create a collaborative and inclusive environment, (iii) establish goals, plan tasks, and meet objectives.

7 Brief list of topics to be covered

1. Course overview & Manual: Meeting Agreement; Review of group dynamics.
2. Project constraints, tasks and GANTT charts.
3. Finalized Material/Energy balances and updated literature review.
4. Process design: Process simulation using HYSYS/ASPEN and Safety Review; Hazards, operability, and inherent safety (HAZOP analysis).
5. Design of major equipment, codes, and standards and HAZOP analysis.
6. Design equations and heuristics, codes, and standards.
7. Process Design and Analysis: Materials selection, equipment specification, and economic evaluation.
8. Capital costs, operating costs, and return on investment.
9. Final project presentation and report

## Additional Course Syllabus Information

| Information Item               | Information                                                                      |
|--------------------------------|----------------------------------------------------------------------------------|
| <b>Instructor:</b>             | Dr. Emmanuel Dada                                                                |
| <b>Section # and CRN:</b>      | P02 CRN 20557; P82 CRN 20558                                                     |
| <b>Office Location:</b>        | C.L. Wilson 201 B                                                                |
| <b>Office Phone:</b>           | 936-261-9968                                                                     |
| <b>Email Address:</b>          | <a href="mailto:eadada@pvamu.edu">eadada@pvamu.edu</a> ; emmanuel.dada@ymail.com |
| <b>Office Hours:</b>           | Virtual: MWF 10:00 a.m. – 2:00 p.m.                                              |
| <b>Mode of Instruction:</b>    | Hybrid/Internet-(a)Synchronous Instructional Method                              |
| <b>Course Location:</b>        | New Electrical Engr Bldg 115 (T); C L Wilson Engineering Bldg 109K (R)           |
| <b>Class Days &amp; Times:</b> | T 3:30 – 4:20 p.m.;<br>R 3:30 - 6:20 p.m.                                        |

### General Course Information Table

**Access to Learning PVAMU**  
**Resources:** phone: (936) 261-

University Bookstore: phone:

Library:  
 1500; web:  
<http://www.tamu.edu/pvamu/library/>(936)  
 261-1990;  
 web: <https://www.bkstr.com/Home/10001-10734-1?demoKey=d>

### Course Goals or

The

goal of this course is to provide a capstone design experience for chemical engineering students who have completed all of their design coursework at the junior level and below.

### Overview:

## Course Outcomes/Objectives

At the end of this course, the student will have achieved and demonstrated the following outcomes.

- 1 Be able to design a system, component, or process to meet desired needs.
- 2 Demonstrate an understanding of professional and ethical responsibility.
- 3 Be able to demonstrate the broad education necessary to understand the impact of engineering solutions in a global and societal context.
- 4 Be able to recognize the need for and ability to engage in life-long learning.
- 5 Demonstrate a knowledge of contemporary issues

## Course Requirements & Evaluation Methods

This course will utilize the following instruments to determine student grades and proficiency of the learning outcomes for the course. Continuous assessment of students' homework assignments, oral presentations and written design reports will be used to evaluate their competence in ABET student outcomes 2 (ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors), 3 (an ability to communicate effectively with a range of audiences), and 5

(ability to (i) function effectively on a team whose members together (ii) provide leadership, create a collaborative and inclusive environment, (iii) establish goals, plan tasks, and meet objectives).

**Presentation** – oral presentations, some of which are graded, to develop and demonstrate an ability to communicate effectively in oral mode.

**Homework Exercises** – written assignments, often in letter report format, designed to supplement and reinforce course material. The letter report format serves to develop and demonstrate an ability to communicate effectively in written mode.

**Quizzes** – announced or surprise in-class assignments to promote student accountability **Project Report** – the central feature of this course is an open ended design project on a relevant, contemporary, technical problem in the student's discipline. The report is the medium by which design accomplishments are demonstrated and also serves to develop and demonstrate an ability to communicate effectively in written mode.

**Class Participation** – daily attendance and participation in class discussions

**Grading Matrix** (points will vary according to instructor's grading system)

| Instrument                                      | Total       |
|-------------------------------------------------|-------------|
| Homework Assignments                            | 5%          |
| Midterm progress report                         | 5%          |
| Final presentation                              | 70%         |
| Final project report                            | 20%         |
| <b>Total</b>                                    | <b>100%</b> |
| Discount for lack of participation              | -10%        |
| <i>Extra credit (as assigned by instructor)</i> |             |

### Grade Determination:

A = 100 – 90pts;  
B = 89 – 80pts; C  
= 70 – 79pts; D =  
60 – 69pts;  
F = 59pts or below

## Course Procedures

### Textbook Policy

Students must acquire the textbook that is listed as “required” on the course syllabus. The textbook must be acquired by the 10<sup>th</sup> class day. Students are not allowed to share textbooks with other students who are currently registered in the same class. Failure to acquire (or show proof of purchase) the required textbook by the 10<sup>th</sup> class day will result in the student being administratively dropped from the course. The University will assess financial obligations for the course to the student as with any other dropped class according to the fee schedule. In addition, your financial aid may be affected by the subsequent registration action(s).

Go to <http://www.pvamu.edu/pages/195.asp> for the Roy G. Perry College of Engineering Textbook Policy.

### Conduct:

1. Students will conduct themselves in a manner that is respectful to their fellow classmates and the instructor at all times.
2. **Cell phones, ipads and smart phones or similar electronic devices MUST** be turned off and stowed away during class time. Students are **NOT** allowed to leave class to answer cell phones or use these devices.
3. Students caught using ipads and smart phones or similar electronic devices during exams will receive **ZERO** for the exam and be subject to sanctions as stipulated under **Academic Misconduct**.
4. Students should be prepared to stay in the classroom for the duration of the exam. Students who have any condition that may require them to leave the exam room should make prior arrangements with the Instructor. Students who decide to leave the exam room for any other reason must handover their exam paper and consider the exam over for them.
5. Programmable calculators are **NOT** allowed in class.

6. Students should dress professionally and are **NOT** allowed to wear caps/hats in class.
7. Students are NOT allowed to bring food to the classroom or eat in class
8. Arrive to class prepared to discuss lesson with your project binder.

## Submission of Assignments:

There will be project assignments, reports and presentations. All presentations will be team presentations and each student is required to contribute to the success of the team. It is recommended that a member of the group be assigned the duty of recorder, and maintain the minutes of meetings (with listing of attendees) and a notebook with pertinent information. Individual reports are to be submitted at mid term and at the end of the semester detailing the contribution of each team member. A team report is to be submitted at midterm and a final report is to be submitted at the end of the semester. **In the event that it becomes necessary to remove a member from a team, the following procedure must be followed:**

- The team minus the affected member, must meet to discuss the action to be taken.
- The team must then meet with the affected student and discuss the action to be taken.
- A letter must be submitted to the instructor giving justification for the action to be taken. The letter must be signed by all team members and a copy must be sent to the affected student.
- The instructor will then schedule a meeting with the team members and the affected student for final discussion and appropriate action.

*All homework assignments are due directly to the Instructor, prior to the start of class or the assignment will not be accepted. All homework assignments and exams should be written on one side of the page only, and should use the appropriate cover sheet, with the name, assignment title and date. All pages should be numbered. Failure to use the correct cover sheet will result in the assignment grade being reduced by 20%.*

**Formatting Documents:** Microsoft Word is the standard word processing tool used at PVAMU. If you're using other word processors, be sure to use the "save as" tool and save the document in either the Microsoft Word, Rich-Text, or plain text format. **Exam Policy**

Exams should be taken as scheduled. No makeup examinations will be allowed except under documented emergencies (See Student Handbook).

## Professional Organizations and Journals

*As directed by instructor.*

## References

*As directed by instructor.*

## 16 WEEK CALENDAR

|                          |                                                                                                                                   |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| <b>Week One:</b> Topic   | Course overview & Manual: Meeting Agreement; Review of group dynamics                                                             |
| Chapter (s):             |                                                                                                                                   |
| Assignment (s):          | Reading: Group dynamics                                                                                                           |
| <b>Week Two:</b> Topic   | Project constraints, tasks and GANTT chart                                                                                        |
| Chapter (s):             |                                                                                                                                   |
| Assignment (s):          | Homework 1: Group dynamics and GANTT chart                                                                                        |
| <b>Week Three:</b> Topic | Finalized Material/Energy balances and updated literature review                                                                  |
| Chapter (s):             |                                                                                                                                   |
| Assignment (s):          | Homework 2                                                                                                                        |
| <b>Week Four:</b> Topic  | Process design: Process simulation using HYSYS/ASPEN and Safety Review; Hazards, operability and inherent safety (HAZOP analysis) |
| Chapter (s):             |                                                                                                                                   |
| Assignment (s):          | Homework 3                                                                                                                        |
| <b>Week Five:</b> Topic  | Design of major equipment, codes and standards and HAZOP analysis                                                                 |

Chapter (s):  
Assignment (s):                      Reading: Design equations and heuristics, codes and standards

**Week Six:** Topic                      Design of major equipment, HAZOP analysis  
Chapter (s):  
Assignment (s):                      Homework 4

**Week Seven:** Topic                      Design of major equipment  
Chapter (s):  
Assignment (s):                      Reading: Codes and standards

**Week Eight:** Topic                      Design of major equipment  
Chapter (s):  
Assignment (s):                      **Mid Term**

**Week Nine:** Topic  
Chapter (s):  
Assignment (s):                      **Spring Break**

**Week Ten:** Topic                      Process Design and analysis: Materials selection  
Chapter (s):  
Assignment (s):                      Reading: Materials selection

**Week Eleven:** Topic                      Process Design and analysis: Equipment specification  
Chapter (s):  
Assignment (s):                      Reading: Mechanical engineering design and Plant layout

**Week Twelve:** Topic                      Process Design and analysis: Process control; final safety review and HAZOP analysis  
(s):  
Assignment (s):                      Reading: Process control and instrumentation

**Week Thirteen:** Topic                      Process Design and analysis: Economic Evaluation  
Chapter (s):  
Assignment (s):                      Capital costs, operating costs and return on investment

**Week Fourteen:** Topic                      Process Design and Analysis: Outline of project presentation  
Chapter (s):  
Assignment (s):                      Completion of detailed plant design

**Week Fifteen:** Topic                      Course Review  
Chapter (s):  
Assignment (s):                      Final draft of project report due

**Week Sixteen**                      **Final Presentation; Final Report due**

## University Rules and Procedures

### Disability statement (See Student Handbook):

Students with disabilities, including learning disabilities, who wish to request accommodations in class should register with the Services for Students with Disabilities (SSD) early in the semester so that appropriate arrangements may be made. In accordance with federal laws, a student requesting special accommodations must provide documentation of their disability to the SSD coordinator.

## Academic misconduct (See Student Handbook):

You are expected to practice academic honesty in every aspect of this course and all other courses. Make sure you are familiar with your Student Handbook, especially the section on academic misconduct. Students who engage in academic misconduct are subject to university disciplinary procedures.

## Forms of academic dishonesty:

1. Cheating: deception in which a student misrepresents that he/she has mastered information on an academic exercise that he/she has not mastered; giving or receiving aid unauthorized by the instructor on assignments or examinations.
2. Academic misconduct: tampering with grades or taking part in obtaining or distributing any part of a scheduled test.
3. Fabrication: use of invented information or falsified research.
4. Plagiarism: unacknowledged quotation and/or paraphrase of someone else's words, ideas, or data as one's own in work submitted for credit. Failure to identify information or essays from the Internet and submitting them as one's own work also constitutes plagiarism.

## Nonacademic misconduct (See Student Handbook)

The university respects the rights of instructors to teach and students to learn. Maintenance of these rights requires campus conditions that do not impede their exercise. Campus behavior that interferes with either (1) the instructor's ability to conduct the class, (2) the inability of other students to profit from the instructional program, or (3) campus behavior that interferes with the rights of others will not be tolerated. An individual engaging in such disruptive behavior may be subject to disciplinary action. Such incidents will be adjudicated by the Dean of Students under nonacademic procedures.

## Sexual misconduct (See Student Handbook):

Sexual harassment of students and employers at Prairie View A&M University is unacceptable and will not be tolerated. Any member of the university community violating this policy will be subject to disciplinary action.

## Attendance Policy:

Prairie View A&M University requires regular class attendance. Excessive absences will result in lowered grades. Excessive absenteeism, whether excused or unexcused, may result in a student's course grade being reduced or in assignment of a grade of "F". Absences are accumulated beginning with the first day of class.

## Student Academic Appeals Process

Authority and responsibility for assigning grades to students rests with the faculty. However, in those instances where students believe that miscommunication, errors, or unfairness of any kind may have adversely affected the instructor's assessment of their academic performance, the student has a right to appeal by the procedure listed in the Undergraduate Catalog and by doing so within thirty days of receiving the grade or experiencing any other problematic academic event that prompted the complaint.

## Technical Considerations for Online and Web-Assist Courses

### Minimum Hardware and Software Requirements:

- Pentium with Windows XP or PowerMac with OS 9
- 56K modem or network access
- Internet provider with SLIP or PPP
- 8X or greater CD-ROM
- 64MB RAM

- Hard drive with 40MB available space
- 15" monitor, 800x600, color or 16 bit

- Sound card w/speakers
- Microphone and recording software
- Keyboard & mouse
- Netscape Communicator ver. 4.61 or Microsoft Internet Explorer ver. 5.0 /plug-ins

Participants should have a basic proficiency of the following computer skills:

- Sending and receiving email
- A working knowledge of the Internet
- Proficiency in Microsoft Word
- Proficiency in the Acrobat PDF Reader
- Basic knowledge of Windows or Mac O.S.

**Netiquette (online etiquette):** students are expected to participate in all discussions and virtual classroom chats when directed to do so. Students are to be respectful and courteous to others in the discussions. Foul or abusive language will not be tolerated. When referring to information from books, websites or articles, please use APA standards to reference sources.

**Technical Support:** Students should call the Prairie View A&M University Helpdesk at 936-261-2525 for technical issues with accessing your online course. The helpdesk is available 24 hours a day/7 days a week. For other technical questions regarding your online course, call the Office of Distance Learning at 936-261-3290 or 936-261-3282

## Communication Expectations and Standards:

All emails or discussion postings will receive a response from the instructor within 48 hours.

You can send email anytime that is convenient to you, but I check my email messages continuously during the day throughout the work-week (Monday through Friday). I will respond to email messages during the work-week by the close of business (5:00 pm) on the day following my receipt of them. Emails that I receive on Friday will be responded to by the close of business on the following Monday.

## Submission of Assignments:

Assignments, Papers, Exercises, and Projects will be distributed and submitted through your online course. Directions for accessing your online course will be provided. Additional assistance can be obtained from the Office of Distance Learning.

## Discussion Requirement:

Because this is an online course, there will be no required face to face meetings on campus. However, we will participate in conversations about the readings, lectures, materials, and other aspects of the course in a true seminar fashion. We will accomplish this by use of the discussion board.

Students are required to log-on to the course website often to participate in discussion. It is strongly advised that you check the discussion area daily to keep abreast of discussions. When a topic is posted, everyone is required to participate. The exact use of discussion will be determined by the instructor.

**It is strongly suggested** that students type their discussion postings in a word processing application and save it to their PC or a removable drive before posting to the discussion board. This is important for two reasons: 1) If for some reason your discussion responses are lost in your online course, you will have another copy; 2) Grammatical errors can be greatly minimized by the use of the spell-and-grammar check functions in word processing applications. Once the post(s) have been typed and corrected in the word processing application, it should be copied and pasted to the discussion board.

## Video Conferencing Etiquette

When using Zoom, WebEx or other video conferencing tools, confirm the visible area is tidy, clear of background clutter, inappropriate or offensive posters, and other distractions. Ensure you dress appropriately and avoid using high traffic or noisy areas. Stay muted when you are not speaking and avoid eating/drinking during session. Before class session begins, test audio, video and lighting to alleviate technology issues. **Technical Support**

Students should go to the [Password Reset Tool](#) if they have password issues. The page will provide instructions for resetting passwords and contact information if login issues persist. For other technical questions regarding eCourses, call the Center for Instructional Innovation and Technology Services (CIITS) at 936-261-3283 or email [ciits@pvamu.edu](mailto:ciits@pvamu.edu).

## Communication Expectations and Standards

Emails or discussion postings will receive a response from the instructor, usually in less than 48 hours. Urgent emails should be marked as such. Check regularly for responses.

## Discussion Requirement

Online courses often require minimal to no face-to-face meetings. However, conversations about the readings, lectures, materials, and other aspects of the course can take place in a seminar fashion. This will be accomplished by the use of the discussion board. The exact use of discussion will be determined by the instructor.

**It is strongly suggested** that students type their discussion postings in a word processing application such as Word and save it to their PC or a removable drive before posting to the discussion board. This is important for two reasons: 1) If for some reason your discussion responses are lost in your online course, you will have another copy; 2) Grammatical errors can be greatly minimized by the use of the spell-and-grammar check functions in word processing applications. Once the post(s) have been typed and corrected in the word processing application, copy and paste to the discussion board.

## COVID-19 Campus Safety Measures

To promote public safety and protect students, faculty, and staff during the COVID-19 pandemic, Prairie View A&M University has adopted policies and practices for the Fall 2020 academic term to limit virus transmission. Students must observe the following practices while participating in face-to-face courses and course-related activities (office hours, help sessions, transitioning to and between classes, study spaces, academic services, etc.):

- **Self-monitoring** - Students should follow CDC recommendations for self-monitoring. Students who have a fever or exhibit symptoms of COVID-19 should participate in class remotely and should not participate in face-to-face instruction.
- **Face Coverings** - Face coverings (cloth face covering, surgical mask, etc.) must be properly worn in all non-private spaces including classrooms, teaching laboratories, common spaces such as lobbies and hallways, public study spaces, libraries, academic resource and support offices, and outdoor spaces where 6 feet of physical distancing is difficult to reliably maintain.
- **Physical Distancing** - Physical distancing must be maintained between students, instructors, and others in course and course-related activities.
- **Classroom Ingress/Egress** - Students must follow marked pathways for entering and exiting classrooms and other teaching spaces. Students should leave classrooms promptly after course activities have concluded, should not congregate in hallways and should maintain 6-foot physical distancing when waiting to enter classrooms and other instructional spaces.
- **Face-to-face Class** - To attend a face-to-face class, students must wear a face covering (or a face shield if they have an exemption letter). If a student refuses to wear a face covering, the instructor should ask the student to leave and join the class remotely. If the student does not leave the class, the faculty member should report that student to the Office for Student Conduct for adjudication. Additionally, the faculty member may choose to teach that day's class remotely for all students.

- **COVID-19 Guidelines for Student Conduct Adjudication** - The mandatory COVID-19 Training/Certification taken by all students serves as the 1st Warning for violation of COVID-19 Guidelines.
  - 1<sup>st</sup> incident: upon review of Incident Report and finding of responsibility — Conduct Probation
  - 2<sup>nd</sup> incident: upon review of Incident Report and finding of responsibility — Suspension
  - Consult the Code of Student Conduct in the Student Planner or [Student Conduct website](#) for additional information on Conduct Probation and Suspension.
- **Personal Illness and Quarantine** - Students required to quarantine must participate in courses and course-related activities remotely and must not attend face-to-face course activities. Students should notify their instructors of the quarantine requirement. Students under quarantine are expected to participate in courses and complete graded work unless they have symptoms that are too severe to participate in course activities. Students experiencing personal injury or illness that is too severe for the student to attend class qualify for an excused absence. To receive an excused absence, students must provide appropriate documentation to the Office for Student Conduct, [studentconduct@pvamu.edu](mailto:studentconduct@pvamu.edu).

## End of Semester Course Assessment Report

**This summary contains the following Information**

### **1. Performance Statistics**

- Total number of students in class
- The class average performance **(stated as %)** in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department. **You cannot use any number of your choice**
- Percentage of students who scored below the expected average in each outcome.

### **2. Implementation Summary**

- Brief summary of plans implemented during the semester based on last assessment report

### **3. Perceived Problems**

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

#### 4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

#### 5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

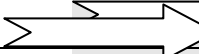
#### 5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer NO.

# END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT CHEG 4482-P02

## SENIOR DESIGN & PROFESSIONALISM II SPRING 2022 SEMESTER

Report Prepared by: Dr. Emmanuel A. Dada    Date: July 14, 2022

| Semester                      | Analysis Type                                                                                                                                                       | Number of Student s                                                                                                                                                                                                                                           | Outcome 2<br>Ability to design a system, component or process |                                                  |               |                                                                                                                                                                                                                                                  | Outcome 3<br>Oral and written communication skills |                                                  |               |                                                                                                                                                                                                                                                                                 | Outcome 5<br>Ability to function in multi-disciplinary teams |                                                  |               |                                      |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------|---------------|--------------------------------------|
|                               |                                                                                                                                                                     |                                                                                                                                                                                                                                                               | Expected Class Average                                        | Expected Percent of students at or above average | Class Average | % Student s meeting Expected Average                                                                                                                                                                                                             | Expected Class Average                             | Expected Percent of students at or above average | Class Average | % Student s meeting Expected Average                                                                                                                                                                                                                                            | Expected Class Average                                       | Expected Percent of students at or above average | Class Average | % Student s meeting Expected Average |
| Spring 2022                   | Direct                                                                                                                                                              | 22                                                                                                                                                                                                                                                            | 75                                                            | 70                                               | 83            | 100                                                                                                                                                                                                                                              | 75                                                 | 70                                               | 83            | 91                                                                                                                                                                                                                                                                              | 75                                                           | 70                                               | 86            | 100                                  |
| Spring 2021                   | Direct                                                                                                                                                              | 26                                                                                                                                                                                                                                                            | 75                                                            | 70                                               | 83            | 100                                                                                                                                                                                                                                              | 75                                                 | 70                                               | 85            | 85                                                                                                                                                                                                                                                                              | 75                                                           | 70                                               | 86            | 100                                  |
|                               |                                                                                                                                                                     |                                                                                                                                                                                                                                                               |                                                               |                                                  |               |                                                                                                                                                                                                                                                  |                                                    |                                                  |               |                                                                                                                                                                                                                                                                                 |                                                              |                                                  |               |                                      |
| Implementation Summary        | Items implemented from previous report or after meeting previous instructor<br>    | -Lectures given to cover the design of major equipment<br>-Review codes for pressure vessel and heat exchanger design<br>-Classes coordinated with the PVAMU Library in Fall 2019 to teach student how to locate and use reference materials                  |                                                               |                                                  |               | Students were required to submit progress report drafts throughout the semester along with a rough draft of the final report. Corrections and feedback were provided to the students in time for them to make edits before the final submission. |                                                    |                                                  |               | Group members were required to submit confidential evaluation with every group assignment. Team leader compiled meeting minutes, completed tasks summaries, an action items for the group at the end of each week to assess group dynamics and performance.                     |                                                              |                                                  |               |                                      |
| Perceived Problems            | Perceived problems are directly related to the PC and the sub items under them<br> | -Students have difficulty applying relevant design equations to process components in the proper units<br>-Students have a weak sense of correct order magnitude for correct sizing                                                                           |                                                               |                                                  |               | Some grammatical errors and some students not following instructions on how to write summaries and the use of the College of Engineering Senior Design Report Manual partly affected report quality.                                             |                                                    |                                                  |               | Conflicting work schedules and lack of participation by some group members prevented some teams meeting their project milestones in a timely manner.                                                                                                                            |                                                              |                                                  |               |                                      |
| Plans for Addressing Problems | Plans for address specific measures to address PC and their sub areas<br>        | Recommendations:<br>-Continue to assign component design homework problem in the early part of the semester<br>-Add a design assignment at the end of CHEG 4472 (Fall semester) on a simpler system (HEX or pressure changer) for students to gain experience |                                                               |                                                  |               | The instructor should:<br>Continue to require draft reports and progress reports to students to critique and identify strong and weak points and how grammar, clarity and organization could be improved.                                        |                                                    |                                                  |               | Recommendations:<br>-Continue to require student confidential group evaluations.<br>-Utilize individual assessments where there is an opportunity<br>-Continue to have team leaders submit weekly records of meeting minutes and summaries of completed tasks and action items. |                                                              |                                                  |               |                                      |
| Overall Trend over Periods    | Ascertain if there were improvements over previous semesters                                                                                                        | Students' performance over the two-semester period was above the expected average. And for both semesters, there is a slight improvement from 2021 avg 82.6% to 2022 semester avg 83%.                                                                        |                                                               |                                                  |               | 91 % of students in the 2022 spring semester met the expected class average better than 85% of students in spring semester that met the expected average.                                                                                        |                                                    |                                                  |               | Students' performance over the two-semester period was above the expected average. And for both semesters, there is a slight improvement from 2021 avg 85.6% to 2022 semester avg 86.4%.                                                                                        |                                                              |                                                  |               |                                      |

|                        |                                                                                               |     |     |     |
|------------------------|-----------------------------------------------------------------------------------------------|-----|-----|-----|
| Were Expectations Met? | Class Average $\geq 75\%$ and $\geq 70\%$ of Students Performed at or Above Expected Average. | YES | YES | YES |
|------------------------|-----------------------------------------------------------------------------------------------|-----|-----|-----|

**Grade Sheet Showing  
Student and Class Performance in Outcomes  
The computed semester average in each outcome  
as stated in the Assessment report are  
highlighted in boldface**

**Grade Sheet Showing Student and Class Performance in Course Outcomes**  
**CHEG 4248 SPRING 2022 Semester**

|                                            | OUTCOME 2 | OUTCOME 3 | OUTCOME 5 |
|--------------------------------------------|-----------|-----------|-----------|
|                                            | 83        | 84        | 85        |
|                                            | 83        | 83        | 85        |
|                                            | 83        | 83        | 85        |
|                                            | 83        | 85        | 85        |
|                                            | 83        | 85        | 93        |
|                                            | 85        | 82        | 93        |
|                                            | 85        | 83        | 93        |
|                                            | 85        | 82        | 93        |
|                                            | 85        | 83        | 93        |
|                                            | 78        | 84        | 90        |
|                                            | 78        | 82        | 90        |
|                                            | 78        | 81        | 90        |
|                                            | 78        | 80        | 90        |
|                                            | 87        | 90        | 80        |
|                                            | 87        | 88        | 80        |
|                                            | 87        | 88        | 80        |
|                                            | 87        | 87        | 80        |
|                                            | 82        | 83        | 83        |
|                                            | 82        | 69        | 83        |
|                                            | 82        | 89        | 83        |
|                                            | 82        | 74        | 83        |
|                                            | 82        | 76        | 83        |
| Class Average                              | 83.0      | 82.7      | 86.4      |
| Standard Deviation                         | 3.0       | 4.9       | 4.9       |
| Expected Class Average                     | 75        | 75        | 75        |
| Expected percent of students above average | 70        | 70        | 70        |
| Total number of students                   | 22        | 22        | 22        |
| % Students meeting Expected Average        | 100       | 91        | 100       |

**OUTCOME SPECIFIC ASSIGNMENTS  
USED TO ASSESS OUTCOMES**

**(Provide at least two assignments used to specifically measure each outcome and justify the suitability of the assignments for the outcome being measured)**



## **ASSIGNMENTS FOR OUTCOME 2**

Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

**CHEMICAL ENGINEERING DEPARTMENT  
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET  
SENIOR DESIGN & PROFESSIONALISM II  
SPRING 2022**

**Instructor: Dr. Emmanuel A. Dada**

**Title of Assignment**

**Final Project Report**

**Outcome Measured Using this Assignment**

**Outcome 2**

**An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factor.**

**Check the engineering design characteristics related to this assignment**

|   |                                                                                                                                                    |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------|
| X | Involves identifying the specific needs to be met by defining/understanding the problem and developing plans for the project to satisfy the need   |
| X | Involves conducting a review of the literature and performing preliminary design by generating alternative ideas/solutions and applying creativity |
| X | Involves performing detailed engineering design leading to specification and fabrication/selection of components for system being designed.        |
| X | Involves consideration of one or more of the following (Please check those involved in this assignment.)                                           |
|   | Public health                                                                                                                                      |
| X | Safety and welfare                                                                                                                                 |
| X | Global factors                                                                                                                                     |
|   | Cultural factors                                                                                                                                   |
|   | Social factors                                                                                                                                     |
| X | Environmental factors                                                                                                                              |
| X | Economic factors                                                                                                                                   |
|   |                                                                                                                                                    |

**Brief justification of why this assignment is suitable for this outcome**

Information provided is a portion of the final project report that demonstrates students ability to communicate through formal technical report writing, and the rubric used to score this outcome for one of the groups

## End of Semester Project Report Format

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#### 1. Letter of Transmittal

The letter of transmittal captures the main points in in the EXECUTIVE SUMMARY.

(i) It clearly spells out why the report has been prepared.

(ii) Essential results, conclusions and recommendations are presented

See your College of Engineering Senior Design Manual for an example.

#### 2. The EXECUTIVE SUMMARY

Your Executive Summary is a carefully distilled form of your complete design report and should have the following components:.

- (a) It should clearly state the need for the design and its objectives
- (b) It should clearly summarize what was done and main findings ( process and production capacity, plant location and plant design and capital cost estimates, the capital investment , return on investment including, discounted cash flow internal rate of return, payback period etc)
- (c) How the final results were obtained
- (d) Clearly presented conclusions and recommendations.

## **Design Constraints and Design Basis**

### **External constraints:**

- 1. Physical laws
- 2. Standards and codes
- 3. Economic
- 4. Government and safety regulations
- 5. Resources

### **Internal constraints:**

- 1. Choice of process
- 2. Process conditions
- 3. Materials and equipment
- 4. Time (for completion of design)
- 5. Personnel

### **Setting the Design Basis**

- 1. Production rate
- 2. Purity specifications of the main product
- 3. The system of units to be used
- 4. The national, local, or company design codes that must be followed
- 5. Details of raw materials that are available

6. Information on potential sites where the plant might be located, including climate data, seismic conditions, and infrastructure availability
7. Information on the conditions, availability, and price of utility services such as fuel gas, steam, cooling water, process air, process water, and electricity that will be needed to run the process

---

The grading rubrics for evaluation of the Senior Design II projects CHEG 4248 (a continuation of the the fall 2021 Senior Design I CHEG 4247) are presented below. The students are to be evaluated as outlined in the rubrics with emphasis on the following:

- 
- Justification of plant location and capacity
  - Provide a process description and Process Flow Diagram (PFD) for the plant showing the major items of equipment, and indicating the materials of construction and the operating temperatures and pressures
  - Material and energy balances with summary table for the process with streams information showing a mass balance for each major equipment
  - A complete HYSYS/ASPEN simulation report of the process
  - Chemical engineering design of major equipment such as (i) reactor(s), (ii) absorption column(s) and (iii) distillation columns
  - Estimates of the Major Equipment Capital Cost (Capex)
  - Estimates of Operating Cost (Opex)
  - Preparation of a net present value and investor's rate of return analysis for the investment over a 15-year life, assuming the company's current capital hurdle rate is 15%.
  - Preparation of a project milestone schedule
  - Preparation of a P&ID for a section of the process showing the control scheme to ensure safe operation of the unit, and carrying out a HAZOP analysis of the section of the process selected
  - Preparation of a safety report indicating the safety measures required for the plant bearing in mind any toxic and flammable materials handled

In addition, the names of the presenters for each design project have been included in the rubrics to enable each presenter to be evaluated as well.

