Letter of Transmittal

To: Senior Management

From: Engineering Department

Subject: Modular Distributed Ammonia Synthesis

To Whom It May Concern,

The enclosed report is our design team's response to senior management's proposal for an anhydrous ammonia plant located in the Minnesota River Valley. The design also includes the upstream production of hydrogen and nitrogen. We are pleased to deliver this requested process design as it is technically feasible, economically attractive, and safe. This report entails a thorough discussion of all aspects that went into the design, including but not limited to optimization of the system, economics, risk analyses, and safety considerations. If additional information is desired, the team would be happy to provide such details. We thank you for taking the time to consider this report.

Regards,

Team 9

CHE 4224

Spring 2020

AIChE National Student Design Competition

Modular Distributed Ammonia Synthesis

April 2, 2020

Group Number 9

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Abstract

The preliminary design of an anhydrous ammonia plant was performed. In the United States, the Corn Belt is the largest consumer of anhydrous ammonia fertilizer, yet the Corn Belt obtains most of its fertilizer from the Gulf Coast. The transportation of ammonia fertilizer from the Gulf Coast to the Corn Belt is both costly and hazardous. To mitigate the additional safety and cost burdens associated with transportation of anhydrous ammonia, it is the objective of this project to produce the preliminary design of a plant located in the Minnesota River Valley. The project memo states this location to be especially suited for ammonia production due to its high demand in agricultural use within this region of the United States.

The plant is designed to produce 50 metric tons per day of anhydrous ammonia with a product purity of 99.5% by mass. The reactants utilized to produce anhydrous ammonia can be expensive and hazardous to transport, so it is the objective of this preliminary design to also design onsite production of both hydrogen and nitrogen. The desired purity is 99.9% by mole for both hydrogen and nitrogen.

The design selected to meet these requirements includes a pressure swing adsorption system for nitrogen production, which includes two adsorption towers, three double pipe heat exchangers, and three reciprocating compressors. The steam methane reforming for hydrogen production includes: one packed bed reactor, one membrane reactor, two shell and tube heat exchangers, one reciprocating compressor, one fired heater and two adsorption towers. The Haber-Bosch process was utilized for ammonia production, and includes one packed bed reactor, two shell and tube heat exchangers, three reciprocating compressors, one flash drum, one air cooled heat exchanger, and three storage tanks. Aspen HYSYS was utilized to simulate the process and evaluate methods for optimization.

A safety analysis was performed by examining mistakes that have occurred over the last 50 years in ammonia production that have led to safety issues. By discovering what could go wrong and what has gone wrong in the past, accommodations were made to produce an inherently safer design. Loss of containment was the biggest concern associated with the project resulting in focus throughout the process of mitigating this risk through inherent safety.

An economic analysis has been completed on the design with an expected project life of 20 years. The economic analysis yielded the net present value to be $15,000,000 in 2020 US dollars, and the DCFROR to be 13%. This displays the economic feasibility of the project as the minimum rate of return is 8%. The payback period was found to be approximately 8.3 years, and the breakeven product price was found to be $460. The design team has determined from this analysis that the project is both technically and economically feasible.

A sensitivity analysis was performed to determine the risk associated with the project. The impact of variation of the capital investment, raw material cost, operating cost, and revenue on the net present value and DCFROR were analyzed. Each variable was analyzed at a ±10%, ±20%, and ±30% variation. The variation of revenue had the greatest impact on the project. Through this analysis the team has deemed the risks associated with the project low. This supports the recommendation to move forward to the detailed design phase of the project.

Introduction

The objective of this project is to perform a preliminary design, evaluate the economics, and mitigate potential safety hazards of an anhydrous ammonia plant. Compared to other commercial fertilizers, anhydrous ammonia fertilizer has the highest nitrogen content (*1*). Nitrogen is a crucial component for crop growth (*2*). Through years of producing crops the soil can become depleted of nitrogen, making ammonia popular among farmers for crop production (*1*). Additionally, ammonia production is crucial to the world population, as it is reported to be at least two to three billion larger in size due to the crop yield created by ammonia-based fertilizers and other chemicals (*3*).

In the United States, corn production has historically been the largest consumer of ammonia (*4*). Currently, most of the ammonia used in the Corn Belt is produced on the Gulf Coast; yet, this shipment is costly and hazardous (*5*). Implementation of an ammonia plant within the Corn Belt has the potential to not only alleviate these issues, but also be quite profitable. To meet these demands and alleviate these issues, the designed plant's location will be in the region of the Minnesota River Valley. Additionally, the project memo states this to be the chosen location for this ammonia production facility due to the high ammonia demand for agricultural use. This region also offers the availability of sweet natural gas from neighboring states that can be sent directly to the plant via distribution lines (*6*).

The plant is designed to produce 50 metric tons per day, 110,231 lbs. per day, of commercial-grade anhydrous ammonia, of 99.5% by mass. This ammonia can be sold as is for fertilization, through injecting the liquid ammonia into the ground (*7)*. This results in no additional downstream processing of ammonia being necessary in the plant.

In this process ammonia is produced through the reaction of nitrogen and hydrogen over a ruthenium-cesium catalyst via the following reaction:

$$\mathrm{N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}}$$

To lower production costs and mitigate safety concerns of large onsite storage, the design contains the upstream production of hydrogen and nitrogen needed for this reaction. The team designed different options for both hydrogen and nitrogen production. The team analyzed pressure swing adsorption and membranes for nitrogen production. Steam methane reforming and electrolysis were analyzed for hydrogen production. The process description includes only the selected options; however, in the section of "important considerations" information on how these selections were made is provided. After production, the anhydrous ammonia is stored onsite in tanks that conform to the requirements of 29CFR1910.111 (*8)*.

The project is set to purchase equipment in mid-2020, but for construction to not begin until mid-2021. Beginning construction in 2021 allows time to obtain a construction permit, which can take at least 6 months to obtain from time of submission. The permit request includes the completed design basis, site characteristics, and all expected environmental discharge. The purchase of equipment takes place prior to permit issuance to provide a schedule advantage. Due to the design of this project production is set to begin in mid-2024.

The plant was analyzed with an expected lifespan of 20 years. Depreciation, write-offs, inflation, and taxes were also considered. The net present value, rate of return, and risks were all considered to determine the economic feasibility of the plant. In deciding the optimal process, the team prioritized a mitigated carbon footprint of the plant, lowered economic losses, and increased inherent safety. An overview of the process is shown below in Figure 1. Throughout this report information regarding the steam methane reforming unit will be referred to as hydrogen production, information regarding the pressure swing adsorption unit will be referred to as nitrogen production, and information referring to the Haber-Bosch process unit will be referred to as ammonia production.

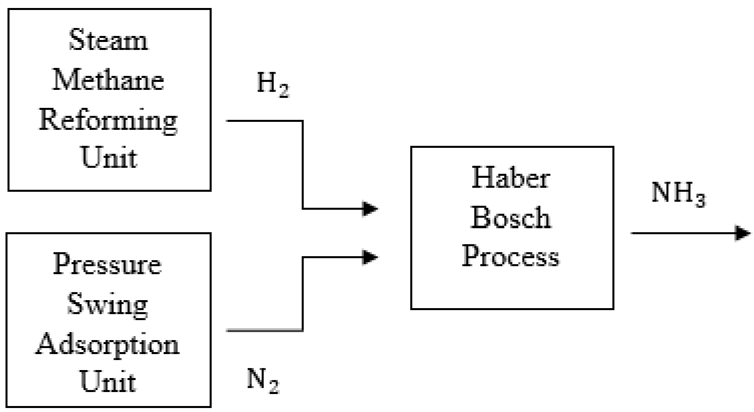

Figure 1: Block Flow Diagram of Process

Process Flow Diagram and Material Balances

The process flow diagram for the preliminary design of the nitrogen production section of the plant is shown in Figure 2, along with the stream summary table, Table 1. The process flow diagram for the preliminary design of the hydrogen production section of the plant is displayed in Figure 3, with the stream summary table in Table 2. The preliminary design of the ammonia production section of the plant is displayed in Figure 4, and the stream summary table for this section is in Table 3.

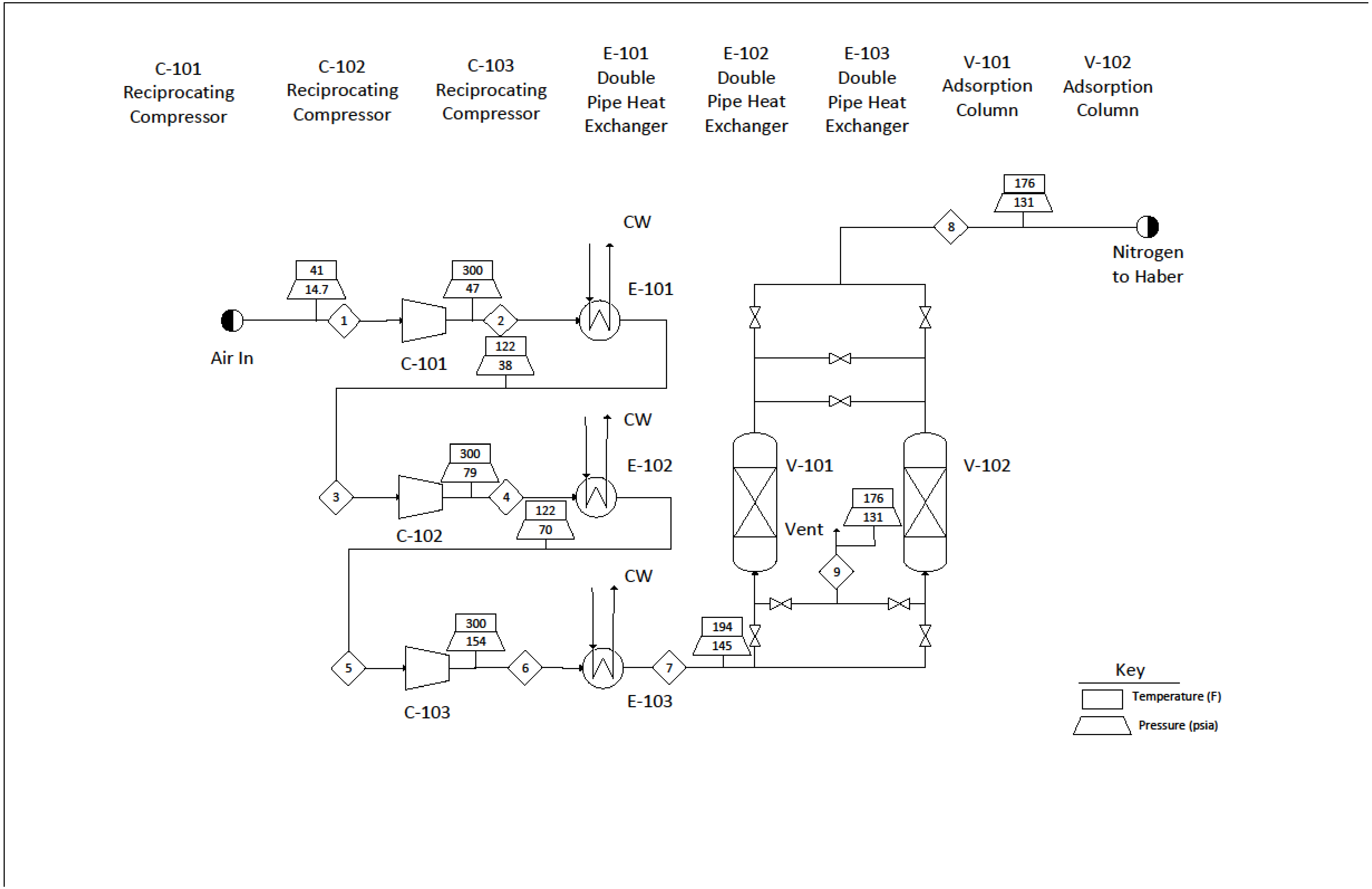

Figure 2: Process Flow Diagram of Nitrogen Production

Table 1: Nitrogen Stream Summary Table

	Unit	Nitrogen Production								
Stream ID #		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Vapour Fraction		1	1	1	1	1	1	1	1	1
Temperature	F	41	300	122	300	122	300	194	176	176
Pressure	psia	15	47	38	79	70	154	145	131	131
Molar Enthalpy	Btu/lbmole	-931	891	-371	887	-378	879	120	-835	658
Molar Flow	lbmole/hr	250	250	250	250	250	250	250	136	114
Master Comp Molar Flow (Argon)	lbmole/hr	2	2	2	2	2	2	2	2	0
Master Comp Molar Flow (CO)	lbmole/hr	0	0	0	0	0	0	0	0	0
Master Comp Molar Flow (CO2)	lbmole/hr	1	1	1	1	1	1	1	1	0
Master Comp Molar Flow (H2O)	lbmole/hr	0	0	0	0	0	0	0	0	0
Master Comp Molar Flow (Nitrogen)	lbmole/hr	195	195	195	195	195	195	195	59	137
Master Comp Molar Flow (Oxygen)	lbmole/hr	53	53	53	53	53	53	53	53	0
Mass Flow	lb/hr	7,259	7,259	7,259	7,259	7,259	7,259	7,259	3,936	3,323
Actual Volume Flow	barrel/day	391,071	186,226	176,201	110,511	95,266	56,744	51,746	183,915	221,169
Molar Density	lbmole/ft3	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

