Dimethyl Ether Production from Methanol

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INTRODUCTION AND PROJECT CONCEPT

Background

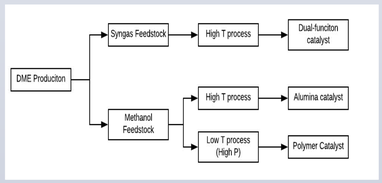
- Demand for alternative liquid fuels have risen in the past years, due to a dwindling supply of current fuels, and increased environmental awareness.
- DME (Dimethyl Ether) is a low-sulfur diesel fuel alternative that produces very little soot and NO_x emissions when burned [1].
- Cleaner alterative that performs well against traditional diesel fuel [2].

Concept

- Production of DME for use as a fuel.

$$2CH_3OH \leftrightarrow CH_3OCH_3 + H_2O$$

- Dehydration of methanol produces DME and water.
- Production goal is 250,000 gal/day.
- Class 4 feasibility study for the construction of a DME plant in Lake Charles, LA.



- Decision Tree for Process shown above.

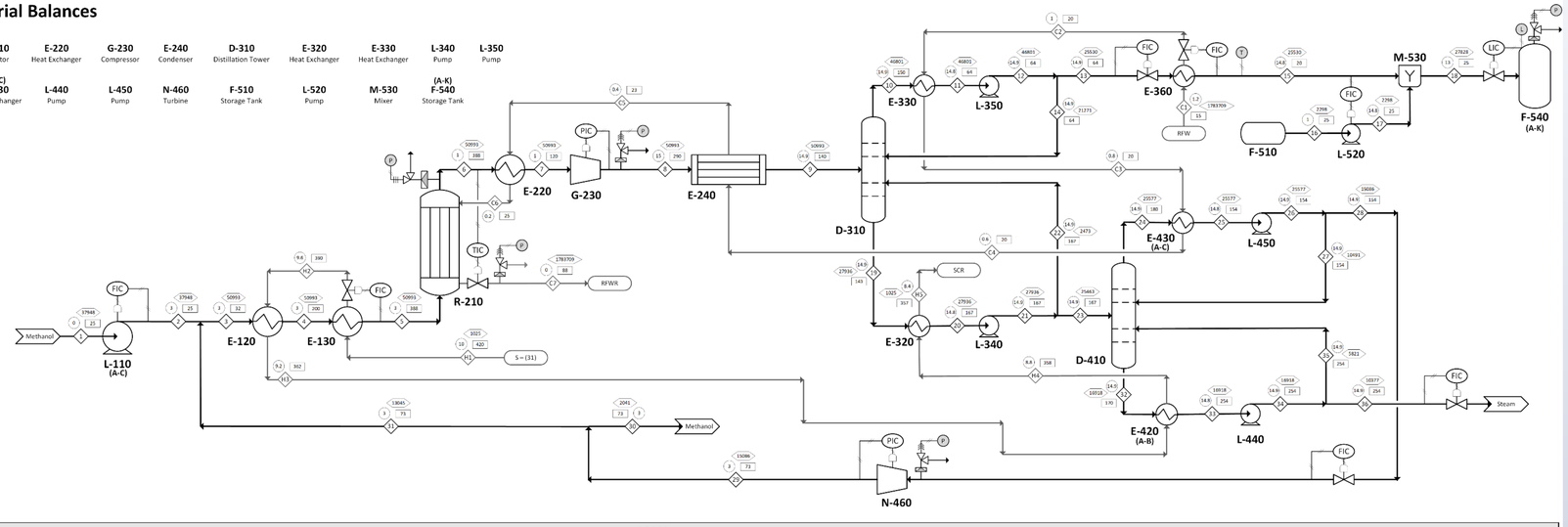
Process Flow Diagram and Material Balances