#### **References:**

**1. Gael D. Ulrich and Palligarnai T. Vasudevan, "Chemical Engineering : Process Design and Economics, A practical Guide", second edition, 2004, Process Publishing, New Hampshire, USA, ISBN 0-9708768-2-3**

**2. Gavin Towler and Ray innott, “Chemical Engineering Design : Principles, Practice and Economics of Plant and Process Design” Butterworth-Heinemam, ISBN 978-0-08-096659-5, second edition, 2013**

**3. Perry’s Chemical Engineering Handbook, sith edition or latest**

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**4. Turton, R., Bailie, R., Whiting, W., and Shaeiwits, J. A. “Analysis, Synthesis, and Design of Chemical Processes,” 4<sup>th</sup> Edition Prentice-Hall PTR, Upper Saddle River, New Jersey 07458, 2008.**

**5. “Plant Design and Economics for Chemical Engineers” by Peters, M.S., K.D. Timmerhaus and R.E. West, 5<sup>th</sup> edition, 2003, McGraw-Hill, ISBN 0—07-239266-5.**

**DEPARTMENT OF CHEMICAL ENGINEERING  
SENIOR DESIGN & PROFESSIONALISM II CHEG 4248  
COURSE ASSESSMENT GRADING & OUTCOME  
ASSESSMENT SHEET FOR SPRING 2022 SEMESTER**

**ABET Student Learning Outcome 2:** An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factor.

Assignments that test competency in this area will include problems testing students' understanding of the design process involving *devising a system, component, or process to meet desired needs and specifications within constraints, through an iterative, creative, decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources into solutions.*

Name: \_\_\_\_\_

Title of Assignment: \_\_\_\_\_ Due Date \_\_\_\_\_

| Competency Area                                                                                                                                                                                                                                                                              | Points Assigned | Points Received |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------|
| <b>1. Ability to Define/Understand the Problem and then Plan the Project</b>                                                                                                                                                                                                                 | <b>60</b>       |                 |
| (i) Identify the customer and the needs.                                                                                                                                                                                                                                                     | 8               |                 |
| (ii) Identify and list the design objectives.                                                                                                                                                                                                                                                | 8               |                 |
| (i) Identify the design constraints.                                                                                                                                                                                                                                                         | 4               |                 |
| (ii) Define the design strategy and methodology.                                                                                                                                                                                                                                             | 4               |                 |
| (iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.                                                                                                                                                                             | 20              |                 |
| (iv) Develop a Gantt chart and critical path analysis for managing the project.                                                                                                                                                                                                              | 8               |                 |
| (v) Establish major milestones for tracking progress and define performance metrics to measure success                                                                                                                                                                                       | 8               |                 |
| <b>2. Ability to Conduct a Review of the Literature</b>                                                                                                                                                                                                                                      | <b>80</b>       |                 |
| (i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).                                                                                                                                   | 20              |                 |
| (ii) Gather information on relevant fundamentals, theory / concept (demonstrate technical competence) and relate them to the design.                                                                                                                                                         | 40              |                 |
| (iii) Provide the sources in a list of references properly cited in the literature review section and relevant sections of the report.                                                                                                                                                       | 20              |                 |
| <b>3. Ability to perform preliminary design by generation of ideas and applying creativity through generation of ideas and evaluation of candidate solutions</b>                                                                                                                             | <b>60</b>       |                 |
| (i) Perform process design and analysis with design constraints; Sorting/screening of process technology alternatives based on availability and cost of raw materials, reaction selectivity and yield, thermodynamic barriers to separating undesired components, and safety and operability | 40              |                 |
| (ii) Evaluate candidate solutions to arrive at feasible designs                                                                                                                                                                                                                              | 20              |                 |
| <b>4. Ability to Perform Preliminary and Detailed Design</b>                                                                                                                                                                                                                                 | <b>200</b>      |                 |
| (i) Prepare a process flow diagram (PFD) and present a detailed description of the process indicating the functions of the major equipment components and controls, stream connectivity, safety, and other                                                                                   | 20              |                 |

|                                                                                                                                                                                                                                                                                                       |            |  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--|
| technical matters of importance                                                                                                                                                                                                                                                                       |            |  |
| (ii) Carry out a HYSYS/ASPEN simulation of the process showing a converged HYSYS/ASPEN model of the process. State assumptions/parameters used in modeling major equipment                                                                                                                            | 20         |  |
| (ii) Prepare a chemical engineering design of (i) reactor(s), (ii) absorption column(s) and (ii) product distillation units, stating the materials of construction and the operating temperatures and pressures                                                                                       | 60         |  |
| (iii) Prepare mechanical engineering design of the reactor(s) and distillation columns with appropriate dimensioned sketches                                                                                                                                                                          | 20         |  |
| (iii) Identify applicable codes and standards for the chemical and mechanical engineering designs. Indicate assumptions made and their justification, and support calculations should be in consistent units; either English Units or SI. Indicate possible sources of error                          | 20         |  |
| (iv) Economic Evaluation: Estimate capital costs including engineering, materials, installation, interest, return on investment, taxes and contingency. Total unit conversion cost of product, a sensitivity study on the price of the raw material, and the economic methods used should be included | 30         |  |
| (v) Prepare a control scheme to ensure safe operation of the plant and carry out Safety Reviews; Hazards, operability and inherent safe (including the use of Safety Data Sheets submitted in the Appendix) or HAZOP analysis                                                                         | 30         |  |
| <b>Total</b>                                                                                                                                                                                                                                                                                          | <b>400</b> |  |

INSERT SAMPLE STUDENT FINAL PROJECT REPORT

# THE PRODUCTION OF DIMETHYL ETHER

87%

Taylon Owens

Amiya Rogers

Cinthia Sahin

Laura Ukpede

Senior Design Report

Spring 2022

Department of Chemical Engineering

Prairie View A&M University

Faculty Advisor: Dr. Emanuel Dada, Prairie View A&M University

May 3, 2022

## Letter of Transmittal

May 3, 2022

Department of Chemical Engineering  
Prairie View A&M University  
100 University Dr,  
Prairie View, TX 77446

Dear Dr. Dada,

As it pertains to our senior design problem statement, we have successfully completed our analysis of the production of dimethyl ether (DME) comes through the dehydration of methanol. We conclude that this method is a more efficient way to produce dimethyl ether versus the other alternatives that were evaluated. The project has the goal of producing 50,000 metric tons per year from a plant that will be based in Plaquemine, Louisiana. This is achieved by sourcing methanol at a relatively subsidized price and using efficient processes to produce DME at a purity level of over 90%. The high quality of DME produced, and the incorporation of a recycling stream and wastewater treatment for other uses means that the process has been determined to not only be economically viable, but also environmentally sustainable.

The report presented here thus expounds on the processes that were undertaken to complete the project objectives in coherence with the realized problem statement. In this regard, the report defines the project's scope and then details how it was planned and the delegation of tasks. The report also contains a literature review section which expounds on previous work that has been done in the production of DME, and how this work presented relevant resources and reference points for the completion of the project. Other sections of the report include process selection and description, the relevant energy and material balances for the chosen process, a discussion of how the process was completed, and finally recommendations for the production of DME in the future.

Four team members were involved in carrying out various tasks to complete the project's objectives. These members are Taylon Owens, Amiya Rogers, Cinthia Sahin and Laura Ukpede. Throughout the course of the project, ~~the~~ team leader, Taylon Owens, assigned specific roles to team members and coordinated each member's efforts to ensure that deliverables were completed within the stipulated timeframe. The estimated overall profit were \$23MM with a 22% return on investment. Consequently, all the project's goals were realized within the given time of eleven (11) weeks. The processes undertaken to accomplish this are thus elaborated in the succeeding report.

OLC

---

Taylon Owens

---

Amiya Rogers

---

Cinthia Sahin

---

Laura Ukpede

## Abstract

The Production of 50,000 metric ton dimethyl ether (DME) was designed by using the dehydration method of methanol. Methanol is fed into a recycle stream and is fed into a reactor where dehydration occurs and produces DME and water. Once this is done, the existing stream is fed into a distillation column that produces DME as product in the distillate and a mixture of methanol and water in the bottoms. The bottoms stream is fed to another distillation column where the remaining methanol is recycled back into the feed and the bottoms stream is disposed of as wastewater. Within this design process one main assumption is considered. The design process assumed to be at 90% conversion.

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# **1. Project Scope**

## **1.1 Problem Statement**

The purpose of this project is to design a system that produces dimethyl ether (DME) at the required 99.9% purity.

## **1.2 Client Identification and Recognition of Need**

For our process we decided that it would be best to get our methanol from the gulf coast which will cost us \$359.00 per metric ton. The reasoning behind this, is because methanol purchased from the gulf coast is relatively cheaper and the gulf coast is transportation hub which would make transporting our product (DME) easier. Once we purchase the methanol, we plan to use to produce 50,000 metric ton of DME per year through the process of methanol dehydration. Once the DME is produced, we plan to sell to Ford, FPT, Powertrain, and China at \$900.00 per metric ton.

## **1.3 Project Goals and Objectives**

For this project we decided it would be best to list out important tasks that would progress our process along. We first started with understanding our process which led us to figuring out parameters regarding major equipment there after we shifted our focus to our process design where we devolved our process flow diagram and overall material balance. Lastly we wrapped up our project by creating a cost analysis followed by safety consideration. Each of the following major tasks were split into phases and sub tasks.

## 1.4 Contemporary issues and impact of project on society

The production of dimethyl ether is a relatively eco-friendly process being that global warming potentials are low compared to chlorofluorocarbons which are traditionally coolants. However high exposure can lead to headaches, dizziness, light headedness, and even loss of consciousness. Also, it is highly flammable and can cause fires. With this being said, the process of Methanol Dehydration was the best option for our team.

## 2. Project Planning and Task Identification

### 2.1 Task Identification

The following is the list of tasks that was delegated to our process. HYSYS/ASPEN simulation of process, chemical engineering design, economic evaluation, safety and hazop analysis, overall report, visual & oral presentation.

### 2.2 Timelines

In order to ensure all tasks were accomplished, it was important to identify major tasks and subtasks. This allowed for maximum productivity and ensured project completion. The use of a Gantt chart provided a visual reference of what needed to be completed and by when. Table 1 and Figure 1 detail the organization of the project over the course of the semester.

Table 1: Overview of Project Completion

| Task                        | Time period        |
|-----------------------------|--------------------|
| HYSYS/ASPEN Simulation      | Feb. 18-25         |
| Chemical Engineering Design | Feb. 28-March.28   |
| Economic Evaluation         | March. 30-April 13 |
| Safety and Hazop Analysis   | March. 30-April 13 |
| Finish report               | April. 9-16        |

Above is the identification of the major tasks needed to complete the project and the dates by which each should be completed.

|                                                      |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|------------------------------------------------------|-------------------|------------------------------------|-----------|----------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| PROJECT TITLE:                                       |                   | PRODUCTION OF DIMETHYL ETHER (DME) |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Project start                                        |                   | 2/18/2022                          |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Display Week                                         |                   | 0                                  |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| TASKS AND SUB-TASKS                                  | OWNER             | START DATE                         | END DATE  | DURATION |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| HYSYS/ASPEN Simulation of Process                    |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Incldae Small Equipment                              | All               | 18-Feb-22                          | 25-Feb-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Verify Recycle Stream                                | All               | 18-Feb-22                          | 25-Feb-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Converge                                             | All               | 18-Feb-22                          | 25-Feb-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Chemical Engineering Design                          |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Design of Major Equipment                            | All               | 28-Feb-22                          | 28-Mar-22 | 4 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Detailed Unit P&ID (Reactor)                         | Taylor & Amiya    | 28-Feb-22                          | 28-Mar-22 | 4 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Listing Equipment and Specification                  | Laura & Cinthia   | 28-Feb-22                          | 28-Mar-22 | 4 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Economic Evaluation                                  |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cost of Major Equipment Using CAPCOST Software       | Cinthia and Laura | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fixed Capital Costs                                  | Taylor            | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Utilities                                            | Taylor            | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Fixed Capital Investments                            | Taylor            | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Manufacturing Production costs Peters and Timmerhaus | Amiya             | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Complete Economic Analysis/ Cash Flow Diagram        | All               | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Safety and HAZOP Analysis                            |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Methanol Safety-Hazards                              | Laura             | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Reactor & Catalyst Safety-Hazards                    | Taylor            | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DME Safety-Hazards                                   | Amiya             | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Specific Unit Breakdown (Distillation)               | Cinthia           | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Startup/Shutdown HAZOP                               | Amiya             | 30-Mar-22                          | 13-Apr-22 | 2 weeks  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Finish Report                                        |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Complete Rough Draft                                 | All               | 9-Apr-22                           | 16-Apr-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Complete Final Draft                                 | All               | 9-Apr-22                           | 16-Apr-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Visual & Oral Presentation                           |                   |                                    |           |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Complete Presentation                                | All               | 9-Apr-22                           | 16-Apr-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Presentation Practice                                | All               | 9-Apr-22                           | 16-Apr-22 | 1 week   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Above is the Gantt chart that details the major tasks and subtasks. As shown, the anticipated completion date and duration for each task is listed.

This section of the report gives an overview of the manufacturing processes pertinent to DME. The section also examines DME's production routes, its physical and chemical properties, as well as safety aspects including handling and storage.

### 3.1. Overview of Manufacture of DME

Dimethyl ether (DME) is an organic compound that is well-known as a propellant and coolant. It can be used as an alternative fuel for diesel engines, due to its relatively low carbon footprint and high-performance characteristics. In normal conditions, DME presents as a colorless gas and liquifies at about 75 psi ("Alternative Fuels Data Center: Dimethyl Ether", n.d.). Other applications of DME include; as a solvent, an aerosol and a refrigerant.

The production of DME encompasses various sources including; biomass, fossil fuels and methanol. In the U.S., the idealized source for the production of DME is natural gas. The most common means of production for DME encompasses synthesis from syngas generated from fossil fuels.

The molecular formula for DME is thus presented as  $\text{CH}_3\text{OCH}_3$ , which can consequently be simplified to  $\text{C}_2\text{H}_6\text{O}$ .

### 3.2. Production Routes

There are two distinctive routes for the production of DME entailing, the indirect route and the direct route. The indirect route involves the dehydration of methanol which is readily available to produce DME. On the other hand, the direct route involves the production of syngas from a variety of sources, which can then be converted to methanol and then to DME. These production routes are examined in details in the following sections.

#### 3.2.1. Indirect Synthesis Route

The indirect synthesis of DME takes a more traditional approach whereby, methanol is obtained from a variety of sources, purified and then converted to DME (Azizi et al., 2014). As

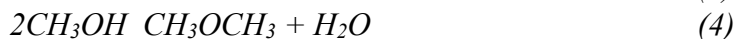
stated above, this production route fundamentally involves the dehydration of methanol resulting in the production of DME, and water as a by-product. This process is given by the following reaction.



According to Azizi et al., (2014), the most preferred method of methanol dehydration to produce DME involves a solid-acid catalyst and involves either the Langmuir-Hinshelwood or Eley-Rideal kinetic models. In both these models, water and DME act as reaction inhibitors at temperatures of above 300°C and therefore, this production route is favored at lower temperatures (Azizi et al., 2014).

### 3.2.2. Direct Synthesis Route

Recent research and technology have developed means of synthesizing DME directly from syngas using a single reactor. This process encompasses the formation of methanol, a water-gas shift, and methanol dehydration (Falco, 2021). This series of process is presented as follows includes; methanol formation, water-gas shift, methanol dehydration, and the overall reaction.



In the reactions above, both the formation of methanol and the water-gas shift occur within the overall process of converting syngas to DME. The formation of methanol is crucial in the synthesis of DME, whereas water-gas shift produces CO<sub>2</sub> which can then be recycled and use in reforming methane, and consequently syngas. The recycling of CO<sub>2</sub> with methane to produce syngas is given by the following reaction (Azize et al., 2014).



The direct synthesis of DME from syngas is a highly exothermic reaction and measures should be put in place to regulate temperature and prevent run-away. This production although being relatively more efficient, involves a complicated process and is thus more costly and resource intensive.

A summary of the process routes considered for this project is presented in the following table.

Table 2: Characteristics of Each Alternative

| ALTERNATIVE | PROCESS                                      | PROS                                                                                                                                                                                                          | CONS                                                                                                                                                                                                        |
|-------------|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1           | Methanol Dehydration                         | <ul style="list-style-type: none"> <li>- Consumes less time and cost of equipment</li> <li>-Catalyst deactivation occurs at relatively high temp (400C).</li> <li>-Relatively simpler process flow</li> </ul> | <ul style="list-style-type: none"> <li>-Requires more downstream separation technologies</li> <li>-Sourcing of methanol may present challenges.</li> <li>-Marginally lower DME yield</li> </ul>             |
| 2           | Indirect Synthesis from biogas feedstock     | <ul style="list-style-type: none"> <li>-Marginally higher yield of DME</li> <li>-The risk of water build up in the process is alleviated</li> <li>-Energy Efficiency is maximized</li> </ul>                  | <ul style="list-style-type: none"> <li>-Sourcing of biogas feedstock presents a challenge.</li> <li>-Process requires more equipment.</li> <li>-Relatively Costly and time-consuming</li> </ul>             |
| 3           | Direct Synthesis from Natural Gas Feed Stock | <ul style="list-style-type: none"> <li>-Higher yield of DME in comparison to methanol dehydration.</li> <li>-No risk of water build-up</li> </ul>                                                             | <ul style="list-style-type: none"> <li>-Exothermic reaction may lead to runaway reaction.</li> <li>-Catalyst deactivation at temp above 300C</li> <li>-Relatively more costs and time-consuming.</li> </ul> |

### 3.3. Physical and Chemical Properties

At atmospheric pressure and room temperature, DME presents as an odorless, colorless gas. Under severe or prolonged exposure to heat, any DME containers rupture violently ("Dimethyl ether", n.d.). DME has several other physical properties, some of which are summarized in the following table ("Fundamental Aspects of Dimethyl Ether", n.d.).

Table 3: DME Properties

| Property                 | Value        |
|--------------------------|--------------|
| Molecular weight         | 46.07        |
| Boiling point            | 248.3 K      |
| Freezing point           | 131.7 K      |
| Critical pressure        | 52.5 atm     |
| Critical Temperature     | 402.0 K      |
| Heat of melting          | 25.6 cal/g   |
| Heat of vaporization     | 111.6 cal/g  |
| Specific Heat @ 248 K    | 0.535 cal/kg |
| Density at 1 atm and 25C | 1.91855 g/L  |

As a chemical compound, DME is considered relatively stable with reactions or decomposition occurring at severe conditions. In this regard, the decomposition rate of DME is estimated at 1% per year when subjected to a temperature of 493K.

Another chemical property that defines DME is that is a powerful solvent with high solubility for both polar and non-polar substances. In this regard, 1 volume of water takes up 37 volumes of DME. It is also soluble I ether, ethyl alcohol, acetone and chloroform ("Dimethyl ether", n.d.).

### 3.4. Handling, Safety and Storage

There are various hazard identifiers used to define DME. In the US, the National Fire Protection Association's codes and standards, NFPA 704, categorizes the gas at a flammability of 4 (NFPA, 2021). This means that the gas is extremely flammable with an ability to vaporize completely at ambient environmental conditions (NOAA Office of Response and Restoration, n.d.). The gas' hazard identification information is presented in the following table.

Table 4: DME Identifiers

| Category              | Designation |
|-----------------------|-------------|
| DME CAS no.           | 115-10-06   |
| NFPA Flammability no. | 4           |
| NFPA Health no.       | 2           |
| NFPA stability no.    | 1           |

Exposure to the gas has several health effects including frostbites when exposed to the skin, pain and redness when exposed to the eyes, and sore throat, drowsiness, loss of consciousness, and headaches when inhaled ("ICSC 0454 -DIMETHYL ETHER", n.d.). The following table summarizes the health hazards related to exposure to DME.

Table 5: DME Health Hazards

| Exposure   | Symptom                                                      |
|------------|--------------------------------------------------------------|
| Inhalation | Headaches, sore throat, drowsiness and loss of consciousness |
| Skin       | Frostbites                                                   |
| Eyes       | Blurry vision, pain and redness                              |

The following sections describe the various safety and handling procedures pertinent to DME.

#### 3.4.1. Handling and Storage

Based on the hazardous nature of DME, there are various recommended protocols on how to handle and store the gas. The handling of DME encompasses a variety of personal precautions

such as the wearing and usage of protective gear as well as an intricate understanding of emergency procedures pertinent to the gas. These precautions include; the wearing of self-contained breathing apparatus when in contaminated areas, constant monitoring of oxygen levels and supply within production of contaminated areas ("Safety Data Sheet -DME", 2018), and only allowing trained personnel to respond to uncontrolled leakages. An additional precaution is the use of Personal Protective Equipment PPE of a grade B minimum encompassing; fire-retardant clothing, mechanical resistant gloves and self-contained breathing apparatus ("ICSC 0454 -DIMETHYL ETHER", n.d.). Finally, the lower explosive limit (LEL) should be 10% for the combustible gas ("Safety Data Sheet -DME", 2018).

There are also a variety of measures that should be adopted to handle and store the equipment used in the process of manufacturing and using DME. The most important measures in this regard include, constant inspection of gas cylinders to ensure no damage, not tampering with pressure relief devices in valves and cylinders ("Safety Data Sheet -DME", 2018), and storing gas containers in a cool, well-ventilated and dry area away from direct sources of heat. Additionally, the temperature in the storage area should be limited to a maximum of 52°C (or 125°F), the gas containers for DME should be stored in an upright, well-fastened position, and there should be segregation of full and empty containers. Finally, the cylinders containing DME should be kept at least 20 ft from any heat source.

### **3.4.2. Safety**

As an alternative fuel source, DME exhibits a better safety proposition than other synthetic fuels, because it is a circular hydrogen carrier, meaning it utilizes hydrogen to store energy in a vector form (Styring et al., 2021). DME is synthesized using different methods and

from varying sources, which means that each of its synthesis processes have different safety ratings.

Generally, the synthesis of DME using direct synthesis has lower risk potential, than using indirect synthesis because of the additional processes involved in the latter (De Falco, n.d.). In this regard, the direct synthesis of DME bypasses the synthesis of methanol. Indirect synthesis of DME on the other hand, involves the synthesis of methanol from shale/natural gas. Because methanol is categorized as a category 2 flammable liquid and category 3 toxic substance (De Falco, n.d.), safety precautions have to be put in place when using the indirect method for the synthesis of DME.

The safety risks associated with indirect synthesis include risk of fires and exposure to toxins if in contact with the reactants over prolonged periods of time. In this regard, 200 ppm is the permissible exposure limit (PEL) dictated by the Occupational Safety and Health Administration (Yang et al., 2015).

Another safety consideration in the production of DME using indirect synthesis from methanol, is the incorporation of a floating head storage tank (Yang et al., 2012). This tank alleviates the safety concerns associated with the flammability and volatility of methanol and other raw materials.

### **3.5. Uses of DME**

DME has a variety of uses. The most prominent of these include as a refrigerant (R-E170), as a solvent, as a propellant in industrial aerosol products, and finally, for purposes including transportation fuel, domestic use, and power generation.

## **4. Process Selection**

### **4.1 Market Analysis and Trends**

In order to determine our plant capacity, an analysis had to first be conducted to determine how much DME is currently being produced and compare it with the future demand of DME. The current capacity for DME is about 3 million metric tons while the demand is expected to grow by 530,000 tons by 2025 (Fleisch et. al 2012). It is important to note that specific demand data could not be found so we predicted the future demand using previous years' growth as an indicator. After finding the current production, competitors were researched to see how much they were producing. Plant capacities were found ranging from 20,000 metric tons per year (MTPY) to 100,000 MTPY. From these numbers it was deemed that 50,000 MTPY was a reasonable capacity for the plant design. From this capacity, the material balance was able to be calculated, which will be discussed later in this report.

### **4.2 Reaction Routes to Producing Product**

After conducting a literature review, the proposed alternatives were narrowed to: Methanol Dehydration to form DME (alternative 1), DME production using biogas feedstock (alternative 2), and indirect DME production using a natural gas feedstock (alternative 3). These three were specifically chosen due to representing the present and future possibilities of DME while taking into account availability of research to complete the design.

### **4.3 Process Screening Using Gross Profit Analysis**

One of the main goals for the design was to design a system that is profitable. In order to make sure the selected alternative was profitable, a theoretical economic indicator analysis, shown in equation 1, had to be completed to ensure profitability.

$$\text{Products} * \text{Price} - \text{Reactants} * \text{Price} \quad (6)$$

If the difference came out to be negative then the calculated alternative would not be profitable, but rather cause debt. If the difference was positive then the given alternative would be profitable, thus being a good choice to start a design around.

#### 4.4 Process Comparison and Selection

For the process comparison and selection, each alternative was compared on the basis of economics, impact on the environment, potential location, and safety. Each team member rated the category on a scale of 1-5 based on the literature review and discussed aspects of each alternative. The following chart shows how each alternative scored in each category.

Table 6: Process Comparison and Selection

| Considerations: | Alternative 1       | Alternative 2 | Alternative 3 | Weight, % |
|-----------------|---------------------|---------------|---------------|-----------|
| Economics       | 18                  | 10            | 12            | 40        |
| Environment     | 13                  | 16            | 20            | 25        |
| Location        | 14                  | 13            | 9             | 25        |
| Safety          | 13                  | 13            | 16            | 10        |
| <b>Total</b>    | <b><u>15.25</u></b> | 12.5          | 13.65         | 100       |

As shown in Table 6, the alternative with the highest score was methanol dehydration to form DME. The chemical formula can be seen below and was used to conduct the theoretical economic indicator analysis.

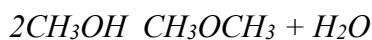


Table 7: Theoretical Economic Indicator for Methanol Dehydration to form DME

|                         | <b>A</b> | <b>B</b> | <b>C</b> |
|-------------------------|----------|----------|----------|
| mol                     | 2        | 1        | 1        |
| Molecular Weight kg/mol | .03204   | .04607   | .01802   |

|           |        |        |        |
|-----------|--------|--------|--------|
| kg        | .06408 | .04607 | .01802 |
| kg/kg DME | 1.39   | 1      | .391   |
| cents/kg  | \$0.36 | \$0.71 | 0      |

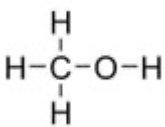
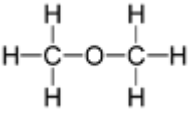
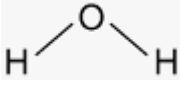
Shown in Table 7 is the preliminary economic analysis that was conducted to ensure that the chosen alternative would be profitable. A represents methanol, B is DME, and C is water. After utilizing equation 6 the theoretical indicator was found to be \$0.21cents/kg DME or \$210/MT DME.

## 5. Process Description

### 5.1 Process Chemistry

The irreversible chemical equation for methanol dehydration, equation 1, shows that for every two moles of methanol, one mole of DME and water is produced. The chemical conditions for each component used in the process is show in Table 8.

Table 8: Chemical Conditions for Components

| Conditions                | Components                                                                          |                                                                                      |                                                                                       |
|---------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                           | <i>Methanol</i>                                                                     | <i>Dimethyl Ether</i>                                                                | <i>Water</i>                                                                          |
| <i>Molecular Weight</i>   | 32.04 g/mol                                                                         | 46.07 g/mol                                                                          | 18.02 g/mol                                                                           |
| <i>Chemical Formula</i>   | CH <sub>3</sub> OH                                                                  | CH <sub>3</sub> OCH <sub>3</sub>                                                     | H <sub>2</sub> O                                                                      |
| <i>Chemical Structure</i> |  |  |  |
| <i>Boiling Point</i>      | 64.70°C                                                                             | -24°C                                                                                | 100°C                                                                                 |
| <i>Melting Point</i>      | -94.60°C                                                                            | -141°C                                                                               | 0°C                                                                                   |
| <i>Flash Point</i>        | 9.7°C                                                                               | -41.1°C                                                                              | -                                                                                     |
| <i>Density</i>            | 0.79 g/cm <sup>3</sup>                                                              | 1.97 g/cm <sup>3</sup>                                                               | 1 g/cm <sup>3</sup>                                                                   |

The mole balance and rate law equations are shown in Table 9. F is defined as flow rate, while W, represents catalyst weight. The rate law equations also show the relationship between

the reactants and products. Methanol dehydration is favored at lower temperatures because it is an exothermic reaction. Therefore, a tubular packed bed reactor is used due to its low operating cost, high conversion per unit mass of catalyst, and ideal for catalytic processes with low temperatures. Maintaining a low temperature is critical to reduce the formation of by-products such as ethylene, carbon monoxide, hydrogen, and coke.

Table 9: Kinetic Rate Equations

| Species               | Mole Balance Equation                                            | Initial Flow Rate                              | Rate Laws                                                     |
|-----------------------|------------------------------------------------------------------|------------------------------------------------|---------------------------------------------------------------|
| <i>Methanol</i>       | $dF_{\text{CH}_3\text{OH}}/dW = r'_{\text{CH}_3\text{OH}}$       | $F_{\text{CH}_3\text{OH}}(0) = 274$<br>kmol/hr | $r'_{\text{CH}_3\text{OH}} = -k_1 C_{\text{CH}_3\text{OH}}^2$ |
| <i>Dimethyl Ether</i> | $dF_{\text{CH}_3\text{OCH}_3}/dW = r'_{\text{CH}_3\text{OCH}_3}$ | $F_{\text{CH}_3\text{OCH}_3}(0) = 0$           | $r'_{\text{CH}_3\text{OCH}_3} = -2r_{\text{CH}_3\text{OH}}$   |
| <i>Water</i>          | $dF_{\text{H}_2\text{O}}/dW = r'_{\text{H}_2\text{O}}$           | $F_{\text{H}_2\text{O}}(0) = 0$                | $r'_{\text{H}_2\text{O}} = -2r_{\text{CH}_3\text{OH}}$        |

## 5.2 Process Flow Diagram and Process Description

The dimethyl ether process receives pure liquid methanol from a pipeline, it is then pumped into a mixer and mixes with the recycled liquid methanol. This methanol mixer is then pumped into a vaporizer where it will change phases from liquid to vapor. This vapor methanol mixer continues into a heater that heats up the combined vapor stream to the desired reactor inlet temperature. The effluent from the furnace is fed to the catalytic packed bed reactor. In the reactor, the methanol is being dehydrated by a gamma alumina catalyst and converted into DME and Water. The reactor operates at 90% conversion and the tubes are packed with  $\gamma\text{-Al}_2\text{O}_3$ . The product from the reactor is then cooled and sent to the first distillation column where the DME separation occurs. The overhead product is the desired DME product which is stored in a tank

between a 7 through 14 bar and up to 52°C. The bottoms products are, now in the liquid phase, methanol and water which are sent to a second distillation column for further separation. The second distillation overhead product is methanol which will be recycled back into the system and the bottoms product is wastewater which will be sent to SNF Holding Company Plaquemine treatment facility. Wastewater treatment will reduce pollutants in water and negative health effects on life species.

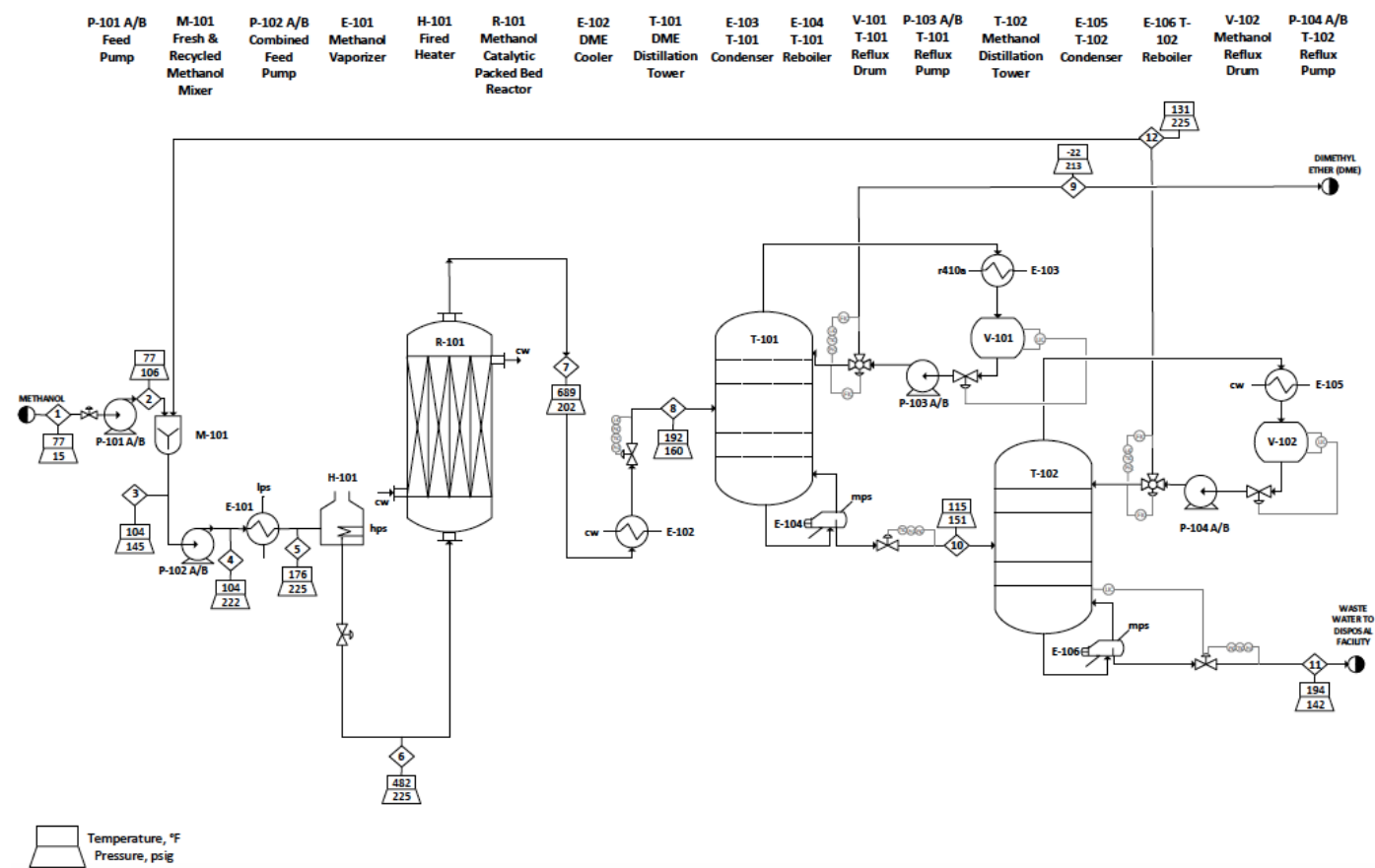


Figure 2: Production of Dimethyl Ether Process Flow Diagram

## 6. Material and Energy Balances

### 6.1 Material Balances

As previously mentioned, the basis of calculation was determined to be 50,000 MTPY of DME.