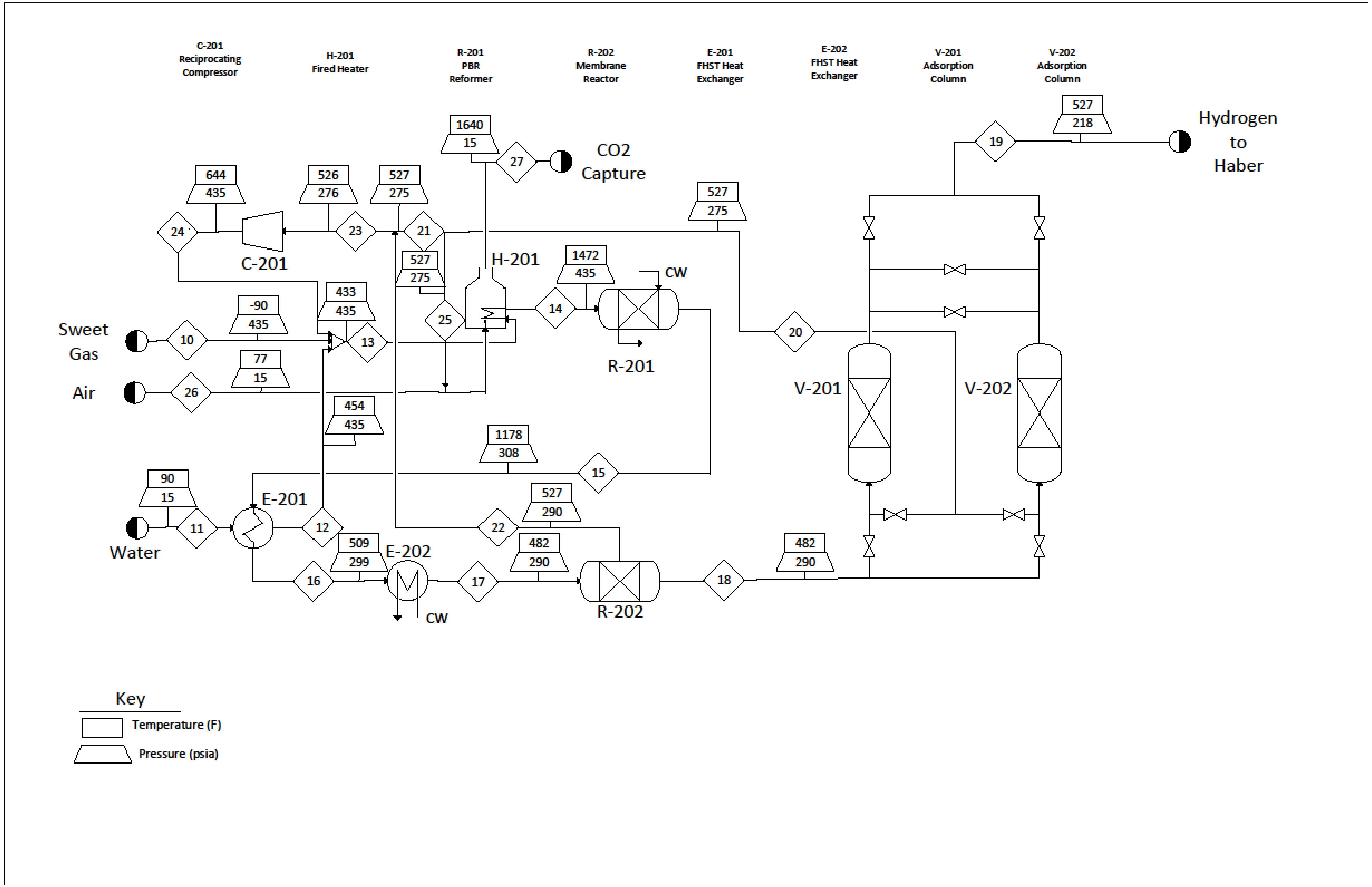

Figure 3: Process Flow Diagram of Hydrogen Production

Table 2: Hydrogen Stream Summary Table

	Unit	Hydrogen Production													
Stream ID #		**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Vapour Fraction		1	0	1	1	1	1	1	1	1	1	1	1	1	1
Temperature	F	-90	90	454	433	1472	1178	509	482	482	527	527	527	527	526
Pressure	psia	435	15	435	435	435	308	299	290	290	218	276	276	290	276
Molar Enthalpy	Btu/lbmole	-34638	-122811	-101492	-86121	-73798	-68417	-75671	-75932	-25141	5268	-97959	-97959	-94614	-95818
Molar Flow	lbmole/hr	179	357	357	973	973	1050	1050	1050	798	408	390	157	279	436
Molar Flow (CO)	lbmole/hr	0	0	0	4	4	41	41	41	0	0	10	4	0	4
Molar Flow (CO2)	lbmole/hr	0	0	0	187	187	189	189	189	4	0	120	48	139	187
Molar Flow (Ethane)	lbmole/hr	18	0	0	53	53	53	53	53	0	0	20	8	27	36
Molar Flow (H2O)	lbmole/hr	0	357	357	444	444	404	404	404	208	1	159	64	23	87
Molar Flow (Hydrogen)	lbmole/hr	0	0	0	76	76	193	193	193	583	407	27	11	65	76
Molar Flow (Methane)	lbmole/hr	161	0	0	208	208	170	170	170	4	0	54	22	25	47
Molar Flow (Nitrogen)	lbmole/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Molar Flow (Oxygen)	lbmole/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mass Flow	lb/hr	3115	6434	6434	21453	21453	21453	21453	21453	5153	842	9967	4009	7861	11870
Liquid Volume Flow	barrel/day	693	441	441	2465	2465	2600	2600	2600	1437	805	1029	414	913	1327
Actual Volume Flow	barrel/day	5047	440	30298	87876	198765	256389	153666	153832	118560	115650	62995	25340	43366	71007
Molar Density	lbmole/ft3	0.15	3.47	0.05	0.05	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03

	Unit	Hydrogen Production			
Stream ID #		**24**	**25**	**26**	**27**
Vapour Fraction		1	1	1	1
Temperature	F	644	527	77	1640
Pressure	psia	435	276	15	15
Molar Enthalpy	Btu/lbmole	-94581	-97959	-4	-103956
Molar Flow	lbmole/hr	436	233	130	341
Molar Flow (CO)	lbmole/hr	4	6	0	0
Molar Flow (CO2)	lbmole/hr	187	72	0	147
Molar Flow (Ethane)	lbmole/hr	36	12	0	0
Molar Flow (H2O)	lbmole/hr	87	95	0	154
Molar Flow (Hydrogen)	lbmole/hr	76	16	0	0
Molar Flow (Methane)	lbmole/hr	47	32	0	0
Molar Flow (Nitrogen)	lbmole/hr	0	0	27	27
Molar Flow (Oxygen)	lbmole/hr	0	0	103	13
Mass Flow	lb/hr	11870	5958	4063	10414
Liquid Volume Flow	barrel/day	1327	615	263	816
Actual Volume Flow	barrel/day	50444	37654	218259	2236146
Molar Density	lbmole/ft3	0.04	0.03	0.00	0.00

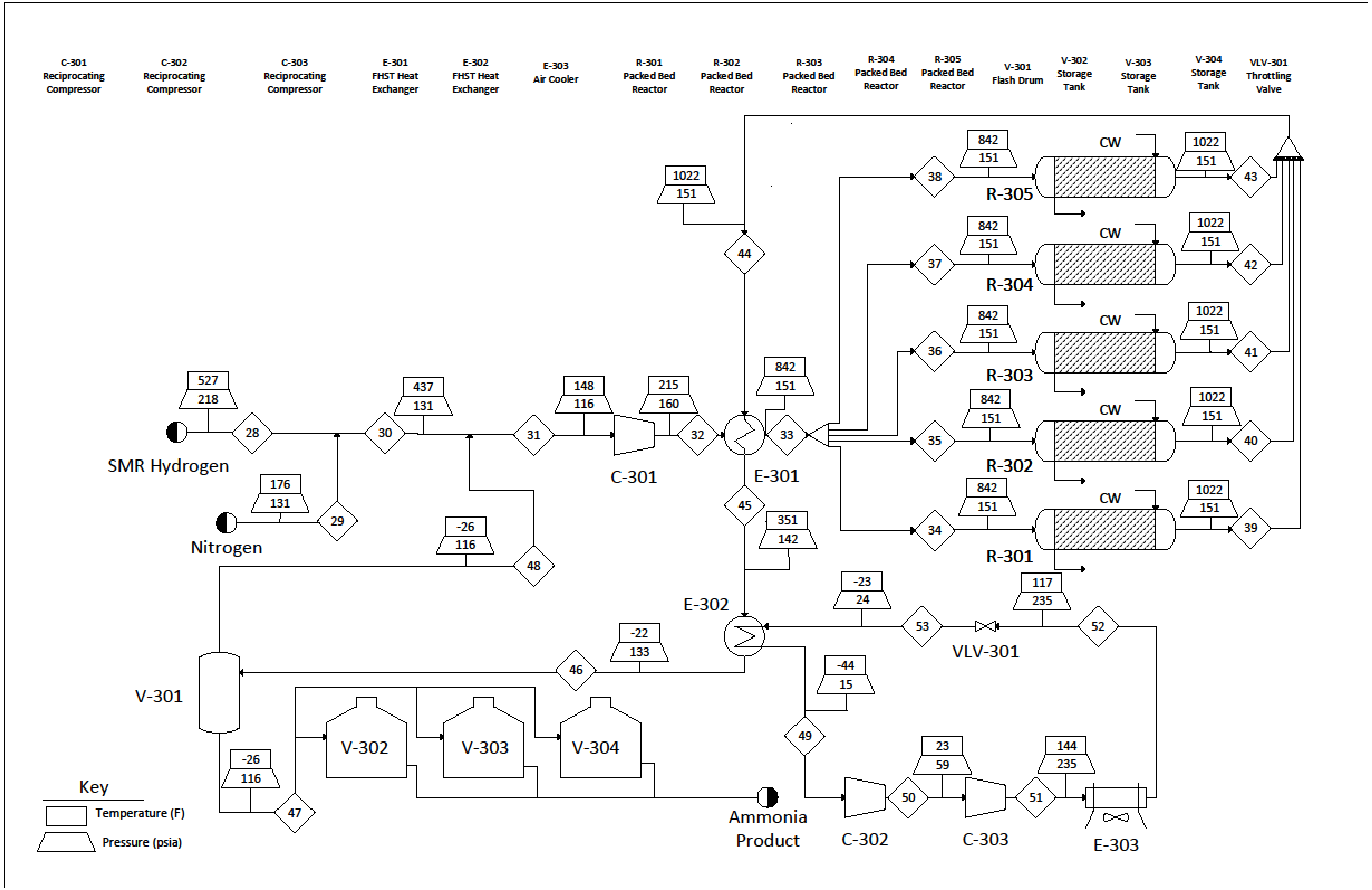

Figure 4: Process Flow Diagram of Ammonia Production

Table 3: Ammonia Stream Summary Table

	Unit	Ammonia Production														
Stream ID #		**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**
Vapour Fraction		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Temperature	F	527	176	437	148	215	842	842	842	842	842	842	1022	1022	1022	1022
Pressure	psia	218	131	131	116	160	151	151	151	151	151	151	151	151	151	151
Molar Enthalpy	Btu/lbmole	2783	675	2254	-1292	-819	3787	3787	3787	3787	3787	3787	968	968	968	968
Molar Flow	lbmole/hr	408	137	545	1425	1425	1425	285	285	285	285	285	231	231	231	231
Master Comp Molar Flow (Ammonia)	lbmole/hr	0	0	0	123	123	123	25	25	25	25	25	78	78	78	78
Master Comp Molar Flow (H2O)	lbmole/hr	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0
Master Comp Molar Flow (Hydrogen)	lbmole/hr	407	0	407	904	904	904	181	181	181	181	181	100	100	100	100
Master Comp Molar Flow (Nitrogen)	lbmole/hr	0	137	137	387	387	387	77	77	77	77	77	51	51	51	51
Master Comp Molar Flow (Oxygen)	lbmole/hr	0	0	0	10	10	10	2	2	2	2	2	2	2	2	2
Master Comp Molar Flow (Propane)	lbmole/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mass Flow	lb/hr	842	3830	4671	15109	15109	15109	3022	3022	3022	3022	3022	3022	3022	3022	3022
Std Ideal Liq Vol Flow	barrel/day	805	325	1130	2960	2960	2960	592	592	592	592	592	470	470	470	470
Actual Volume Flow	barrel/day	85192	30546	172029	342492	276908	566605	113321	113321	113321	113321	113321	104565	104565	104565	104565
Molar Density	lbmole/ft3	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

	Unit	Ammonia Production											
Stream ID #		**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**
Vapour Fraction		1	1	1	1	1	0	1	1	1	1	0	1
Temperature	F	1022	1022	1022	351	-22	-26	-26	-44	23	144	117	-23
Pressure	psia	151	151	151	142	133	116	116	15	59	235	235	24
Molar Enthalpy	Btu/lbmole	968	968	968	-4710	-9942	-31149	-3486	-46711	-45835	-44201	-50337	-50337
Molar Flow	lbmole/hr	231	231	1156	1156	1156	270	886	1668	1668	1668	1668	1668
Comp Molar Flow (Ammonia)	lbmole/hr	78	78	392	392	392	268	123	0	0	0	0	0
Comp Molar Flow (H2O)	lbmole/hr	0	0	1	1	1	1	0	0	0	0	0	0
Comp Molar Flow (Hydrogen)	lbmole/hr	100	100	500	500	500	0	500	0	0	0	0	0
Comp Molar Flow (Nitrogen)	lbmole/hr	51	51	253	253	253	0	252	0	0	0	0	0
Comp Molar Flow (Oxygen)	lbmole/hr	2	2	10	10	10	0	10	0	0	0	0	0
Comp Molar Flow (Propane)	lbmole/hr	0	0	0	0	0	0	0	1668	1668	1668	1668	1668
Mass Flow	lb/hr	3022	3022	15108	15108	15108	4594	10514	73544	73544	73544	73544	73544
Std Ideal Liq Vol Flow	barrel/day	470	470	2351	2351	2351	510	1842	9939	9939	9939	9939	9939
Actual Volume Flow	barrel/day	104565	104565	522825	303007	133100	467	150975	2092544	568751	152594	11082	678184
Molar Density	lbmole/ft3	0.01	0.01	0.01	0.02	0.04	2.47	0.03	0.00	0.01	0.05	0.64	0.01

Process Description

Nitrogen Production

For 50 metric tons of ammonia to be produced per day, 41.7 metric tons of nitrogen must be produced per day. The group employed pressure swing adsorption to meet this demand. Before entering the pressure swing adsorption column, the feed stream of air, stream 1, is compressed to the desired operating pressure of 145 psia by C-101, C-102, and C-103. E-101 and E-102 serve as interstage coolers between C-101, C-102, and C-103. The stream exits C-103, and is cooled to 195 °F, by E-103. This cooled stream, stream 7, then enters the pressure swing adsorption system, V-101 and V-102. The stream enters V-101 where pressurization and adsorption will occur, while depressurization and desorption occur in V-102. Each bed will operate with a time shift of 65 seconds from the other bed's current operation (*9)*. Stream 8 is then sent to the downstream process of ammonia production.

Hydrogen Production

The mechanism employed to produce 50 metric tons per day of ammonia requires 9.2 metric tons per day of hydrogen to be available. The onsite production of hydrogen utilizes steam methane reforming. Natural gas and water must be purchased for this process. Natural gas is obtained from the distribution line system (*6)*. The sweet natural gas is sent to mix with stream 12, which is water that has been heated by E-204 to steam. The natural gas and steam mixture, stream 13, is then heated prior to entering the reactor by H-201, to ensure it is at the desired reaction temperature of 1470 °F. The natural gas and steam mixture exiting H-201 then enters R-201, and is reacted over a Ni-Al_2O_3 catalyst via the following reactions:

$$CH_{4(g)} + H_2O_{(g)} \leftrightarrow CO_{(g)} + 3H_{2(g)} \qquad (Rxn.\ 1)$$

$$CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2(g)} + H_{2(g)} \qquad (Rxn.\ 2)$$

The unreacted material and products are then cooled by E-205 to reach the desired reaction temperature of the following reactor, R-202 of 480 °F. This reactor serves to produce hydrogen via the water gas shift mechanism over a copper membrane catalyst, shown below:

$$CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2(g)} + H_{2(g)}$$

R-202 has two streams that exit it, with one containing most of the undesired byproduct and unreacted material, stream 22. Stream 18 also exits R-202 and enters the pressure swing adsorption system, V-201 and V-202. Stream 18 enters V-201, the first adsorption column, where pressurization and adsorption occur, and depressurization and desorption occur in V-201.

The columns operate off a time shift, 65 s (*9)*. The purified hydrogen in stream 19, then goes to the downstream process. The adsorbed material is purged and sent to a t-splitter in stream 20. Part of the stream, stream 25, is sent to the fired heater, H-201, and is utilized as a fuel. H-201 also serves to convert the unreacted carbon monoxide in stream 25, to carbon dioxide. Exiting the t-splitter is also stream 21, which is combined with stream 22, and recycled back to the process by stream 23. Stream 23 must be compressed by C-201 to achieve the desired operating pressure of R-201, which is 435 psia.

Ammonia Production

The Haber-Bosch process was utilized to produce 50 metric tons per day of ammonia. The process begins with stream 28, carrying hydrogen, and stream 29, carrying nitrogen combining with the recycle stream, 48. C-301 serves to compress the feed to the desired pressure of the reaction, 145 psia. This compressed feed then enters E-301 to be heated to the reaction temperature of 840 °F, utilizing heat integration. The reaction takes place in R-301, R-302, R-303, R-304, and R-305 over a ruthenium-cesium catalyst, via the following reaction chemistry:

$$\mathrm{N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}}$$

The streams exiting R-301, R-302, R-303, R-304, and R-305 combine to form stream 44 to then be utilized for heat integration in E-302. This stream, now labeled stream 45, then enters E-303 to be further cooled for separation of the desired ammonia product and unreacted nitrogen and hydrogen. The separation takes place in V-301. The unreacted hydrogen and nitrogen are recycled back in stream 46, and the ammonia is sent to storage tanks V-302, V-303, and V-304 in stream 47.