(A-C) L-110 Centrifugal Pump; E-120 Heat Exchanger; E-130 Heat Exchanger; R-210 Reactor; E-220 Heat Exchanger; G-230 Compressor; E-240 Condenser; D-310 Distillation Tower; E-320 Heat Exchanger; E-330 Heat Exchanger; L-340 Pump; L-350 Pump; E-360 Heat Exchanger; D-410 Distillation Tower; (A-B) E-420 Heat Exchanger; (A-C) E-430 Heat Exchanger; L-440 Pump; L-450 Pump; N-460 Turbine; F-510 Storage Tank; L-520 Pump; M-530 Mixer; (A-K) F-540 Storage Tank

Continuous Production of Methanol Process Flow Diagram — Drawn: 04/30/2018 — By:

Diagram Key

- Stream Number
- Stream Pressure (barg)
- Temperature (°C)
- Flow Rate (kg/h)
- Feed / Exit Stream
- RFW — Refrigerated Water (15°C)
- RFWR — Refrigerated Water Return (88°C)
- S – (P) — Steam – (Pressure in barg) (420°C)
- SCR — Steam Condensate Return (357°C)
- TIC — Temperature Indicator & Controller
- FIC — Flow Rate Indicator & Controller
- PIC — Pressure Indicator & Controller
- LIC — Level Indicator & Controller
- T — Temperature Alarm
- P — Pressure Alarm
- L — Level Alarm
- Rupture Disk
- Measurement Point
- Signal Point
- Control Valve
- Relief Valve



100%

Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	C - 1	C - 2	C - 3	C - 4	C - 5	C - 6	C - 7	H-1	H-2	H-3	H-4	H-5
Flowrate (kg/h)	37948	37948	50993	50993	50993	50993	50993	50993	13045	50993	2302	46744	46796	46744	46744	46796	21247	25500	46796	21271	16918	25577	25530	16918	16918	25577	25530	2298	6767	2298	10153	25577	27828																
Temperature (°C)	25	25	42	200	388	388	120	290	140	0	0	64	64	64	25	25	25	25	167	167	167	167	167	154	154	154	154	154	154	125	0	0	0	200	200	200	15	20	20	20	23	25	88	420	390	360	355	355
Pressure (barg)	0	3	3	3	3	1	1	15	15	15	15	15	15	15	15	1	15	15	15	15	15	15	15	15	15	15	15	15	3	3	3	15	15	15	15	15	1	1	1	1	0	0	0	10	10	9	9	8
Molar Vapor Fraction	30.22%	7.04%	15.20%	99.72%	99.81%	100.00%	100.00%	100.00%	70.87%	16.68%	16.79%	98.44%	98.44%	98.44%	37.15%	100.00%	100.00%	37.15%	88.82%	89.73%	88.82%	88.82%	88.82%	98.89%	98.89%	98.89%	98.89%	98.89%	99.06%	98.98%	1.89%	99.15%	99.15%	99.17%	99.17%	99.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Material	**MW (kg/kgmol)**																																															
Methanol	32	37948	37948	50771	50771	50771	15231	15231	15231	15231	8	8	8	5	4	5	-	-	5	27938	27938	27938	12698	15239	25142	25142	25142	10057	15086	15086	12823	2263	254	254	254	102	152	-	-	-	-	-	-	-	-	-	-	-	-	-
Dimethyl ether	46	-	-	219	219	219	25765	25765	25765	25765	46788	46788	46788	25526	21267	25526	-	-	25526	473	473	473	215	258	430	430	430	172	258	258	219	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water	18	-	-	3	3	3	9997	9997	9997	9997	-	-	-	-	-	-	-	-	-	18336	18336	18336	8334	10004	5	5	5	2	3	3	3	-	16664	16664	16664	6665	10001	-	-	-	-	-	-	-	-	-	-	-	-	-
Lube	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2298	2298	2298	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process Steam	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	958.388	958.388	958.388	958.388	958.388
Process Water	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1783708.9	1783708.9	1783708.9	1783708.9	1783708.9	1783708.9	1783708.9	-	-	-	-	-