From this number, the overall material balance was able to be calculated using the stoichiometric ratio of the reaction. The capacity was first taken from a yearly time period to 152 MTPD. This number was then converted into a mass flow rate and then to a molar flow rate. After applying the stoichiometric ratio, the wastewater flow rate and feed flow rate were calculated. In order to complete the individual unit balances, assumptions about the molar compositions were made (Diemer et. al 2010).

#### Block Flow Diagram Material Balance

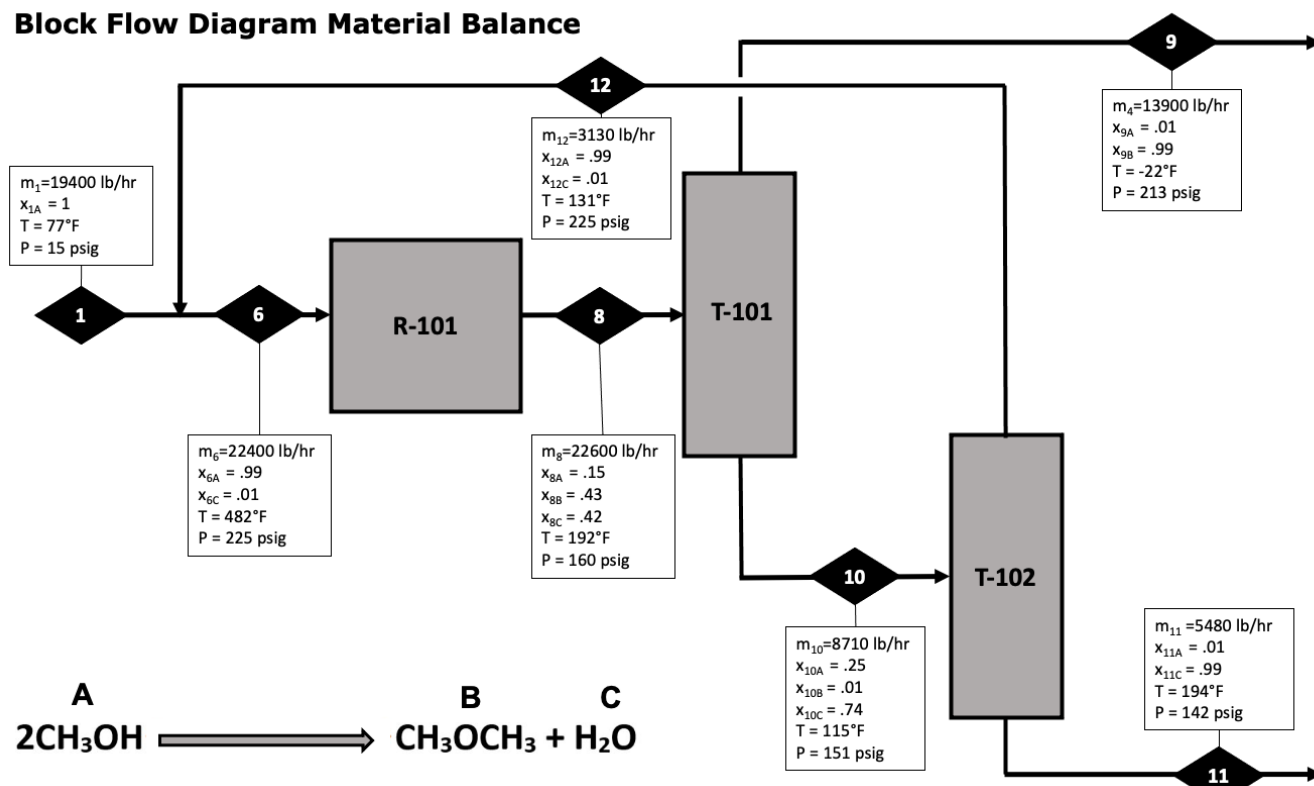


Figure 3: Material Balance for Design

Figure 3 shows the total material balance for each process stream. Using the assumed molar compositions and the degree of freedom (DOF) analysis, the individual stream flowrates were able to be calculated.

## 6.2 Energy Balances

In order to complete the energy balance around the reactor, temperature, flowrates, and specific heat capacities were needed, as shown in Equation 7. The temperature for the reactor was determined based off the literature review and the specific heat capacity was calculated at ambient temperature. Since the streams were mixed, the molar compositions were used to determine the specific heat capacity for each component in the stream. The individual heat capacities were then added to get the total heat capacity for the stream.

$$\sum mC_pT_2 = \sum mC_pT_3 \quad (7)$$

In order to calculate the total energy balance, the process was simulated in ASPEN. Using the degree of freedom (DOF) analysis, the ASPEN simulation was simulated vessel by vessel. First, the reactor was converged by defining the temperatures and pressures for each stream and only defining the molar composition and molar flow for the input streams. After checking to see if the output values matched the calculated values in Figure 3, a separator was added to the simulation. Since the input stream for the first distillation column was calculated by Aspen, the composition and molar flow rate for the bottoms stream was only defined. Once the simulation ran again, it was proved that the molar flow rate and compositions Aspen calculated for the first overhead stream also matched the calculations in Figure 3. Lastly, the same steps were followed for the last distillation column until a fully converged simulation which molar flows and compositions for each stream matched the material balance that is shown in Figure 3. The recycle stream is split into two streams to make it easier to converge and more accurate. Each stream converged

and the simulated energy balance for the reactor was compared with the calculated energy balance to check accuracy. Since all values were within a 5% error, the simulation was deemed correct and the total energy balance can be seen in Figure 3. The simulated ASPEN is shown in Figure 3 and the energy balance values can be seen in Table 10.

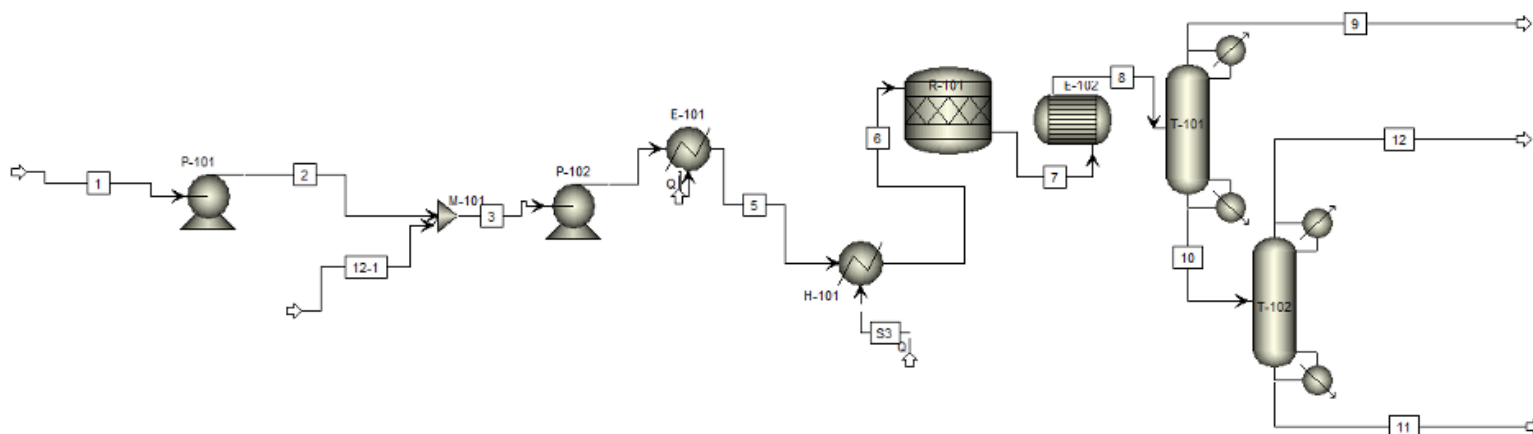


Figure 4: Simulated and Converged ASPEN Plus Diagram

Table 10. Energy Balance Calculations

| Methanol Dehydration<br>R-101 |                            |
|-------------------------------|----------------------------|
| Temperature                   | 689°F                      |
| R-101 Duty                    | $-1.36 \times 10^7$ BTU/hr |
| E-101 Duty                    | $9.67 \times 10^6$ BTU/hr  |
| H-101 Duty                    | $5.40 \times 10^6$ BTU/hr  |
| E-102 Duty                    | $-1.14 \times 10^7$ BTU/hr |

| DME Distillation<br>T-101 |                            |
|---------------------------|----------------------------|
| Temperature               | 86°F/114.8°F               |
| E-103 Duty                | $-3.39 \times 10^6$ BTU/hr |
| E-104 Duty                | $2.36 \times 10^6$ BTU/hr  |

| Methanol Distillation<br>T-102 |                            |
|--------------------------------|----------------------------|
| Temperature                    | 158°F/194°F                |
| E-105 Duty                     | $-1.18 \times 10^7$ BTU/hr |
| E-106 Duty                     | $1.14 \times 10^7$ BTU/hr  |

## 7. Utilities

To carry out the production of DME, power, steam, cooling water, wastewater disposal, and refrigerants were all considered. Table 11 summarizes the necessary utility requirements for each piece of major equipment.

Table 11. Summary of Utilities

| Power kWh/y                           |        |
|---------------------------------------|--------|
| P-101 A/B                             | 56900  |
| P-102 A/B                             | 75800  |
| P-103 A/B                             | 41100  |
| P-104 A/B                             | 7900   |
| Steam kg/y                            |        |
| E-101 (lps)                           | 193000 |
| H-101 (hps)                           | 50000  |
| E-104 (mps)                           | 10000  |
| E-106 (mps)                           | 49000  |
| Cooling Water m <sup>3</sup> /y       |        |
| R-101                                 | 104000 |
| E-102                                 | 149000 |
| E-105                                 | 29100  |
| Wastewater Disposal m <sup>3</sup> /y |        |
| T-102                                 | 19900  |
| Refrigerant r140a GJ/y                |        |
| E-103                                 | 432    |
|                                       |        |

## 8. Equipment List and Description

### 8.1 P-101

This pump is responsible for increasing and regulating the initial pressure of methanol before it is delivered the system. The pump increases the pressure of fresh methanol from 1 bar to 7.3 bar, before it is fed to the vaporizer.

## 8.2 P-102

This pump is responsible for increasing and regulating the pressure of the combined stream of methanol after it leaves the mixer. The pump increases the pressure of fresh methanol from 10.0 bar to 15.2 bar, before it is fed to the vaporizer.

## 8.3 E-101

This is a vaporizer that takes methanol from a liquid to a gaseous state. It is made of carbon steel and has a cross-sectional area of 1.02 m<sup>2</sup>. The vaporizer has a heat transfer area of 56.3 m<sup>2</sup> and a duty of  $1.02 \times 10^7$  kJ/hr.

## 8.4 H-101

The third component in the process flow is a furnace that is responsible for heating methanol to the idealized temperature of 250°C before it is fed to the reactor. The furnace is constructed using carbon steel to withstand high temperature. It has a maximum pressure rating of 45 bar and a duty of  $5.7 \times 10^6$  kJ/hr.

## 8.5 R-101

This is a catalytic packed bed reactor. There are 34 tubes each comprised of 733.03 kg of  $\gamma$ -Al<sub>2</sub>O<sub>3</sub> catalyst and as the methanol passes through the tubes it is dehydrated to form DME and water. Each tube has a diameter of .03m while the reactor has a diameter of 1.33 meters and an overall height of 4.48 meters. The construction of the tower section of the reactor comprises mild carbon steel (A516 grade), whereas the tubing is made of stainless steel (grade 316). This reaction is exothermic and if the temperature gets too high, the process will begin to form byproducts and

the catalyst will deactivate. To prevent this, cooling water is passed through the shell side of the reactor to maintain the desired temperature. Its maximum pressure rating is 15 bar.

## **8.6 E-102**

This is a shell and tube heat exchanger made of carbon steel. It acts as a cooler lowering the temperature of the mixture leaving the reactor. The heat exchanger cools DME/water/methanol mixture from 365°C to 89°C before it is fed to the first distillation column which is responsible for separating DME from the mixture. The maximum pressure rating of the heat exchanger is 14 bar. It comprises a floating-head shell and tube design with the main construction material being carbon steel.

## **8.7 T-101**

This is a tray-type distillation column with 22 valve trays, a reboiler and a condenser. The average tray spacing is .61m, and the column is responsible for the separation of DME from a water/methanol mixture. It is predominantly made of carbon steel, with an overall height of 16m and a diameter of 12m. The feed for the column contains DME, water and methanol. The distillate on the other hand comprises of DME whereas water and methanol mixture is collected at the bottom. The maximum pressure rating for the column is 15 bar.

## **8.8 T-102**

This is a tray-type distillation column with 15 valve trays, a reboiler and a condenser. The average spacing between the trays is .8m. The column is responsible for the separation of methanol that goes into the recycling stream from waste water. It is predominantly made of carbon steel,

with an overall height of 20m and a diameter of 13m. The feed for the column contains traces of DME, water and methanol. The distillate on the other hand comprises of methanol whereas water is collected at the bottom. The maximum pressure rating for the column is 15 bar.

## 9. Specification Sheets

### 9.1 P-101A/B Specifications

| Pump                              |                                             |           |                    |           |
|-----------------------------------|---------------------------------------------|-----------|--------------------|-----------|
| <b>Identification:</b>            | Item:                                       | Pump      |                    |           |
|                                   | Item No:                                    | P-101     | Date               | 2/23/2022 |
|                                   | No. Required                                | 2         |                    |           |
|                                   | C <sub>TPI</sub> (\$)                       |           |                    |           |
| <b>Function:</b>                  | Pump liquid methanol from 1 bar to 15.2 bar |           |                    |           |
| <b>Operation</b>                  | Continuous                                  |           |                    |           |
|                                   |                                             |           |                    |           |
|                                   | Inlet                                       | Outlet    |                    |           |
| <b>Materials Handled</b>          |                                             |           |                    |           |
| Mass Flow(kg/hr)                  | 8778                                        | 8778      |                    |           |
| Mole flow (kgmol/hr)              | 274                                         | 274       |                    |           |
|                                   |                                             |           |                    |           |
| <b>Component Flow (kgmol/hr):</b> |                                             |           |                    |           |
| Dimethyl Ether                    | 0                                           | 0         |                    |           |
| Methanol                          | 274                                         | 274       |                    |           |
| Water                             | 0                                           | 0         |                    |           |
|                                   |                                             |           |                    |           |
| <b>Temperature (C)</b>            | 25                                          | 25        |                    |           |
| <b>Pressure (bar):</b>            | 1                                           | 15.5      |                    |           |
| <b>Vapor Fraction:</b>            | 0.0                                         | 0         |                    |           |
| <b>Design Data:</b>               |                                             |           |                    |           |
| Power (kW)                        | 7.2                                         | Material: | Carbon Steel – A36 |           |
| Efficiency (%)                    | 60                                          | Type:     | Centrifugal        |           |
| $\Delta P$                        | 6.3                                         |           |                    |           |
|                                   |                                             |           |                    |           |
|                                   |                                             |           |                    |           |
| <b>Utilities:</b>                 |                                             |           |                    |           |
|                                   |                                             |           |                    |           |

|           |  |
|-----------|--|
| Comments: |  |
|-----------|--|

## 9.2 P-102A/B Specifications

| Pump                              |                                              |           |                    |           |
|-----------------------------------|----------------------------------------------|-----------|--------------------|-----------|
| <b>Identification:</b>            | Item:                                        | Pump      |                    |           |
|                                   | Item No:                                     | P-102     | Date               | 2/23/2022 |
|                                   | No. Required                                 | 2         |                    |           |
|                                   | C <sub>TPI</sub> (\$)                        |           |                    |           |
| <b>Function:</b>                  | Pump liquid methanol from 10 bar to 15.2 bar |           |                    |           |
| <b>Operation</b>                  | Continuous                                   |           |                    |           |
|                                   |                                              |           |                    |           |
|                                   | Inlet                                        | Outlet    |                    |           |
| <b>Materials Handled</b>          |                                              |           |                    |           |
| Mass Flow(kg/hr)                  | 10,200                                       | 10,200    |                    |           |
| Mole flow (kgmol/hr)              | 318                                          | 318       |                    |           |
|                                   |                                              |           |                    |           |
| <b>Component Flow (kgmol/hr):</b> |                                              |           |                    |           |
| Dimethyl Ether                    | 0                                            | 0         |                    |           |
| Methanol                          | 315                                          | 315       |                    |           |
| Water                             | 3.18                                         | 3.18      |                    |           |
|                                   |                                              |           |                    |           |
| <b>Temperature (C)</b>            | 40                                           | 40        |                    |           |
| <b>Pressure (bar):</b>            | 10                                           | 15.2      |                    |           |
| <b>Vapor Fraction:</b>            | 0.0                                          | 0         |                    |           |
| <b>Design Data:</b>               |                                              |           |                    |           |
| Power (kW)                        | 9.6                                          | Material: | Carbon Steel – A36 |           |
| Efficiency (%)                    | 60                                           | Type:     | Centrifugal        |           |
| ΔP                                | 5.2                                          |           |                    |           |
|                                   |                                              |           |                    |           |
|                                   |                                              |           |                    |           |
| Utilities:                        |                                              |           |                    |           |
|                                   |                                              |           |                    |           |
| Comments:                         |                                              |           |                    |           |

## 9.2 E-101 Specifications

|           |
|-----------|
| Vaporizer |
|-----------|

|                                   |                                                |           |              |           |
|-----------------------------------|------------------------------------------------|-----------|--------------|-----------|
| <b>Identification:</b>            | Item:                                          | Vaporizer |              |           |
|                                   | Item No:                                       | M-101     | Date         | 3/24/2022 |
|                                   | No. Required                                   | 1         | By:          | C.Sahin   |
|                                   | C <sub>TPI</sub> (\$)                          |           |              |           |
| <b>Function:</b>                  | Vaporization of liquid methanol                |           |              |           |
| <b>Operation</b>                  | Continuous                                     |           |              |           |
|                                   |                                                |           |              |           |
|                                   | In                                             | Out       |              |           |
| <b>Materials Handled</b>          |                                                |           |              |           |
| Mass Flow(kg/hr)                  | 10,200                                         | 10,200    |              |           |
| Mole flow (kgmol/hr)              | 318                                            | 318       |              |           |
|                                   |                                                |           |              |           |
| <b>Component Flow (kgmol/hr):</b> |                                                |           |              |           |
| Dimethyl Ether                    | 0.0                                            | 0.0       |              |           |
| Methanol                          | 315                                            | 315       |              |           |
| Water                             | 3.18                                           | 3.18      |              |           |
|                                   |                                                |           |              |           |
| <b>Temperature (C)</b>            | 40                                             | 80        |              |           |
| <b>Pressure (bar):</b>            | 15.2                                           | 15.5      |              |           |
| <b>Vapor Fraction:</b>            | 0.0                                            | 1.0       |              |           |
| <b>Design Data:</b>               |                                                |           |              |           |
| Cross-sectional area              | 1.02 m <sup>2</sup>                            | Material: | Carbon Steel |           |
| Diameter                          | 1.14 m                                         |           |              |           |
| Duty (Q) kJ/hr                    | 1.02 * 10 <sup>7</sup>                         |           |              |           |
| Heat transfer area                | 56.3 m <sup>2</sup>                            |           |              |           |
| Maximum Pressure rating           | 15 bar                                         |           |              |           |
| Utilities:                        | Low Pressure<br>Steam 4.5 bar =<br>24160 kg/hr |           |              |           |
|                                   |                                                |           |              |           |
| Comments:                         |                                                |           |              |           |

### 9.3 H-101 Specifications

| Electric Furnace       |                       |                  |      |           |
|------------------------|-----------------------|------------------|------|-----------|
| <b>Identification:</b> | Item:                 | Electric Furnace |      |           |
|                        | Item No:              |                  | Date | 3/24/2022 |
|                        | No. Required          | 1                | By:  | C.Sahin   |
|                        | C <sub>TPI</sub> (\$) |                  |      |           |
| <b>Function:</b>       | Heat stream to 250°C  |                  |      |           |

| Operation                        | Continuous       |           |              |  |
|----------------------------------|------------------|-----------|--------------|--|
|                                  |                  |           |              |  |
|                                  | In               | Out       |              |  |
| <b>Materials Handled</b>         |                  |           |              |  |
| Mass Flow(kg/hr)                 | 10,200           | 10,200    |              |  |
| Mole flow (kgmol/hr)             | 318              | 318       |              |  |
|                                  |                  |           |              |  |
| <b>Component Flow (Kmol/hr):</b> |                  |           |              |  |
| Dimethyl Ether                   | 0                | 0         |              |  |
| Methanol                         | 315              | 315       |              |  |
| Water                            | 3.18             | 3.18      |              |  |
|                                  |                  |           |              |  |
| <b>Temperature (C)</b>           | 80               | 250       |              |  |
| <b>Pressure (bar):</b>           | 15.5             | 15.5      |              |  |
| <b>Vapor Fraction:</b>           | 1                | 1         |              |  |
| <b>Design Data:</b>              |                  |           |              |  |
| Superheated Temperature (C)      | 400              | Material: | Carbon Steel |  |
| Duty (Q) kJ/hr                   | $5.7 * 10^6$     |           |              |  |
| Maximum Pressure rating          | 45 bar           |           |              |  |
| Utilities:                       | hps = 6255 kg/hr |           |              |  |
|                                  |                  |           |              |  |
| Comments:                        |                  |           |              |  |

## 9.4 R-101 Specifications

| Reactor                          |                                                  |                              |      |           |
|----------------------------------|--------------------------------------------------|------------------------------|------|-----------|
| <b>Identification:</b>           | Item:                                            | Catalytic Packed Bed Reactor |      |           |
|                                  | Item No:                                         | R-101                        | Date | 3/24/2022 |
|                                  | No. Required                                     | 1                            | By:  | C.Sahin   |
|                                  | C <sub>TPI</sub> (\$)                            |                              |      |           |
| <b>Function:</b>                 | Dehydration of methanol to produce DME and water |                              |      |           |
| <b>Operation</b>                 | Continuous                                       |                              |      |           |
|                                  |                                                  |                              |      |           |
|                                  | In                                               | Out                          |      |           |
| <b>Materials Handled</b>         |                                                  |                              |      |           |
| Mass Flow(kg/hr)                 | 10,200                                           | 10,200                       |      |           |
| Mole flow (kgmol/hr)             | 318                                              | 318                          |      |           |
|                                  |                                                  |                              |      |           |
| <b>Component Flow (Kmol/hr):</b> |                                                  |                              |      |           |
| Dimethyl Ether                   | 0                                                | 136.92                       |      |           |
| Methanol                         | 315.25                                           | 47.76                        |      |           |

|                                     |                                                                                                                                               |                        |              |  |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|------------------------|--------------|--|
| Water                               | 3.18                                                                                                                                          | 133.74                 |              |  |
|                                     |                                                                                                                                               |                        |              |  |
| <b>Temperature (C)</b>              | 250                                                                                                                                           | 365                    |              |  |
| <b>Pressure (bar):</b>              | 15.5                                                                                                                                          | 13.9                   |              |  |
| <b>Vapor Fraction:</b>              | 1.0                                                                                                                                           | 1.0                    |              |  |
| <b>Design Data:</b>                 |                                                                                                                                               |                        |              |  |
| Diameter (m)                        | 1.33                                                                                                                                          | Material:              | Carbon Steel |  |
| Overall height (m)                  | 4.48                                                                                                                                          |                        |              |  |
| Number of Tubes                     | 34                                                                                                                                            | Area (m <sup>2</sup> ) | 12.41        |  |
| Maximum Pressure rating             | 15 bar                                                                                                                                        |                        |              |  |
| Combined Tube Volume m <sup>3</sup> | 19                                                                                                                                            |                        |              |  |
|                                     |                                                                                                                                               |                        |              |  |
| Utilities:                          | CW                                                                                                                                            | 12951.38<br>kg/hr      |              |  |
|                                     |                                                                                                                                               |                        |              |  |
| Comments:                           | Temperature maintained by cooling water<br>Catalyst in tubes is $\gamma$ -Al <sub>2</sub> O <sub>3</sub><br>Total catalyst weight is 24923 kg |                        |              |  |

## 9.5 E-102 Specifications

| Reactor Effluent Cooler          |                                                        |                               |      |           |
|----------------------------------|--------------------------------------------------------|-------------------------------|------|-----------|
| <b>Identification:</b>           | Item:                                                  | Shell and Tube Heat Exchanger |      |           |
|                                  | Item No:                                               | E-102                         | Date | 3/24/2022 |
|                                  | No. Required                                           | 1                             | By:  | C.Sahin   |
|                                  | C <sub>TPI</sub> (\$)                                  |                               |      |           |
| <b>Function:</b>                 | To cool the DME stream coming from the reactor to 89°C |                               |      |           |
| <b>Operation</b>                 | Continuous                                             |                               |      |           |
|                                  |                                                        |                               |      |           |
|                                  | Hot in                                                 | Hot out                       |      |           |
| <b>Materials Handled</b>         |                                                        |                               |      |           |
| Mass Flow(kg/hr)                 | 10,200                                                 | 10,200                        |      |           |
| Mole flow (kgmol/hr)             | 318                                                    | 318                           |      |           |
|                                  |                                                        |                               |      |           |
| <b>Component Flow (Kmol/hr):</b> |                                                        |                               |      |           |
| Dimethyl Ether                   | 136.92                                                 | 136.92                        |      |           |
| Methanol                         | 47.76                                                  | 47.76                         |      |           |
| Water                            | 133.74                                                 | 133.74                        |      |           |
|                                  |                                                        |                               |      |           |
| <b>Temperature (C)</b>           | 365                                                    | 89                            |      |           |

|                         |                                              |                  |                                                   |  |
|-------------------------|----------------------------------------------|------------------|---------------------------------------------------|--|
| <b>Pressure (bar):</b>  | 13.9                                         | 10.4             |                                                   |  |
| <b>Vapor Fraction:</b>  | 1.0                                          | 1.0              |                                                   |  |
| <b>Design Data:</b>     |                                              |                  |                                                   |  |
| Q (kJ/h)                | $1.2 \times 10^7$                            | Material:        | Carbon Steel                                      |  |
| A (m <sup>2</sup> )     | 101.8                                        |                  |                                                   |  |
| Maximum Pressure rating | 14 bar                                       |                  |                                                   |  |
|                         |                                              |                  |                                                   |  |
|                         |                                              |                  |                                                   |  |
| Utilities:              | cw                                           | 18566.41<br>kg/h | T <sub>in</sub> = 30°C<br>T <sub>out</sub> = 45°C |  |
|                         |                                              |                  |                                                   |  |
| Comments:               | Process stream in shell (DME/methanol/water) |                  |                                                   |  |

## 9.6 T-101 Specifications

| 1 <sup>st</sup> Distillation Column |                                  |                   |                |           |
|-------------------------------------|----------------------------------|-------------------|----------------|-----------|
| <b>Identification:</b>              | Item:                            | DME Separator     |                |           |
|                                     | Item No:                         | T-101             | Date           | 3/24/2022 |
|                                     | No. Required                     | 1                 | By:            | C.Sahin   |
|                                     | C <sub>TPI</sub> (\$)            |                   |                |           |
| <b>Function:</b>                    | Separate DME from methanol/water |                   |                |           |
| <b>Operation</b>                    | Continuous                       |                   |                |           |
|                                     |                                  |                   |                |           |
|                                     | Feed                             | Liquid Distillate | Liquid Bottoms |           |
| <b>Materials Handled</b>            | Methanol/DME/Water               | Methanol/DME      | Methanol/Water |           |
| Mass Flow(kg/hr)                    | 10245.83                         | 6292.36           | 3952.83        |           |
| Mole flow (kgmol/hr)                | 318.43                           | 137               | 181.4          |           |
|                                     |                                  |                   |                |           |
| <b>Component Flow (kgmol/hr):</b>   |                                  |                   |                |           |
| Dimethyl Ether                      | 136.92                           | 135.63            | 1.81           |           |
| Methanol                            | 47.76                            | 1.37              | 45.35          |           |
| Water                               | 133.74                           | 0.00              | 134.24         |           |
|                                     |                                  |                   |                |           |
| <b>Temperature (C)</b>              | 89                               | -30               | 46             |           |
| <b>Pressure (bar):</b>              | 11                               | 14.7              | 10.4           |           |
| <b>Vapor Fraction:</b>              | 1                                | 0.0               | 0.0            |           |

|                             |                        |                          |                                |                             |                      |
|-----------------------------|------------------------|--------------------------|--------------------------------|-----------------------------|----------------------|
| <b>Design Data:</b>         |                        |                          |                                |                             |                      |
| Reflux ratio                | 1.7                    | Material:                | Carbon Steel                   |                             |                      |
| Number of actual trays      | 22                     |                          |                                |                             |                      |
| Tray Spacing (m)            | 1                      |                          |                                |                             |                      |
| Total tower height (m)      | 16                     |                          |                                |                             |                      |
| Column diameter (m)         | .8                     |                          |                                |                             |                      |
| Maximum Pressure rating     | 15 bar                 |                          |                                |                             |                      |
| <b>Associated Component</b> |                        |                          |                                |                             |                      |
| Condenser (E-103)           | refrigerant : 432 GJ/y | A = 100.6 m <sup>2</sup> | Q = 3.58x10 <sup>6</sup> kJ/hr | Fixed head, carbon steel    | Max pressure = 10bar |
| Reboiler (E-104)            | mps: 1256 kg/hr        | A = 22m <sup>2</sup>     | Q = 2.49x10 <sup>6</sup> kJ/hr | Floating head, carbon steel | Max pressure = 11bar |
| Reflux Drum (V-101)         | L = 2.89m              | D = 1.14m                | Carbon Steel                   | Max pressure = 10.3 bar     |                      |
| Reflux Pump (P-103 A/B)     | Power = 5.2 kW         | Efficiency = 40%         | ΔP = 4.6bar                    | Centrifugal/Carbon Steel    |                      |
| Utilities:                  |                        |                          |                                |                             |                      |
|                             |                        |                          |                                |                             |                      |
| Comments:                   |                        |                          |                                |                             |                      |

## 9.7 T-102 Specifications

| 2 <sup>nd</sup> Distillation Column |                              |                    |                |           |
|-------------------------------------|------------------------------|--------------------|----------------|-----------|
| <b>Identification:</b>              | Item:                        | Methanol Separator |                |           |
|                                     | Item No:                     | T-102              | Date           | 3/24/2022 |
|                                     | No. Required                 | 1                  | By:            | C.Sahin   |
|                                     | C <sub>TPI</sub> (\$)        |                    |                |           |
| <b>Function:</b>                    | Separate methanol from water |                    |                |           |
| <b>Operation</b>                    | Continuous                   |                    |                |           |
|                                     |                              |                    |                |           |
|                                     | Feed                         | Liquid Distillate  | Liquid Bottoms |           |
| <b>Materials Handled</b>            |                              |                    |                |           |
| Mass Flow(kg/hr)                    | 3952.83                      | 1417.3             | 2485.26        |           |
| Mole flow (kgmol/hr)                | 181.4                        | 44.43              | 137            |           |

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|                                   |                  |                         |                                |                             |                       |
|-----------------------------------|------------------|-------------------------|--------------------------------|-----------------------------|-----------------------|
|                                   |                  |                         |                                |                             |                       |
| <b>Component Flow (kgmol/hr):</b> |                  |                         |                                |                             |                       |
| Dimethyl Ether                    | 1.81             | 0.00                    | 0.00                           |                             |                       |
| Methanol                          | 45.35            | 43.99                   | 1.37                           |                             |                       |
| Water                             | 134.24           | .44                     | 135.63                         |                             |                       |
|                                   |                  |                         |                                |                             |                       |
| <b>Temperature (C)</b>            | 46               | 55                      | 90                             |                             |                       |
| <b>Pressure (bar):</b>            | 10.4             | 15.5                    | 9.8                            |                             |                       |
| <b>Vapor Fraction:</b>            | 0.0              | 1.0                     | 0.0                            |                             |                       |
| <b>Design Data:</b>               |                  |                         |                                |                             |                       |
| Reflux ratio                      | 4.472            | Material:               | Carbon Steel                   |                             |                       |
| Number of actual trays            | 15               |                         |                                |                             |                       |
| Tray spacing (m)                  | 1                |                         |                                |                             |                       |
| Total tower height (m)            | 20               |                         |                                |                             |                       |
| Column diameter (m)               | 1.16             |                         |                                |                             |                       |
| Maximum Pressure rating           | 15 bar           |                         |                                |                             |                       |
| <b>Associated Components</b>      |                  |                         |                                |                             |                       |
| Condenser (E-105)                 | cw: 294250 kg/hr | A = 22.7 m <sup>2</sup> | Q = 1.24x10 <sup>7</sup> kJ/hr | Floating head, carbon steel | Max pressure = 7 bar  |
| Reboiler (E-106)                  | mps: 6130 kg/hr  | A = 83.0 m <sup>2</sup> | Q = 1.20x10 <sup>7</sup> kJ/hr | Floating head, carbon steel | Max pressure = 11 bar |
| Reflux Drum (V-102)               | L= 2.53m         | D = .85m                | Carbon steel                   | Max pressure 7.3 bar        |                       |
| Reflux Pump (P-104 A/B)           | Power = 1.0 kW   | Efficiency = 40%        | $\Delta P = 4.1\text{bar}$     | Centrifugal/Carbon Steel    |                       |
| Utilities:                        |                  |                         |                                |                             |                       |
|                                   |                  |                         |                                |                             |                       |
| Comments:                         |                  |                         |                                |                             |                       |

## **10. Equipment Costs and Capital Investment**

To determine the various equipment costs, a modified version of CAPCOST software was applied on Microsoft Excel. In this regard, the software used properties such as vessel sizing and construction material to determine the estimated costs of various equipment throughout the process flow. The Chemical Engineering Plant Cost Index (CEPCI) was then used to adjust the realized estimates for inflation to the current year. Using CAPCOST, the purchased equipment costs and bare module costs were realized and summarized in Table 11 as shown below.