Energy Balance and Utility Requirements

Below in Table 4, an energy balance has been provided; additionally, in Table 5 the utility requirements are displayed.

Energy Balance

Below is the energy summary for the given process.

Table 4: Energy Balance

Stream	Molar Enthalpy (Btu/lbm)	Stream	Molar Enthalpy (Btu/lbm)
1	-931.196	27	-103956
2	890.5461	28	2783.371
3	-370.993	29	675.0804
4	887.0348	30	2254.165
5	-377.523	31	-1292.32
6	879.2921	32	-818.817
7	120.1409	33	3786.759
8	-834.6526335	34	3786.759
9	657.5421603	35	3786.759
10	-34638.3	36	3786.759
11	-122811	37	3786.759
12	-101492	38	3786.759
13	-86120.5	39	968.2813
14	-73798.3	40	968.2813
15	-68417.2	41	968.2813
16	-75671.2	42	968.2813
17	-75931.7	43	968.2813
18	-25140.8	44	968.2813
19	5268.37602	45	-4709.93
20	-97959.4	46	-9941.57
21	-97959.4	47	-31149.4
22	-94614.3	48	-3485.82
23	-95818.4	49	-46711.3
24	-94581.1	50	-45835.4
25	-97959.4	51	-44201.1
26	-3.95859	52	-50336.8
27	-103956	53	-50336.8

Utility Requirements

This process requires electricity and cooling water for operation. The utility requirements are broken up by hydrogen production, nitrogen production, and ammonia production in Table 5. The ammonia production utilizing the Haber-Bosch process, requires the most electricity and cooling water.

Table 5: Utility Requirements

	Electricity (BTU/hr)	Cooling Water (lb/hr)
Nitrogen Production		
C-101	457208	-
C-102	313904	-
C-103	313904	-
E-101	-	9995
E-102	-	10019
E-103	-	6015
Hydrogen Production		
C-201	539096	-
E-201	-	8930
Ammonia Production		
C-301	675576	-
C-302	1460336	-
C-303	2726188	-
R-301	-	25709
R-302	-	25709
R-303	-	25709
R-304	-	25709
R-305	-	25709
Total	1624112	34959

Equipment List and Unit Descriptions

For an overview of the equipment within each unit Table 6 is provided. More detail sizing information is provided in Tables 7-20.

Table 6: Overall Process Equipment Summary

Nitrogen Production			
Unit	Sizing	MAWP	MOC
C-101	457208 Btu/hr	47 psia	CS
C-102	313904 Btu/hr	79 psia	CS
C-103	313904 Btu/hr	154 psia	CS
E-101	16 ft^2	210 psia	SS
E-102	23 ft^2	100 psia	SS
E-103	43 ft^2	130 psia	SS
V-101	207 ft^3	195 psia	CS
V-102	207 ft^3	195 psia	CS
Hydrogen Production			
Unit	Sizing	MAWP	MOC
C-201	741 hp	435 psia	SS
E-201	354 ft^2	485 psia	SS
E-202	146 ft^2	276 psia	SS
H-201	17930000 Btu/hr	435 psia	SS
R-201	27 ft^3	485 psia	SS
R-202	386 ft^3	340 psia	SS
V-201	848 ft^3	340 psia	SS
V-202	848 ft^3	340 psia	SS
Ammonia Production			
Unit	Sizing	MAWP	MOC
C-301	921 hp	160 psia	SS
C-302	1964 hp	59 psia	SS
C-303	3636 hp	235 psia	SS
E-301	1840 ft^2	210 psia	SS
E-302	7770 ft^2	195 psia	SS
E-303	311 ft^2	285 psia	CS
R-301	151 ft^3	200 psia	SS
R-302	151 ft^3	200 psia	SS
R-303	151 ft^3	200 psia	SS
R-304	151 ft^3	200 psia	SS
R-305	151 ft^3	200 psia	SS
V-301	12.75 ft^3	166 psia	SS
V-302	28894 ft^3	250 psia	CS
V-303	28894 ft^3	250 psia	CS
V-304	28894 ft^3	250 psia	CS

Reactors

Reactors were utilized in this process for hydrogen production in the steam methane reforming unit and ammonia synthesis in the Haber-Bosch process, shown in Tables 6 and 7, respectively. The design pressure for all reactors is 50 psi larger than the operating pressure, for safety purposes (*22*). All reactors used in this process are suggested to be made of stainless steel, due to its ability to withstand temperatures well above the operating temperatures of each reactor (*10*). Stainless steel is also resistant to hydrogen embrittlement, and all the reactors encounter hydrogen (*28*).

The reactors were simulated in Aspen HYSYS. The kinetic data obtained from literature for each reaction occurring at the desired operating conditions over the catalyst used was utilized to set the reactions occurring within the reactors in Aspen HYSYS. For each reaction the weight of catalyst per feed flow rate at the given conversion was obtained from literature. This was then used to determine the weight of catalyst needed using Equation 1 in Appendix A. Once the weight of the catalyst was found the volume of the reactor was determined using Equation 2 in Appendix A.

Hydrogen Production

Table 7: Hydrogen Production Reactor Specifications

Parameters	**R-201**	**R-202**
Type	PBR	Membrane
MOC	SS	SS
Temperature (°F)	900	482
Design Pressure (psia)	485	340
Orientation	Horizontal	Horizontal
Capacity (ft^3)	27	386
Length (ft)	6.75	16.25
Diameter (ft)	2.25	5.5
Internals	Ni-Al_2O_3	Cu

In this process two reactors were used to produce hydrogen. R-201 serves to produce hydrogen and carbon monoxide from water and methane, this reaction is known as steam reforming. This reaction takes place at a pressure of 435 psia and a temperature of 1184 °F. It is important to note that the water gas shift reaction, which produces carbon dioxide and hydrogen from carbon monoxide and water, also takes place in this reactor in small quantities. R-201 is designed as a packed bed reactor, PBR, due to their effectiveness at high temperatures and pressures, and low operating, maintenance, and capital costs (*11*). Ni-Al_2O_3 is the catalyst selected to be used in this reactor because it is highly active and durable *(12).* For simulation in Aspen HYSYS the kinetic data was obtained from (*13*). R-201 has a cooling jacket to maintain the temperature below the autoignition of the components.

The second reactor, R-202, produces carbon dioxide and hydrogen from the carbon monoxide and unreacted water exiting R-201. R-202 is a membrane reactor. Membrane reactors contain, as the name implies, a catalytic membrane within the pressurized vessel. Through combining separation with the reaction, as the product is removed the reaction conversion is increased due to Le Châtelet's principle (*14*). It was found in the literature that the conversion rate for the water gas shift reaction taking place in R-202, could be increased by 10% when utilizing a membrane reactor instead of a packed bed reactor (*15)*. This increase in conversion was utilized to reduce the cost of the following pressure swing adsorption, an in-depth analysis of this can be found in "other important considerations". The reaction occurring in R-202 was simulated in Aspen HYSYS as done with the other reactors to determine the incoming and exiting flow rates at the given conversion. The kinetics and weight of catalyst per reactant flow rate was obtained from (*15*). Equation 3 in Appendix A was utilized to determine the amount of membrane required for the desired reaction. The reactor is operated at a pressure of 290 psia and a temperature of 482 °F.

Ammonia Production

Table 8: Ammonia Production Reactor Specifications

Parameters	**R-301**	**R-302**	**R-303**	**R-304**	**R-305**
Type	PBR	PBR	PBR	PBR	PBR
MOC	SS	SS	SS	SS	SS
Temperature (°F)	842	842	842	842	842
Design Pressure (psia)	200	200	200	200	200
Orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal
Capacity (ft^3)	151	151	151	151	151
Length (ft)	12	12	12	12	12
Diameter (ft)	4	4	4	4	4
Internals	Ru-Cs	Ru-Cs	Ru-Cs	Ru-Cs	Ru-Cs

R-301, R-302, R-303, R-304, and R-305 serve to produce anhydrous ammonia. These reactors utilize a Ru-Cs catalyst to convert hydrogen and nitrogen to ammonia. This reaction takes place at 150 psia and a temperature of 842 °F. Packed bed reactors were utilized for this reaction, due to the high pressure and temperature associated with the reaction and for the lower capital cost. This reaction at the above specified temperature and pressure was simulated in Aspen HYSYS using kinetic data at the specified temperature, pressure, and catalyst obtained from (*16*), and the weight of catalyst per flow of reactants was obtained from (*17*) to determine the amount of catalyst needed and volume of reactor. Modular manufacturing was utilized to produce these reactors to lower the capital investment and reduce safety concerns associated with the production of ammonia. R-301, R-302, R-303, R-304, and R-305 all have a cooling jacket to maintain a temperature below the component's autoignition temperatures, for safety purposes.

Pressure Swing Adsorption Columns

Pressure swing adsorption technology was employed to provide nitrogen for the downstream reaction and in the steam methane reforming unit to separate hydrogen. For nitrogen and hydrogen, values for each vessel are shown in Tables 8 and 9, respectively. To appropriately size the volume of the pressurized vessels it was necessary to determine the volume of adsorbent needed to create the desired output of product. It is important to note that some of the desired product will be adsorbed in both pressure swing adsorption systems. To account for this, Equation 4 located in Appendix A was used to determine the necessary flow rate into the systems to combat this loss, and experimental product recovery values obtained from (*18*) and (*19*) were utilized.

The volume of the pressurized vessel was calculated using Equation 5 in Appendix A, obtained from (*9*). The system does not operate with 100% efficiency either, as some of the voidage spaces will be empty each cycle (*9*). To account for this a bed voidage factor was used to determine the actual adsorbent and pressurized vessel size that should be purchased (*9*). These calculations are in Appendix B.2. For the bed voidage variable, the more conservative value obtained from (*18*, *20*), is used to account for uncertainty. These smaller bed voidage values result in larger total vessel volumes, which provides a more conservative estimate for capital costs.

As the operating pressure of a pressure swing adsorption system increases the amount adsorbed has logarithmic growth, which results in higher purity at higher pressures (*21*). For both systems, information from literature was obtained to determine which operating pressure would be best suited for this process. For safety purposes, the adsorption towers are designed to withstand operation at a pressure that is 50 psi higher than the actual operating pressure (*22*).

Nitrogen Production

Table 9: Nitrogen Production Pressure Swing Adsorption Specifications

Parameters	**V-101**	**V-102**
MOC	CS	CS
Temperature (°F)	194	194
Design Pressure (psia)	195	195
Orientation	Vertical	Vertical
Capacity (ft^3)	207	207
Height (ft)	18.75	18.75
Diameter (ft)	3.75	3.75
Internals	CMS (3A)	CMS (3A)
Internals	CMS (5A)	CMS (5A)

The nitrogen pressure swing adsorption system, V-101 and V-102, utilizes carbon molecular sieve (CMS 5A) within the column first and then carbon molecular sieve (CMS 3A). This stacking allows for the removal of water vapor by CMS 5A, so that it does not excessively absorb on the CMS 3A preventing oxygen removal and in turn increasing the necessary adsorbent (*19)*. The 3-angstrom pore size of CMS 3A allows oxygen, carbon monoxide, carbon dioxide, and other undesirable air particles to be trapped in the void between carbon particles (*23*). This adsorption column is designed to achieve a nitrogen purity of 99.9% (*18)*. The pressure drop along the adsorption system is 14.5 psia (*24)*. The pressurized vessel's material of construction is suggested to be carbon steel, CS, due to its low cost and the components within the adsorption column are non-acidic (*25*).

Hydrogen Production

Table 10: Hydrogen Production Pressure Swing Adsorption Specifications

Parameters	V-201	V-202
MOC	SS	SS
Temperature (°F)	542	542
Design Pressure (psia)	340	340
Orientation	Vertical	Vertical
Capacity (ft^3)	848	848
Height (ft)	30	30
Diameter (ft)	6	6
Internals	CMS (5A)	CMS (5A)

To separate hydrogen from the other products and unreacted material of R-202, a pressure swing adsorption column was employed, V-201 and V-202. Carbon molecular sieve 5A (CMS 5A), was used as the adsorbent. This adsorbent was selected based on its ability to absorb methane, carbon dioxide, carbon monoxide, and water, as these components are present in the stream carrying the hydrogen product (*19*). The pressure swing adsorption system is designed to produce hydrogen at a purity of 99.9% (*26*). A pressure drop of 14 psia is expected across the vessel (*24*). The material of construction is suggested to be stainless steel as it can withstand hydrogen embrittlement and is unreactive with the components entering (*28*).

Flash drum

Ammonia Production

V-301 is utilized as a flash drum in the downstream process to separate liquid ammonia from the unreacted hydrogen and nitrogen. V-301 was simulated in Aspen HYSYS, which provided liquid and vapor flow rates and densities. Equations 6-10 located in Appendix A were obtained from (*27*), to size the pressurized vessel. The vessel is designed to withstand a pressure 50 psi higher than the operating pressure for safety purposes. The flash drum is recommended to be made of stainless steel, due to the interaction with hydrogen (*28*). Specifications for V-301 are listed in Table 11.

Table 11: Ammonia Flash Drum Specifications

Parameters	V-301
MOC	SS
Temperature (°F)	-26
Design Pressure (psia)	166
Orientation	Vertical
Capacity (ft^3)	12.75
Height (ft)	5.25
Diameter (ft)	1.75

Compressors

Reciprocating compressors were utilized throughout this project due to their durability, efficiency, affordability, and significant product life (*29*). The compressors in this process utilize electric motors as the drivers for their simplified and safer operation (*30*). These motors also typically have lower initial capital cost compared to natural gas motors (*30*). The compressors for this process were simulated in Aspen HYSYS to determine the gas horsepower (GHP). The brake horsepower (BHP) was then calculated from this value using Equation 12 in Appendix A. Using Equation 13 in Appendix A, the purchased horsepower was then found from using the calculated brake horsepower (BHP) and the more conservative driver efficiency obtained from (*31*). The equations used to calculate the purchased horsepower were obtained from (*32*).

Nitrogen Production

The pressure swing adsorption system for nitrogen production, V-101 and V-102, is designed to be operated at a pressure of 145 psia. To achieve this the incoming air stream, 1, is compressed from atmospheric pressure, 14 psia, to 145 psia. This compression takes place in multiple stages, C-101, C-102, and C-103, so that interstage cooling can be employed to maintain the temperature of the stream below 300 °F. It is desirable to keep the stream temperature below 300 °F within the reciprocating compressors to prevent degradation of the lube oil and extend the life of the compressors (*33)*. The material of construction is suggested to be carbon steel, as it is unreactive with air and is low in cost (*25*). Specifications for C-101, C-102, and C-103 can be found below in Table 12.

Table 12: Nitrogen Production Compressor Specifications

Parameters	C-101	C-102	C-103
Type	Reciprocating	Reciprocating	Reciprocating
Drive	Electric	Electric	Electric
MOC	CS	CS	CS
Operating Pressure (psia)	47	79	154
Purchased (hp)	629	440	440
Driver Efficiency (%)	30	30	30

Hydrogen Production

C-201, shown in Table 13, is employed in the steam methane reforming production of hydrogen, to increase the recycle stream, 23, pressure from 275 psia to 435 psia. This pressure increase takes place to ensure the reaction within R-201 occurs at the desired reaction pressure. Due to the corrosive nature of the components in stream 23 it is recommended for the material of construction to be stainless steel for C-201 (*28*).