STUDY OBJECTIVES

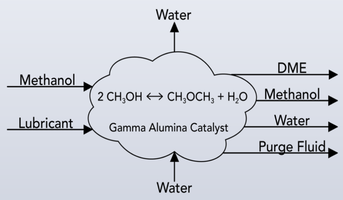
- Construct of process for production of 250,000 gal/day of fuel grade according to parameters below (ASTM D7901.144734)

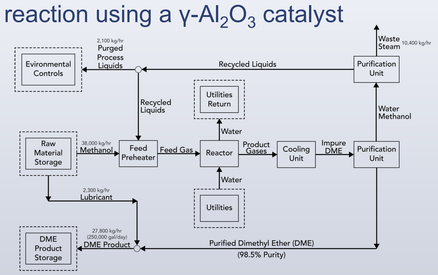
DME Fuel Composition Requirements	
Dimethyl Ether	98.5% by mass (minimum)
Methanol	0.05% by mass (maximum)
Water	0.03% by mass (maximum)
Methyl Formate	0.00% by mass

- Economic analysis to determine profitability of the study.
- Evaluation of design safety and controls to minimize risk.
- Recommend further action.

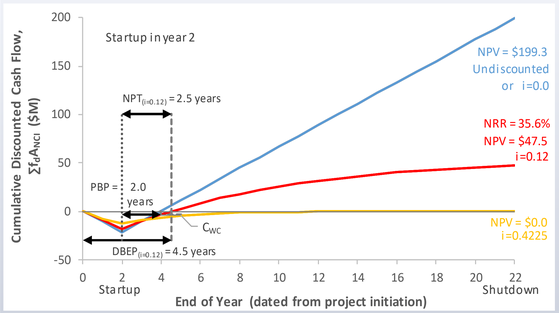
PROCESS OVERVIEW

- Continuous, high temperature gas phase reaction using a γ-Al_2O_3 catalyst





ECONOMIC ANALYSIS



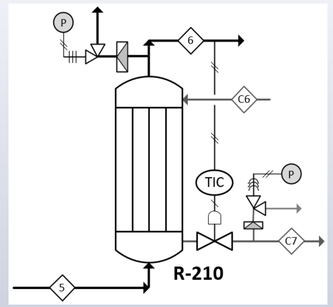
- 2 year startup, 20 year operation until shutdown
- Total Capital Investment: $21,563,690
- Annual Expenses: $257,827,840
- Annual Revenue: $273,750,000
- Net Annual Profit (after-tax): $11,941,620
- Annual After-Tax Rate of Return = 83%

(Based on DME sale price of $3.00/gal)

- DME production expense: $2.85/gal
- DME profit: $0.131/gal
- DCFRR = 42.25%

SAFETY CONSIDERATIONS

- P&ID around the reactor (R-210). Shows a temperature control the cooling of the reactor.
- Relief valves designed for both exit streams.
- HAZOP report designed around the reactor.
- Distillation columns designed to hold liquid in case of emergency shutdown.



CONCLUSIONS AND RECOMMENDATIONS

- TSRM Inc. recommends that this plant is a **GO.**
- Producing and selling a product in a growing market
- Economic analysis produced promising result
  - DCFRR=42.25%
  - After tax rate of return=83%
- Very safe design with steps to minimize risk within the process

REFERENCES

[1] M. I. Arbab, H. H. Masjuki, M. Varman, M. A. Kalam, S. Imtenan, and H. Sajjad, “Fuel properties, engine performance and emission characteristic of common biodiesels as a renewable and sustainable source of fuel,” Renew. Sustain. Energy Rev., vol. 22, pp. 133–147, 2013.

[2] J. P. Szybist, S. Mclaughlin, and S. Iyer, Emission and performance benchmarking of a prototype dimethyl ether fueled heavy-duty truck, no. February. 2014.

ACKNOWLEDGEMENTS

TSRM would like to thank the Chemical Engineering department at the University of New Hampshire for support and resources on this project. TSRM would also like to extend thanks to Dr. Chris McLarnon for support on the project as well.