Table 12. Summary of Equipment Costs Using CAPCOST

|                             |                           |                              |                             |              |                                |                             |                                 |                         |
|-----------------------------|---------------------------|------------------------------|-----------------------------|--------------|--------------------------------|-----------------------------|---------------------------------|-------------------------|
|                             |                           |                              | <b><u>Unit Number</u></b>   | <b>100</b>   |                                |                             |                                 |                         |
|                             |                           |                              | <b><u>CEPCI</u></b>         | <b>710</b>   |                                |                             |                                 |                         |
| <b>User Added Equipment</b> |                           |                              |                             |              |                                |                             |                                 |                         |
| <b>Evaporators</b>          | <b>Type</b>               | <b>Area (square meters)</b>  | <b>Pressure (barg)</b>      | <b>MOC</b>   | <b>Volume (cubic meters)</b>   |                             | <b>Purchased Equipment Cost</b> | <b>Bare Module Cost</b> |
| K-101                       | Vessel with Internal Coil |                              | 20                          | Carbon Steel | 16.6                           |                             | \$65,100                        | \$284,000               |
| <b>Exchangers</b>           | <b>Exchanger Type</b>     | <b>Shell Pressure (barg)</b> | <b>Tube Pressure (barg)</b> |              | <b>MOC</b>                     | <b>Area (square meters)</b> | <b>Purchased Equipment Cost</b> | <b>Bare Module Cost</b> |
| E-101                       | Floating Head             | 85                           | 16.7                        |              | Stainless Steel / Carbon Steel | 118                         | \$34,300                        | \$194,000               |
| E-102                       | Fixed, Sheet, or U-Tube   | 13.7                         | 12                          |              | Stainless Steel / Carbon Steel | 101                         | \$42,200                        | \$201,000               |
| E-103                       | Floating Head             | 13.4                         | 13.2                        |              | Stainless Steel / Carbon Steel | 22                          | \$32,700                        | \$155,000               |
| E-104                       | Floating Head             | 18.6                         | 8.4                         |              | Stainless Steel / Carbon Steel | 22.7                        | \$32,800                        | \$158,000               |
| E-105                       | Floating Head             | 8.88                         | 13.2                        |              | Stainless Steel / Carbon Steel | 83                          | \$42,100                        | \$199,000               |
| E-106                       | Fixed, Sheet, or U-Tube   | 12.4                         | 16.6                        |              | Stainless Steel / Carbon Steel | 12.4                        | \$27,600                        | \$133,000               |

| Fired Heaters       | Type                           | Heat Duty (MJ/h)       | Steam Superheat (°C) | MOC          | Pressure (barg)           |                 | Purchased Equipment Cost | Bare Module Cost |
|---------------------|--------------------------------|------------------------|----------------------|--------------|---------------------------|-----------------|--------------------------|------------------|
| H-101               | Process Heater                 | 5070                   |                      | Carbon Steel | 54                        |                 | \$868,000                | \$1,990,000      |
| Pumps (with drives) | Pump Type                      | Power (kilowatts)      | # Spares             | MOC          | Discharge Pressure (barg) |                 | Purchased Equipment Cost | Bare Module Cost |
| P-101               | Centrifugal                    | 7.2                    | 1                    | Carbon Steel | 31                        |                 | \$12,640                 | \$65,000         |
| P-102               | Centrifugal                    | 9.6                    | 1                    | Carbon Steel | 15.2                      |                 | \$9,810                  | \$42,700         |
| P-103               | Centrifugal                    | 5.2                    | 1                    | Carbon Steel | 11.2                      |                 | \$11,480                 | \$46,800         |
| P-104               | Centrifugal                    | 1                      | 1                    | Carbon Steel | 8.8                       |                 | \$8,760                  | \$34,900         |
|                     |                                |                        |                      |              |                           |                 |                          |                  |
| Towers              | Tower Description              | Height (meters)        | Diameter (meters)    | Tower MOC    | Demister MOC              | Pressure (barg) | Purchased Equipment Cost | Bare Module Cost |
| T-101               | 22 Stainless Steel Valve Trays | 16                     | 0.8                  | Carbon Steel |                           | 18              | \$82,600                 | \$220,000        |
| T-102               | 10 Stainless Steel Valve Trays | 20                     | 1.16                 | Carbon Steel |                           | 18              | \$73,600                 | \$309,000        |
|                     |                                |                        |                      |              |                           |                 |                          |                  |
| Vessels             | Orientation                    | Length/Height (meters) | Diameter (meters)    | MOC          | Demister MOC              | Pressure (barg) | Purchased Equipment Cost | Bare Module Cost |
| V-101               | Vertical                       | 2.89                   | 1.14                 | Carbon Steel |                           | 12.4            | \$9,640                  | \$55,700         |
| V-102               | Vertical                       | 2.53                   | 0.85                 | Carbon Steel |                           | 8.8             | \$6,650                  | \$30,500         |
|                     |                                |                        |                      |              |                           |                 |                          |                  |
|                     |                                |                        |                      |              |                           | Total Purchased |                          | \$1,359,980      |

*----- Contd.*

|                                          |  |             |           |       |      |                          |  |                       |
|------------------------------------------|--|-------------|-----------|-------|------|--------------------------|--|-----------------------|
|                                          |  |             |           |       |      | Equipment<br>Cost        |  |                       |
|                                          |  |             |           |       |      | Total<br>Adjusted<br>10% |  | \$1,495,978           |
| Catalyst                                 |  | Weight (Kg) | Unit Cost | Units | Cost |                          |  | Total Cost            |
| $\gamma$ -Al <sub>2</sub> O <sub>3</sub> |  | 24523       | 207.4     | 24523 |      |                          |  | \$5,086,070.20        |
| Project<br>Estimate                      |  |             |           |       |      |                          |  | Total                 |
| <b>Project<br/>Estimate</b>              |  |             |           |       |      |                          |  | <b>\$6,582,048.20</b> |

The realized costs were then adjusted using a 10-percent margin of error to accommodate any additional equipment that may have been overlooked. From the table above the final project estimate was determined to be \$6,583,797.20.

## 11. ASPEN Simulation of Process

As shown in Figure 4, the process was simulated using ASPEN Plus. In order to ensure that the system converged, a step-by-step design was implemented. What this means is that each piece of equipment was individually placed and converged before moving to the next piece of equipment. By having each piece of equipment converge, the overall design was able to converge once all equipment was simulated.

## 12. Economic Evaluation

An overview of the economic analysis can be seen in Table 13 below.

Table 13. Economic Summary

| <b>Economic Evaluation</b>                |        |
|-------------------------------------------|--------|
| Total Capital Investment, $10^6$          | \$10.2 |
| Annual Total Production Costs, $10^6$     | \$34   |
| Annual Sales, $10^6$                      | \$37   |
| Payback Period, yrs                       | 4.2    |
| Return on Investment, %/year              | 22     |
| Discounted Cash Flow Rate of Return, %/yr | 13     |
| Net Present Value, $10^6$                 | \$8    |
| Salvage Value, $10^6$                     | \$1    |
| Cumulative profit, $10^6$                 | \$23   |

Figure 5 shows the cash flow diagram for the system. It is important to note that the values represented already take into account the total production costs. As seen, in year 13, profit turns back negative. This is due to an assumed 2% inflation rate for total production costs coupled with the depreciation of equipment.

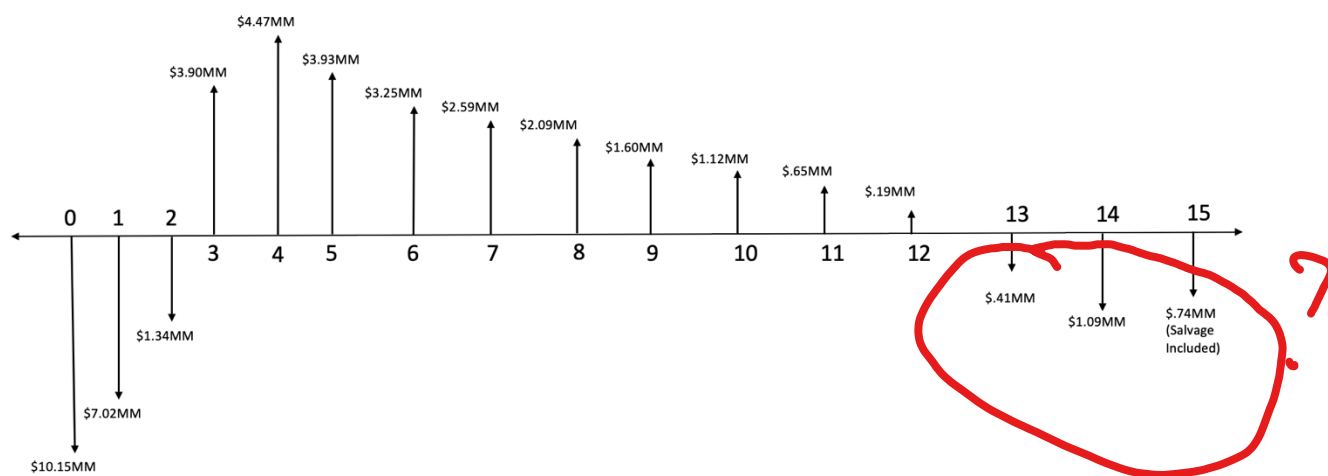


Figure 5. Cash Flow Diagram

### 13. Safety and HAZOP Analysis

Safety plays a crucial role in the success of the project. A hazard and operability (HAZOP) analysis presents a means of assessing how various components within the plant may deviate from their normal operations and pose safety and health risks to personnel, and how to mitigate these deviations. For this project, a HAZOP analysis was conducted for the second distillation column, the methanol tower, which is responsible for the separation of methanol for recycling from water/methanol mixture.

The methanol tower is a distillation column comprising of a feed line, a distillate line and a bottom line. It is a crucial component in the proposed plant for the synthesis of DME from methanol to be established in Plaquemine, Louisiana.

The general Guidelines for Safety Guidelines in Accordance with Rules and Regulations of Plaquemine, Louisiana are as follows (Ayres, 2016):

#### I. Pre Line Opening Job Preparations –

- The shutting down and energy isolation of all process systems prior to any line opening involving process piping, equipment or vessels (4.1.1).
- The draining and/or depressurization of all process piping, equipment or vessels to ensure clearance of hazardous materials (4.1.2).
- Ensuring temperatures for the process piping, equipment or vessels have sufficiently cooled to allow for safe work (4.1.3).

## II. Line Opening Job Planning –

- The barricading of affected areas with a minimum of 10 ft radius as a precautionary area (4.2.1.1)
- The issuance of permits strictly by authorized personnel (4.2.2.1)

With the above guidelines the project involved a maximum exposure of 200 ppm from methanol. In addition, the general guidelines adopted by the City of Plaquemine where the proposed plant is expected to be established, the HAZOP analysis for the second distillation which constitutes the methanol tower can be conducted as follows.

**I. T-102 Feed Line – Entry of reactants (methanol/water mixture) into the distillation column.**

| No. | Parameter   | Guideword | Deviation                          | What if?                                                              | Possible Causes                           | Consequence                                                                         | Safeguards                                                                                          | Action                                                                                                                                                   |
|-----|-------------|-----------|------------------------------------|-----------------------------------------------------------------------|-------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Pressure    | More      | Pressure increase in the feed line | There is pressure build up in the feed line leading into the tower    | - Blockage in the system                  | - Failure of feed line tube<br>- Risk of expansion of column and bursting           | Installation of quick-pressure relief valves at strategic locations before and after the column.    | - Installation of a secondary pressure relief device.<br>- Checking maintenance schedule and procedures                                                  |
|     |             | Less      | Pressure decreases in feed line    | There are sudden pressure losses in the streams leading to the column | - Leakages in the system                  | - Insufficient reactant material entering the column                                | Pressure alarms at the feed, distillate and bottom streams                                          | - Installation of pressure gauge<br>- Checking maintenance schedule and procedures                                                                       |
| 3   | Flow        | Reverse   | Backflow from T-102                | The contents of the tower flow back to the feed line                  | - Clogging and blockages within the tower | - Pressure and temperature increase in the column                                   | - Check valve to prevent backflow                                                                   | - determining the best utilization of energy from recycle stream while preventing backflow- Following the stipulated maintenance schedule and procedures |
| 4   | Temperature | More      | Increase in feed temperature       | There is sudden increase in temperature at the feed of T-102          | - Clogging of inlet into tower            | Subsequent increase in pressure, risk of explosion and ineffectiveness of the tower | - Temperature alarms at feed entry point.<br>- Panel alarms to warn of high pressure or temperature | - Installation of a temp gauge<br>- Checking maintenance schedule and procedures                                                                         |

**II. T-102 Distillate Line – Transportation of recycled methanol from the distillation column back to the mixer.**

| No. | Parameter   | Guideword | Deviation                                | What if?                                                                                      | Possible Causes                                            | Consequence                                                                                           | Safeguards                                                                                           | Action                                                                                                                                                      |
|-----|-------------|-----------|------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Pressure    | More      | Pressure increase in the distillate line | There is pressure build up in the distillate line transporting recycled methanol to the mixer | -Blockage in the mixer or further up the distillation line | - Failure of distillate line tube<br>- Risk of expansion of mixer and bursting.<br>- Failure of mixer | Installation of quick-pressure relief valves at strategic locations before the mixer.                | - Installation of a secondary pressure relief device.<br>- Checking maintenance schedule and procedures                                                     |
|     |             | Less      | Pressure decreases in feed line          | There are sudden pressure losses in the stream leading to the mixer                           | - Leakages in the distillate line                          | - Inefficiencies within the tower leading to less methanol distillate                                 | Pressure alarms at the exit of the column where the distillate line begins.                          | - Installation of pressure gauge<br>- Checking maintenance schedule and procedures                                                                          |
| 3   | Flow        | Reverse   | Backflow to T-102                        | The contents of the distillate line flow back to the tower                                    | - Clogging and blockages within the line                   | - Pressure and temperature increase in the column                                                     | - Check valve to prevent backflow                                                                    | - determining the best utilization of energy from recycle stream while preventing backflow-<br>Following the stipulated maintenance schedule and procedures |
| 4   | Temperature | More      | Increase in distillate line temperature  | There is sudden increase in temperature at distillate line transporting recycled methanol     | - Clogging of inlet into the mixer                         | Subsequent increase in pressure, risk of explosion and ineffectiveness of the tower                   | - Temperature alarms at mixer entry point.<br>- Panel alarms to warn of high pressure or temperature | -Installation of a temp gauge<br>- Checking maintenance schedule and procedures                                                                             |

**III. T-103 Bottom Line – Transportation of wastewater from the distillation column to treatment plant.**

| No. | Parameter   | Guideword | Deviation                            | What if?                                                                                              | Possible Causes                          | Consequence                                                                           | Safeguards                                                                                                                    | Action                                                                                                                                                      |
|-----|-------------|-----------|--------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Pressure    | More      | Pressure increase in the bottom line | There is pressure build up in the bottom-line transporting wastewater to treatment plant              | -Blockages within bottom line            | - Failure of bottom-line tube<br>- Risk of expansion and bursting of the line.        | Installation of quick-pressure relief valves at strategic locations within the line.                                          | - Installation of a secondary pressure relief device.<br>- Checking maintenance schedule and procedures                                                     |
|     |             | Less      | Pressure decreases in bottom line    | There are sudden pressure losses in the stream within the bottom line leading away from the tower     | - Leakages in the bottom line            | - Inefficiencies within the tower causing decreased flow of wastewater from the tower | Pressure alarms at the exit point from the tower joining the bottom line                                                      | - Installation of pressure gauge<br>- Checking maintenance schedule and procedures                                                                          |
| 3   | Flow        | Reverse   | Backflow to T-102                    | The contents of the bottom line flow back to the tower                                                | - Clogging and blockages within the line | - Pressure and temperature increase in the column                                     | - Check valve to prevent backflow                                                                                             | - determining the best utilization of energy from recycle stream while preventing backflow-<br>Following the stipulated maintenance schedule and procedures |
| 4   | Temperature | More      | Increase in bottom line temperature  | There is sudden increase in temperature at bottom line transporting wastewater to the treatment plant | - Clogging of the line at various points | Subsequent increase in pressure, risk of explosion and ineffectiveness of the tower   | - Temperature alarms at exit point of the tower to the bottom line.<br>- Panel alarms to warn of high pressure or temperature | -Installation of a temp gauge<br>- Checking maintenance schedule and procedures                                                                             |

## 14. Discussion

Over the course of completing the design, there were assumptions made for the molar compositions of the process streams and for the heat exchanger duties. These values were obtained through literature reviews. As mentioned, the energy balance was assumed to be correct from ASPEN Plus due to similar results being obtained for the reactor energy balance. The economic analysis was assumed to be over a 15 year life span, and a 2% inflation rate was assumed. It is also important to note that for calculation purposes, 8,000 on stream hours was used. Moreover, the median salary for an operator in Plaquemine is \$59,029 (Glassdoor 2022). As a result, we generously set our operator salary at \$70,000 per year and determined that we need three operators per shift and three shifts per day.

not

clear

## 15. Conclusion and Recommendations

Overall, 50,000 MTPY of DME is being produced at 99.9% purity. This system would be in operation for 329 days out of the year (90% utilization). It is recommended to not produce more than that due to the still emerging market for DME. It has not yet been discovered how to solely rely on DME for transportation fuel, so the market is currently limited. The selected process of methanol dehydration allows for pure methanol to be imported via pipeline and reacted to form DME. Specifically for this design, it is recommended to salvage after year 12 to prevent the negative losses in years 13-15. However, with the present salvage at year 15, the overall profit is \$23MM with a 22% return on investment. As a result of this, it is recommended to continue with the design of this plant. Further analysis on E-102 is also recommended due to the drastic drop in temperature. There may be an additional opportunity for energy savings by recovering the lost heat.

## 16. References

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Styring, P., Dowson, G. R., & Tozer, I. O. (2021). Synthetic Fuels Based on Dimethyl Ether as a Future Non-Fossil Fuel for Road Transport From Sustainable Feedstocks. *Frontiers in Energy Research*, 9, 240.

Yang, A. S., Antrassian, C. V., & Kurtzman, J. D. (2020). Production of Dimethyl Ether (DME) for Transportation Fuel.

## 17. Appendix

|                                       |              |
|---------------------------------------|--------------|
| <b>Direct Costs</b>                   |              |
| Purchased equipment, E'               | 1.496        |
| Delivery, fraction of E'              | 0.150        |
| Subtotal: delivered equipment         | 1.646        |
| Purchased equipment installation      | 0.773        |
| Instrumentation&Controls(installed)   | 0.592        |
| Piping (installed)                    | 1.119        |
| Electrical systems (installed)        | 0.181        |
| Buildings (including services)        | 0.296        |
| Yard improvements                     | 0.165        |
| Service facilities (installed)        | 1.152        |
| Total direct costs                    | 5.924        |
| <b>Indirect Costs</b>                 |              |
| Engineering and supervision           | 0.543        |
| Construction expenses                 | 0.675        |
| Legal expenses                        | 0.066        |
| Contractor's fee                      | 0.362        |
| Contingency                           | 0.724        |
| Total indirect costs                  | 2.370        |
| <b>Fixed capital investment (FCI)</b> | <b>8.294</b> |
| <b>Working capital (WC)</b>           | <b>1.465</b> |
| <b>Total capital investment (TCI)</b> | <b>9.758</b> |

Figure 6. Direct and Indirect Costs

## **ASSIGNMENTS FOR OUTCOME 3**

**An ability to communicate effectively with a range of audiences  
(Written and Oral, Demonstrated by Parts of Final Project Report &  
Presentation Slides)**

**CHEMICAL ENGINEERING DEPARTMENT  
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET  
SENIOR DESIGN & PROFESSIONALISM II  
SPRING 2022**

Instructor: Dr. Emmanuel A. Dada

Title of Assignment

**Final Project Powerpoint Presentation**

Outcome Measured Using this Assignment

**Outcome 3**

**An ability to communicate effectively with a range of audiences**

Check the communication problem characteristics related to this assignment

|                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Ability to prepare an executive summary for the report</b>                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Requires students to:                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                                                                                  | Prepare an executive summary up to 3 pages                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Ability to organize, plan and properly format a written technical report</b>                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Requires students to:                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| x                                                                                                | Organize report by chapters, major sections, subsections and paragraphs                                                                                                                                                                                                                                                                                                                                                                                        |
| x                                                                                                | Provide Title Page, and Table of Contents, list of Figures, and List of Tables properly formatted.                                                                                                                                                                                                                                                                                                                                                             |
| x                                                                                                | Provide figure and table numbers with titles and reference and discuss each table and figure in accord with standard practice.                                                                                                                                                                                                                                                                                                                                 |
| x                                                                                                | Properly cite references in the report and provide well formatted reference list at the end.                                                                                                                                                                                                                                                                                                                                                                   |
| x                                                                                                | Prepare the written report in accord with standard report formatting Manual                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Ability to compose original texts and properly apply the conventions of written language.</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Requires students to:                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| X                                                                                                | Properly apply capitalization, punctuation, and penmanship, to communicate clearly and spell proficiently,                                                                                                                                                                                                                                                                                                                                                     |
|                                                                                                  | Apply standard grammar and usage to communicate clearly and effectively in writing <b>using complete sentences</b> , good subject-verb agreement, pronoun referents, and parts of speech, properly using adjectives, adverbs, prepositional phrases appropriately, conjunctions to connect ideas to make writing vivid and precise, and use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report. |
| <b>Ability to provide appropriate discussion, conclusions and recommendations</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Requires students to                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| X                                                                                                | summarize the goals, objectives, and indicate whether they were met.                                                                                                                                                                                                                                                                                                                                                                                           |
| X                                                                                                | summarize the report chapter by chapter                                                                                                                                                                                                                                                                                                                                                                                                                        |
| X                                                                                                | summarize constraints and codes and indicate whether they were met for design reports<br>Summarizes how issues relating to public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors were considered/addressed for design reports.                                                                                                                                                                          |
| X                                                                                                | Provide logical conclusions Provide logical conclusions and recommendations (including strengths and weaknesses)                                                                                                                                                                                                                                                                                                                                               |

**Brief justification of why this assignment is suitable for this outcome**

Grading Scheme

The students are assessed by external evaluators who are professional engineers for their skills in presenting their projects and defending their projects via a powerpoint presentation mode. The students are graded based on some rubrics detailed below. The students written report as attached for outcome 2 above are graded based on the below grading rubrics.

The grading rubrics for evaluation of the Senior Design II projects CHEG 4248 (a continuation of the fall 2021 Senior Design I CHEG 42472) are presented below. The students are to be evaluated as outlined in the rubrics with emphasis on the following:

- Justification of plant location and capacity
- Provide a process description and Process Flow Diagram (PFD) for the plant showing the major items of equipment, and indicating the materials of construction and the operating temperatures and pressures
- Material and energy balances with summary table for the process with streams information showing a mass balance for each major equipment
- A complete HYSYS/ASPEN simulation report of the process
- Chemical engineering design of major equipment such as (i) reactor(s), (ii) absorption column(s) and (iii) distillation columns
- Estimates of the Major Equipment Capital Cost (Capex)
- Estimates of Operating Cost (Opex)
- Preparation of a net present value and investor's rate of return analysis for the investment over a 15-year life, assuming the company's current capital hurdle rate is 15%.
- Preparation of a project milestone schedule
- Preparation of a P&ID for a section of the process showing the control scheme to ensure safe operation of the unit, and carrying out a HAZOP analysis of the section of the process selected
- Preparation of a safety report indicating the safety measures required for the plant bearing in mind any toxic and flammable materials handled

In addition, the names of the presenters for each design project have been included in the rubrics to enable each presenter to be evaluated as well.

#### **References:**

**1. Gael D. Ulrich and Palligarnai T. Vasudevan, "Chemical Engineering : Process Design and Economics, A practical Guide", second edition, 2004, Process Publishing, New Hampshire, USA, ISBN 0-9708768-2-3**

**2. Gavin Towler and Ray Innot, "Chemical Engineering Design : Principles, Practice and Economics of Plant and Process Design" Butterworth-Heinemann, ISBN 978-0-08-096659-5, second edition, 2013**

**3. Perry's Chemical Engineering Handbook, sixth edition or latest**

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**4. Turton, R., Bailie, R., Whiting, W., and Shaeiwits, J. A. "Analysis, Synthesis, and Design of Chemical Processes," 4<sup>th</sup> Edition Prentice-Hall PTR, Upper Saddle River, New Jersey 07458, 2008.**

5. "Plant Design and Economics for Chemical Engineers" by Peters, M.S., K.D. Timmerhaus and R.E. West, 5<sup>th</sup> edition, 2003, McGraw-Hill, ISBN 0—07-239266-5.

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DEPARTMENT OF CHEMICAL ENGINEERING  
SENIOR DESIGN & PROFESSIONALISM II CHEG 4248  
COURSE ASSESSMENT GRADING & OUTCOME  
ASSESSMENT SHEET FOR SPRING 2022 SEMESTER

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**ABET Student Learning Outcome 3: An ability to communicate effectively with a range of audiences (Written Technical Communication)**

Assignments that test competency in written communication will include problems that test the student's ability to logically arrange information, use correct grammar, use appropriate format, use discipline specific conventions including citations, and use acceptable graphical conventions.

---

Name: \_\_\_\_\_

Title of Assignment: \_\_\_\_\_ Due Date \_\_\_\_\_

| Competency Area                                                                                                                                                                                       | Points Assigned | Points Received |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------|
| <b>1. Ability to prepare an executive summary for the report</b>                                                                                                                                      | <b>10</b>       |                 |
| Students are able to prepare an executive summary of 5 to 8 pages                                                                                                                                     | 10              |                 |
| <b>2. Ability to organize, plan and properly format a written technical report</b>                                                                                                                    | <b>80</b>       |                 |
| (i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units. | 20              |                 |
| (i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units. | 20              |                 |
| (ii) Students provide Title Page, and Table of Contents, list of Figures, and List of Tables properly formatted.                                                                                      | 12              |                 |
| (iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual. | 12              |                 |
| (iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table, and completely discuss each table in the report.      | 12              |                 |
| (v) Students properly cite references in the report and provide well formatted reference list at the end.                                                                                             | 12              |                 |
| (vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.                                                                     | 12              |                 |
| <b>3. Ability to compose original texts and properly apply the conventions of written language</b>                                                                                                    | <b>50</b>       |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--|
| (i) Properly apply capitalization, punctuation, and penmanship, to communicate clearly.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 15         |  |
| (ii) Spell proficiently                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 10         |  |
| (iii) Apply standard grammar and usage to communicate clearly and effectively in writing including <ul style="list-style-type: none"> <li>• <b>using complete sentences</b>, varying the types such as compound and complex to match meanings and purposes</li> <li>• properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech</li> <li>• properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise</li> <li>• properly using prepositional phrases to elaborate written ideas</li> <li>• properly using conjunctions to connect ideas meaningfully</li> </ul> | 20         |  |
| (vi) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 5          |  |
| <b>4. Ability to provide appropriate discussion, conclusions and recommendations</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>60</b>  |  |
| (i) Summarize the goals, objectives, and indicate whether they were met.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 10         |  |
| (ii) Summarize the results.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 30         |  |
| (iii) Summarize constraints and codes and indicate whether they were met.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 10         |  |
| (iv) Provide logical conclusions and recommendations (including strengths and weaknesses).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 10         |  |
| <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>200</b> |  |

### SENIOR DESIGN & PROFESSIONALISM II CHEG 4248

#### Oral Design Presentation Evaluation Form

|                                      |
|--------------------------------------|
| Title of Presentation:               |
| Date of Presentation: April 23, 2022 |
| Name of Examiner/Appraiser:          |

| Performance Criteria                                                                                                                      | Not Acceptable<br>(0-59.9%)                                                | Below Expectations<br>(60-69.9%)                                           | Average meets<br>minimal expectations<br>70-79.9                           | Very Good<br>Meets Expectations<br>(80-89.9%)                              | Excellent Exceeds<br>Expectations (90-<br>100%)                            |
|-------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| <b>1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation**</b>                      | <b>20 40 59</b>                                                            | <b>60 65 69</b>                                                            | <b>70 75 79</b>                                                            | <b>80 85 89</b>                                                            | <b>90 95 99</b>                                                            |
| Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding. | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Slides are well prepared and are effective in helping                                                                                     |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |

|                                                                                                                                                                                                                     |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| audience to understand ( <i>adequate and relevant technical content and view graphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented</i> ) | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Modern presentation techniques are used ( <i>may include visually enhanced transitions, animations, video, and sound clips</i> ).                                                                                   | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| <b>Average for this Performance Criteria</b>                                                                                                                                                                        |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
| <b>2. Ability to Articulate Subject Knowledge (Technical Content)*</b>                                                                                                                                              |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
| Client identification and recognition of need                                                                                                                                                                       | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Project goals and objectives, and planning                                                                                                                                                                          | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Process screening and selection, PFD and process description                                                                                                                                                        | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Process chemistry, and material and energy balances                                                                                                                                                                 | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Quality of chemical engineering design/and analysis, and design constraints                                                                                                                                         | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Design within economic, societal and environmental constraints(including contemporary issues and broader impact on society)                                                                                         | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Hazard and Safety considerations****                                                                                                                                                                                | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Questions are responded to in a clear professional manner after restating questions to audience                                                                                                                     | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| <b>Average for this Performance Criteria</b>                                                                                                                                                                        |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
| <b>3. Appearance and Ability to Provide Good Oral Delivery**</b>                                                                                                                                                    |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
| Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence                                                               | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Good posture and eye contact with the audience are maintained ( <i>should not read from prepared notes</i> ) and elicits the attention of the audience                                                              | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Presenters dress appropriately for the occasion.                                                                                                                                                                    | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| Efforts of all group members/Group dynamics***                                                                                                                                                                      | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
| <b>Average for this Performance Criteria</b>                                                                                                                                                                        |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
| <b>OVERALL AVERAGE GROUP PERFORMANCE</b>                                                                                                                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
| <b>NAME OF PRESENTER</b>                                                                                                                                                                                            | <b>OVERALL PERFORMANCE OF PRESENTER</b>                                    |                                                                            |                                                                            |                                                                            |                                                                            |
|                                                                                                                                                                                                                     | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
|                                                                                                                                                                                                                     | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
|                                                                                                                                                                                                                     | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |

|  |                                                                            |                                                                            |                                                                            |                                                                            |                                                                            |
|--|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
|  | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |
|  | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> |

\*ABET Student Outcome 2 ; \*\*ABET Student Outcome 3; \*\*\* ABET Student Outcome 5; \*\*\*\*Program Criterion 9b

INSERT A SAMPLE STUDENT'S COPY OF THE POWERPOINT PRESENTATION

# PRODUCTION OF DIMETHYL ETHER

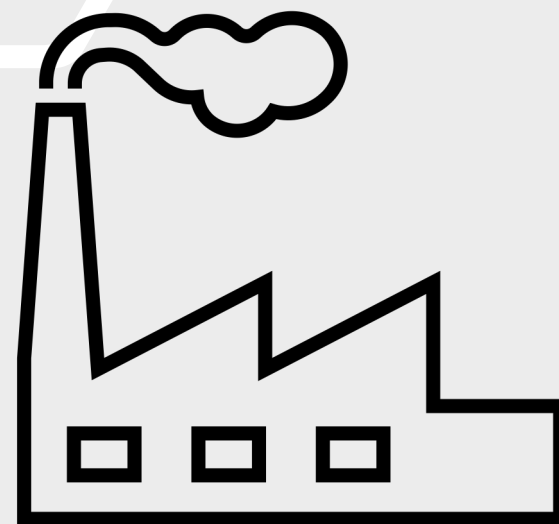
## ***DADA TEAM 4***

Amiya Rogers — 88%

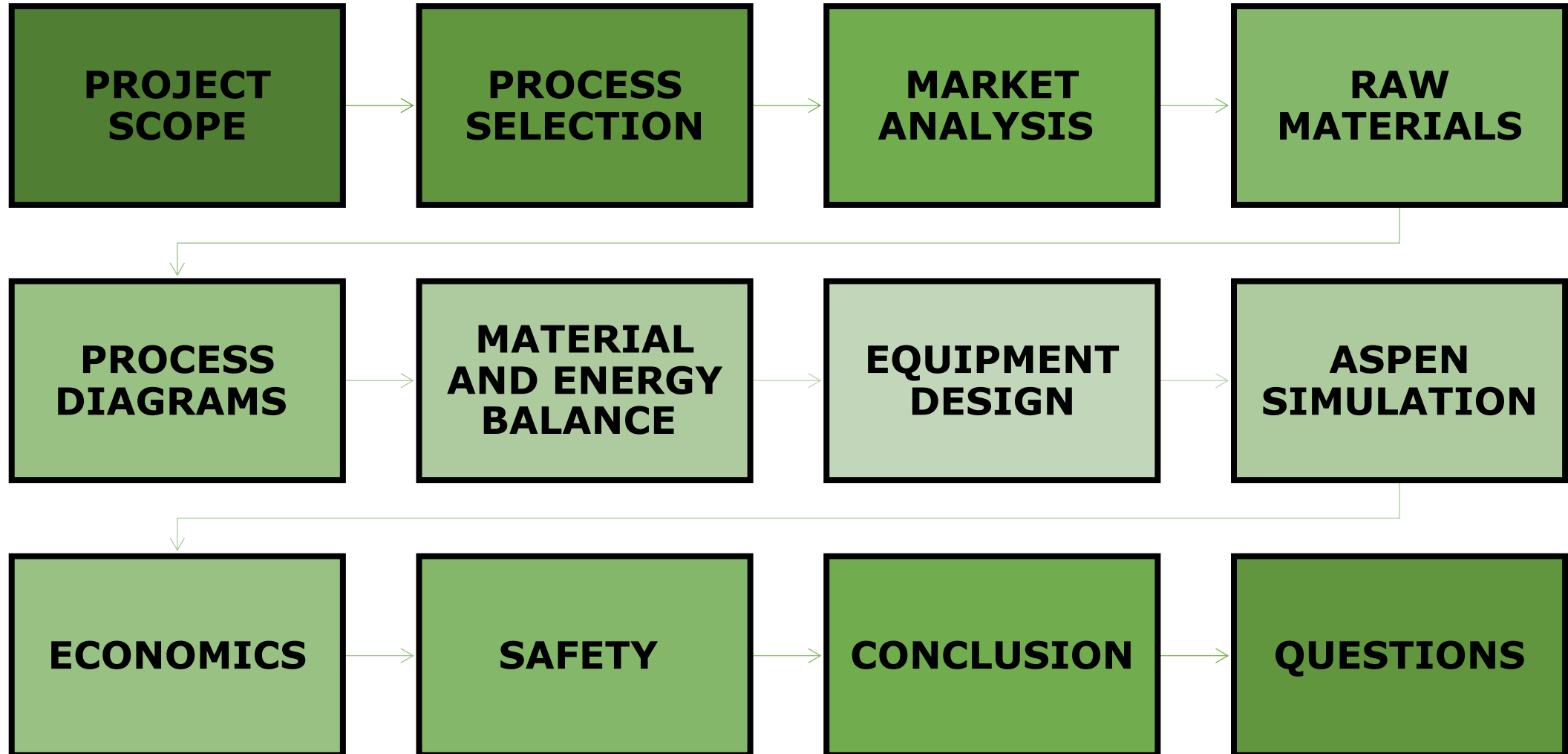
Cinthia Sahin — 88%

Laura Ukpede — 87%

Taylon Owens — 90%



# OUTLINE



# **PROJECT SCOPE**

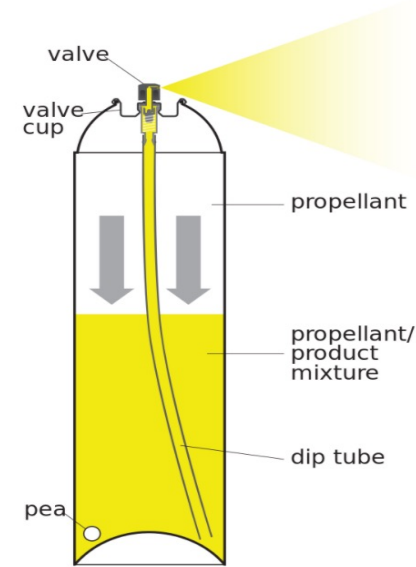
# PROBLEM STATEMENT

The purpose of this project is to design a system that produces Dimethyl Ether (DME) at the required 99.9% purity.