Table 13: Hydrogen Production Compressor Specifications

Parameters	C-201
Type	Reciprocating
Drive	Electric
MOC	SS
Operating Pressure (psia)	435
Purchased (hp)	741
Driver Efficiency (%)	30

Ammonia Production

C-301 is in the downstream production of ammonia to increase the incoming reactant mixture stream, 31, to the desired pressure of 145 psia for R-301, R-302, R-303, R-304, and R-305. It is suggested that C-301 be made of stainless steel, to prevent hydrogen embrittlement or reaction with any of the components (*28)*. A vapor compression refrigeration cycle is used to cool stream 49, so ammonia can be separated from the unreacted material. This cycle requires the compression of the refrigerant (*34*). C-302 and C-303 are used to increase the pressure of stream 49 from 15 to 235 psia. The material of construction is suggested to be stainless steel due to the hydrogen present in stream 49 (*28*). Specifications for C-301, C-302, and C-303 can be found below in Table 14.

Table 14: Ammonia Production Compressor Specifications

Parameters	**C-301**	**C-302**	**C-303**
Type	Reciprocating	Reciprocating	Reciprocating
Drive	Electric	Electric	Electric
MOC	SS	SS	SS
Operating Pressure (psia)	160	59	235
Purchased (hp)	921	1,964	3,636
Driver Efficiency (%)	30	30	30

Heat Exchangers

The equations obtained from (*35*) was used to calculate the heat transfer coefficients for all the employed heat exchangers, using Equations 14 and 15 in Appendix A. The heat transfer area was then calculated using Equation 16 in Appendix A, with the calculations located in Appendix B.5. The duties, inlet, and outlet temperatures were obtained from simulation of each heat exchanger in Aspen HYSYS. The more conservative film heat transfer and fouling resistance values were used to account for the uncertainty of the heat exchanger duty. This will result in smaller overall heat transfer coefficients, which will result in larger heat transfer surface areas. These larger areas provide a more moderate capital cost estimate. All heat exchangers were designed to withstand a pressure 50 psi above the operating pressure.

Nitrogen Production

E-101 and E-102, shown in Table 15, are interstage coolers used after C-101 and C-102, respectively. As stated previously these heat exchangers are employed to maintain the temperature within the compressors below 300 °F, and to extend the product life of the compressors (*32*). A double pipe heat exchanger design was selected for E-101 and E-102, because of industrial typical practices and the low surface area requirement for the needed heat transfer (*36*). Cooling water flows on the tube-side of E-101 and E-102, so the tubes are suggested to be made of stainless steel to prevent corrosion (*28*). The shell-side is suggested to be made of carbon steel, due to its nonreactivity with air and low cost (*25*).

E-103, shown in Table 15, serves to lower the temperature of the incoming air stream to V-101 and V-102, because the amount of adsorbate adsorbed decreases with increasing temperature (*21*). E-103 is designed as a double pipe heat exchanger due to the low surface area requirement, for the given heat transfer. Air flows through the shell-side and is suggested to be made of carbon steel due to its low cost (*25*). The tube-side is suggested to be made of stainless steel, due to the corrosiveness of cooling water (*37*).

Table 15: Nitrogen Production Heat Exchanger Specifications

Parameters	**E-101**	**E-102**	**E-103**
Type	Double Pipe	Double Pipe	Double Pipe
Area (ft^2)	16	23	43
Heat Duty (BTU/hr)	103,120	171,365	171,745
Design Pressure (psia)	210	100	130
Tube			
Max Operating Temp (°F)	120	120	120
MOC	SS	SS	SS
Shell			
Max Operating Temp (°F)	300	300	300
MOC	CS	CS	CS

Hydrogen Production

E-201, shown in Table 16, utilizes heat integration of stream 15, to heat the incoming water, stream 11, to steam for reaction in R-201. E-201 is designed as a shell and tube heat exchanger, which serves the advantage of being able to withstand high pressures, small pressure drop, and flexibility in design (38). The shell and tube side are both recommended to be made of stainless steel, due to the corrosiveness of the incoming water and stream 15.

E-202, shown in Table 16, cools the material exiting R-201 to the desired reaction temperature of R-202. This is a shell-and-tube heat exchanger with cooling water on the tube-side and stream 16 on the shell-side. It is suggested that the material of construction for both the tube-side and-shell side be stainless steel to prevent corrosion.

Table 16: Hydrogen Production Heat Exchanger Specifications

Parameters	**E-201**	**E-202**
TEMA Type	BEP	BEP
Area (ft^2)	354	146
Heat Duty (BTU/hr)	7,609,075	3,160,020
Design Pressure (psia)	485	276
Tube		
Max Operating Temp (°F)	454	120
MOC	SS	SS
Shell		
Max Operating Temp (°F)	1178	509
MOC	SS	SS

Ammonia Production

E-301 utilizes heat integration of stream 44, to heat stream 32 to the desired reaction temperature of R-301, R-302, R-303, R-304, and R-305.. The shell-side contains the products and unreacted material of the ammonia reactors and the tube -ide contains the reactants flowing into the ammonia reactors. It is suggested that both the shell-and-tube side be made of stainless steel.

After utilization in E-301 stream 44 now labeled stream 45 then enters E-302 and is cooled to -22 °F. This cooling takes place so that stream 46 can then be flashed in V-301, to separate the desired ammonia product from the unreacted material. To achieve the desired temperature of -22 °F a vapor compression refrigeration cycle was utilized, where E-302 serves as the condenser. E-302 is designed as a shell-and-tube heat exchanger, with stream 45 on the shell-side and the refrigerant on the tube-side. The material of construction is suggested to be stainless steel on both the tube-side and shell-side, to extend the lifetime of E-302. Specifications for E-301 and E-302 are shown below in Table 17.

Table 17: Ammonia Production Heat Exchanger Specifications

Parameters	E-301	E-302
TEMA Type	BEP	BEP
Area (ft^2)	1840	7770
Heat Duty (BTU/hr)	5,696,380	6,912,430
Design Pressure (psia)	210	195
Tube		
Max Operating Temp (°F)	1022	351
MOC	SS	SS
Shell		
Max Operating Temp (F)	842	-22
MOC	SS	SS

Heaters

Hydrogen Production

A fired heater, H-201, was utilized to heat stream 13 to the desired reaction temperature of R-201. A fired heater was selected due to its ability to utilize the waste from the pressure swing adsorption system, V-201 and V-202, as fuel (*39*). Within the heater the waste is combusted to carbon dioxide and water. This combustion releases heat to increase the temperature of stream 13 to 1470 °F prior to entering R-201. The thermal efficiency was found from literature to be 75% (*40)*. H-201 was simulated in Aspen HYSYS to obtain the duty required. The material of construction is suggested to be stainless steel, due to corrosiveness of the material within it and extreme heat transfer (*28*). H-201 specifications can be found below in Table 18.

Table 18: Hydrogen Production Heater Specifications

Parameters	H-201
Type	Fired Heater
MOC	SS
Heat Duty (BTU/hr)	17,930,000
Max Operating Temperature (°F)	1640
Design Pressure (psia)	435
Thermal Efficiency (%)	75

Air Cooled Heat Exchanger

Ammonia Production

E-303, shown in Table 19, is an air cooler used in the vapor compression refrigeration cycle that is present in the ammonia production process to cool stream 45 to -27 °F. E-303 is modeled in Aspen HYSYS to obtain the heat duty, mass flow rate, and density of air needed to condense the refrigerant propane to a saturated liquid at 117 °F, prior to it being flashed across a Joule Thomson valve to substantially drop the temperature of propane. The surface area was calculated using Equation 17 in Appendix A, utilizing the values obtained from Aspen HYSYS. These equations were obtained from (*41)*.

Table 19: Ammonia Production Air Cooler Specifications

Parameters	E-303
Type	Air Cooler
MOC	CS
Heat Duty (BTU/hr)	11,700,000
Design Pressure (psia)	285
Area (ft^2)	311

Storage Tanks

Ammonia Production

The anhydrous ammonia produced by the process must be stored on site until shipment can remove it. V-302, V-303, and V-304 store the ammonia and the specifications for the vessels are shown in Table 20 below. The storage of anhydrous ammonia is regulated by the U.S. Department of Labor. The anhydrous ammonia will be stored at 200 psia. For safety purposes, the tanks are designed for storage at 250 psia and with 85% occupancy of the tank, following the ASME Boiler and Pressure Vessel Code listed in the project memo. The vessels are stored under pressure at atmospheric temperature. The vessels are designed to hold 10 days of production each, that is 750 metric tons of ammonia at the above specifications. The volume of the required vessel was obtained from Equation 18 in Appendix A. The material of construction is suggested to be stainless steel for this vessel.

Table 20: Ammonia Production Storage Vessel Specifications

Parameters	**V-302**	**V-303**	**V-304**
MOC	SS	SS	SS
Temperature (F)	90	90	90
Design Pressure (psia)	250	250	250
Orientation	Vertical	Vertical	Vertical
Capacity (ft^3)	28,894	28,894	28,894
Height (ft)	96.75	96.75	96.75
Diameter (ft)	19.5	19.5	19.5

Equipment Cost Summary

To determine the economic feasibility of the project, the estimated bare module cost of each piece of equipment was calculated. This cost is influenced by the material of construction, design pressure, cost of installation, and size. These prices were optimized throughout the process to reduce expenses, while also maintaining safe margins of error. The capital costs listed in Table 21, were found using Equations 19-22 located in Appendix A. The project is projected to begin construction in mid-2021, to allow time to obtain a construction permit. However, the equipment is expected to be purchased in 2020. The estimates for the bare module costs for all prices of equipment were not in 2020 USD but were in 2001 USD. Thus, these prices had to be scaled to 2020 USD to account for the escalation of equipment costs and are presented at this escalated value in Table 21 below.

Table 21: Equipment Cost Summary

Equipment	Capital Cost
Adsorbers	
V-101	$217,800
V-102	$217,800
V-201	$916,200
V-202	$916,200
Storage Tanks	
V-302	$129,000
V-303	$129,000
V-304	$129,000
Air cooler	
E-303	$241,500
Heat Exchangers	
E-101	$21,500
E-102	$24,400
E-103	$19,900
E-201	$210,200
E-202	$190,700
E-301	$364,300
E-302	$1,034,100
Heaters	
H-201	$1,660,200
Flash drum	
V-301	$46,700
Compressors	
K-101	$597,200
K-102	$525,300
K-103	$525,100
K-201	$636,900
K-301	$698,100
K-302	$1,009,000
K-303	$1,429,900
Reactors	
R-201	$143,500
R-202	$407,000
R-301	$141,400
R-302	$113,100
R-303	$99,200
R-304	$90,500
R-305	$84,200
Total	$12,968,900

For comparison purposes, the bare module capital cost breakdown between the three processes is shown in Figure 5. This figure displays that the equipment for ammonia production resulted in the highest capital cost investment. Whereas nitrogen production resulted in the lowest capital cost investment.

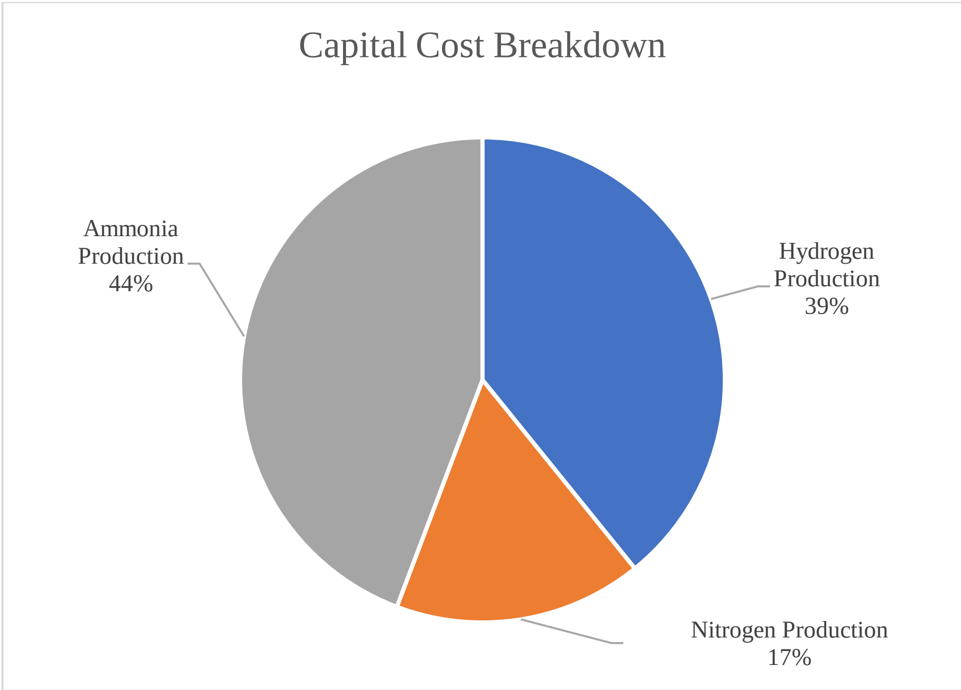

Figure 5: Capital Cost Breakdown by Unit

Fixed Capital Investment Summary

The bare module capital cost shown in Table 22, was then multiplied by a contingency factor to cover any unforeseen circumstances, as shown in Equation 23 in Appendix A (*25)*. The grassroots cost in 2020 USD was then calculated using Equation 24 in Appendix A, to account for auxiliary facility costs, using the factor and equation obtained from Turton et al. (*25)*. The grassroots cost was the value utilized in the cash flow table to determine the economic feasibility of the project. Table 22 below displays the bare module cost, the total module cost, and the grassroots cost.

Table 22: Total Installation Capital Cost Investment

	Capital Investment
Bare Module Cost	$13,000,000
Total Module Cost	$15,300,000
Grassroots Costs	$21,800,000

Safety, Health, and Environmental Considerations

Introduction

In the process, there are several materials to consider when discussing safety, health, and environmental concerns. Material properties of ammonia, hydrogen, nitrogen, methane, air, carbon dioxide, and water are shown and compared in Table 23. The material that stands out in the process, in terms of quantity and safety, is ammonia. Two things that stand out about ammonia are its strong reactivity with water and its high toxicity limits, 100 ppm (*42*). Ammonia, under normal conditions, is very stable and has flammability limits of 15% to 28% by volume of ammonia in air (*43*). For hydrogen, the most concerning property is the flammability of the gas. Hydrogen's flammability limits are 4%-75%, so hydrogen burns over wide concentrations in air (*45*). While not as flammable as hydrogen, methane's risk is the same. Methane's flammability limits are 5%-15% by volume in air (*46*). The other materials present no or minimal risk (*45-49*).

Table 23: Material Properties

Material	**Ammonia**	**Hydrogen**	**Nitrogen**	**Methane**	**Air**	**Carbon Dioxide**	**Water**
Molecular Weight (g/mol)	17.03	2.02	28.01	16.04	28.96	44.01	18.02
Boiling Point (°F)	-28.03	-423.2	-320.4	-258.7	-317.8	-109.2	212
Flammability Limits	15-28	4-75	-	5-15	-	-	-
Flash Point (°F)	-	-	-	-306	-	-	-
Auto Ignition Temperature (°F)	1204	1058	-	999	-	-	-
Liquid Density (lbm/ft^3)	42.57	4.43	50.47	26.38	0.07	48.25	62.4
Reactivity of Water	strong	poor	poor	poor	poor	poor	-
Toxicity Limits (ppm)	100	41,000	900,000	1,000	-	5,000	-

The materials listed above were placed in an interaction matrix generator, with the results being shown in Table 24 (*51*). The table outlines if a material is compatible with another, shown in green, or if there is caution between the two materials, shown in yellow. Four material combinations came back with a note of caution. For ammonia interacting with water, the caution is that heat is generated. For carbon dioxide and water interacting, the caution is that heat is generated, and it becomes corrosive. For ammonia and carbon dioxide interacting, the caution is that heat is generated. For hydrogen and air interacting, there is the caution of heat being generated along with the mixture being unstable when heated and possibly resulting in an intense or explosive reaction.

Table 24: Interaction Matrix

	Water					
Ammonia	Caution	**Ammonia**				
Hydrogen	Compatible	Compatible	**Hydrogen**			
Nitrogen	Compatible	Compatible	Compatible	**Nitrogen**		
Methane	Compatible	Compatible	Compatible	Compatible	**Methane**	
Air	Compatible	Compatible	Caution	Compatible	Compatible	**Air**
Carbon Dioxide	Caution	Caution	Compatible	Compatible	Compatible	Compatible

On the site of the process, ammonia is the only hazardous material that is being stored. Specific hazards of ammonia can be viewed above in Table 23. The team has planned for three storage tanks to be available, instead of one, to minimize the risk. This safer alternative has been put in place to limit the amount of ammonia that would be released in the chance of a loss of containment.

For ammonia, hydrogen, and methane, a more in-depth hazard identification was constructed. Along with material properties and the interaction matrix, the inventory estimates, process technology, equipment, and operating condition hazards were listed. The most common hazard is the high temperature and high pressure the process is operating at. These can be found in Table 25 below.

Table 25: Hazard Identification Summary

Material	**Source**	**Hazards**
Ammonia	Material Properties	Ammonia is highly toxic to humans and animals if exposed.
	Interaction Matrix	Ammonia can generate heat when exposed to water or carbon dioxide. Ammonia is corrosive when exposed to carbon dioxide.
	Inventory Estimates	There is a risk of leaking ammonia out of storage tanks if there is a loss of containment.
	Process Technology, Equipment and Operating Conditions	There are three storage tanks on ammonia. When ammonia is present in tank, there should be no welding or heat source nearby. Due to the high level of pressure when stored, this could lead to an explosion if heated or over pressurized.
Hydrogen	Material Properties	Hydrogen gas is a highly flammable gas that can combust at low concentrations.
	Interaction Matrix	Hydrogen, when mixed with air, is unstable when heated. The two can also generate heat and lead to an intense or explosive reaction.
	Inventory Estimates	-
	Process Technology, Equipment, and Operating Conditions	Hydrogen is used in the process which operates at high temperatures and high pressures.
Methane	Material Properties	Methane is highly flammable.
	Interaction Matrix	Methane does not react with any of the materials listed.
	Inventory Estimates	-
	Process Technology, Equipment, and Operating Conditions	Methane is used in the process which operates at high temperatures and high pressures.

Several hazards are mentioned in Table 26 along with a rating for different potential consequences if that hazard were to happen. Specifically, equipment damage, environmental compliance, loss of life, disruption of other business units, legal and PR, and the community impact are discussed and if the hazard will have no, low, medium, or a high impact.

Table 26: Potential Consequence Summary

Number	**Hazard**	**Equipment Damage**	**Environmental Compliance**	**Loss of Life**	**Disruption of Other Business Units**	**Legal/PR**	**Community Impact**
1	Toxicity (AA)	-	-	high	medium	high	low
2	VCE (AA)	high	-	high	high	high	medium
3	Flammability (H)	medium	-	medium	low	low	low
4	VCE (H)	high	-	high	high	high	medium
5	Toxicity (M)	-	-	low	low	low	low
6	Water and CO2 reactivity	medium	-	low	low	low	low
7	Water and Ammonia reactivity	medium	-	medium	low	low	low
8	Ammonia and CO2 reactivity	medium	-	low	low	low	low

The team's preliminary design includes several safeguards that are incorporated. Whenever working with chemicals, personal protective equipment (PPE) should be worn to minimize the exposure to chemicals and hazards that can cause illness or injury. Employees who regularly work with anhydrous ammonia and are subject to overexposure should be provided with the necessary PPE. Specific PPE for working with the process and anhydrous ammonia are safety goggles, impervious gloves and clothes, boots, and gas masks (*51*). In addition, during clean up procedures, shoe covers should be worn to minimize the possibility of a slip. It is advised to keep water on hand in case of leak or exposure (*51*). All storage containers should be completely cleaned and ventilated, and never welded on unless it is an open container. These containers should be kept away from flames and hot surfaces. Another safeguard set in place is utilizing modular manufacturing in the ammonia reactors to alleviate the amount that would be released if an incident were to occur. The ammonia storage tanks on site are set to be spaced so that if one leaked, it would not affect the other two tanks. The team also added 50 psi to all of the vessels' operating pressure so they would be designed to withstand a higher pressure. The last safeguard set in place is the use of stainless steel in areas where corrosion could be a possibility. In the detailed design, additional safeguards need to be set in place such as fire protection, training procedures and alarms, for example high level alarms on storage tanks.

For the process, reasons for the project to be terminated would be if the plant site was determined to be inadequate for the process. If a catastrophe were to occur onsite, the project could possibly be terminated. Detailed design needs to be concerned with making sure the proper alarms are placed correctly to mitigate an accident occurring. PSM and RMP have no special concerns that have not already been stated. Overall, the process is hazardous, but has steps in place to minimize the risks associated with those hazards.

Listed below in Table 27 is a list of hazards that could be a problem to the process. Alongside the hazards are the inherently safer design concepts the team has set in place to lessen the risks if any of the hazards happened. The team has utilized minimization, substitution, and moderation.

Table 27: Inherently Safer Design Application Summary

Hazard	Inherently Safer Concept	How Incorporated in Prelim Design
Ammonia toxicity	Minimization	Due to modular manufacturing and multiple storage tanks in the process, if ammonia's containment was lost, the amount of ammonia lost would be reduced and less toxic material leaked.
Ammonia VCE	Minimization	Due to modular manufacturing and multiple storage tanks in the process, if ammonia's containment was lost, the amount of ammonia lost, and the size of vapor clouds would be reduced.
Hydrogen flammability	Minimization	The process is producing hydrogen onsite instead of buying it in order to make a continuous process instead of onsite storage.
Hydrogen VCE	Minimization	The process is producing hydrogen onsite instead of buying it in order to make a continuous process instead of onsite storage.
Methane toxicity	Substitution	For methane, the membrane reactor was selected resulting in less throughout the process which lessens what would get released.
Water and CO2 reactivity	Substitution	Any equipment that would encounter water reacting with CO2, stainless steel has been used to prevent corrosion.
Water and Ammonia reactivity	Moderation	Utilizing refrigeration in the process, the magnitude of the consequences if ammonia was to react with water would be reduced.
Ammonia and CO2 reactivity	Moderation	Utilizing refrigeration in the process, the magnitude of the consequences if ammonia was to react with CO2 would be reduced.

Process Safety Considerations

Minimizing Environmental Impacts

In the group's design of producing ammonia, there is no liquid or solid waste generated by the process, but there is gaseous waste. The plant is producing 6,448 lbs. of carbon dioxide per hour. Given that roughly 1400 lbs. of carbon dioxide emission is allowed, the remaining amount of carbon dioxide being released is 5,046 lbs. per hour (*53*). On an annual basis, the plant is producing 21,219 tons of carbon dioxide waste. The best available control technology the group is putting into place to manage these emissions is capturing the carbon dioxide (*54*). To capture, the carbon dioxide will be trapped at its source of emission. Per ton of carbon dioxide, there is an allowance cost of $40 (*55*). On an annual basis, the cost of capturing the carbon dioxide would be roughly $850,000.

Assessing and Mitigating Potential Health Impacts

For the process, health risks were looked at for ammonia, hydrogen, nitrogen, methane, carbon dioxide, and water. These risks are outlined in Table 28 below. To mitigate these health risks, plant workers will be utilizing PPE to limit exposure to these materials in case loss of containment does occur. As mentioned in picking the best available control technology, carbon dioxide waste is managed to limit the amount exposed to the environment and therefore mitigating the health risks.

Table 28: Key Health Risks

Material	**Health Hazard**
Ammonia	Ammonia causes severe burns and eye damage, very toxic to aquatic life, and may displace oxygen and cause rapid suffocation.
Hydrogen	Hydrogen may displace oxygen and cause rapid suffocation.
Nitrogen	Nitrogen may displace oxygen and cause rapid suffocation.
Methane	Methane may displace oxygen and cause rapid suffocation.
Carbon Dioxide	Carbon Dioxide may increase respiration and heart rate and may displace oxygen and cause rapid suffocation.
Water	Water in the form of steam can cause extensive burns and eye damage.

Safety - Learning from Experience

When creating the preliminary design, precautions were taken by looking at a paper that documented 50 years of history in the manufacturing of ammonia (*56*). By discovering what could go wrong and what has gone wrong in the past, accommodations were made to produce an inherently safer design. This is to reduce and possibly avoid hazards.

In item 48, an incident involving a tank of ammonia overflowing occurred. The root cause for this incident was the failure of high-level alarms and a shutdown system, and the action taken was to install reliable additional high-level alarms and trip systems. In the detailed design, when working with ammonia storage tanks, multiple high-level alarms and trip systems are to be set in place along with conforming to the requirements of 29CFR1910.111 put in place by OSHA (*57*).

In item 85, due to improper welding during construction there was an ammonia tank floor and foundation failure. In item 217, there were defects in the manufacturing causing weld zone cracks in the ammonia converter. To mitigate these risks, simplification was set in place by using modular manufacturing in the design instead of stick built. Using modular manufacturing, there is better control over the manufacturing process, which in turn, can lessen the risks and hazards.

Other Important Considerations

Nitrogen Production

As mentioned previously membrane technology was also considered to produce nitrogen. The membrane technology was sized using Equations 25 and 26, located in Appendix A. A perovskite membrane was selected to pursue. The incoming stream to the membrane would need to be compressed to 29 psia and heated to 932 F, for the perovskite membrane that was selected (*58*). The team hoped that the need for a smaller compressor may offset the more expensive membrane required. However, as shown in Table 29 the project is so sensitive to capital cost, the net present value was much lower using pressure swing adsorption technology.

Table 29: Comparison of Pressure Swing Adsorption to Pervoskite Membrane

	Pressure Swing Adsorption	Membrane
Total Capital Cost of Nitrogen Production Unit	$2,149,000	$19,482,700
Operating Cost/yr	$356,300	$33,871
NPV	$15,000,000	$7,000,000

Information on how all operating costs were calculated are available in the following section “Manufacturing/Utility Costs”, along with calculation information in Appendix B. The net present value calculations are further discussed in the “Economic Analyses" section. The cash flow table for membrane technology is in Appendix C. With this information of the greater economic burden associated with membrane technology the team moved forward with pressure swing adsorption.

Hydrogen Production Steam Methane Reforming versus Electrolysis

For hydrogen production, electrolysis was considered as a greener production pathway due to the possibility of zero greenhouse emissions from this process (*59*). Electrolysis does provide high purity hydrogen with only water needed, which is relatively safer compared to steam methane reforming (*60*). The electrolysis was sized by determining the molar flow of hydrogen needed from the Haber process simulation, thermodynamics was then utilized for solving for the electrical energy requirement and checked against literature values (*61*). The equations utilized for solving for both electrolysis capital cost and operating cost can be found in 27-29, located in Appendix A.

For determining the capital cost and type of electrolyzer the design team used data provided by Sayed M. Saba et al. (*62*). An alkal-system electrolyzer was determined best suitable for the specified needs of the amount of hydrogen produced. The costing was based on a kW input basis. Table 30, shown below, compares the capital and operating cost of the electrolysis unit to the selected steam methane reforming unit.

Table 30: Comparison of Steam Methane Reforming and Electrolysis

	Steam Methane Reforming	Electrolysis
Capital Investment in Hydrogen Production Unit	$5,265,700	$6,039,500
Operating Cost/yr	$163,400	$10,972,600
Raw Material Cost/yr	$16,300	$18,100

The price of operating cost outweighed the environmental and safety benefits of electrolysis. The team moved forward with steam methane reforming, as the project was economically feasible with the given operating and raw material cost. As mentioned before an in-depth explanation of how operating and raw material cost are calculated will be provided in the following “Manufacturing/Operating Cost” Section.

Hydrogen Production- Water gas shift Reactor – Packed Bed versus Membrane Reactor

As mentioned previously a membrane reactor was utilized for the water gas shift reaction taking place in R-202 instead of a packed bed reactor. This resulted in an increase in capital investment in R-202, but a decrease in capital investment in V-201 and V-202. Table 31 compares the total bare module capital investment in 2020 USD, when utilizing a packed bed reactor versus a membrane reactor. The table also displays a comparison of the reactor's capital investment, the fired heater's capital investment, and the pressure swing adsorption system (PSA)'s capital investment, utilizing both of the reactors.

Table 31: Comparison of Packed Bed Reactor to Membrane Reactor

	Packed Bed Reactor	Membrane Reactor
Total Bare Module Cost	$25,800,000	$13,000,000
Reactor Capital Investment	$20,000	$400,000
PSA Capital Investment	$14,000,000	$1,800,000
Heater Capital Investment	$2,900,000	$1,700,000
Operating and Raw Material Cost of SMR	$1,500,000	$750,000

Through utilizing a membrane reactor, the conversion rate was higher which in turn lowered the amount of material that needed to be removed by the pressure swing adsorption system, V-201 and V-202. This decreased the cost of the pressure swing adsorption system from approximately $14 million dollars to $2 million dollars. This increase in conversion resulted in a decrease in methane, carbon monoxide, carbon dioxide, and water, which decreased the amount of material recycled back. This decreased the flow rate of the material being heated by H-201, the fired heater, which in turn decreased the size of the fired heater.

The other equipment pieces involved in the steam methane reforming, had minute changes in capital investment that are within the uncertainty of costing. That is why the only capital investment displayed is the pieces of equipment with substantial changes from the utilization of a different reactor. To display the overall impact on the project the total bare module cost has been displayed, which is the sum of the capital investment of each piece equipment.

Hydrogen Production – Optimization

The team noted the expensive capital cost associated with hydrogen production. To combat this, the team hoped to optimize the reactors. The team began by optimizing the reformer reactor, R-201. The team simulated reactor pressures of 435 psia, 508 psia, and 580 psia in Aspen HYSYS utilizing the reaction data found in (*13*). It should be noted that for 435 psia only one compressor was needed to achieve these pressures; however, for both the 508 psia and 580 psia an additional compressor was utilized. This resulted in a sharp increase in the cost of operation of R-201 at pressures 508 psia and 580 psia. The team found the pressure of 435 psia to be the best option to move forward with, as the capital investment was the lowest.

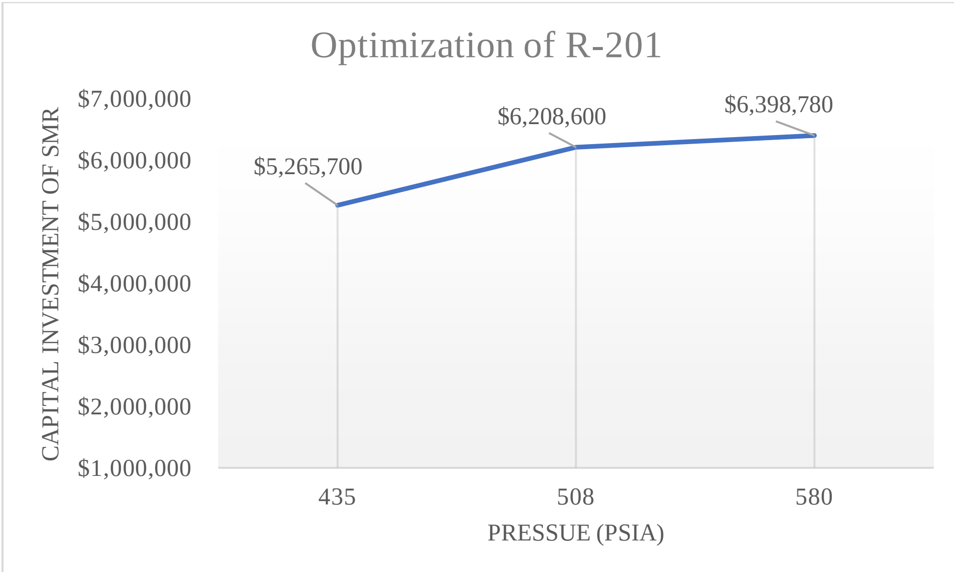

Figure 6: Capital investment of the steam methane reforming at various pressures

For the water gas shift reaction taking place in R-202, the kinetic data utilized was available at pressures from 145 psia to 290 psia (*15*). The team sought to determine if a lower reaction pressure would in turn lower the capital investment associated with hydrogen production. The team simulated the process with a reaction pressure at 290 psia, 218 psia, and 145 psia. Figure 7 displays the impact of different pressures on the steam methane reforming capital investment. The decrease in pressure of steam methane reforming not only increases the capital investment of steam methane reforming but also C-301 located in the ammonia production unit of the plant, as the incoming stream from the hydrogen unit will need to be compressed further. For the purpose of this analysis only the capital investment of Steam Methane Reforming has been included.