# PRODUCT USES

- Refrigerant (R-E170)
- Solvent
- Propellant in industrial aerosol products.
- Potential use for transportation fuel, domestic use, and power generation



# **PROCESS SELECTION**

# PROCESSES CONSIDERED

| ALTERNATIVE | PROCESS                                      | PROS                                                                                                                                                                                                              | CONS                                                                                                                                                                                           |
|-------------|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1           | Methanol Dehydration                         | <ul style="list-style-type: none"> <li>Consumes less time and cost of equipment</li> <li>Relatively simpler process flow</li> <li>Catalyst deactivation occurs at relatively high temperature (400 C).</li> </ul> | <ul style="list-style-type: none"> <li>Requires more downstream separation technologies.</li> <li>Sourcing of methanol may present challenges.</li> <li>Marginally lower DME yield.</li> </ul> |
| 2           | Indirect Synthesis from biogas feedstock     | <ul style="list-style-type: none"> <li>Marginally higher DME yield.</li> <li>Water build up in the process is alleviated.</li> <li>Energy efficiency is maximized.</li> </ul>                                     | <ul style="list-style-type: none"> <li>Sourcing of biogas feedstocks presents a challenge.</li> <li>Process requires more equipment.</li> <li>Relatively costly and time consuming</li> </ul>  |
| 3           | Direct Synthesis from Natural Gas Feed Stock | <ul style="list-style-type: none"> <li>Higher Yield of DME.</li> <li>Low production cost.</li> <li>Abundantly available feedstock</li> </ul>                                                                      | <ul style="list-style-type: none"> <li>Highly exothermic.</li> <li>Low production rate</li> <li>Higher operating temperature.</li> </ul>                                                       |

# PROCESS SELECTION MATRIX

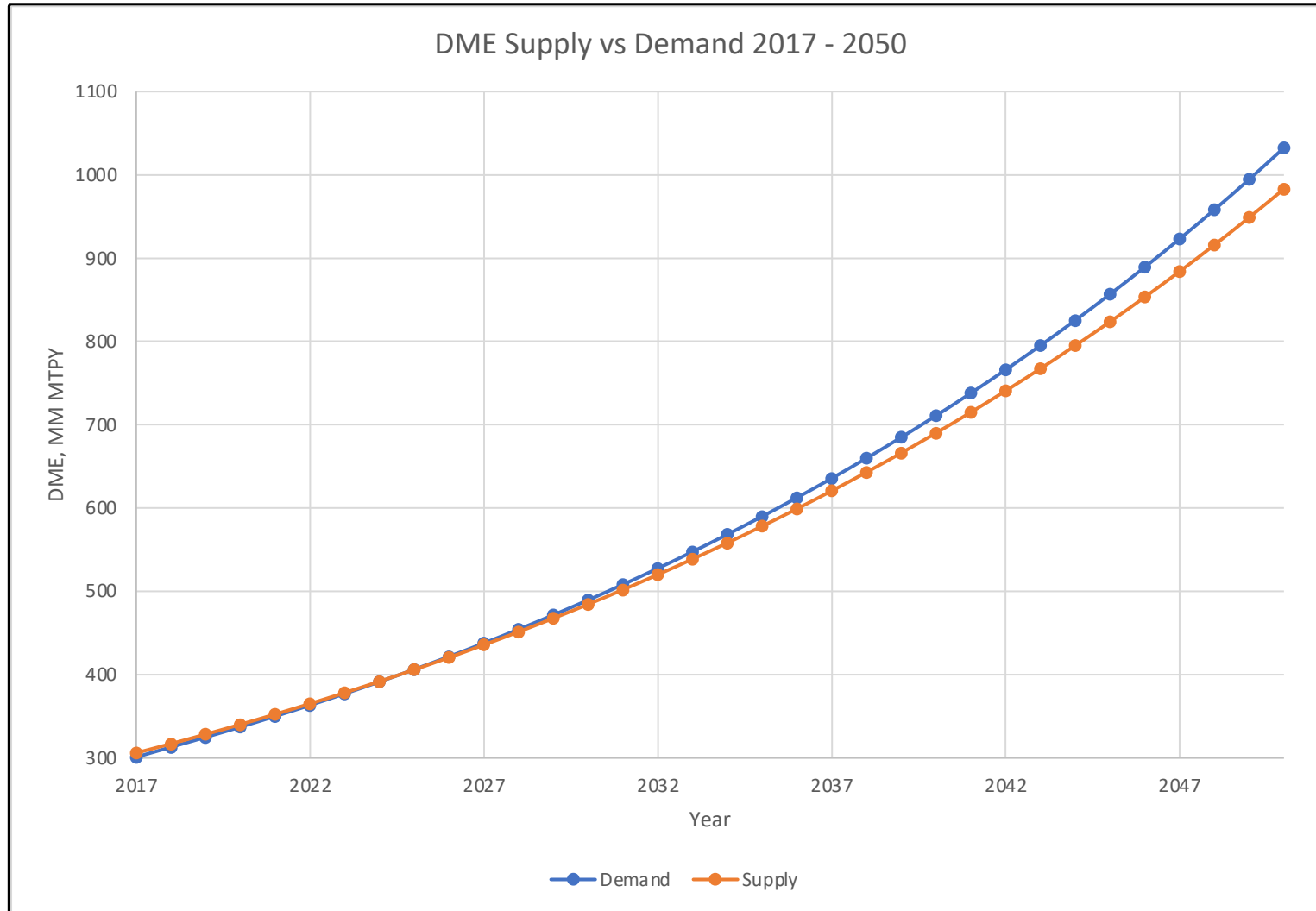
| CONSIDERATIONS | ALTERNATIVE 1<br>Methanol<br>Dehydration | ALTERNATIVE 2<br>Indirect Synthesis<br>from<br>biogas feedstock | ALTERNATIVE 3<br>Direct Synthesis<br>from Natural Gas<br>Feed Stock | WEIGHT |
|----------------|------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------------|--------|
| Economics      | 18                                       | 10                                                              | 12                                                                  | 40%    |
| Environmental  | 13                                       | 16                                                              | 20                                                                  | 25%    |
| Location       | 14                                       | 13                                                              | 9                                                                   | 25%    |
| Safety         | 13                                       | 13                                                              | 16                                                                  | 10%    |
| Total          | <u>15.25</u>                             | 12.5                                                            | 13.65                                                               | 100%   |

# PROJECT PLANNING (GANTT CHART)

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| PROJECT TITLE: |  | PRODUCTION OF DIMETHYL ETHER (DME) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | </ |
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# **MARKET ANALYSIS**

# MARKET ANALYSIS



## PLANT STARTUP:

2026

2 Year Build-Time

## DEMAND BASIS:

50,000 Metric Tons Per Year  
(5% of 1MM Gap)

## DEMAND BASIS:

90% Utilization

# CLIENT IDENTIFICATION



# PLANT LOCATION

## LOCATION:

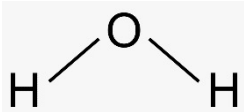
Plaquemine, Louisiana

Plaquemine Cogeneration Facility: Steam and Power  
Port of Plaquemines for Cooling Water



# **RAW MATERIALS**

# CHEMICAL CONDITIONS

| Conditions         | Methanol                                                                                                       | Dimethyl Ether                                                                                                                                                        | Water                                                                               |
|--------------------|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Molecular Weight   | 0.071 lb/mol                                                                                                   | 0.102 lb/mol                                                                                                                                                          | 0.039 lb/mol                                                                        |
| Chemical Formula   | CH <sub>3</sub> OH                                                                                             | CH <sub>3</sub> OCH <sub>3</sub>                                                                                                                                      | H <sub>2</sub> O                                                                    |
| Chemical Structure | $  \begin{array}{c}  \text{H} \\    \\  \text{H}-\text{C}-\text{O}-\text{H} \\    \\  \text{H}  \end{array}  $ | $  \begin{array}{c}  \text{H} \quad \text{H} \\    \quad   \\  \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\    \quad   \\  \text{H} \quad \text{H}  \end{array}  $ |  |
| Boiling Point      | 148.46 ° F                                                                                                     | -11.2°F                                                                                                                                                               | 212°F                                                                               |
| Melting Point      | -138.28°F                                                                                                      | -221.8°F                                                                                                                                                              | 32°F                                                                                |
| Flash Point        | 49.46°F                                                                                                        | -41.98°F                                                                                                                                                              | -                                                                                   |
| Density            | 0.029 lb/in <sup>3</sup>                                                                                       | 0.071 lb/in <sup>3</sup>                                                                                                                                              | 0.036 lb/in <sup>3</sup>                                                            |

# RAW MATERIALS



**A (Methanol)**

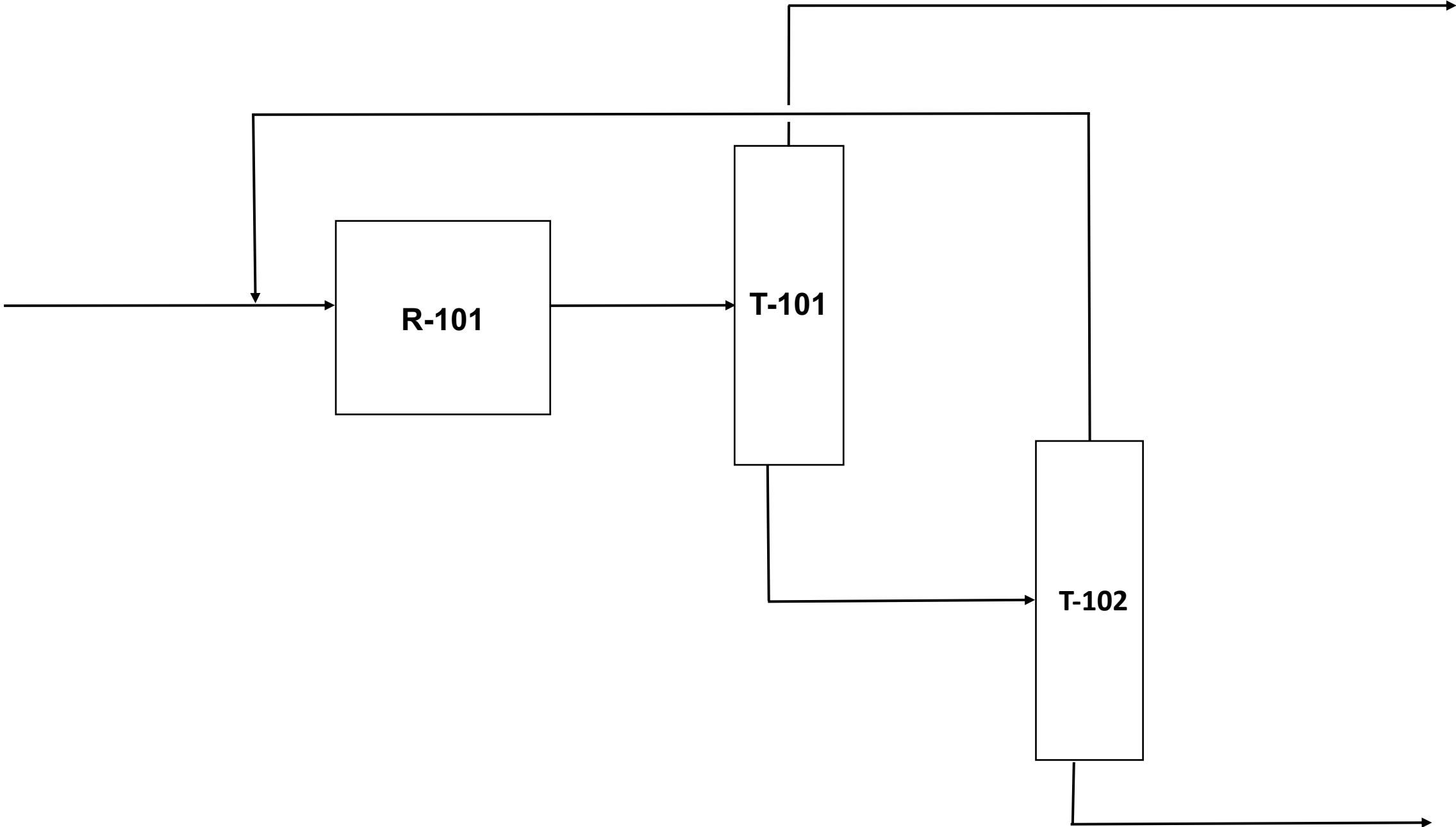
**B (DME)**

**C (Water)**

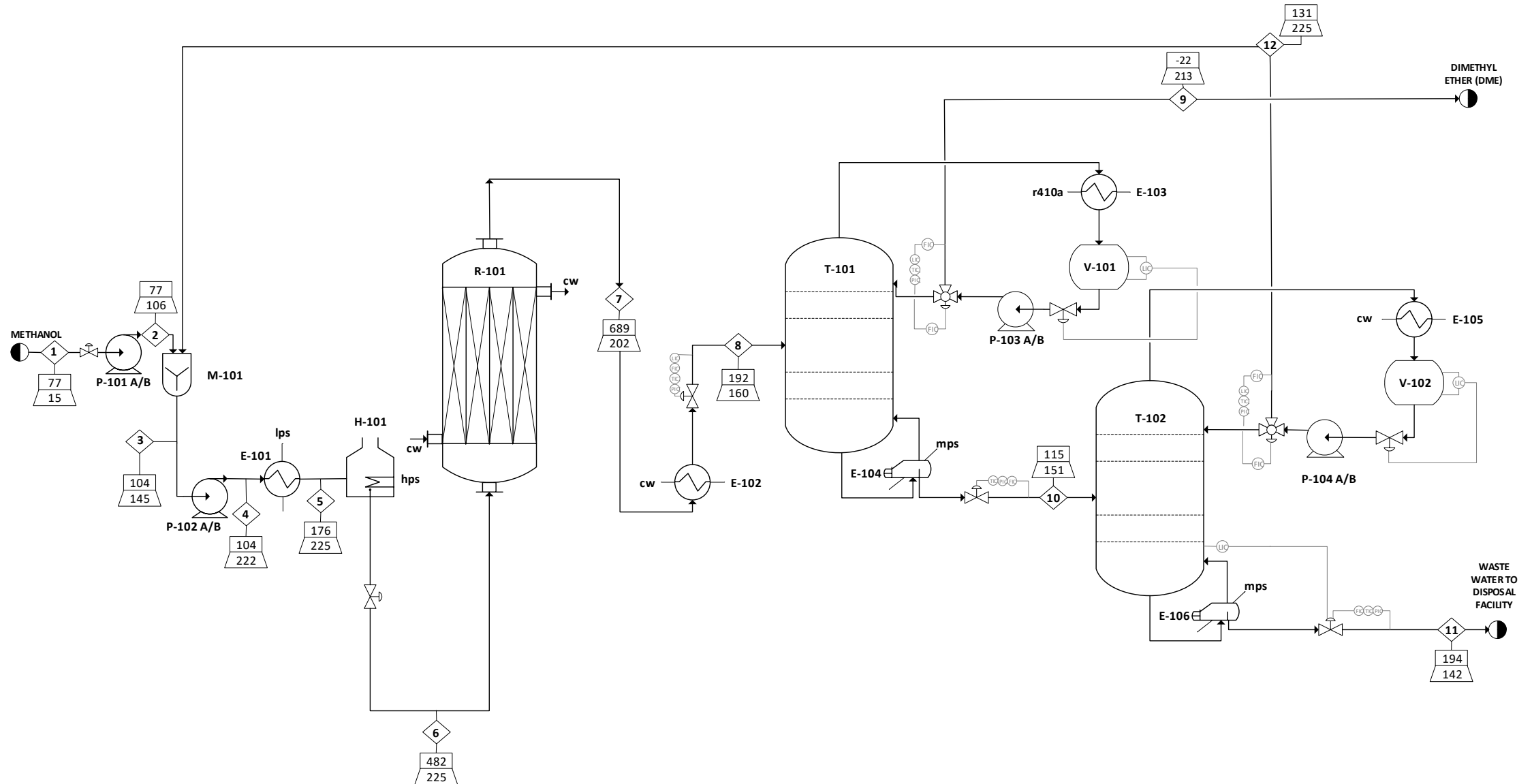
|                                    | <b>A</b>    | <b>B</b>     | <b>C</b>     |
|------------------------------------|-------------|--------------|--------------|
| <b>mol</b>                         | 2           | 1            | 1            |
| <b>Molecular Weight<br/>lb/mol</b> | 0.071lb/mol | 0.102 lb/mol | 0.040 lb/mol |
| <b>lb</b>                          | 0.141 lb    | 0.102 lb     | 0.040 lb     |
| <b>lb/lb DME</b>                   | 3.06 lb     | 2.20 lb      | .862 lb      |
| <b>cents/lb</b>                    | \$0.16      | \$0.41       | \$0.24       |

# **PROCESS DIAGRAMS**

# BLOCK FLOW DIAGRAM



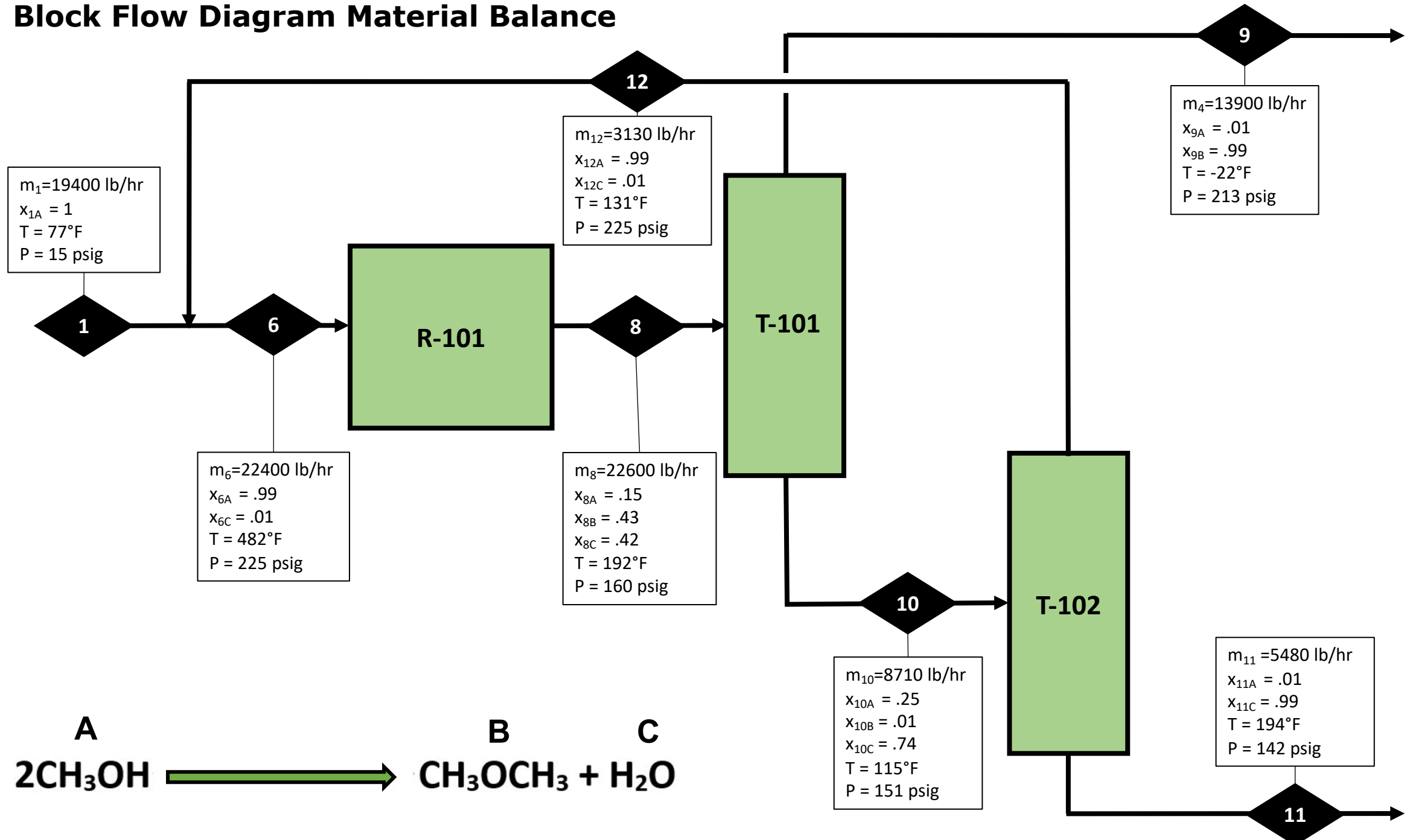
# PROCESS FLOW DIAGRAM



Temperature, °F  
Pressure, psig

# **MATERIAL AND ENERGY BALANCE**

# Block Flow Diagram Material Balance



# MATERIAL BALANCE

STREAM CONDITIONS

| Stream Description     | Pure Methanol to Pump | Pure Methanol to Mixer | Mixed Stream to P-102 | Methanol to Vaporizer | Combined Methanol to Furnace | Combined Feed to R-101 | Reactor Effluent to Cooler | Methanol+ DME + Water to T-101 | Dimethyl Ether Product | Methanol + Water to T-102 | Wastewater to Disposal | Recycled Methanol to Mixer |
|------------------------|-----------------------|------------------------|-----------------------|-----------------------|------------------------------|------------------------|----------------------------|--------------------------------|------------------------|---------------------------|------------------------|----------------------------|
| Steam Number           | 1                     | 2                      | 3                     | 4                     | 5                            | 6                      | 7                          | 8                              | 9                      | 10                        | 11                     | 12                         |
| Temperature (F)        | 77                    | 77                     | 104                   | 104                   | 176                          | 482                    | 689                        | 192                            | -22                    | 115                       | 194                    | 131                        |
| Pressure (psig)        | 15                    | 106                    | 145                   | 222                   | 225                          | 225                    | 202                        | 160                            | 213                    | 151                       | 142                    | 225                        |
| Methanol Mole Fraction | 1                     | 1                      | .99                   | .99                   | .99                          | .99                    | .15                        | .15                            | .01                    | .25                       | .01                    | .99                        |
| DME Mass Fraction      | 0                     | 0                      | 0                     | 0                     | 0                            | 0                      | .43                        | .43                            | .99                    | .01                       | 0                      | 0                          |
| Water Mass Fraction    | 0                     | 0                      | .01                   | .01                   | .01                          | .01                    | .42                        | .42                            | 0                      | .74                       | .99                    | .01                        |
| Mass Flow (lb/hr)      | 19352                 | 19352                  | Methanol 22268        | Methanol 22268        | Methanol 22268               | Methanol 22268         | Methanol 3374              | Methanol 3374                  | Methanol 97            | Methanol 3203             | Methanol 97            | Methanol 3107              |
|                        |                       |                        | Water 126             | Water 126             | Water 126                    |                        | DME 13907                  | DME 13907                      | DME 13776              | DME 184                   | Water 5382             |                            |
|                        |                       |                        |                       |                       |                              | Water 126              |                            |                                |                        |                           |                        | Water 126                  |
|                        |                       |                        |                       |                       |                              |                        |                            |                                |                        |                           |                        |                            |

# ENERGY BALANCE

| Methanol Dehydration<br>R-101 |                            |
|-------------------------------|----------------------------|
| Temperature                   | 689°F                      |
| R-101 Duty                    | $-1.36 \times 10^7$ BTU/hr |
| E-101 Duty                    | $9.67 \times 10^6$ BTU/hr  |
| H-101 Duty                    | $5.40 \times 10^6$ BTU/hr  |
| E-102 Duty                    | $-1.14 \times 10^7$ BTU/hr |

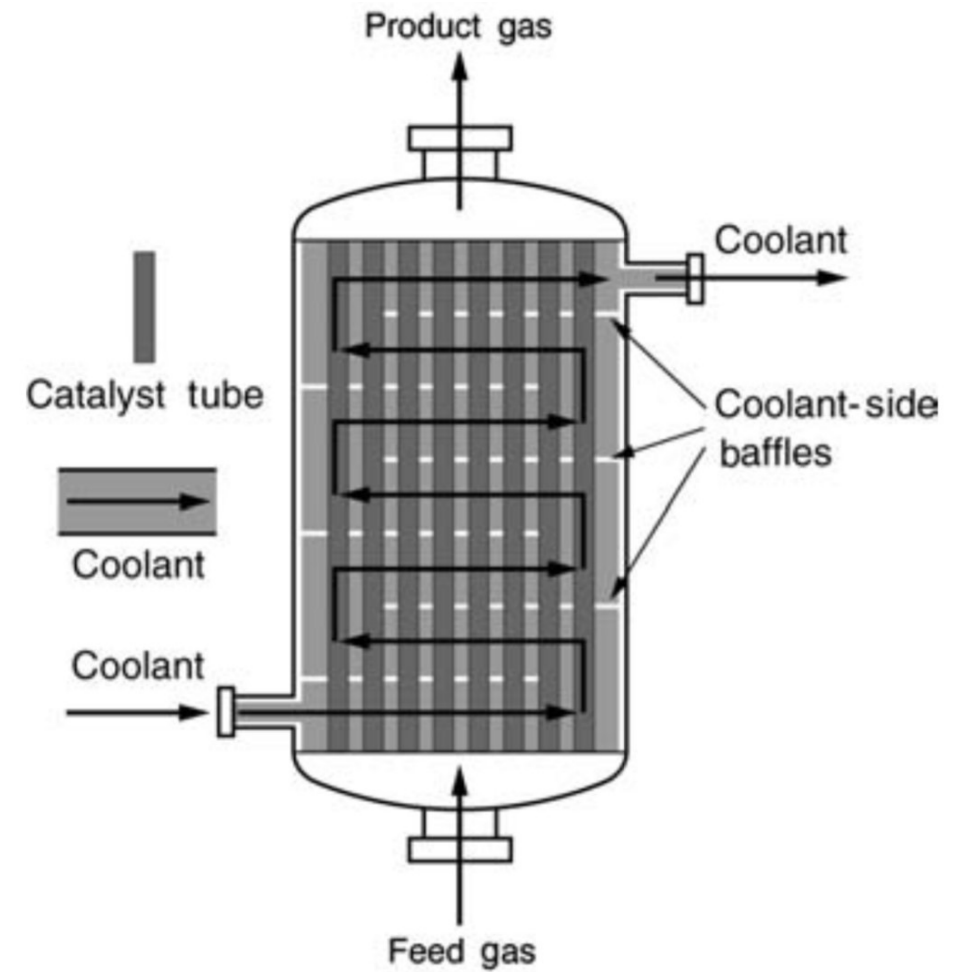
| DME Distillation<br>T-101 |                            |
|---------------------------|----------------------------|
| Temperature               | 86°F/114.8°F               |
| E-103 Duty                | $-3.39 \times 10^6$ BTU/hr |
| E-104 Duty                | $2.36 \times 10^6$ BTU/hr  |

| Methanol Distillation<br>T-102 |                            |
|--------------------------------|----------------------------|
| Temperature                    | 158°F/194°F                |
| E-105 Duty                     | $-1.18 \times 10^7$ BTU/hr |
| E-106 Duty                     | $1.14 \times 10^7$ BTU/hr  |

# **EQUIPMENT DESIGN**

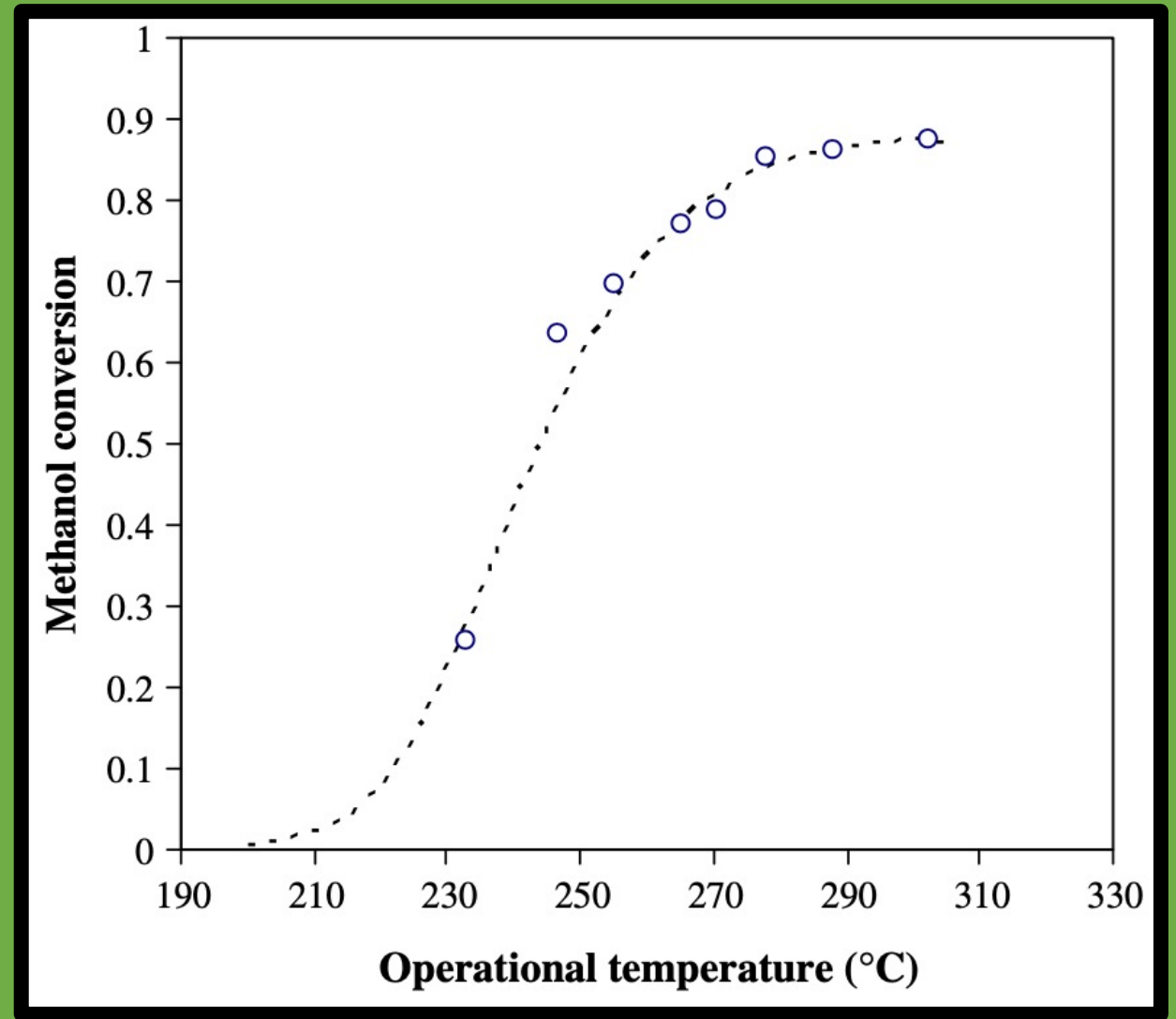
# REACTION KINETICS

- Reaction: Methanol Dehydration
- Reactor Type: Catalytic Packed Bed Reactor
- Catalyst:  $\gamma\text{-Al}_2\text{O}_3$
- Conversion: 90%
- Exothermic Reaction