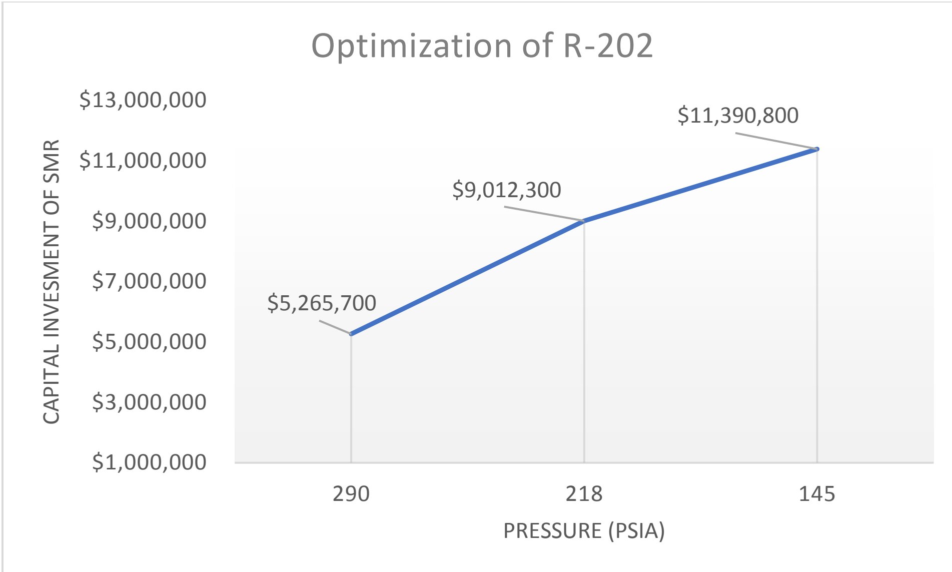

Figure 7: Capital Investment of Steam Methane Reforming at various pressures.

The lower pressure did lower the capital investment in R-202, but it increased the capital investment in the other associated equipment enough to offset this reduction in price. The increase in other equipment at a lower pressure was a result of the pressure swing adsorption system being most efficient at higher pressures (*21*). By lowering the pressure of the stream exiting R-202, V-201 and V-202 increased in size and price. The lower reaction pressure also yielded a lower conversion rate, which increased other equipment such as the fired heater, H-201 and the recycle compressor, C-201. The fired heater's cost and size increased due to the need to heat a larger stream entering R-201, as more material was being recycled back. The compressor also increased in size due to the larger recycle stream.

Ammonia Production – Modular versus Stick Built

Modular manufacturing of the ammonia reactor served to both lower the capital investment and create a more inherently safe design. The cost of modular manufacturing decreases for each additional unit produced. The cost of each additional module was calculated using equations 30 and 31 in Appendix A, and Table 32 displays the capital cost associated with modular manufacturing versus a stick-built reactor.

Table 32: Comparison of Stick-Built to Modular Manufactured

Equipment	Stick-Built	Modular
R-301	$ 545,400	$ 141,400
R-302	-	$ 113,100
R-303	-	$ 99,200
R-304	-	$ 90,500
R-305	-	$ 84,200
Total	$ 545,400	$ 528,400

Parallel operation was selected for these reactors. This allows the reactors to, at a lower production rate, continue producing ammonia if one reactor is out for maintenance. The unit scale selected to design the modular manufactured reactors is 10 metric tons per day each, as this is the maximum size that can be transported. Only the reactors were modular manufactured for the sake of simplicity within the plant, through reducing the connections and equipment required the process is inherently simpler.

Manufacturing/Operating Costs (exclusive of Capital Requirements)

Revenue

To determine the sales price, the team looked to online resources to find common sale prices of anhydrous ammonia fertilizer within the corn belt. The team found prices ranging from $595 to $622 per ton in 2019 dollars (*63,64*). With the expectation that the project would be most sensitive to revenue, the more conservative value of $595 obtained from (*63*) was used for the economic analysis.

It was assumed that the 50 metric tons per day scale is right sized for continuous, year-round operation and seasonal variation in fertilizer demand, and will be leveled out through sales to other facilities that convert ammonia to other forms. The revenue was multiplied by a service factor of 0.98. This service factor accounts for down time in the plant associated with maintenance and other factors.

As mentioned previously this sales price is given in 2019 USD, so an escalation rate of 2% was used. This 2% escalation rate was selected, based on typical industry best practices, to try and create the most accurate economic analyses (*65*). The results of this escalation are displayed in Table 33. The washout assumption was applied meaning the profit margin between operating cost and revenue was assumed to remain constant during the project life, so the revenue was escalated to the year of 2020. This is the year that operating costs were found at.

The first year of production 2024, is only a half year of production. The revenue in this year has been modified accordingly.

Table 33: Revenue Escalation

Year	Sales Price $/2000 lbs. (*65*)
2019	$ 595.00
2020	$ 606.90

Cost of Labor

Utilizing Equation 32 in Appendix A, the number of operators for the process was determined. Excluding pumps and vessels, the number of pieces of equipment along with a P value with an assumption of zero were used to find the number of operators. There are 8 pieces of equipment from the Haber-Bosch process, 7 from the SMR, and 7 from the PSA for a total of 22 pieces of equipment. To run the plant, it was determined that 15 operators needed to be hired. The annual salary of an operator was found from data provided from the Bureau of Labor Statistics for a chemical plant operator in Minnesota (*66*). In Table 34, the estimated annual labor cost for the 15 operators is shown.

Table 34: Annual Labor Costs

Factor	**Overall**
P	0
Nol	3.37
Nnp	22
Operators Needed	15
Average Salary	$51,340
Labor Costs/year	$770,100

Utilities

To produce the desired quantity of ammonia, electricity and cooling water were utilized in the process with electricity being the more expensive of the two. A cost of $0.10 per kW-hr was used for electricity and a cost of $2.46 per 1000 gallons was used for the cooling water (*67-68*). Electricity cost was calculated using the power from compressors and an air cooler from the PSA, SMR, and the Haber-Bosch process. Using Equation 33 which involves the specific heat of cooling water, the change in temperature, and the cooling water duty, the mass flow rate was calculated. Specific heat of water is known to be 1 BTU/lbm-°F and the change in temperature was found to be 30°F. Once the group found the mass flow rate, the yearly cost of cooling water was calculated. In Tables 35 and 36, the cost breakdown and total annual cost is shown for electricity and cooling water, respectively.

Table 35: Cost for Electricity

Process	Equipment	$ per kWh	kW	Btu/hr	$ per year
PSA	C-101	$0.10	134	456203	$121,455
PSA	C-102	$0.10	92	314941	$83,846
PSA	C-103	$0.10	92	314599	$83,756
SMR	C-102	$0.10	158	539460	$143,620
Haber	C-105	$0.10	198	675604	$179,866
Haber	C-106	$0.10	428	1460738	$388,891
Haber	C-107	$0.10	799	2725619	$725,640
Haber	E-303	$0.10	292	997369	$265,529
				Total	**$1,992,602**

Table 36: Cost for Cooling Water

Process	Equipment	$ per 1000 gal	lb/hr	$ per year
PSA	E-101	$2.46	9994.6	$25,846
PSA	E-102	$2.46	10,019	$25,908
PSA	E-103	$2.46	6,015	$15,554
SMR	E-202	$2.46	8,886	$22,979
SMR	Cooling Jacket	$2.46	223,874	$578,928
Haber	Reactor	$2.46	127,932	$330,826
			Total	**$ $1,000,040**

Raw Materials

The raw materials that were accounted for were liquid methane and water. Using the cost of $3.96 per 1000 feet cubed and $2.46 per 1000 gallons and flow rates, the cost of raw materials was found (*68-69*). In Table 37, the annual raw material cost is shown.

Table 37: Raw Material Cost

Material	$	Flow Rate	$ per year
Water	$2.46	2918	$16,591
Methane	$3.96	1,181	$40,968
		Total	**$57,560**

Operating costs calculated consist of labor costs, utilities, and raw materials, the most expensive being utilities and the least expensive being raw materials. It is important to note, operating costs are cut in half in the year 2024 due to production not beginning until the middle of year 2024. Starting in 2025, the remainder of the project timeline is assumed to be at full operation. In Table 38, the total annual operating cost is shown.

Table 38: Total Annual Operating Cost

Source	**Cost**
Labor	$770,100
Utilities	$3,026,589
Raw Materials	$57,560
Total	**$3,854,249**

Economic Analysis

Cash Flow Table

To determine the profit obtained from the process, a cash flow table was constructed, shown below in Table 39. For this analysis, a tax rate of 25% and Minimum Acceptable Rate of Return of 8% were assumed. The analysis is for a 20-year useful plant life, with depreciation being accounted for with Modified Accelerated Cost Recovery System (MACRS). It has also been assumed that construction will last three years beginning in mid-2021, and production beginning in mid-2024. A 5-year depreciation system was utilized due to this plant's role in chemical production (*70*). This depreciation rate was obtained from Stermole et al. (*71*).

Table 39: Cash Flow Table

End of Year	2020	21	22	23	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Production, tons					8943	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885
Sales Price, $/tons					607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607
Sales Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
+Salvage																								
-Royalities																								
Net Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
-Raw Material Costs					28204	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409
-Operating Costs					1843744	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487
Waste Removal					424382	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764
-Depreciation					4357550	6972081	4183248	2509949	2509949	1254975														
- Amortization																								
- Depletion																								
- Loss Forward						1226677	1937011																	
- Writeoff																								
Taxable Income					(1226677)	(1937011)	141487	3751798	3751798	5006772	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747	6261747
-Tax @ 25%							35372	937949	937949	1251693	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437	1565437
Net Income					(1226677)	(1937011)	106115	2813848	2813848	3755079	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310
+Depreciation					4357550	6972081	4183248	2509949	2509949	1254975	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+ Depletion																								
+ Loss Forward						1226677	1937011																	
+ Writeoff																								2178775
working capital	(2178775)																							
- Fixed Capital	(21787752)																							
Cash Flow	(23966527)	0	0	0	3130873	6261747	6226375	5323797	5323797	5010054	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	4696310	6875085
Discount Factor (P/Fi*,n)	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
Discounted Cash Flow	(23966527)	0	0	0	2301285	4261639	3923672	3106385	2876282	2506274	2175300	2014167	1864969	1726823	1598911	1480473	1370808	1269267	1175247	1088192	1007585	932949	863842	1170932
NPV @ i* =	14748474																							
DCFROR =	0																							
B/C =	2																							
GROR =	12																							
PVR	1																							
Discounted Payback Period (yrs)	8																							
Break even feed price	$460																							

Working capital is typically estimated by taking 5-30% of the total fixed capital cost for chemical plants (*72*). For the purposes of this analysis, it was estimated to be 10% of the fixed capital cost due to the single final product. The net present value (NPV) was calculated from summing the discounted cash flow obtained from the cash flow table. The net present value considers the fixed capital cost, operating cost, revenue and deprecation for the project over the project life. The NPV for this project was found to be $15,000,000.

To ensure that the upstream production of nitrogen and hydrogen are more economically attractive than purchasing these two reactants, two additional net present values were calculated. These cash flow tables are in Appendix C. The capital cost, operating cost, and raw material costs were adjusted to consider production versus buying the reactants. The price of hydrogen and nitrogen were found from literature to be $3.53/kg and $1.52/kg in 2019$, respectively (*73,74*). Through purchasing nitrogen and hydrogen, the project also incurs delivery fees, fuel surcharges, and environmental fees, that total over $500 per month (*74*). The escalation rate of 2% was used to produce what these values would be in the future corresponding years. In Table 40, these NPV values are displayed for comparison. The economic analysis displays that for the given minimum rate of return, project lifespan, and rate of production it is more economically attractive to produce nitrogen and hydrogen onsite instead of buying either reactant.

Table 40: NPV Values

	H2 bought & N2 produce	H2 produce & N2 bought	H2 & N2 produce
NPV	-$36,000,000	$13,000,000	$15,000,000

The Discounted Cash Flow Rate of Return (DCFROR) was also calculated. For the project to be economically attractive the DCFROR needs to be greater than the Minimum Acceptable Rate of Return of 8%. The DCFROR was calculated to be 13%. The discounted payback period was found to be 8.3 years. The team also found the breakeven product price to be $460. At this sales price the net present value of the project becomes zero.

Sensitivity Analyses

A sensitivity analysis was performed to determine how sensitive the economic attractiveness is to the capital cost, operating cost, revenues, and raw material costs. These variables were selected due to the uncertainty associated with each variable. The revenue and raw material prices may fluctuate with market prices. The capital cost is a function of the CEPCI, and there is resultant uncertainty due to this.

The impact of these variables on the NPV and DCFROR were analyzed, by varying the parameters by 10%, 20% and 30%. This analysis was performed through holding constant all other variables, but the variable being analyzed. The outcome of variation of 10%, 20%, and 30% is shown in Tables 41-44.

Table 41: Impact of Variation of Capital Cost on Economic Attractiveness of Project

Capital Cost					
Capital Cost	Variance (%)	NPV	Change in NPV	DCFROR	Change DCFROR
$15,251,426	-30	$20,815,778	$6,067,304	17%	32%
$17,430,202	-20	$18,807,047	-$4,058,572	15%	20%
$19,608,977	-10	$16,798,316	-$2,049,841	14%	9%
$21,787,752	0	$14,748,474	$0	13%	0%
$23,801,870	10	$12,780,853	-$1,967,621	12%	-8%
$25,965,677	20	$10,656,036	-$4,092,439	11%	-15%
$28,129,483	30	$9,319,881	-$5,428,593	10%	-20%

Table 42: Impact of Variation of Raw Material Cost on Economic Attractiveness of Project

Raw Material					
Raw Material Cost	Variance (%)	NPV	Change in NPV	DCFROR (%)	Change DCFROR
$39,486.30	-30	$14,883,841	$135,366	13%	0%
$45,127.20	-20	$14,852,422	$103,948	13%	0%
$50,768.10	-10	$14,821,003	$72,529	13%	0%
$56,409.00	0	$14,748,474	$0	13%	0%
$62,049.90	10	$14,758,166	$9,691	13%	0%
$67,690.80	20	$14,685,347	-$63,128	13%	0%
$73,331.70	30	$14,653,783	-$94,691	13%	0%

Table 43: Impact of Variation of Operating Cost on Economic Attractiveness of Project

Operating Cost					
Operating Cost	Variance (%)	NPV	Change in NPV	DCFROR (%)	Change DCFROR
2185050	-30	$20,951,193	$6,202,719	15%	14%
2497200	-20	$18,897,324	$4,148,849	14%	10%
2809350	-10	$16,843,454	$2,094,980	13%	0%
3121500	0	$14,748,474	$0	13%	0%
3433650	10	$12,735,715	-$2,012,760	12%	-5%
3745800	20	$10,681,845	-$4,066,629	11%	-10%
4057950	30	$8,627,976	-$6,120,499	11%	-16%

Table 44: Impact of Variation of Revenue on Economic Attractiveness of Project

Revenue					
Revenue	Variance (%)	NPV	Change in NPV	DCFROR	Change DCFROR
$7,598,085	-30	-$3,347,592	-$18,096,067	6%	-55%
$8,683,526	-20	$2,698,133	-$12,050,341	9%	-33%
$9,768,966	-10	$8,743,859	-$6,004,616	11%	-15%
$10,854,407	0	$14,748,474	$0	13%	0%
$11,939,848	10	$20,835,310	$6,086,836	15%	14%
$13,025,288	20	$22,519,761	$7,771,286	16%	26%
$14,110,729	30	$32,926,761	$18,178,287	18%	38%

The sensitivity analysis, shown in Figure 8 below, displays that at the worst-case scenario variation of 30% for raw materials, operating cost and capital cost analyzed, the project is still economically attractive. The analysis showed that the attractiveness of the project is most sensitive to a variation in revenue, as shown below in Figure 8. It should be noted as mentioned before the lower sales price value in the range found was used for the economic analysis, with the hopes to provide a more conservative economic analysis. The project is secondly most sensitive to capital cost. This risk should be mitigated through the precautions taken throughout the design to provide the most conservative estimate on capital cost. From the tornado chart displays that variations in raw material cost have minute effects on the net present value of the project.

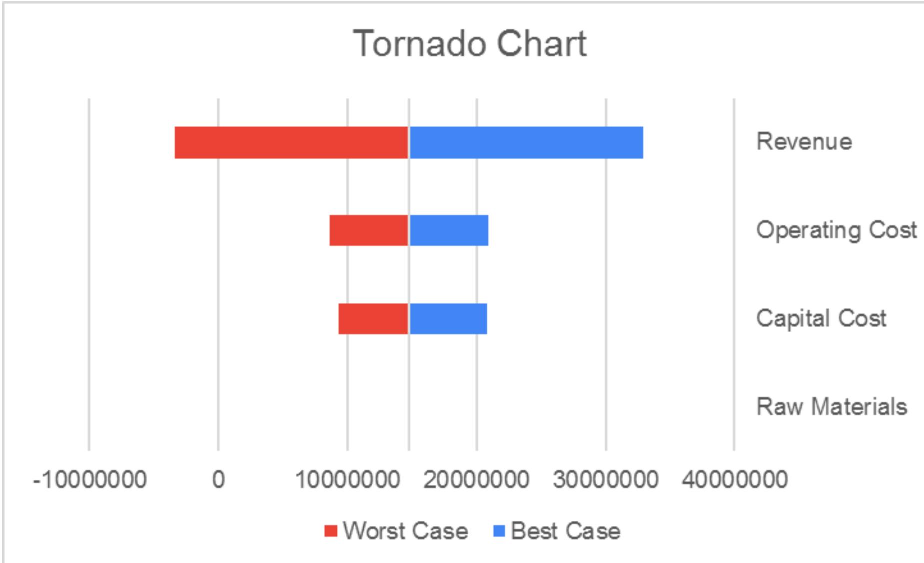

Figure 8: 30% Variation Sensitivity Analysis

Conclusions and Recommendations

The design process carried out indicates that an anhydrous ammonia plant with onsite production of hydrogen and nitrogen is not only technically feasible, but also economically attractive. The plant's specifications of 50 metric tons per day, with a 99.5% mass purity were met, along with environmental and safety requirements. The plant is economically attractive due to its net present value of $15,000,000 which is larger than $0, and a rate of return of 13% which is larger than the 8% minimum rate of return.

As shown in the sensitivity analysis, the project is most sensitive to revenue. It is worth stating again that the lowest selling price of anhydrous ammonia per ton that was obtained was utilized for this economic analysis. Though at a -30% variation the project does become unattractive, the team still suggests moving forward with the project. This is due to the initial sales price used for all calculations of $606.90, being at the lower end of sales price range found. The risks that have been considered are not of great concern at this time, so it is recommended to move forward with the project.

Acknowledgements

The design team would like to thank the American Institute of Chemical Engineers for creating the project for the 2020 AIChE Student Design Competition. The team is grateful for the challenging and intriguing problem statement that has allowed the team to learn and grow our understanding of how vast chemical engineering is. The opportunity to stretch this knowledge has been a perplexing, yet rewarding, journey.

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Appendices

Appendix A

Reactor Equations

$$\frac{W}{F} = \frac{Catalyst\ Weight\ (g)}{Reactor\ Flow\ (\frac{mol}{s})} \quad (1)$$

$$\rho_{Cat}\ (\frac{kg}{m^3}) = \frac{Catalyst\ Mass\ (kg)}{Catalyst\ Volume\ (m^3)} \quad (2)$$

$$SA_{Membrane}(m^2) = 2\pi R_{Reactor}(m) L_{Reactor}(m) \quad (3)$$

Pressure Swing Adsorption Equations

$$\dot{m_{in}} = \frac{\dot{m}_{out}}{PR_{x} * x_A} \quad (4)$$

$\dot{m_{in}}$= molar flow rate of into pressure swing adsorption system

$PR_A = product\ recovery$

$x_A = mole\ fraction\ of\ product\ A\ present\ in\ m_{in}$

$\dot{m}_{out} = desired\ molar\ flow\ rate\ of\ product\ out\ of\ pressure\ swing\ adsorption\ system$

$$V_{ads} = \frac{x_B \cdot \dot{m_{in}} \cdot R \cdot T_{in} \cdot D}{\varepsilon_p \cdot P \cdot \varepsilon_b} \quad (5)$$

$V_{ads} = volume\ of\ adsorbent\ needed$

$x_B = mole\ fraction\ of\ material\ adsorbed$

$\dot{m_{in}}$= molar flow rate of into pressure swing adsorption system

R = gas constant 0.082060$\frac{L-atm}{K-mol}$

$T_{in} = Temperature\ of\ \dot{m_{in}}$ (K)

$P = Pressure\ of\ \dot{m_{in}}$ (atm)

$D = \frac{time\ total}{bed}\ (s)$

$\varepsilon_p = particle\ voidage$

$\varepsilon_b = bed\ voidage$

Flash Drum Equations

$$F_{lv} = \frac{W_l}{W_v}\sqrt{\frac{\rho_v}{\rho_l}} \quad (6)$$

$$K_{Drum} = \exp\ (A + Bln(F_{lv}) + Cln(F_{lv})^2 + Dln(F_{lv})^3 + Eln(F_{lv})^4) \quad (7)$$

$A = -1.877478097$

$B = -0.8145804597$

$C = -0.1870744085$

$D = -0.0145228667$

$E = -0.0010148518$

$$U_{Perm} = K_{Drum}\sqrt{\frac{\rho_l - \rho_v}{\rho_v}} \quad (8)$$

$$A_c = \frac{V \cdot MW_v}{3600 \cdot U_{Perm} \cdot \rho_v} \quad (9)$$

$$D = \sqrt{\frac{4A_c}{\pi}} \quad (10)$$

Compressor Equations

$$GHP(kW) = \frac{GHP(\frac{kJ}{hr})}{3600} \quad (11)$$

$$BHP = GHP + GHP^{0.4} \quad (12)$$

$$\dot{W}_{Driver}(kW) = \frac{BHP}{\eta_{Driver}} \quad (13)$$

Heat Exchanger Equations

$$U_o = \frac{1}{\frac{d_O}{h_i d_i} + R_{fi}\frac{d_O}{d_i} + \frac{d_O \ln(\frac{d_O}{d_i})}{2k_W} + R_{fo} + \frac{1}{h_O}} \quad (14)$$

U_o= Overall Heat Transfer Coefficient (BTU/h·ft²·°F)

d_o = outer diameter (ft)

d_i = outer diameter (ft)

R_{fi} = inner Fouling Resistance (h·ft²·°F/BTU)

R_{fo} = Fouling Resistance (h·ft²·°F/BTU)

K_w = Conductive Heat Transfer Coefficient (BTU/h·ft·°F)

h = Convective Heat Transfer Coefficient (BTU/h·ft²·°F)

$$LMTD = LMTD_{countercurrent} = \frac{(T_{h,i} - T_{c,o}) - (T_{h,o} - T_{c,i})}{\ln(\frac{T_{h,i} - T_{c,o}}{T_{h,o} - T_{c,i}})} \quad (15)$$

$T_{h,i}$ = Hot in stream Temperature (°F)

$T_{h,o}$ = Hot out stream Temperature (°F)

$T_{c,i}$ = Cold in stream Temperature (°F)

$T_{c,o}$ = Cold out stream Temperature (°F)

$$A = \frac{Q}{U*LMTD} \quad (16)$$

A= Transfer Area

Q = Total Heat Transfer (Btu/hr)

U_o= Overall Heat Transfer Coefficient (BTU/h·ft²·°F)

Fans Equations

$$A_{Face} = \dot{m}_{air}\rho_{air}V_{Face} \quad (17)$$

Storage Tank Equations

$$D = \sqrt[3]{\frac{4*V}{3*\pi}} \quad (18)$$

Capital Cost Equations (*25*)

$$log_{10}C_p^0 = K_1 + K_2 log_{10}A + K_3[log_{10}A]^2 \quad (19)$$

C_p^0 = Base Purchase Cost 2001 US$

K = Table A.1 Coefficients (*25*)

A = Sizing Unit

$$log_{10}F_p = C_1 + C_2 log_{10}P + C_3(log_{10}P)^2 \quad (20)$$

F_p= Pressure Factor

C = Table A.2 Coefficients (*25*)

P = Pressure (Barg)

$$C_{BM} = C_p^0[B_1 + B_2F_pF_M] \quad (21)$$

C_{BM} = Bare Module Cost US 2001$

C_p^0 = Base Purchase Cost ($)

F_m= Material of Construction Factor (*25*)

F_p= Pressure Factor

B = Table A.4 Constants (*25*)

$$Cbm(2020) = CEPCI(2019\$)(C_{bm2001\$})(\text{escalation factor}) \quad (22)$$

CEPCI 2019$ obtained from (*75*)

Escalation factor 1.02 obtained from (*65*)

Fixed Capital Investment Summary (*25*)

$$C_{TM} = 1.18 \sum_{i=1}^{n} C_{Bm,i} \quad (23)$$

$C_{TM} = Total\ Module\ Cost\ in\ 2020\ US\$$

$$C_{GR} = C_{TM} + 0.50 \sum_{i=1}^{n} C_{BM,i} \quad (24)$$

$C_{GR} = Grassroots\ Costs\ in\ 2020\ US\$$

Membrane Equations

$$\text{Surface Area} = \frac{\text{Transfer Rate}}{\frac{P_{O_2}}{ST} * (\Delta P)} \quad (25)$$

$\text{Transfer Rate} = O_{\%} * V$

$O_{\%} = \text{volumetric percent of Oxygen in Air}$

$V = \text{volumetric flow rate of Air} \left(\frac{cm^3}{hr}\right)$

$P_{O_2} = \text{permeability of } O_2 \text{ through membrane} \left(\frac{cm^3 cm}{cm^2 * sec * cm\ Hg}\right)$

$ST = \text{Separation Thickness (cm)}$

$$\Delta P = P_s - P_T \text{ (cm Hg)} \quad (26)$$

$P_T = \text{Partial pressure of Oxygen on Tube Side (cm Hg)}$

$P_S = \text{Partial Pressure of Oxygen on Shell Side (cm Hg)}$

Electrolysis Equations

$$\text{Energy Required (kW)} = \frac{\dot{m}_{H_2O} \Delta G}{3600} \quad (27)$$

$\dot{m}_{H_2O} = \text{molar flow rate of water in mole/hour}$

$\Delta G = change\ in\ Gibbs\ Free\ energy$ (76)

$Capital\ Invesment\ \$ = Energy\ Requirement * \$500$ obtained from (*62*) (28)

Electrolysis Operating Cost $ = $price of electricity * energy requirement (29)

Modular Manufacturing Equation

$$k_n = k_1 n^{log_2 p} \qquad (30)$$

k_n= the cost of the nth unit

k_1=the cost of the first of a kind unit

p= 0.8

$$K(N) = \sum_1^N k_n \qquad (31)$$

K(N) = total cost of a modular unit

Operating cost

$$N_{OL} = (6.29 + 31.7P^2 + 0.23N_{NP})^{0.5} \qquad (32)$$

$$Q = \dot{m} * C_{Pcw} * \Delta T_{CW} \qquad (33)$$

Appendix B

Below is the calculations performed to determine the size and cost of the reformer for steam methane reforming R-201 on the left and costing and sizing of the water gas shift reactor for R-202 on the right.

	reformer	
Hydrogen Reactor Costing		
Flow of Methane =		
Total Flow =	441396.7	mol/h
Wcat = 1.5F		
Cat =	662095.05	g
	662.09505	kg
	0.66209505	metric tons of catalyst
Bulk Density =	0.9	kg/L
Reactor Volume =	735.6611667	
	0.7356611667	m3
L/D Ratio	3	
Reactor Diameter	0.6784047788	m
Reactor Height	2.035214336	m
A =	0.7356611667	
K1 =	3.5565	
K2 =	0.3776	
K3 =	0.0905	
log10Cp =	3.507766169	
Cpo =	3219.334981	

Water gas shift with membrane reactor		
For 93% conversion, W/F = 500 gmcathr/molCO		
W/F =	500	gm cat hr/mol CO
mol CO/hr	18.44082538	kmol/hr
	18440.82538	mol/hr
W =	9220412.691	gm cat
	9220.412691	kg cat
Catalyst density =	0.9	g/cm3
Density =	0.9	kg/L
Density =	900	kg/m3
Reactor Volume =	10.24490299	m3
L/D Ratio	3	
Reactor Diamete	1.632170678	
Reactor Height	4.896512033	
A =	10.24490299	
K1 =	3.5565	
K2 =	0.3776	
K3 =	0.0905	
log10Cp =	4.030479678	
Cpo =	$10,727.03	

total flow rate out of R-202	476
CH4 (not to psa)	11.424
H2 (not to psa)	29.7024
CO2 (not to psa)	62.832
H20 (not to psa)	10.2816
total recycle	114.24
H2 (to psa)	264.0848
H2o (psa)	94.0576
CO2 and CH4 (psa)	3.6176
total to psa	361.76

P =	33.45	bar
Fp =	2.670066346	
B1 =	1.49	
B2 =	1.52	
Fm =	3.5	
Cbm =	50526.66723	
Catalyst Cost =	66209.505	
Total Cost (Vessel+Catalyst)=	$ 116,736.17	
2020	143515.3059	
Conditions:		
T =	640	C
P =	1	atm
X =	0.8	

P =	23.45
Fp =	4.133858079
B1 =	1.49
B2 =	1.52
Fm =	3.5
Cbm =	$251,893.56
Membrane Cost	21620.30975
Total Cost (Vesse	$ 273,513.87
2019	$407,017.46

Reactor Radius:	0.8160853389	m
Reactor Circumference:	5.127615411	m
Reactor Outer SA:	25.10743056	m2
	270.2538718	ft2
Membrane cost:	21620.30975	

Below is the Calculations to size and cost the packed bed reactor, R-301, for ammonia production.