# CATALYST: $\gamma$ -Al<sub>2</sub>O<sub>3</sub>

- Operates at high pressure
- Commonly used catalyst for Methanol Dehydration
- High activity
- Increase temperature ensures increased conversion



# R-101 Specifications Sheet

| Identification  |                                                  |
|-----------------|--------------------------------------------------|
| Item            | Catalytic Packed Bed Reactor                     |
| Item No         | R-101                                            |
| Function        | Dehydration of methanol to produce DME and water |
| Operation       | Continuous                                       |
| Catalyst        | $\gamma$ -Al <sub>2</sub> O <sub>3</sub>         |
| Catalyst Weight | 54900 lbs                                        |

| Materials Handled              | In    | Out   |
|--------------------------------|-------|-------|
| Mass Flow (lb/hr)              | 22400 | 22600 |
| Mole flow (lbmol/hr)           | 702   | 702   |
|                                |       |       |
| <b>Component Flow lbmol/hr</b> |       |       |
| Dimethyl Ether                 | 0     | 302   |
| Methanol                       | 695   | 105   |
| Water                          | 7     | 295   |
|                                |       |       |
| <b>Temperature (°F)</b>        | 482   | 689   |
| <b>Pressure (psig)</b>         | 225   | 202   |
| <b>Vapor Fraction</b>          | 1.0   | 1.0   |

| Design Data                          |                                                                                        |
|--------------------------------------|----------------------------------------------------------------------------------------|
| Diameter (ft)                        | 4.36                                                                                   |
| Overall height (ft)                  | 14.7                                                                                   |
| Number of Tubes                      | 34                                                                                     |
| Maximum Pressure rating (psig)       | 218                                                                                    |
| Combined Tube Volume ft <sup>3</sup> | 62.3                                                                                   |
| Area (ft <sup>2</sup> )              | 40.7                                                                                   |
| Construction of Material             | Carbon Steel                                                                           |
| Utilities (CW)                       | 28600                                                                                  |
| Duty (Btu/hr)                        | -1.36x10 <sup>7</sup>                                                                  |
| Comments                             | -Temperature maintained by cooling water.<br>- Shell side Methanol<br>-Tube Side Water |

# T-101 Specifications Sheet

| Identification           |                                       |
|--------------------------|---------------------------------------|
| Item                     | 1 <sup>st</sup> distillation column   |
| Item No                  | T-101                                 |
| No. Required             | 1                                     |
| Function                 | Separates DME from methanol and water |
| Operation                | Continuous                            |
| Material Of Construction | Carbon Steel                          |

| Design Data                    |      |
|--------------------------------|------|
| Number of actual trays         | 22   |
| Total tower height (ft)        | 52.5 |
| Column diameter (ft)           | 2.62 |
| Maximum Pressure rating (psig) | 218  |
| Reflux ratio                   | 1.7  |
| Tray Spacing (ft)              | 2.00 |

| Materials Handled              | Feed<br>Methanol + DME + Water | Liquid Distillate<br>Methanol + DME | Liquid Bottoms<br>Methanol + Water |
|--------------------------------|--------------------------------|-------------------------------------|------------------------------------|
| Mass Flow (lb/hr)              | 22600                          | 13900                               | 8710                               |
| Mole flow (lbmol/hr)           | 702                            | 302                                 | 400                                |
| <b>Component Flow lbmol/hr</b> |                                |                                     |                                    |
| Dimethyl Ether                 | 302                            | 299                                 | 400                                |
| Methanol                       | 105                            | 3.02                                | 100                                |
| Water                          | 295                            | 0.00                                | 296                                |
| <b>Temperature (°F)</b>        | 192                            | 86                                  | 115                                |
| <b>Pressure (psig)</b>         | 151                            | 165                                 | 162                                |
| <b>Vapor Fraction</b>          | 1                              | 1                                   | 0.0                                |

| Associated Components          |                   |                          |                                   |                                  |                         |
|--------------------------------|-------------------|--------------------------|-----------------------------------|----------------------------------|-------------------------|
| <b>Condenser (E-103)</b>       | CW = 185000 lb/hr | A = 330 ft <sup>2</sup>  | Q = 3.21 x 10 <sup>6</sup> Btu/hr | - Fixed Head<br>- Carbon Steel   | Max Pressure = 145 psig |
| <b>Reboiler (E-104)</b>        | mps = 2770 lb/hr  | A = 72.2 ft <sup>2</sup> | Q = 2.24.10 <sup>6</sup> Btu/hr   | - Floating Head<br>-Carbon Steel | Max Pressure = 160 psig |
| <b>Reflux Drum (V-101)</b>     | L = 9.48 ft       | D = 3.74 ft              | Carbon Steel                      | Max Pressure = 149 psig          |                         |
| <b>Reflux Pump (P-102 A/B)</b> | Power = 5.2 kW    | Efficiency = 40 %        | ΔP = 66.7 psig                    | Centrifugal/Carbon Steel         |                         |

# T-102 Specifications Sheet

| Identification            |                                     |
|---------------------------|-------------------------------------|
| Item                      | 2 <sup>nd</sup> distillation column |
| Item No                   | T-102                               |
| No. Required              | 1                                   |
| Function                  | Separates methanol from water       |
| Operation                 | Continuous                          |
| Materials Of Construction | Carbon Steel                        |

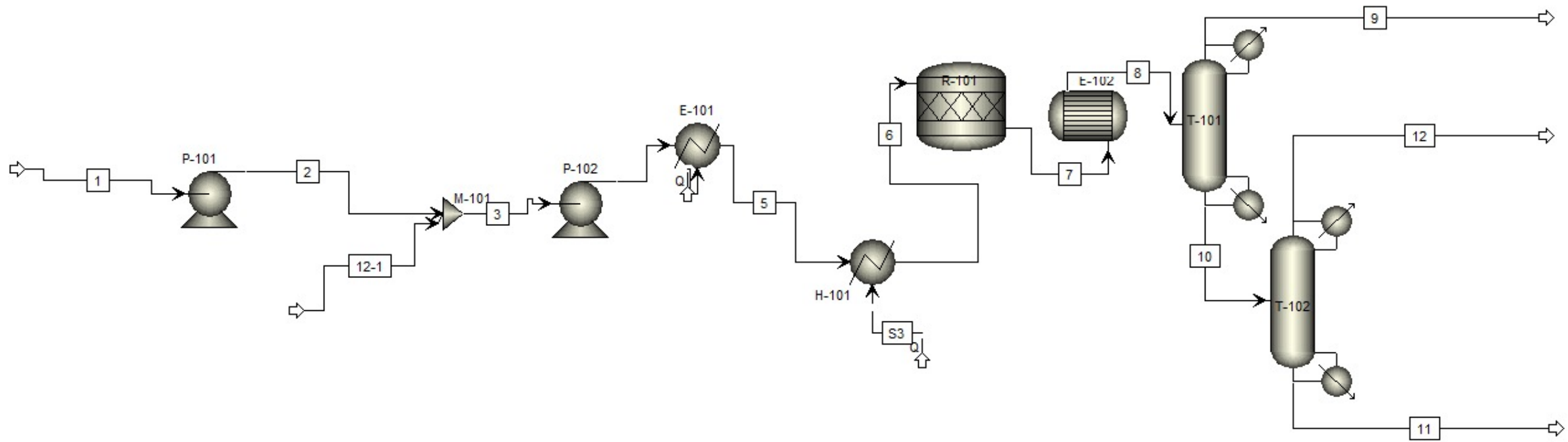
| Design Data                    |      |
|--------------------------------|------|
| Number of actual trays         | 15   |
| Total tower height (ft)        | 65.6 |
| Column diameter (ft)           | 3.81 |
| Maximum Pressure rating (psig) | 218  |
| Reflux ratio                   | 4.5  |
| Tray Spacing (ft)              | 2.62 |

| Materials Handled              | Feed | Liquid Distillate | Liquid Bottoms |
|--------------------------------|------|-------------------|----------------|
| Mass Flow (lb/hr)              | 8710 | 3120              | 5480           |
| Mole flow (lbmol/hr)           | 400  | 98                | 302            |
| <b>Component Flow lbmol/hr</b> |      |                   |                |
| Dimethyl Ether                 | 3.99 | 0.00              | 0.00           |
| Methanol                       | 100  | 97                | 3.02           |
| Water                          | 29   | 0.970             | 299            |
| <b>Temperature (°F)</b>        | 114  | 158               | 194            |
| <b>Pressure (psig)</b>         | 162  | 106               | 107            |
| <b>Vapor Fraction</b>          | 0.0  | 1.0               | 0.0            |

| Associated Components          |                   |                          |                                 |                                   |                         |
|--------------------------------|-------------------|--------------------------|---------------------------------|-----------------------------------|-------------------------|
| <b>Condenser (E-105)</b>       | CW = 649000 lb/hr | A = 74.45ft <sup>2</sup> | Q = 1.18x10 <sup>7</sup> Btu/hr | - Fixed Head<br>- Carbon Steel    | Max Pressure = 102 psig |
| <b>Reboiler (E-106)</b>        | mps = 100 lb/hr   | A = 272 ft <sup>2</sup>  | Q = 1.14x10 <sup>7</sup> Btu/hr | - Floating Head<br>- Carbon Steel | Max Pressure = 160 psig |
| <b>Reflux Drum (V-102)</b>     | L = 8.30 ft       | D = 12.3 ft              | Carbon Steel                    | Max Pressure = 2160 psig          |                         |
| <b>Reflux Pump (P-103 A/B)</b> | Power = 1.0 kW    | Efficiency = 40 %        | ΔP = 55.5 psig                  | Centrifugal/Carbon Steel          |                         |

# **ASPEN SIMULATION**

# SIMULATION

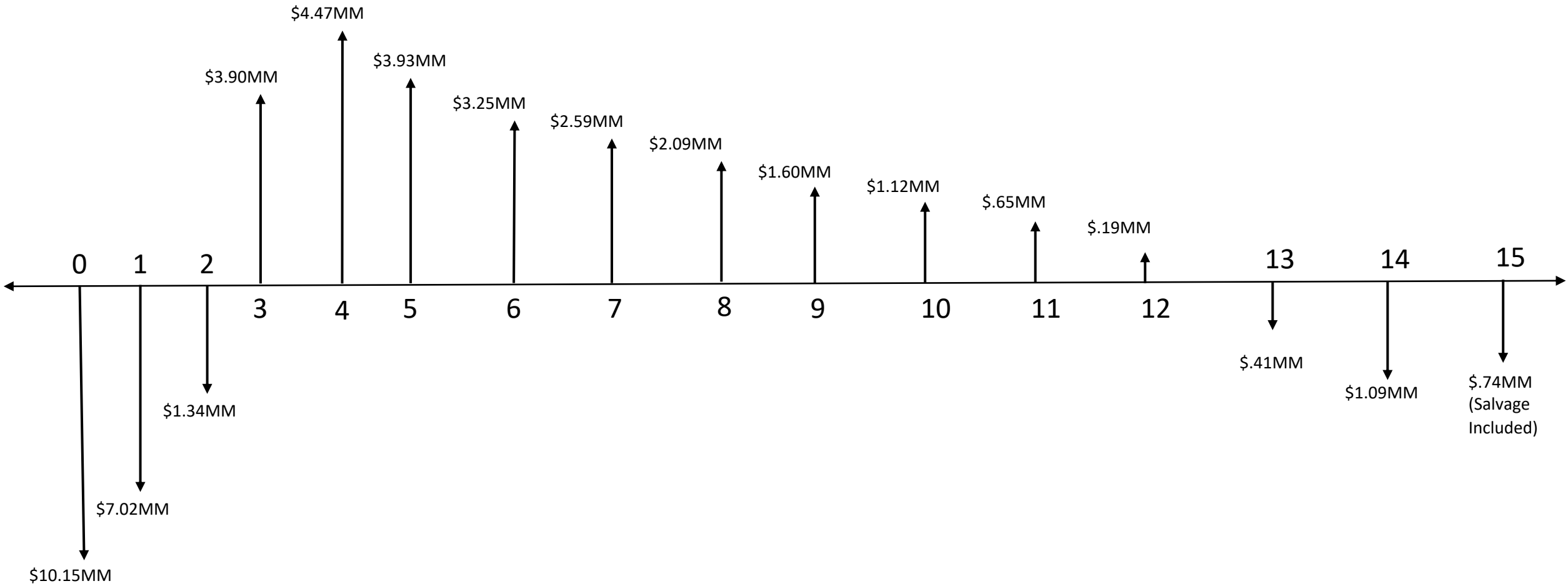


# **ECONOMICS**

# Economic Analysis

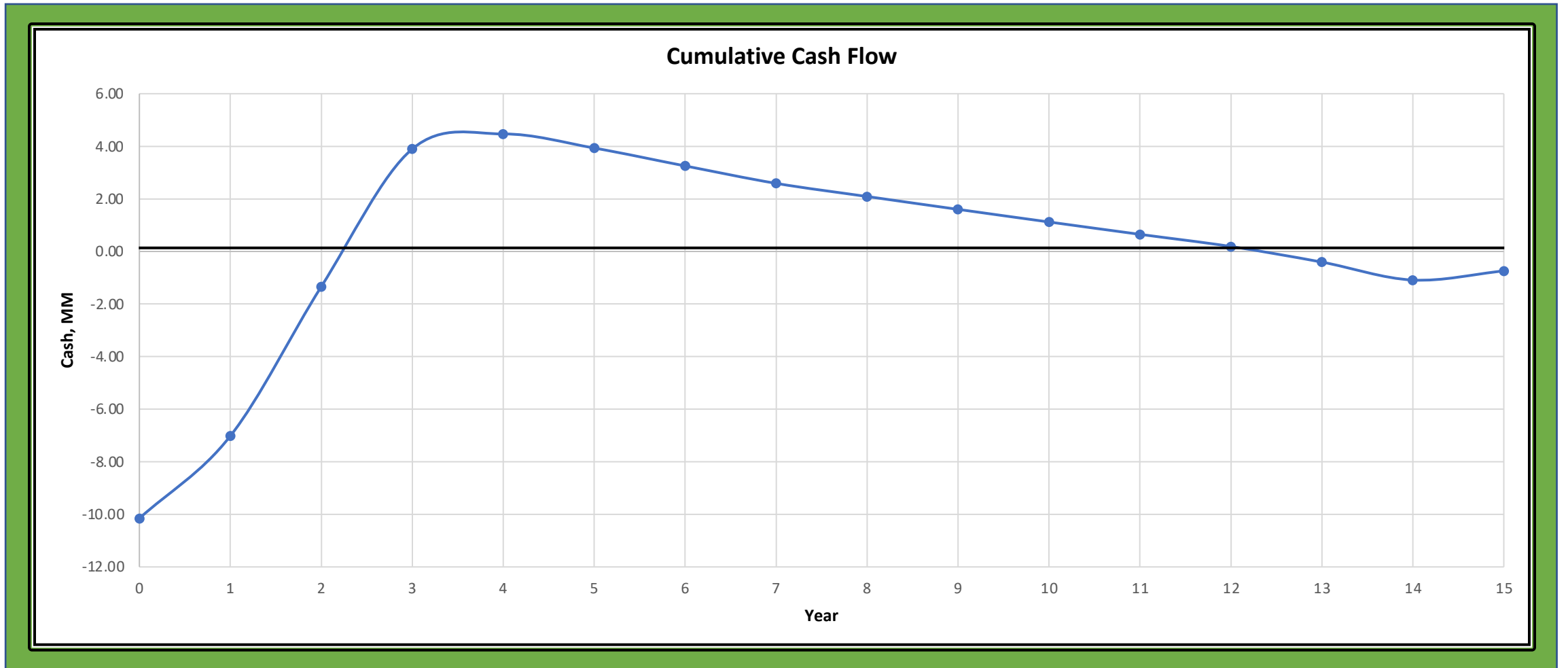
| Economic Evaluation                       |        |
|-------------------------------------------|--------|
| Total Capital Investment, $10^6$          | \$10.2 |
| Annual Total Production Costs, $10^6$     | \$34   |
| Annual Sales, $10^6$                      | \$37   |
| Payback Period, yrs                       | 4.2    |
| Return on Investment, %/year              | 22     |
| Discounted Cash Flow Rate of Return, %/yr | 13     |
| Net Present Value, $10^6$                 | \$8    |
| Salvage Value, $10^6$                     | \$1    |
| Cumulative profit, $10^6$                 | \$23   |

# TCI Cash Flow Diagram



\*Assume 2% TPC Inflation Rate + Depreciation

# Cash Flow



# **SAFETY**

# PROCESS SAFETY HOLDING & HANDLING

## HOLDING

### **Dimethyl Ether**

- Keep away from heat
- Equipment must be grounded
- Store in a cool, well-ventilated area
- Keep away compressed oxygen or strong oxidizers
- Stored between 7-14 bar & up to 52°C

### **Methanol**

- Methanol maximum exposure of 200 ppm (OSHA & EPA)
- Tightly closed container
- Well –ventilated area.
- Equipment must be grounded and bonded.

## HANDLING

- Use of ventilators and breathing protection or local exhaust.
- The use of cold-insulating gloves.
- Oversee the use of Personal Protective Equipment (PPE).



# SAFETY CONSIDERATIONS

| Factor                 | Consideration                                                                                                                                                                                              |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Markings and Labelling | Clear indications of toxicity and flammability reports on equipment at the plant.<br>Toxicity (Exposure limits) - 1900 mg/m <sup>3</sup> , 1000 ppm. ("Dimethyl ether", 2021)<br>NFPA Flammability no. - 4 |
| Waste disposal         | Determination of toxicity and physical properties to determine the proper waste classification and disposal methods.                                                                                       |
| Container disposal     | Draining the containers thoroughly and venting in a safe place away from fire and sparks.<br>Critical temperature – 126.9°C ("Dimethyl ether", 2021)<br>Auto-ignition temperature - 350°C                  |
| Local Legislation      | Waste disposal in accordance with local, regional and national laws and regulations                                                                                                                        |

# Safety Guidelines in Accordance with Rules and Regulations of Plaquemine, Louisiana

## Pre-Line Opening Job Preparations

- The shutting down and energy isolation of all process systems prior to any line opening involving process piping, equipment or vessels (4.1.1).
- The draining and/or depressurization of all process piping, equipment or vessels to ensure clearance of hazardous materials (4.1.2).
- Ensuring temperatures for the process piping, equipment or vessels have sufficiently cooled to allow for safe work (4.1.3).

## Line Opening Job Planning

- The barricading of affected areas with a minimum of 10 ft radius as a precautionary area (4.2.1.1)
- The issuance of permits strictly by authorized personnel (4.2.2.1)



# HAZARD ANALYSIS T-102 FEED LINE

| No. | Parameter   | Guideword | Deviation                          | What if?                                                              | Possible Causes                           | Consequence                                                                         | Safeguards                                                                                          | Action                                                                                                                                                       |
|-----|-------------|-----------|------------------------------------|-----------------------------------------------------------------------|-------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Pressure    | More      | Pressure increase in the feed line | There is pressure build up in the feed line leading into the tower    | -Blockage in the system                   | - Failure of feed line tube<br>- Risk of expansion of column and bursting           | Installation of quick-pressure relief valves at strategic locations before and after the column.    | - Installation of a secondary pressure relief device.<br>- Checking maintenance schedule and procedures                                                      |
|     |             | Less      | Pressure decreases in feed line    | There are sudden pressure losses in the streams leading to the column | - Leakages in the system                  | - Insufficient reactant material entering the column                                | Pressure alarms at the feed, distillate and bottom streams                                          | - Installation of pressure gauge<br>- Checking maintenance schedule and procedures                                                                           |
| 2   | Flow        | Reverse   | Backflow from T-102                | The contents of the tower flow back to the feed line                  | - Clogging and blockages within the tower | - Pressure and temperature increase in the column                                   | - Check valve to prevent backflow                                                                   | - determining the best utilization of energy from recycle stream while preventing backflow<br>- Following the stipulated maintenance schedule and procedures |
| 3   | Temperature | More      | Increase in feed temperature       | There is sudden increase in temperature at the feed of T-102          | - Clogging of inlet into tower            | Subsequent increase in pressure, risk of explosion and ineffectiveness of the tower | - Temperature alarms at feed entry point.<br>- Panel alarms to warn of high pressure or temperature | -Installation of a temp gauge<br>- Checking maintenance schedule and procedures                                                                              |

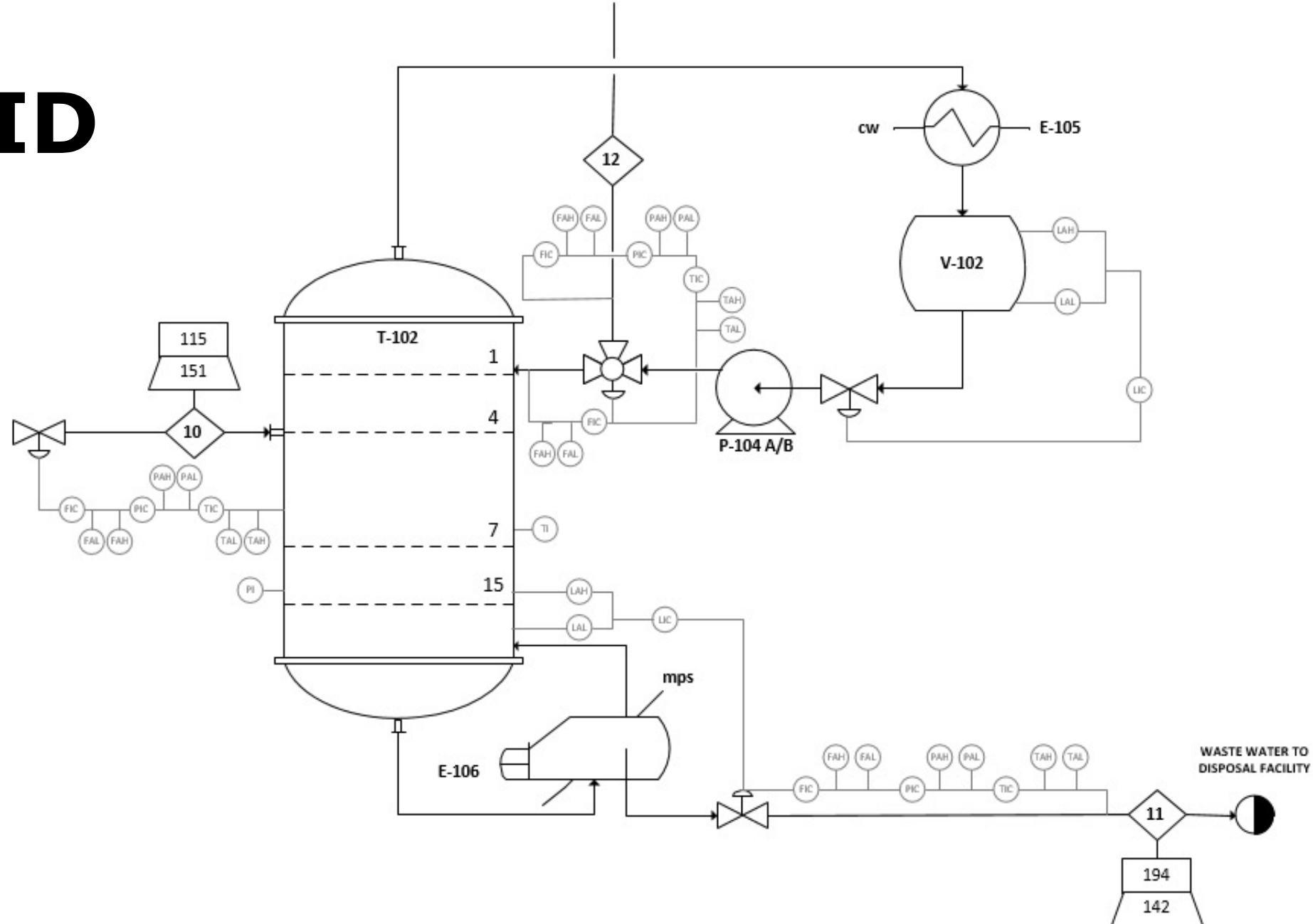
# HAZARD ANALYSIS T-102 DISTILLATE LINE

| No. | Parameter   | Guideword | Deviation                                | What if ?                                                                                     | Possible Causes                                            | Consequence                                                                                           | Safeguards                                                                                           | Action                                                                                                                                                   |
|-----|-------------|-----------|------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Pressure    | More      | Pressure increase in the distillate line | There is pressure build up in the distillate line transporting recycled methanol to the mixer | -Blockage in the mixer or further up the distillation line | - Failure of distillate line tube<br>- Risk of expansion of mixer and bursting.<br>- Failure of mixer | Installation of quick-pressure relief valves at strategic locations before the mixer.                | - Installation of a secondary pressure relief device.<br>- Checking maintenance schedule and procedures                                                  |
|     |             | Less      | Pressure decreases in feed line          | There are sudden pressure losses in the stream leading to the mixer                           | - Leakages in the distillate line                          | - Inefficiencies within the tower leading to less methanol distillate                                 | Pressure alarms at the exit of the column where the distillate line begins.                          | - Installation of pressure gauge<br>- Checking maintenance schedule and procedures                                                                       |
| 2   | Flow        | Reverse   | Backflow to T-102                        | The contents of the distillate line flow back to the tower                                    | - Clogging and blockages within the line                   | - Pressure and temperature increase in the column                                                     | - Check valve to prevent backflow                                                                    | - determining the best utilization of energy from recycle stream while preventing backflow- Following the stipulated maintenance schedule and procedures |
| 3   | Temperature | More      | Increase in distillate line temperature  | There is sudden increase in temperature at distillate line transporting recycled methanol     | - Clogging of inlet into the mixer                         | Subsequent increase in pressure, risk of explosion and ineffectiveness of the tower                   | - Temperature alarms at mixer entry point.<br>- Panel alarms to warn of high pressure or temperature | -Installation of a temp gauge<br>- Checking maintenance schedule and procedures                                                                          |

# HAZARD ANALYSIS T-102 BOTTOM LINE

| No. | Parameter   | Guideword | Deviation                            | What if?                                                                                              | Possible Causes                          | Consequence                                                                           | Safeguards                                                                                                                    | Action                                                                                                                                                       |
|-----|-------------|-----------|--------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Pressure    | More      | Pressure increase in the bottom line | There is pressure build up in the bottom-line transporting wastewater to treatment plant              | -Blockages within bottom line            | - Failure of bottom-line tube<br>- Risk of expansion and bursting of the line.        | Installation of quick-pressure relief valves at strategic locations within the line.                                          | - Installation of a secondary pressure relief device.<br>- Checking maintenance schedule and procedures                                                      |
|     |             | Less      | Pressure decreases in bottom line    | There are sudden pressure losses in the stream within the bottom line leading away from the tower     | - Leakages in the bottom line            | - Inefficiencies within the tower causing decreased flow of wastewater from the tower | Pressure alarms at the exit point from the tower joining the bottom line                                                      | - Installation of pressure gauge<br>- Checking maintenance schedule and procedures                                                                           |
| 2   | Flow        | Reverse   | Backflow to T-102                    | The contents of the bottom-line flow back to the tower                                                | - Clogging and blockages within the line | - Pressure and temperature increase in the column                                     | - Check valve to prevent backflow                                                                                             | - determining the best utilization of energy from recycle stream while preventing backflow<br>- Following the stipulated maintenance schedule and procedures |
| 3   | Temperature | More      | Increase in bottom line temperature  | There is sudden increase in temperature at bottom line transporting wastewater to the treatment plant | - Clogging of the line at various points | Subsequent increase in pressure, risk of explosion and ineffectiveness of the tower   | - Temperature alarms at exit point of the tower to the bottom line.<br>- Panel alarms to warn of high pressure or temperature | -Installation of a temp gauge<br>- Checking maintenance schedule and procedures                                                                              |

# P&ID



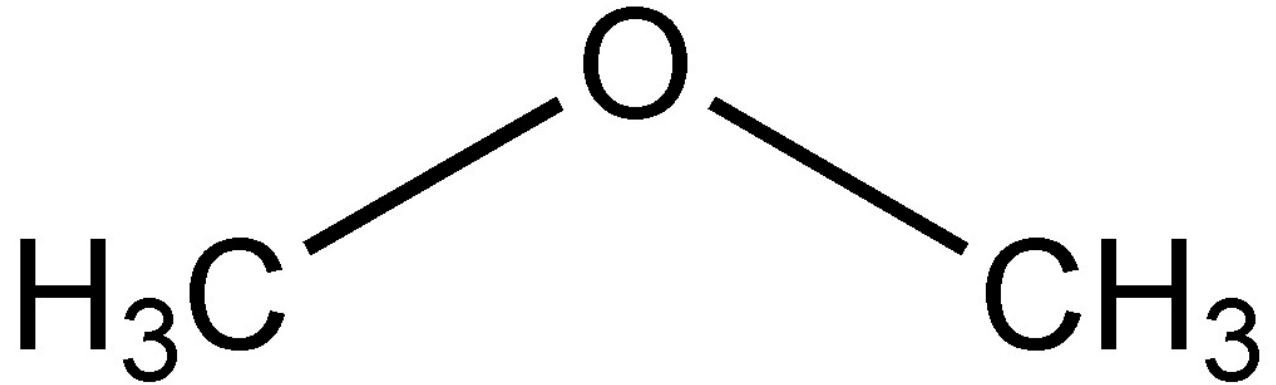


# WASTEWATER TREATMENT

- Reduce Pollutants in Water
  - Negative health effects on life species
- Useful for all aspects of life
  - Irrigation or Recreational Use
- Send Wastewater to SNF Holding Company
  - Plaquemine Facility

# CONCLUSION

- Methanol Dehydration To Form DME
- 99.9% Purity DME
- 90% Plant Utilization (329 Days)
- Collect Salvage After Year 12
- \$23MM Profit, 22% ROI
- Recommend Pursuing Design



# **ACKNOWLEDGEMENTS**

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**Dr. Lealon Martin**

**Industrial Advisory Counsel**

**Roy G. Perry College of Engineering Faculty & Staff**

**Thank you!**

# QUESTIONS?

# **APPENDIX**

# REFERENCES

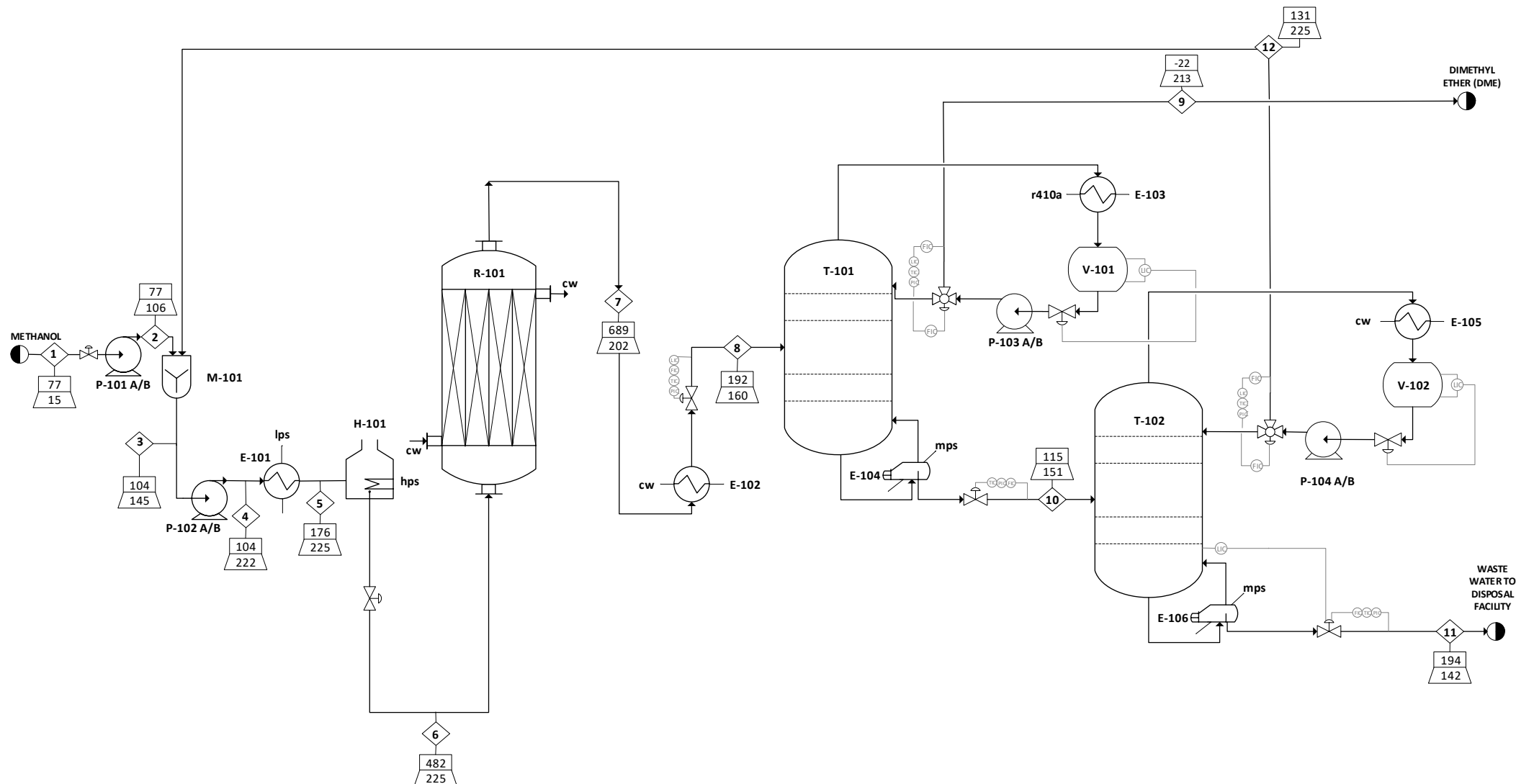
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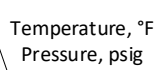
# STOICHIOMETRY



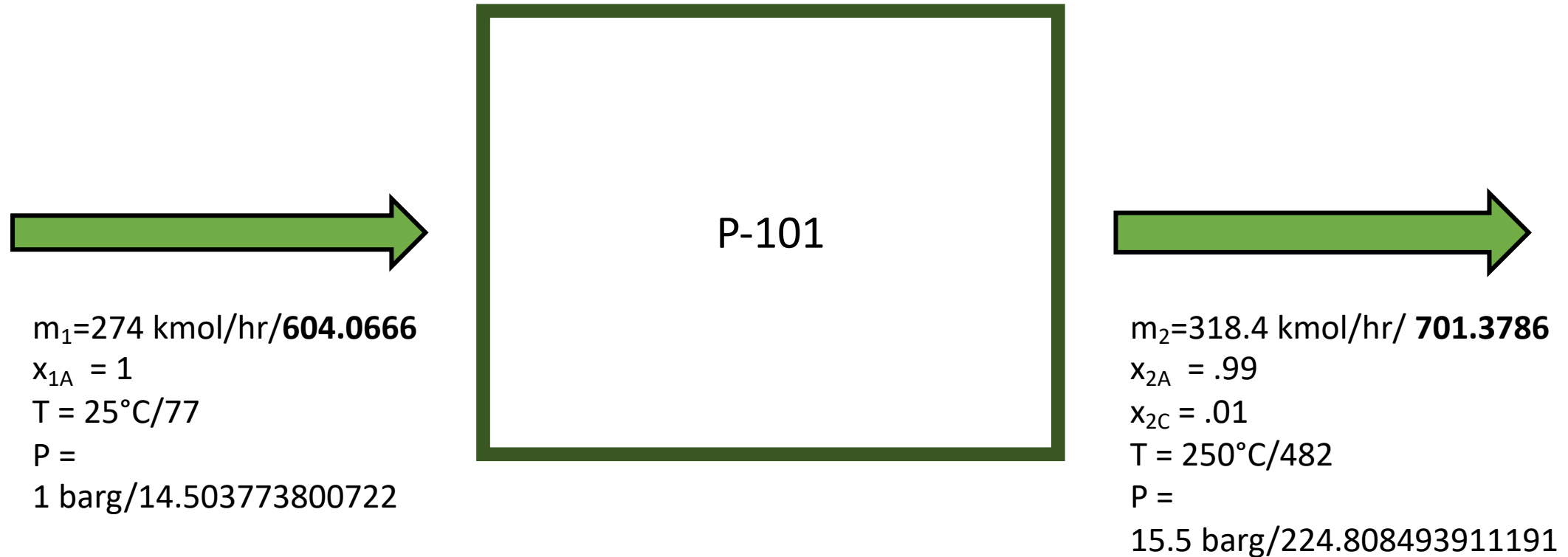
|                              | A (Methanol) | B (Dimethyl Ether) | C (Water) |
|------------------------------|--------------|--------------------|-----------|
| lb-mol                       | 2            | 1                  | 1         |
| Molecular Weight<br>lb/lbmol | 32.04        | 46.07              | 18        |

|                           |                                                   |                                       |                                |                          |                                                         |                        |                                       |                             |                            |                                  |                                      |                                            |                             |                             |                                     |                                      |
|---------------------------|---------------------------------------------------|---------------------------------------|--------------------------------|--------------------------|---------------------------------------------------------|------------------------|---------------------------------------|-----------------------------|----------------------------|----------------------------------|--------------------------------------|--------------------------------------------|-----------------------------|-----------------------------|-------------------------------------|--------------------------------------|
| P-101 A/B<br>Feed<br>Pump | M-101<br>Fresh &<br>Recycled<br>Methanol<br>Mixer | P-102 A/B<br>Combined<br>Feed<br>Pump | E-101<br>Methanol<br>Vaporizer | H-101<br>Fired<br>Heater | R-101<br>Methanol<br>Catalytic<br>Packed Bed<br>Reactor | E-102<br>DME<br>Cooler | T-101<br>DME<br>Distillation<br>Tower | E-103<br>T-101<br>Condenser | E-104<br>T-101<br>Reboiler | V-101<br>T-101<br>Reflux<br>Drum | P-103 A/B<br>T-101<br>Reflux<br>Pump | T-102<br>Methanol<br>Distillation<br>Tower | E-105<br>T-102<br>Condenser | E-106 T-<br>102<br>Reboiler | V-102<br>Methanol<br>Reflux<br>Drum | P-104 A/B<br>T-102<br>Reflux<br>Pump |
|---------------------------|---------------------------------------------------|---------------------------------------|--------------------------------|--------------------------|---------------------------------------------------------|------------------------|---------------------------------------|-----------------------------|----------------------------|----------------------------------|--------------------------------------|--------------------------------------------|-----------------------------|-----------------------------|-------------------------------------|--------------------------------------|

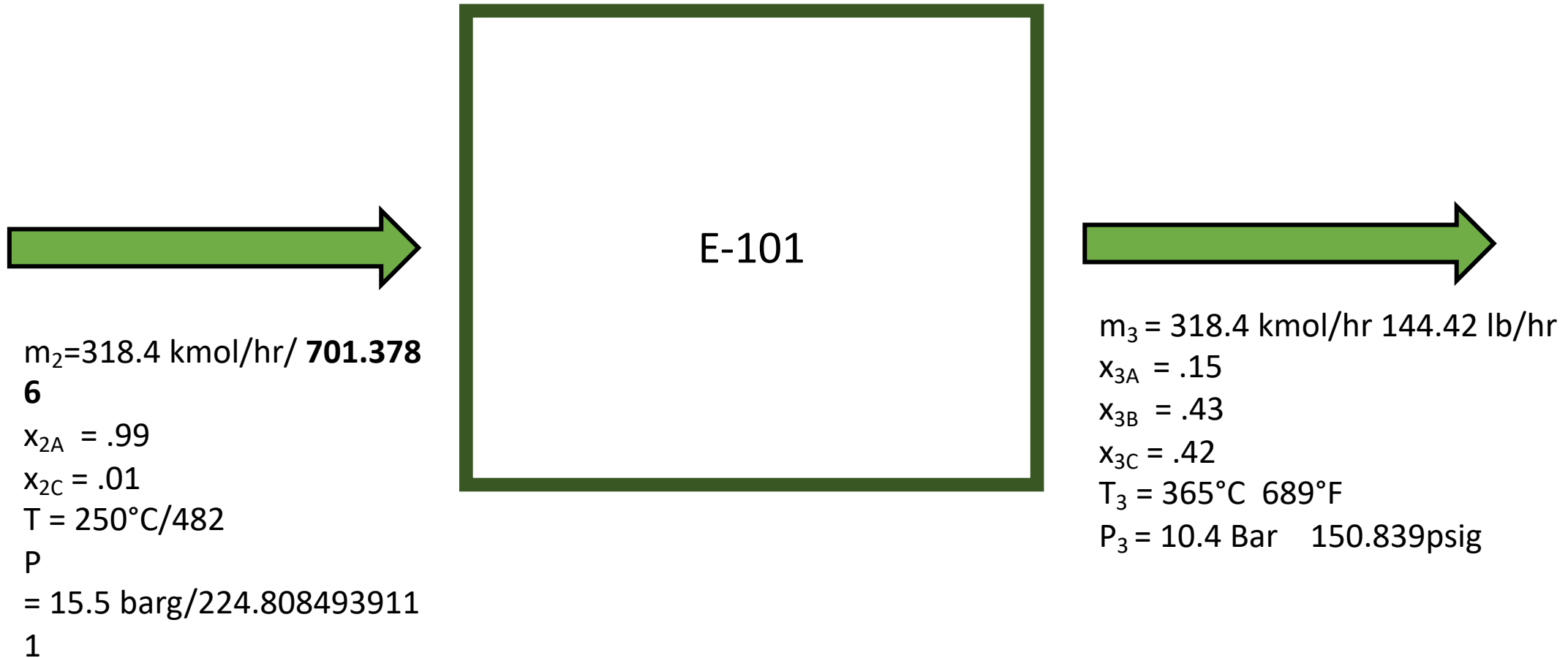


 Temperature, °F  
 Pressure, psig

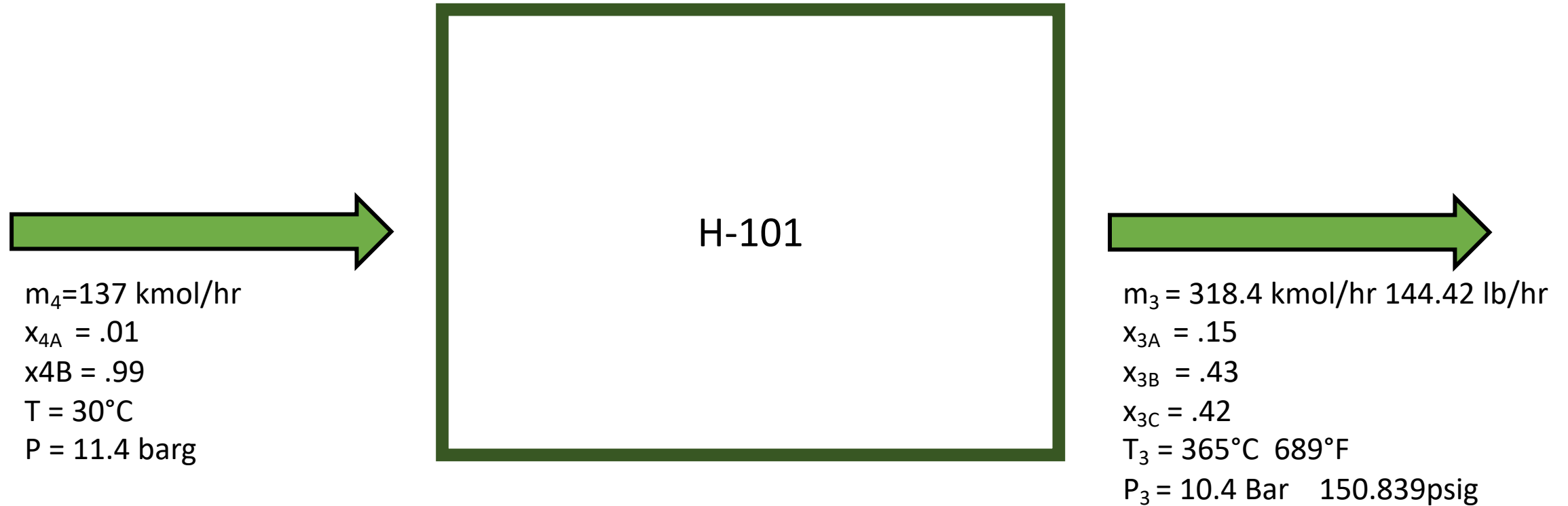
# Pump Material Balance



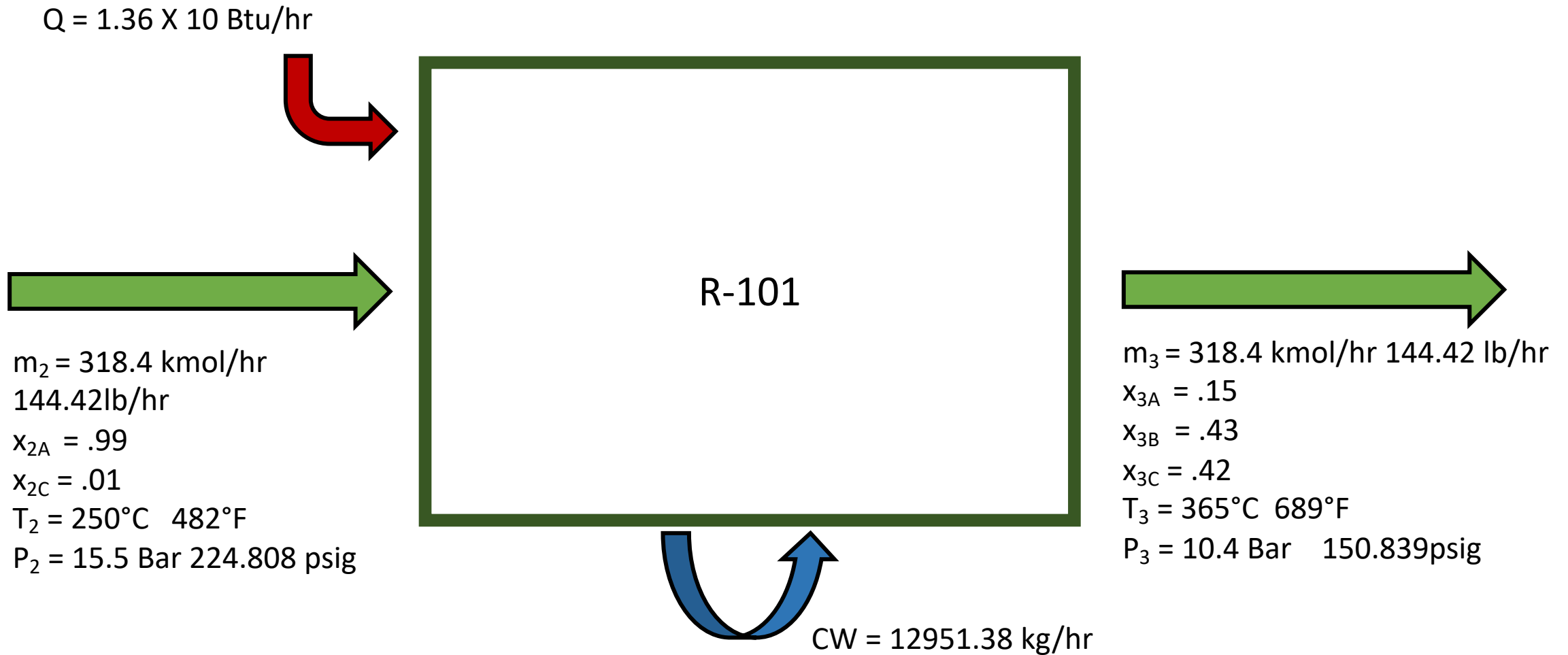
# Vaporizer Material Balance



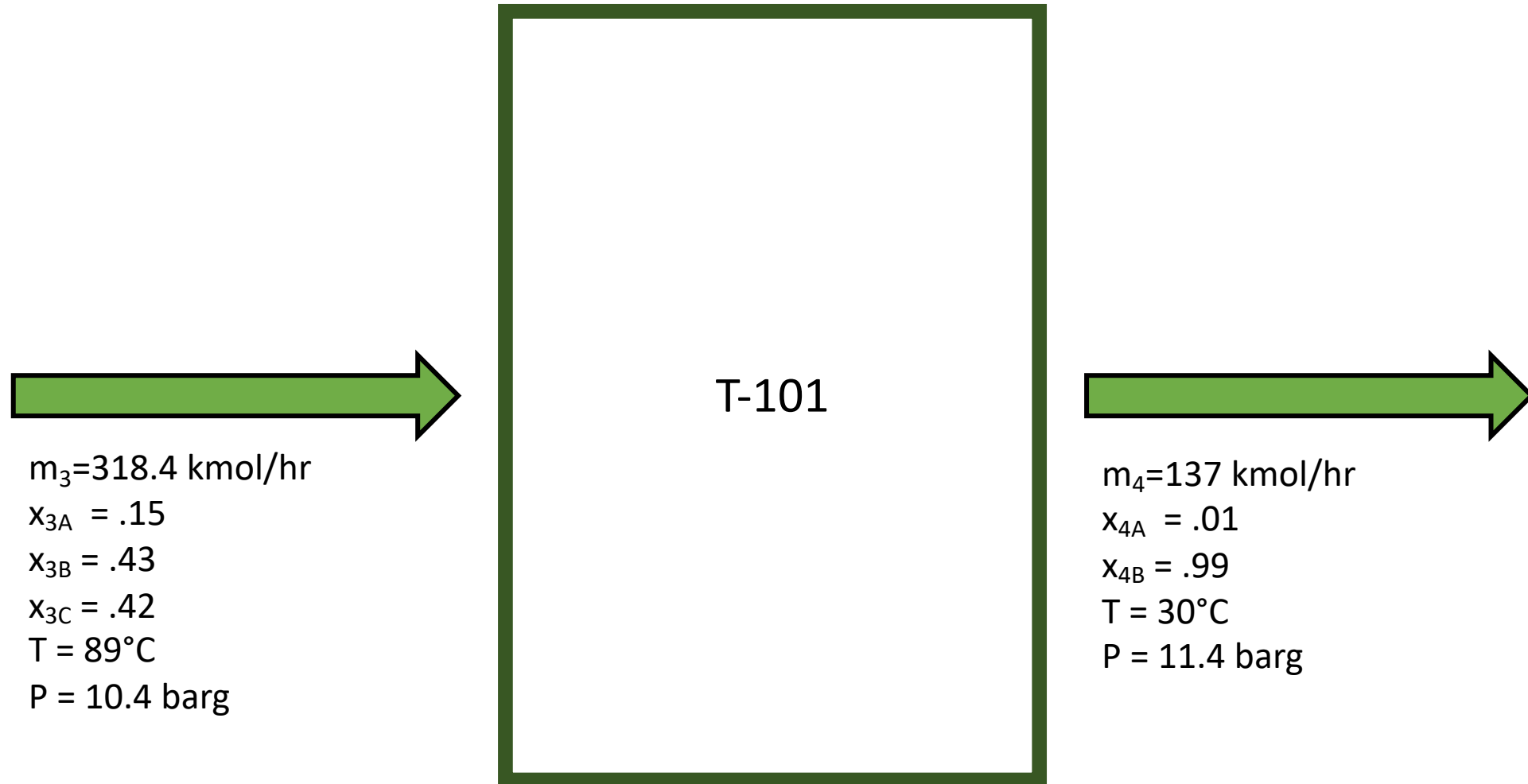
# Furnance Material Balance



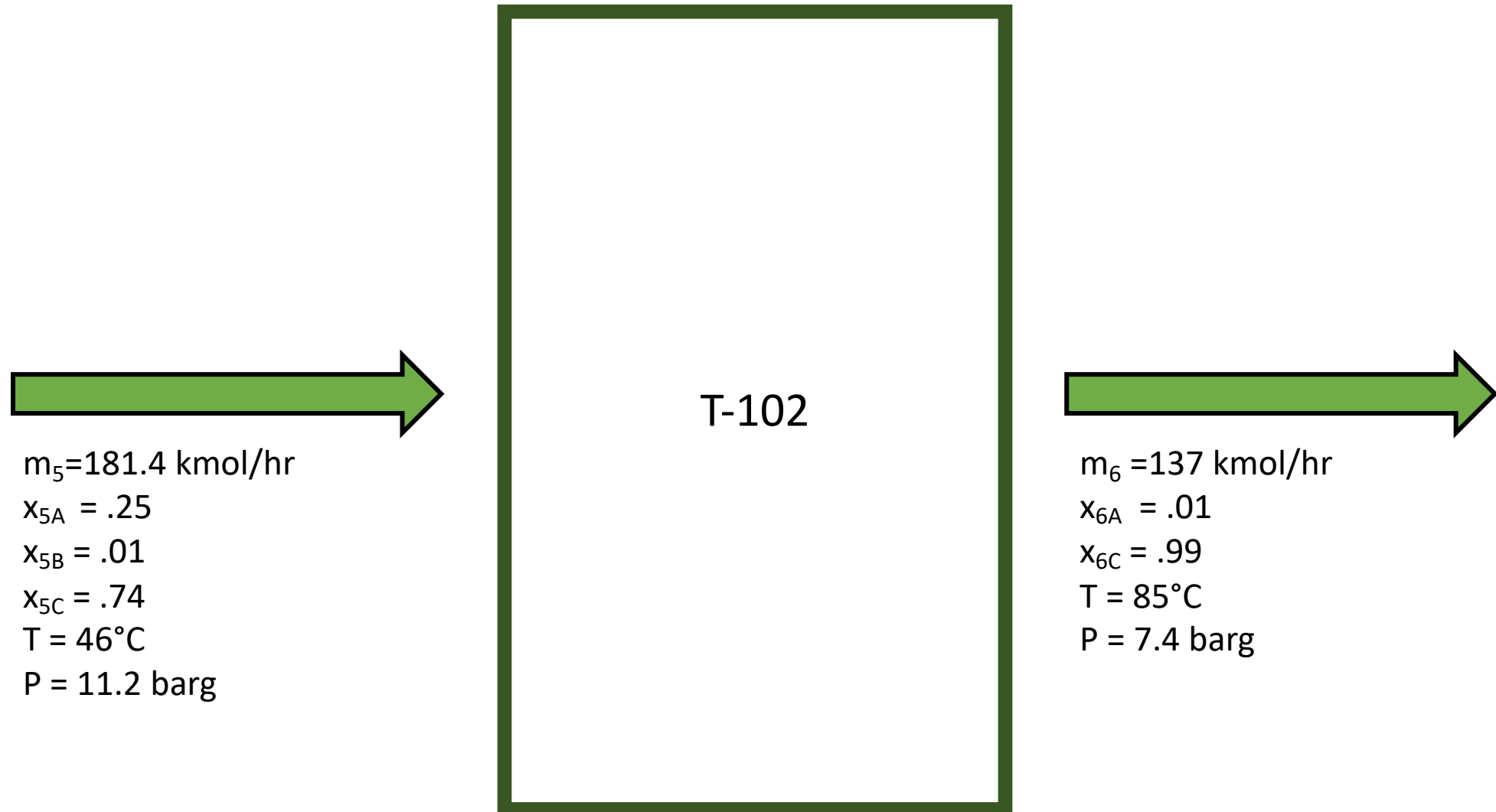
# Dehydration Reactor Material Balance



# 1st Distillation Column Material Balance

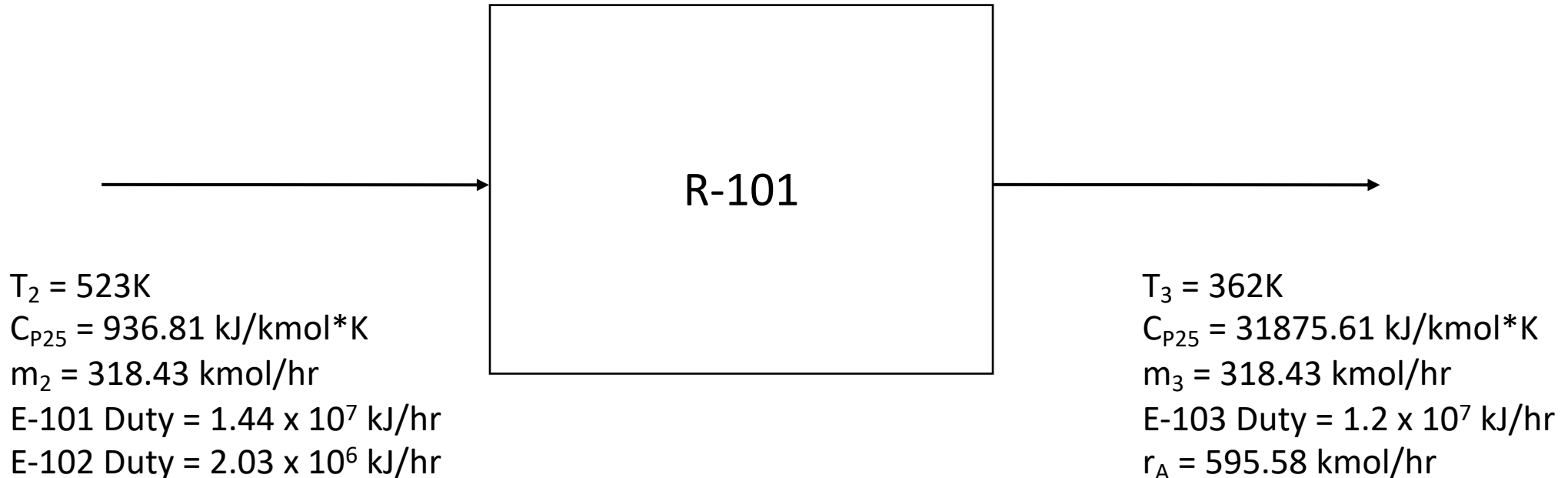


# 2nd Distillation Column Material Balance



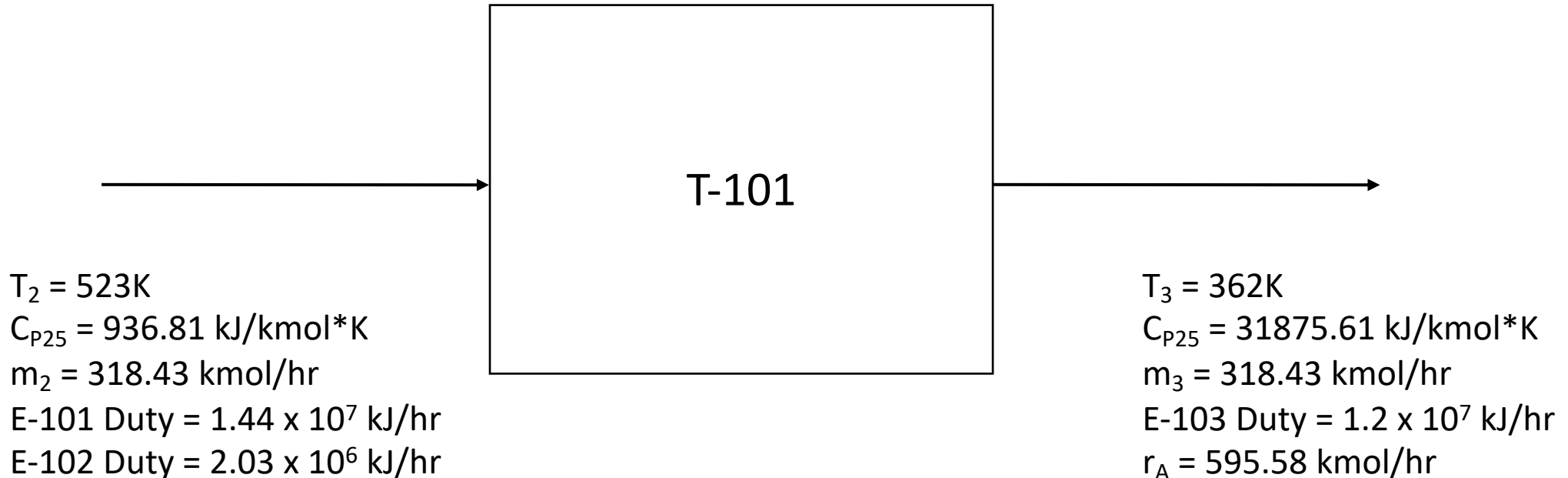
# ENERGY BALANCE

$$\Delta H_{\text{RXN } 280} = -5.9 \times 10^6 \text{ kJ/kmol}$$



# ENERGY BALANCE

$$\Delta H_{\text{RXN } 138} = -5.9 \times 10^6 \text{ kJ/kmol}$$



# ENERGY BALANCE

| Stream                    | 1       | 2       | 3       | 4       | 5       | 6       | 7       | 8       | 9        | 10      | 11      |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|---------|----------|---------|---------|
| Molar Enthalpy (kJ/kmol)  | -238400 | -238305 | -201079 | -200560 | -164896 | -198934 | -234554 | -179812 | -239321  | -280413 | -233583 |
| Mass Enthalpy (kJ/kg)     | -7440.2 | -7437.2 | -6275.5 | -6263.1 | -3579.3 | -6212.3 | -7324.6 | -3915.0 | -12513.8 | -15445  | -7321.9 |
| Molar Entropy (kJ/kmol*K) | -240.2  | -239.9  | -150.1  | -148.6  | -211.9  | -120.2  | -206.5  | -244.2  | -162.9   | -148.7  | -213.1  |
| Mass Entropy (kJ/kg*K)    | -7.5    | -7.5    | -4.7    | -4.6    | -4.6    | -3.8    | -6.4    | -5.3    | -7.6     | -8.2    | -6.7    |

## R-101 Design Equations

$$\textcircled{1} \text{ Mole Balance: } F_{A0} \frac{dx}{dW} = -r'_A = \frac{\text{kg mol}}{\text{kg cat} \cdot \text{hr}}$$

$$\textcircled{2} \text{ Rate Law: } -r'_A = k C_A^2 = \frac{\text{kg mol}}{\text{kg cat} \cdot \text{hr}}$$

$$\textcircled{3} \text{ Stoichiometry: } C_A = \frac{C_{A0}(1-x)}{1+\epsilon x} \frac{P}{P_0} \frac{T_0}{T}, \quad \frac{P}{P_0} = p \quad (\text{pg. 169})$$

$$\begin{aligned} \frac{dp}{dW} &= -\frac{\alpha}{2p} (1+\epsilon x) \frac{T_0}{T} \\ \frac{T_0^2 p}{T} \frac{dp}{dW} &= -\alpha \\ \frac{T_0^2 p^2}{T} \frac{dp}{dW} &= -\alpha \quad (\text{pg. 174}) \end{aligned}$$

$$\textcircled{4} \text{ Combine: } \frac{dx}{dW} = \frac{k C_{A0}^2 (1-x)^2}{F_{A0} (1+\epsilon x)^2} \left( \frac{P}{P_0} \right)^2 \left( \frac{T_0}{T} \right)^2 = \text{kg cat}^{-1}$$

# R-101 Design Equations

$$Q = UA\Delta T_{lm} f_r$$

$$Q = \dot{m} C_p \Delta T$$

$$T_{HIN} = 250^\circ\text{C}$$

$$T_{HOUT} = 305^\circ\text{C}$$

$$T_{CIN} = 30^\circ\text{C}$$

$$T_{COUT} = 45^\circ\text{C}$$

$$\dot{m} = 318.43 \text{ kmol/hr}$$

$$\dot{m} = 318430 \text{ mol/hr}$$

$$C_p = 110 \text{ J/mol K}$$

$$\Delta T = 305 - 250 = 115 + 273$$

$$= 388 \text{ K}$$

$$Q = \dot{m} C_p \Delta T$$

$$= 318430 \frac{\text{mol}}{\text{hr}} (110 \frac{\text{J}}{\text{mol K}}) (388 \text{ K})$$

$$Q = 1.433 \times 10^{10} \text{ J/hr}$$

$$U = 500 \text{ BTU/hr-ft}^2\text{ }^\circ\text{F}$$

$$\Delta T_{lm} = 204.7^\circ\text{C} \rightarrow 508.46^\circ\text{F}$$

$$f_r = 1.0$$

$$Q = 1.433 \times 10^{10} \text{ J/hr}$$

$$Q = 13582219.3 \text{ BTU/hr}$$

$$Q = UA\Delta T_{lm} f_r$$

$$A = \frac{Q}{U\Delta T_{lm} f_r}$$

$$= \frac{13582219.3 \text{ BTU/hr}}{(500 \frac{\text{BTU}}{\text{hr-ft}^2\text{ }^\circ\text{F}}) (508.46^\circ\text{F}) (1.0)}$$

$$A = 53.425 \text{ ft}^2$$

$$A = 4.963 \text{ m}^2$$

Tubes:  $A_T = \pi D L$ ,  $n = A/A_T$

$$D = 1.060 \text{ in} = 0.02667 \text{ m}$$

$$L = 14.477 \text{ ft} = 4.479 \text{ m}$$

$$A_T = (3.14) (0.02667 \text{ m}) (4.479 \text{ m})$$

$$A_T = 0.375 \text{ m}^2$$

$$n = \frac{A}{A_T} = \frac{4.963 \text{ m}^2}{0.375 \text{ m}^2}$$

$$n = 13.2 \approx 14 \text{ Tubes}$$

$$W = 24923 \text{ Kg cat}$$

$$1790.214 \text{ Kg cat per Tube}$$

$$\frac{Q}{A\Delta T_{lm} f_r} = U$$

$$\frac{13582219.3 \text{ BTU/hr}}{(107.039 \text{ ft})(508.46^\circ\text{F})(1)}$$

$$U = 248.167 \frac{\text{BTU}}{\text{hr-ft}^2\text{ }^\circ\text{F}}$$

$$U = 200 \frac{\text{BTU}}{\text{hr-ft}^2\text{ }^\circ\text{F}} \left( \begin{array}{l} \text{within} \\ \text{range} \end{array} \right)$$

$$A = \frac{13582219.3 \text{ BTU/hr}}{(200 \frac{\text{BTU}}{\text{hr-ft}^2\text{ }^\circ\text{F}}) (508.46^\circ\text{F}) (1.0)}$$

$$A = 133.56 \text{ ft}^2$$

$$A = 12.408 \text{ m}^2$$

# T-101 Design Equations

Water: 100°C

$$N_{min} = \frac{\ln \left[ \left( \frac{x_{1k}}{x_{2k}} \right)_D \left( \frac{x_{1k}}{x_{2k}} \right)_B \right]}{\ln \alpha_{1k}}; \alpha_{1k} \approx 9 \text{ (Research)}$$

$$= \frac{\ln \left[ \left( \frac{.99}{.01} \right) \left( \frac{.25}{.01} \right) \right]}{\ln(9)} = 3.5 \approx 4$$

$R_{min}$ :  $q = 0.0$  for saturated vapor (perry's 13-36)

$$1 - q = \sum_j \frac{\alpha_{jk} x_{jk,F}}{\alpha_{jk} - \phi}$$

$$\alpha_{1k} - \phi = \alpha_{1k} x_{1k,F}$$

$$\phi = \alpha_{1k} - \alpha_{1k} x_{1k,F} = \alpha_{1k} (1 - x_{1k,F}) = 5.13 \checkmark$$

$$R_{min} = \sum_j \frac{\alpha_j x_{j,D}}{\alpha_j - \phi} - 1$$

$$= \frac{9 \cdot .99}{9 - 5.13} - 1 = 1.3$$

$$R/R_{min} = 1.2 - 1.3 \text{ (pg 235 in short cut design book)}$$

$$\therefore R = (R_{min})(1.3) = 1.7$$

Gilliland correlation

Number of theoretical trays (pg 236 short cut book)

$$\frac{R - R_{min}}{R + 1} = \frac{1.7 - 1.3}{1.7 + 1} = .15 \therefore \text{use chart on left}$$

$$@ .15, \frac{N - N_{min}}{N + 1} = .45$$

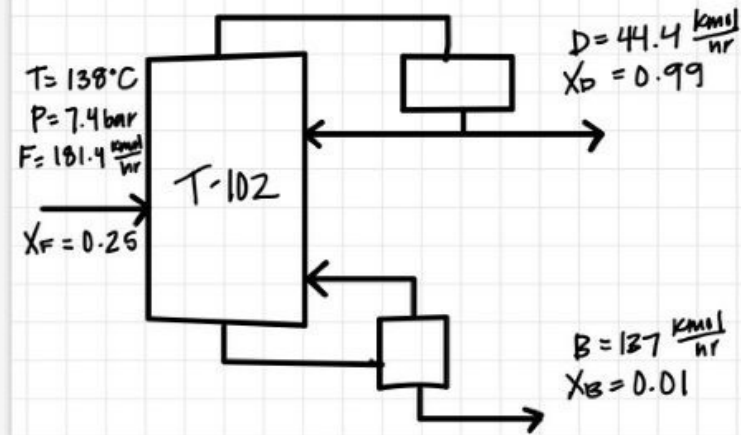
$$.45N + .45 = N - N_{min}$$

$$N_{min} + .45 = .55N$$

$$N = \frac{N_{min} + .45}{.55} = \frac{4.45}{.55} = 8.09 \approx 9$$

$$N/N_{min} = 1.8 - 2.5 = 8/4 = 2.25 \checkmark$$

# T-102 Design Equations



Rectifying

$$y_{N+1} = \frac{R}{R+1} x_N + \frac{x_D}{R+1}$$

$$y_{N+1} = \frac{4.472}{4.472+1} x_N + \frac{0.99}{4.472+1}$$

$$y_{N+1} = 0.817 x_N + 0.181$$

↳ rectifying operating line

Stripping

Feed:  $x_F = 0.25$

$T = 411 \text{ K}$

$P = 7.4 \text{ bar}$

$$y = \frac{q}{q-1} x - \frac{x_F}{q-1} ; q = \frac{H_V - H_F}{H_V - H_L}$$

$$u = \frac{0.05}{0.05-1} x - \frac{0.25}{0.05-1} \rightarrow y = -0.05 x + 0.24$$

↳ stripping operating line

q-line

$$q = \frac{H_V - H_F}{H_V - H_L} = \frac{2704.24 - 2053.42}{2704.24 - 700.885}$$

$q = 0.05$

Interpolate

$$\begin{aligned} H_L & \begin{cases} y_1 = 703.241 & y_2 = 709.301 \\ x_1 = 725 \text{ kPa} & x_2 = 750 \text{ kPa} \end{cases} \end{aligned}$$

$$y = 703.241 + (740 - 725) \left( \frac{709.301 - 703.241}{750 - 725} \right)$$

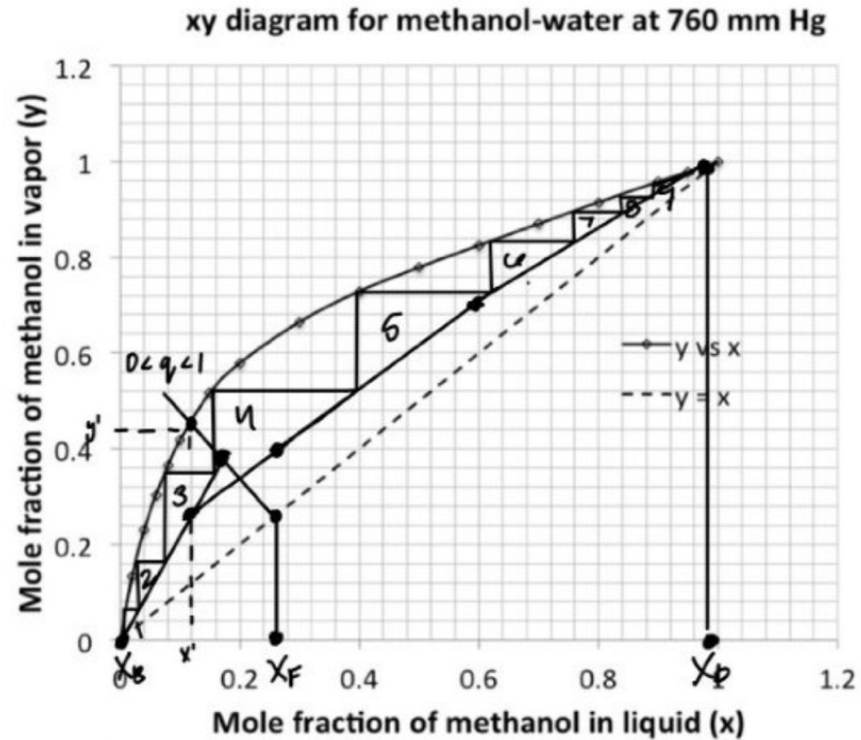
$$H_L = 700.885 \text{ kJ/kg}$$

$$\begin{aligned} H_V & \begin{cases} y_1 = 2703.4 & y_2 = 2704.8 \\ x_1 = 725 \text{ kPa} & x_2 = 750 \text{ kPa} \end{cases} \end{aligned}$$

$$H_V = 2704.24 \text{ kJ/kg}$$

$$H_F = 2053.42 \text{ kJ/kg}$$

# T-102 Design Equations



$$x' = 0.1$$

$$y' = 0.3$$

$$\text{SDL: } y = -0.05x + 0.26$$

$$\text{ROL: } y_{n+1} = 0.917x_n + 0.191$$

$$9 + 1 = \underline{10 \text{ stages}}$$

Minimum Reflux Ratio

$$\frac{R_m}{R_m + 1} = \frac{x_D - y'}{x_D - x'} \xrightarrow{\text{pinch point}} \frac{0.99 - 0.3}{0.99 - 0.1} = 0.775$$

$$\frac{R_m}{R_m + 1} = 0.775 \rightarrow R_m = 0.775R_m + 0.776 \rightarrow 0.225R_m = 0.775 \rightarrow \underline{R_m = 3.44}$$

Reflux Ratio

$$1.3 = \frac{R}{R_{\min}}$$

$$\underline{R = 4.472}$$

# EPA & OSHA Regulations

## OSHA (Methanol)

- The sampling group
- The sampling time at 60 min.
- The sampling volume at 3 L or 5L when humidity is greater than 50%

## EPA (Methanol)

- Occupational exposure through inhalation.
- Exposure through the ambient air from its evaporation during solvent uses.
- Acute effects by inhalation and/or ingestion resulting in blurry vision and disorientation.
- Chronic effects including insomnia, elevated levels of liver enzymes and decreased brain weight.

## EPA (DME)

- Tolerance exemptions that are associated with Dimethyl Ether (DME)
- Regulations of the emission standards associated with DME



# Total Capital Investment

| Direct Costs                        |       |
|-------------------------------------|-------|
| Purchased equipment, E'             | 1.496 |
| Delivery, fraction of E'            | 0.150 |
| Subtotal: delivered equipment       | 1.646 |
| Purchased equipment installation    | 0.773 |
| Instrumentation&Controls(installed) | 0.592 |
| Piping (installed)                  | 1.119 |
| Electrical systems (installed)      | 0.181 |
| Buildings (including services)      | 0.296 |
| Yard improvements                   | 0.165 |
| Service facilities (installed)      | 1.152 |
| Total direct costs                  | 5.924 |
| Indirect Costs                      |       |
| Engineering and supervision         | 0.543 |
| Construction expenses               | 0.675 |
| Legal expenses                      | 0.066 |
| Contractor's fee                    | 0.362 |
| Contingency                         | 0.724 |
| Total indirect costs                | 2.370 |
| Fixed capital investment (FCI)      | 8.294 |
| Working capital (WC)                | 1.465 |
| Total capital investment (TCI)      | 9.758 |

# Utilities

| Steam    |          |             |
|----------|----------|-------------|
| LPS      | MPS      | HPS         |
| \$1.16MM | \$.355MM | \$.392MM    |
| TOTAL    |          | \$1.91MM/yr |

| Cooling Water                        |                        |
|--------------------------------------|------------------------|
| Amount Required, ft <sup>3</sup> /yr | 9.92 x 10 <sup>6</sup> |
| TOTAL                                | \$14,000/yr            |

| Electricity             |                        |
|-------------------------|------------------------|
| Amount Required, kWh/yr | 1.06 x 10 <sup>5</sup> |
| TOTAL                   | \$5,000/yr             |

| Wastewater Disposal                  |                        |
|--------------------------------------|------------------------|
| Amount Required, ft <sup>3</sup> /yr | 7.03 x 10 <sup>5</sup> |
| TOTAL                                | \$11,000/yr            |

| Refrigerant, r140a      |                        |
|-------------------------|------------------------|
| Amount Required, BTU/yr | 4.10 x 10 <sup>8</sup> |
| TOTAL                   | \$5,000/yr             |

# Materials & Labor

| Raw Materials    |              |                             |
|------------------|--------------|-----------------------------|
| Name of Material | Price, \$/lb | Annual Amount<br>MM kg/year |
| Methanol         | .16          | ~71                         |
| TOTAL            |              | \$25.28MM/yr                |

| Labor                         |                |                      |
|-------------------------------|----------------|----------------------|
| Number of Operators per Shift | Shifts Per Day | Operator Rate, \$/hr |
| 3                             | 3              | 34                   |
| TOTAL                         |                | ~\$1MM/yr            |

| Product          |              |                             |
|------------------|--------------|-----------------------------|
| Name of Material | Price, \$/lb | Annual Amount<br>MM kg/year |
| DME              | .41          | 50                          |
| TOTAL            |              | \$45MM/yr                   |

# EMISSIONS

- The use of DME reduces carbon emissions by an average of 25%.
- DME synthesis from methanol is a low carbon footprint process.
- The total final emissions are negative at an estimate of **-39 ktCO<sub>2</sub>eq per year**

| Process stream | Units                  | Value |
|----------------|------------------------|-------|
| Methanol       | KgCO <sub>2eq</sub> /t | -1643 |
| Wastewater     | KgCO <sub>2eq</sub> /t | 500   |

# ASPEN STREAM TABLES

| Stream                | Methanol | Recycle* | DME +<br>Methanol +<br>Water | Methanol +<br>Water | DME     | Recycle | Water   |
|-----------------------|----------|----------|------------------------------|---------------------|---------|---------|---------|
| Mole Flows<br>kmol/hr | 274      | 44.4     | 318.4                        | 177.13              | 141.27  | 34.72   | 142.01  |
| Mass Flows<br>kg/hr   | 8779.55  | 1416.44  | 10196                        | 3687.81             | 6508.18 | 1117.85 | 2569.96 |



## **ASSIGNMENTS FOR OUTCOME 5**

An ability to function effectively on a team whose members together, provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

**CHEMICAL ENGINEERING DEPARTMENT  
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET  
SENIOR DESIGN & PROFESSIONALISM II  
SPRING 2022**

Instructor: Dr. Emmanuel A. Dada

Title of Assignment

**Home Work # 1**

Outcome Measured Using this Assignment

Outcome 5

An ability to function effectively on a team whose members together, provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

**Check the engineering design characteristics related to this assignment**

|   |                                                                                                                                                                                                                               |
|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| X | Involves ability to function as a member of a design team                                                                                                                                                                     |
| X | Involves taking minutes of meetings, assignment of tasks and providing confidential evaluation of group members including self-evaluation of contribution to the group.                                                       |
| X | Student's ability to (1) accommodate the needs of others, (2) share responsibilities, (3) commit to team goals, (4) apply principles of constructive conflict management to interaction with others, and (5) support members. |
| X | Involves consideration of one or more of the following (Please check those involved in this assignment.)                                                                                                                      |
|   | Public health                                                                                                                                                                                                                 |
|   | Safety and welfare                                                                                                                                                                                                            |
| X | Global factors                                                                                                                                                                                                                |
| X | Communicate with team members                                                                                                                                                                                                 |
| X | Social factors                                                                                                                                                                                                                |
| X | Environmental factors                                                                                                                                                                                                         |
| X | Economic factors                                                                                                                                                                                                              |
|   |                                                                                                                                                                                                                               |

**Brief justification of why this assignment is suitable for this outcome**

This assignment will help the students to get engaged with group dynamics and interactions. And be able to schedule their projects' activities and priorities.

# **CHEG 4248 Senior Design & Professionalism II Spring 2022: Home Work 1**

**February 10, 2022**

**Due: February 17, 2022**

**You will be graded based on your ability to function as a member of a design team. Include minutes of meetings, assignment of tasks and confidential evaluation of group members on forms previously provided. Clarity of presentation is essential if you are to avoid losing points.**

- (a) Create a list of major tasks and their respective duration to be accomplished to enable you achieve the goals and objectives for your project**
- (b) Organize the tasks into phases/module**
- (c) Identify sub-tasks and their respective duration**
- (d) Link major tasks and/or sub-tasks when required**
- (e) Identify milestones and deadlines to track an important event**
- (f) Prepare a Gantt Chart print out using Microsoft Project or Excel**

**DEPARTMENT OF CHEMICAL ENGINEERING  
SENIOR DESIGN & PROFESSIONALISM II CHEG 4248  
COURSE ASSESSMENT GRADING & OUTCOME  
ASSESSMENT SHEET FOR SPRING 2022 SEMESTER**

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**ABET Outcome 5:** An ability to function effectively on a team whose members together, provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

*Assignments that test competency in this area will include problems that test a student's ability to (1) accommodate the needs of others, (2) share responsibilities, (3) commit to team goals, (4) apply principles of constructive conflict management to interaction with others, (5) support members, and (6) communicate with team members.*

---

Name: \_\_\_\_\_

Title of Assignment: \_\_\_\_\_ Due Date \_\_\_\_\_

| Competency Area                                                                                                                                                                                                | Max for this Assignment | Your Score |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------|
| <b>Outcome 5:</b> An ability to function effectively on a team whose members together, provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. |                         |            |
| <b>Ability to follow good team management practices and resolving conflicts</b><br><i>Plan group meetings and time management, distribute project tasks evenly,.</i>                                           | 50                      |            |
| <b>An ability to track and meet project schedule</b><br><i>Evaluate performance of team members on a regular basis, and track progress of team members</i>                                                     | 50                      |            |
| <b>TOTAL</b>                                                                                                                                                                                                   | <b>100</b>              |            |

**INSERT SAMPLE COPY OF HOME WORK # 1 FOR OUTCOME 5**

## **CHEG 4248 Senior Design & Professionalism II Spring 2022: Homework 1**

**February 10, 2022**

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- (e) Identify milestones and deadlines to track an important event**
- (f) Prepare a Gantt Chart print out using Microsoft Project or Excel**

93%

**DEPARTMENT OF CHEMICAL ENGINEERING  
SENIOR DESIGN & PROFESSIONALISM II CHEG 4248  
COURSE ASSESSMENT GRADING & OUTCOME  
ASSESSMENT SHEET FOR SPRING 2022 SEMESTER**

**ABET Outcome 5:** An ability to function effectively on a team whose members together, provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

*Assignments that test competency in this area will include problems that test a student's ability to (1) accommodate the needs of others, (2) share responsibilities, (3) commit to team goals, (4) apply principles of constructive conflict management to interaction with others, (5) support members, and (6) communicate with team members.*

Name: \_\_\_\_\_

Title of Assignment: \_\_\_\_\_ Due Date \_\_\_\_\_

| Competency Area                                                                                                                                                                                                | Max for this Assignment | Your Score |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------|
| <b>Outcome 5:</b> An ability to function effectively on a team whose members together, provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. |                         |            |
| <b>Ability to follow good team management practices and resolving conflicts</b><br><i>Plan group meetings and time management, distribute project tasks evenly,.</i>                                           | 50                      | 47         |
| <b>An ability to track and meet project schedule</b><br><i>Evaluate performance of team members on a regular basis, and track progress of team members</i>                                                     | 50                      | 46         |
| <b>TOTAL</b>                                                                                                                                                                                                   | 100                     | 93         |

## Simplified Guide for End of Spring Semester Report

**Assignment Title:** Homework 1

**Due Date:** February 17, 2022

**Team Members:** Willie Conner, Chinenye Ihe, Utomwen Irabor, Shimere Gregory

### MAJOR TASKS

- |                                           |           |
|-------------------------------------------|-----------|
| 1. Plant and Production Capacity Increase | (1 day)   |
| 1. Visio and ASPEN completion             | (2 weeks) |
| 2. Economic Evaluation                    | (4 weeks) |
| 3. HAZOP and safety                       | (2 weeks) |
| 4. Final Written Report                   | (2 weeks) |

### PHASES/MODULES

1. Phase 1 – Plant and Production Capacity Increase
2. Phase 2 – Visio and ASPEN completion
3. Phase 3 – Economic Evaluation
4. Phase 4 – HAZOP and Safety
5. Phase 5 – Final Written Report

### SUB-TASKS

- |                                      |                                                      |
|--------------------------------------|------------------------------------------------------|
| 1. Fall Semester Review              | (January 18 <sup>th</sup> – 25 <sup>th</sup> )       |
| • Plant Production Increase          | (January 18 <sup>th</sup> – 20 <sup>th</sup> )       |
| • Plant Capacity Increase            | (January 20 <sup>th</sup> – 22 <sup>nd</sup> )       |
| • Recalculate Material Balance       | (January 23 <sup>rd</sup> – 25 <sup>th</sup> )       |
| 2. HYSYS/ASPEN Simulation of Process | (January 25 <sup>th</sup> – Feb. 10 <sup>th</sup> )  |
| • Converge the Simulation            | (February 1 <sup>st</sup> – 8 <sup>th</sup> )        |
| • Recalculating Energy Balance       | (February 8 <sup>th</sup> – 10 <sup>th</sup> )       |
| 3. Chemical Engineering Design       | (February 10 <sup>th</sup> – March 3 <sup>rd</sup> ) |
| • Design of Major Equipment          | (February 10 <sup>th</sup> – 20 <sup>th</sup> )      |

- |                                         |                                                      |
|-----------------------------------------|------------------------------------------------------|
| • Listing Equipment and Specification   | (February 21 <sup>st</sup> – March 3 <sup>rd</sup> ) |
| 4. Economic Evaluation                  | (March 3 <sup>rd</sup> – 23 <sup>rd</sup> )          |
| • Raw Material costs                    | (March 3 <sup>rd</sup> – 12 <sup>th</sup> )          |
| • Other variable costs                  | (March 12 <sup>th</sup> – 15 <sup>th</sup> )         |
| • Fixed costs                           | (March 16 <sup>th</sup> – 18 <sup>th</sup> )         |
| • Transportation costs                  | (March 19 <sup>th</sup> – 20 <sup>th</sup> )         |
| • Cash flow and profitability analysis  | (March 20 <sup>th</sup> – 22 <sup>nd</sup> )         |
| • Summary                               | (March 22 <sup>nd</sup> – 23 <sup>rd</sup> )         |
| 5. Safety and HAZOP Analysis            | (March 23 <sup>rd</sup> – April 4 <sup>th</sup> )    |
| 6. Reporting                            | (April 5 <sup>th</sup> – April 23 <sup>rd</sup> )    |
| • Homework Assignments                  | (January 18 <sup>th</sup> – April 23 <sup>rd</sup> ) |
| • Weekly meetings/reports with Dr. Dada | (January 23 <sup>rd</sup> – April 20 <sup>th</sup> ) |
| • Midterm Report                        | (February 26 <sup>th</sup> – March 2 <sup>nd</sup> ) |
| • Final Presentation Prep               | (April 20 <sup>th</sup> – 22 <sup>nd</sup> )         |



#### MAJOR MILESTONES

- | <b>Milestones</b>                    | <b>Deadlines</b>                 |
|--------------------------------------|----------------------------------|
| • Converge Aspen HYSYS Simulations   | February 8 <sup>th</sup> , 2022  |
| • Design Major Equipment             | February 20 <sup>th</sup> , 2022 |
| • Complete Economic Evaluations      | March 23 <sup>rd</sup> , 2022    |
| • Complete Safety and HAZOP Analysis | April 4 <sup>th</sup> , 2022     |
| • Midterm Report                     | February 26 <sup>th</sup> , 2022 |
| • Final Presentation                 | April 23 <sup>rd</sup> , 2022    |
| • Final Report                       | May 1 <sup>st</sup> , 2022       |

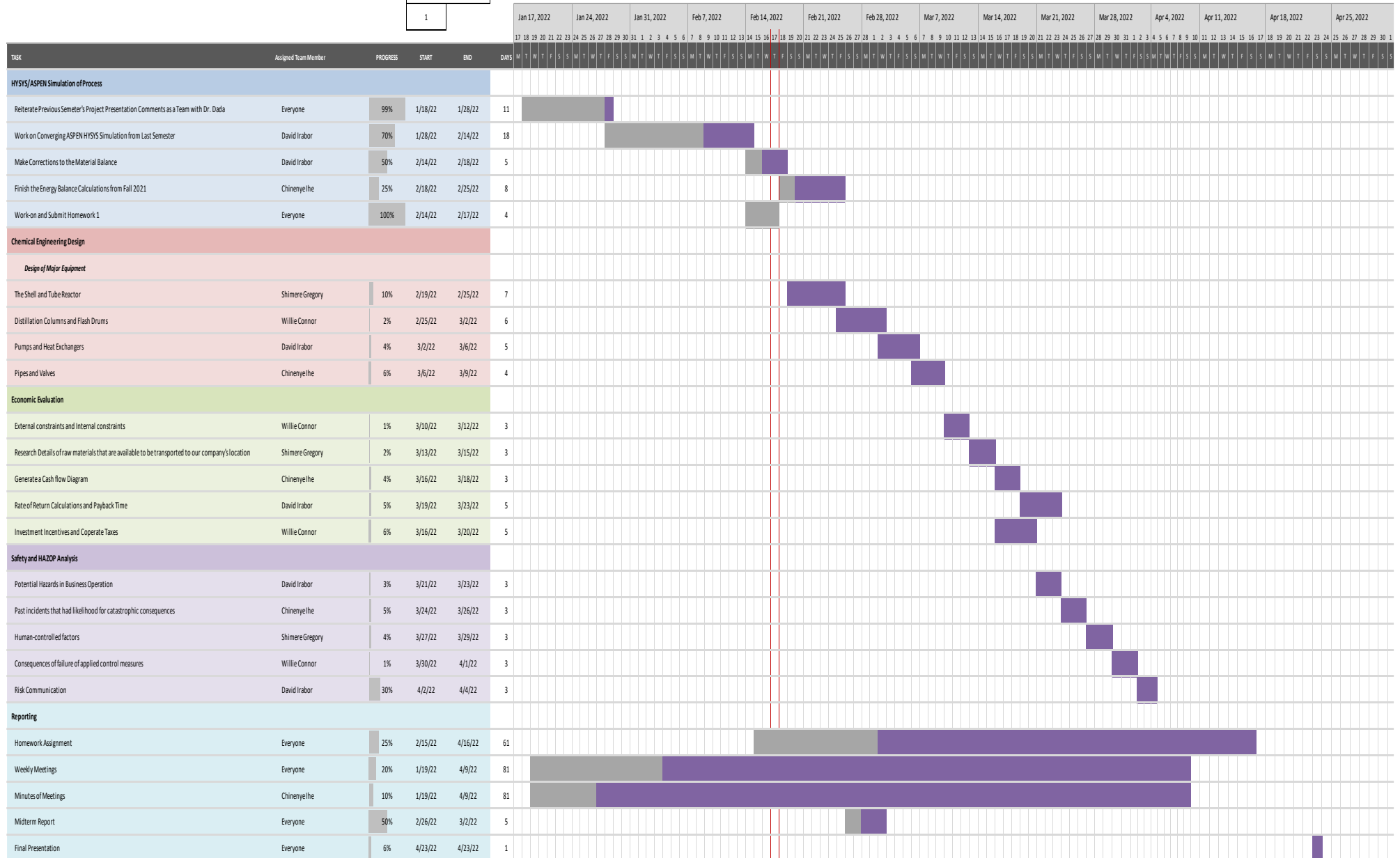
## The Production of Propylene Oxide

**Company:** The Coperations

**Project Team:** Chinenye Ihe, Shimere Gregory, Utomwen Irabor, and Willie Conner

### GANTT CHART

|                           |  |
|---------------------------|--|
| Due April 23rd, 2022      |  |
| Tuesday, January 18, 2022 |  |
| 1                         |  |



OK ✓

**CHEG 4248 Confidential TEAM Member Evaluation**  
**PROJECT TITLE: Production of Propylene Oxide**

TEAM #: **2** ASSIGNMENT/HOMEWK#: **1** LAST NAME: **Ihe** FIRST NAME: **Chinenye**

**Directions:** Fill out the evaluation for EACH member of your team in the correct column. **PLEASE INCLUDE YOURSELF.** Rate the performance of each student in each category on a 5-point scale (1 - Pathetic, 2 - Poor, 3 - Fair, 4 - Good, 5 - Excellent).

Names: A: Chinenye Ihe

B: Utomwen Irabor

C: Shimere Gregory

D: Willie Conner

E.

F:

**Evaluation:**

1. Student attended and contributed to the group meetings.

A: 5                  B: 5                  C: 5                  D: 1                  E:                  F:

2. Student performed his/her assigned tasks in a timely manner.

A: 5                  B: 5                  C: 5                  D: 1                  E:                  F:

3. Student performed technical tasks in a quality manner.

A: 5                  B: 5                  C: 5                  D: 1                  E:                  F:

*OK*

4. Student contributed to setting weekly goals and dates for tasks.

A: 5                  B: 5                  C: 5                  D: 1                  E:                  F:

5. Student was willing to work toward the benefit of the group.

A: 5                  B: 4                  C: 4                  D: 4                  E:                  F:

6. Student kept up to date with current project progress and logbook.

A: 5                  B: 4                  C: 4                  D: 4                  E:                  F:

7. Rate the overall performance of the student as a member of the team on this project.

A: 5                  B: 5                  C: 5                  D: 2                  E:                  F:

**CHEG 4248 SENIOR DESIGN AND PROFESSIONALISM II**  
**SPRING 2022**  
**PROJECT ASSIGNMENT COVER SHEET**

**TEAM NUMBER: 2**

ASSIGNMENT #: 1

Assignment Title: Homework 1

Due Date: February 17, 2022

| <b>No</b> | <b>TEAM Member<br/>Name<br/>TEAM Member<br/>Signature</b> | <b>Brief Description of Work Assigned<br/>to Member</b> | <b>%<br/>Completed<br/>by<br/>Member*</b> | <b>Your<br/>Score</b> |
|-----------|-----------------------------------------------------------|---------------------------------------------------------|-------------------------------------------|-----------------------|
| 1         | Chinenye Ihe                                              | Started Homework 1                                      | <b>100</b>                                | <b>100</b>            |
| 2         | Shimere Gregory                                           | Completed Gantt Chart                                   | <b>100</b>                                | <b>100</b>            |
| 3         | Utomwen Irabor                                            | Worked on Homework 1 and Process<br>Flow Diagram        | <b>100</b>                                | <b>100</b>            |
| 4         | Willie Conner                                             | Worked on minutes of meeting                            | <b>100</b>                                | <b>100</b>            |

\*100% means the member completed his/her assigned work.

*By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and other members of the group.*

# **CHEG 4248 SENIOR DESIGN AND PROFESSIONALISM I SPRING 2022**

## **MINUTES OF TEAM MEETINGS**

Meeting Date: 02/17/2022    Meeting Time: 10:40am    Meeting Location: Zoom

Members Present: Chinenye Ihe, Utomwen Irabor, Shimere Gregory, Willie Conner

Agenda for Meeting (List all items to be discussed or discussed at the meeting)

- ✓ PFD corrections
- ✓ Homework 1/ Gantt Chart
- ✓ Assign Equipements

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

David was the speaker of the meeting, and he went over to the process flow diagram from last semester to make correctios for this semester and divided the tasks between all members of the team. He suggested that we should start to focus more on our equipment sizing for next week so that we can start on calculations.



# CHEG 4248 SENIOR DESIGN AND PROFESSIONALISM II SPRING 2022

## TASK ASSIGNMENT & DELIVERABLES AT MEETINGS

Use this table to document tasks assigned and deliverables completed/submitted by each group member at each meeting. If deliverables are not completed, indicate the actions taken by the group on this individual

Meeting Date: February 17, 2022      Meeting Time: 10:40am      Meeting Location: Zoom

| <b>Name</b>     | <b>Task Assigned</b>                      | <b>Deliverables Completed &amp; Submitted</b>                           |
|-----------------|-------------------------------------------|-------------------------------------------------------------------------|
| Chinenye Ihe    | Start/Add to homework 1                   | Started homework 1, identified major tasks, phases, and sub-tasks       |
| Shimere Gregory | Add Gantt Chart                           | Completed the Gantt Chart with all tasks and start to finish dates      |
| Willie Conner   | Helped to complete the minutes of meeting | Fixed grammatical errors on Homework 1 and wrote the minutes of meeting |
| Utomwen Irabor  | Complete Homework 1                       | Completed homework 1                                                    |

# **CHEG 4248 SENIOR DESIGN AND PROFESSIONALISM II**

## **SPRING 2022**

### **CLASS ATTENDANCE SHEET**

This table documents attendance of students of the Senior Design & Professionalism class as indicated below and will be used to evaluate the sub outcome of ABET criterion 4 Students understanding and demonstration of professional responsibilities.

Meeting Date: February 17, 2022

Meeting Time: 10:40am

Meeting Location: Zoom

| <b>Student Name</b> | <b>Project Title</b> | <b>On time</b> | <b>5 minutes late</b> | <b>Absent</b> |
|---------------------|----------------------|----------------|-----------------------|---------------|
| Utomwen Irabor      | <b>Homework 1</b>    | ✓              |                       |               |
| Chinenye Ihe        | <b>Homework 1</b>    | ✓              |                       |               |
| Shimere Gregory     | <b>Homework 1</b>    | ✓              |                       |               |
| Willie Conner       | <b>Homework 1</b>    |                |                       | ✓             |