	10 bar	425 C
	ruthenium	
Space Time (Mass Acti	0.379	kgNH3/hkgcat
Molec Weight NH3	17.03	kg/kmol
Flow NH3	122.3	kmolNH3/hr
Mass Flow NH3	2082.769	kg/hr
Mass Catalyst:	5495.432718	kg
Density Catalyst:	0.7	g/cm3
	700	kg/m3
Catalyst Volume	7.850618168	m3
Void Fraction:	0.38	
Reactor Volume:	20.6595215	m3
Reactor Volume =	20.6595215	m^3
L/D Ratio	3	
Reactor Diameter	2.062068276	m
Reactor Height	6.186204827	m
Catalyst Density =	0.7	g/cm3
	700	kg/m3
Catalyst Mass =	14461.66505	kg

	10	$/kg
log10Cp = K1 + K2log10(A) + K3(log10(A))^2		
A =	20.6595215	
K1 =	3.5565	
K2 =	0.3776	
K3 =	0.0905	
log10Cp =	4.209612897	
Cpo =	16203.6516	
P =	13.45	
Fp =	3.114440697	
B1 =	1.49	
B2 =	1.52	
Fm =	3.1	
Cbm =	$ 261,935.99	
Catalyst Cost =	$ 144,616.65	
Total Cost (Vessel+Cata	$ 545,378.72	

Costing and Sizing for the Pressure swing adsorption tower within nitrogen production, V-101 and V-102.

Temp (K)	363
Voidage	0.33
R (L *atm/(K-mol))	0.08206
O2 mole fraction	0.21
molar flow rate in (kmole/da	2725
D = time total/bed (s/bed)	64.7
adsorbent used	0.71
denisty (lb/ft)	47.4
h20 mole fraction	0.005
L/D	5
V=pi(D^2/4)l	
D=	
density of zeolite (kg/m^3)	1126
amount of nitrogen removed	0.3

Type	10 bar
Total cost in 2020	217841.357
for two bed	
Cost in 2019 dollar of one bed	145862.357
Cbm	95334.87387
d (m) need to find rounding increments	3.75
l (m)	18.75
P barg	13.44738
CMS Price	70039.2
lb	9240
CMS price for water removal	1939.8
lb	323.3
Cp0=10^(K1+K2*log(A)+K3(log(A))^2)	8071.33893
K1 pg 1251	3.4974
K2	0.4485
K3	0.1074
V (m^3)	5.9
Fp,vessel	5.253588726
B1	2.25
B2	1.82

Pressure (Bar)	Pressure (atm)	V bed (m^3/bed)	V ads (L/bed)	Adsorbent (lb/bed)	D (m)	L (m)
10	9.86923	5.65	131.4	326.3	1.12903	5.64516

Costing and Sizing for the Pressure swing adsorption tower within hydrogen production, V-201 and V-202.

Temp (K)	556
Voidage	0.503
R (L *atm/(K-mol))	0.08206
removal amount	0.489
molar flow rate in (kmole/day)	8688
D = time total/bed (s/bed)	64.7
adsorbent used	0.609
denisty (kg/m^3)	1126
hydrogen removed	0.2

Type	zeolite
Total cost in 2020	916199.4621
for one bed	738365.7321
Cost in 2020 dollar of one bed	738365.7321
Cbm	482591.9818
d (m)	1.83
l (m)	
P barg	23.45
CMS Price	177833.73
lb	58691
Cp0	20942.08528
K1	3.4974
K2	0.4485
K3	0.1074
V (m^3)	24
Fp,vessel	4.574304467
B1	1.49
B2	1.52
Fm (SS)	3.1

Pressure (atm)	V bed (m^3/bed)	V ads (L/bed)	dsorbent (kg/be	D (m)	L (m)
20.00000	23.69246	23692.46460	26677.71514	1.82047	9.10235

Below are the calculations for costing and sizing the flash drum V-301.

Separator Costing

Formulas and Heurstics taken from "Separation Process Engineering" by Wankat

Uperm = Kdrum*SQRT((pl - pv)/pv)

Kdrum = exp(A + B(LN(FLV)) + C(LN(FLV))^2 + D(LN(FLV))^3 + E(LN(FLV))^4)

FLV = (WL/WV)*SQRT(pv/pl)

Ac = (V*MWv)/(Uperm*3600*pv)

D = SQRT((4*Ac)/PI())

A =	-1.877478097	
B =	-0.8145804597	
C =	-0.1870744085	
D =	-0.0145228667	
E =	-0.0010148518	
pv =	0.52172618	lb/ft3
pl =	42.51488771	lb/ft3
WL =	4594.683169	lb/hr
WV =	10570.90753	lb/hr
V =	695.9265985	lbmol/hr
MWv =	15.18968746	lb/lbmol
FLV =	0.04814975621	
Kdrum =	0.4455419013	ft/s
Uperm =	3.997205949	ft/s
Ac =	1.408025817	ft2
D =	1.338937695	ft
D Rounded=	1.5	ft
H/D =	3	ft/ft
H =	4.5	ft
V =	6.336116175	ft3

V =	0.1794188297	m^3
A =	0.1794188297	
K1 =	3.4974	
K2 =	0.4485	
K3 =	0.1074	
log10Cp =	3.222550776	
Cpo =	1669.36297	
P =	23	barg
Fp =	1.498052414	
B1 =	1.49	
B2 =	1.52	
Fm =	3.5	Stainless
Cbm =	$ 15,791.57	
2020	24161.10331	

Costing and sizing calculations for C-101, C-102, and C-103.

P = 10 bar	K-101	
Stage 1 Compressor Energy =	481365.5973	kJ/h
	133.7126659	kW
GHP =	133.7126659	
BHP =	140.7997734	
Driver Efficiency =	0.3	
Driver Power =	469.332578	kW
Ce = a + b*(S^n)		
S =	469.332578	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 532,254.01	
Purchased Horsepower	629.3843737	hp

	K-102	
Stage 2 Compressor Energy =	332413.3279	kJ/h
	92.33703552	kW
GHP =	92.33703552	
BHP =	98.44857147	
Driver Efficiency =	0.3	
Driver Power =	328.1619049	kW
Ce = a + b*(S^n)		
S =	328.1619049	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 468,175.63	
	440.0716777	hp

	K-103	
Stage 3 Compressor Energy =	332092.8645	kJ/h
	92.24801791	kW
GHP =	92.24801791	
BHP =	98.35719645	
Driver Efficiency =	0.3	
Driver Power =	327.8573215	kW
Ce = a + b*(S^n)		
S =	327.8573215	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 468,030.70	
	439.6632253	hp

Compressor C-201 and C-301 calculations

Stage 1 Compressor Energy =	569274.7327	kJ/h
	158.1318702	kW
GHP =	158.1318702	
BHP =	165.7107979	
Driver Efficiency =	0.3	
Driver Power =	552.3693263	kW
Ce = a + b*(S^n)		
S =	552.3693263	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 567,635.13	
Purchased Horsepower:	740.7383139	hp

Stage 1 Compressor Energy =	711870.2799	kJ/h
	197.7417444	kW
GHP =	197.7417444	
BHP =	206.029546	
Driver Efficiency =	0.3	
Driver Power =	686.7651533	kW
Ce = a + b*(S^n)		
S =	686.7651533	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 622,217.94	
Purchased Horsepower:	920.9658059	hp

Calculations for K-302 and K-303.

Stage 1 Compressor Energy =	1541221.851	kJ/h
	428.1171807	kW
GHP =	428.1171807	
BHP =	439.4053903	
Driver Efficiency =	0.3	
Driver Power =	1464.684634	kW
Ce = a + b*(S^n)		
S =	1464.684634	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 899,251.65	
Purchased Horsepower:	1964.171388	hp

Stage 2 Compressor Energy =	2875831.777	kJ/h
	798.8421603	kW
GHP =	798.8421603	
BHP =	813.3293581	
Driver Efficiency =	0.3	
Driver Power =	2711.09786	kW
Ce = a + b*(S^n)		
S =	2711.09786	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	$ 1,274,431.34	
Purchased Horsepower:	3635.636453	hp

Heat exchanger costing and sizing for E-101, E-102 and E-103, involved in nitrogen production.

	E-103	E-101	E-102
Q kj/hr	200600	333300	334100
A m^2	2.775168797	3.961833561	7.385473764
Rfi m^ k/w	0.0001	0.0001	0.0001
Rfo m^2k/w	0.0001	0.0001	0.0001
d1 m	0.02	0.02	0.02
d2 m	0.02	0.02	0.02
w/m^2-k (20000 k	5000	5000	5000
w/m^2-k (20,000 k	1500	1500	1500
Tin shell C	149	149	149
T out shell (C)	90	50	50
Tin tube	32	32	32
Tout tube	49	49	49
kw w/m^2-k	21	21	21
U0	937.5	937.5	937.5
Tlm	77.10281751	89.73622806	48.25327998
F	1	1	1
changeT1	100	100	100
ChangeT2	58	18	18

	interstage	interstage	pre psa
Heat Exchanger	E-101	E-102	E-103
Type	double pipe	double pipe	double pipe
2020	21497.86124	24435.32355	19850.58145
Cbm	14050.8897	15970.79971	12974.23625
P (barg)	6.44	8.88	13.44
k1 (tabel A.1)	3.3444	3.3444	3.3444
k2	0.2745	0.2745	0.2745
k3	-0.0472	-0.0472	-0.0472
B1 (table A.4)	1.74	1.74	1.74
B2	1.55	1.55	1.55
Fm (figure A.18)	1.8	1.8	1.8
identification nun	1.8		
Fp (eq A.3 pg 12	1	1	1
Cp0	3101.741655	3525.56285	2864.069811
A(m^2)	3.96	7.39	2.78
C1 (0 if below 40 barg)			
C2			
C3			

Costing and Sizing of E-201 and E-202 involved in the SMR production of Hydrogen.

	E-201	E-202
Q kj/hr	8033000	288400
A m^2	46.08870722	5.316166665
Rfi m^ k/w	0.0001	0.0001
Rfo m^2k/w	0.0001	0.0001
d1 m	0.02	0.02
d2 m	0.02	0.02
hi w/m^2-k (20000 kpa)	5000	5000
ho w/m^2-k (20,000 kpa)	1500	500
Tin shell C	637	265
T out shell (C)	265	250
Tin tube	32	32
Tout tube	235	49
kw w/m^2-k	21	21
U0	937.5	416.6666667
Tlm	309.8565733	216.9984639
F	0.6	0.6
changeT1	402	216
ChangeT2	233	218

Heat Exchanger	E-201	E-202
Type	shell and tube	shell and tube
2020	210181.2379	190683.6992
Cbm	137373.3581	124629.8688
P (barg)	33.44	18
k1 (tabel A.1)	4.8306	4.8306
k2	-0.8509	-0.8509
k3	0.3187	0.3187
B1 (table A.4)	1.63	1.63
B2	1.66	1.66
FBm	2.8	2.8
identification nun	5	5
Fp (eq A.3 pg 12	1.140558376	1.062321462
Cp0	19819.23365	18976.26796
A(kw or m^2)	46.1	13
C1 (0 if below 5 b	0.03881	0.03881
C2	-0.11272	-0.11272
C3	0.08183	0.08183

Costing and sizing of E-301 and E-302 involved in the production of Ammonia.

Haber Heat Exchangers	E-107	E-108
Q kj/hr	6924000	6379000
A m^2	203.6175351	752.8831038
Rfi m^ k/w	0.0001	0.0001
Rfo m^2k/w	0.0001	0.0001
d1 m	0.02	0.02
d2 m	0.02	0.02
hi w/m^2-k (20000 kpa)	1500	500
ho w/m^2-k (20,000 kpa)	1500	1500
Tin shell C	102	-31
T out shell (C)	450	-42.19
Tin tube	550	177
Tout tube	177	-30
kw w/m^2-k	21	21
U0	652.173913	348.8372093
Tlm	86.90148742	40.48097811
F	0.6	0.6
changeT1	100	219.19
ChangeT2	75	1

	pre reactor	refrigeration
Heat Exchanger	E-301	E-302
Type	shell and tube	shell and tube
2020	364263.3316	1034077.027
Cbm	238080.6089	675867.3381
P (barg)	14.44	13.44
k1 (tabel A.1)	4.8306	4.8306
k2	-0.8509	-0.8509
k3	0.3187	0.3187
B1 (table A.4)	1.63	1.63
B2	1.66	1.66
Fm (figure A.18)	2.8	2.8
identification number (ss tubes and cs shell)	4	4
Fp (eq A.3 pg 1264)	1.042634	1.037073981
Cp0	36762.60389	104780.4376
A(m^2)	204	753
C1 (0 if below 5 barg)	0.03881	0.03881
C2	-0.11272	-0.11272
C3	0.08183	0.08183

H-201 costing and sizing

Fired Heater Costing		
Duty	18914880.61	kJ/h
A =	5254.133504	kW
K1 =	7.3488	
K2 =	-1.1666	
K3 =	0.2028	
log10Cp =	5.815647065	
Cpo =	$ 654,104.39	
P =	29	barg
C1 =	0.1347	
C2 =	-0.2368	
C3 =	0.1021	
Fp =	1.015677943	
Fm =	2.8	
Cbm =	$ 1,860,206.33	

E-303 costing and sizing

AFaceT = mair * pair * V face		
mair =	406674.6337	kg/hr
p air=	1.275	kg/m3
V face =	10972.8	m/h
Aface=	29.06828677	m2
A =	29.06828677	
K1 =	4.0336	
K2 =	0.2341	
K3 =	0.0497	
log10Cp =	4.482623833	
Cpo =	30382.52286	
P =	1.6	
Fp =	1	
B1 =	0.96	barg
B2 =	1.21	
Fm =	3.5	
Cbm =	$ 157,837.21	

Storage tanks V-301, V-302, and V-303 costing and sizing

Tank for Ammonia	
using ss	
	129053.4992
	129053.4992
Cp0	84348.69228
K1	4.8506
K2	-0.3973
K3	0.1445
A = voume (m^3)	847
B1	2.25
B2	1.82
Fm	3.1
D (m)	7.110346383
P (bar)	17.2369
Fp	12.08449262
overall volume	2541
flow rate (30 days)	1547469

Costing and sizing of Membrane, fired heater, and compressor for membrane option.

Membrane Type	hollow fiber
Flux	transfer rate/ area
mass flow rate air (kg/day)	41110
molar flow rate	45359.2
kg/hr	1712.916667
m^3/h	21049.65664
perovskite BaCoxFeyZr1−x−yO3−δ (BCFZ) at 500 C	0.45
volumetric fraction of O2	0.1769
transfer rate (m^3/hr)	3723.684259
nitrogen out fliw m^3/min	284.696606
0.45*60*(10^-2)	0.27
area for temp of 500	13791.42318
4.8*(1*10^-2)*(60)	2.88

Fired Heater Costing		
Duty	756914.672	kJ/h
A =	210.2540756	kW
K1 =	7.3488	
K2 =	-1.1666	
K3 =	0.2028	
log10Cp =	5.733221084	
Cpo =	$ 541,029.67	
P =	29	barg
C1 =	0.1347	
C2 =	-0.2368	
C3 =	0.1021	
Fp =	1.015677943	
Fm =	2.8	
Cbm =	$ 1,538,633.33	
2020 Dollars	$ 2,354,109.00	

	2 bar	
Stage 1 Compressor Energy =	136681.6115	kJ/h
	37.96711431	kW
GHP =	37.96711431	
BHP =	42.25026186	
Driver Efficiency =	0.3	
Driver Power =	140.8342062	kW
Ce = a + b*(S^n)		
S =	140.8342062	kW
a =	260000	
b =	2700	
n =	0.75	
Ce =	370381.1405	
Purchased Horsepower	188.8614872	hp

Costing and Sizing of Electrolysis option for hydrogen production.

H2O	Molar Flow	183.4	kgmole/hr
	Mass Flow	3304.868	kg/hr
	ΔG	237.1	KJ/mole
Energy required (Calculation)		12078.92778	
	Costing	500	$/kW
	Capital Investment	$6,039,464	
cell operating temp		60-80C	
Minnnesota electricity price		10.37	cents/kWh
		0.1037	$/kWh
energy requirement yearly		105811407.3	kWh
Electricity cost (per year)		$10,972,643	

Costing and sizing for the water gas shift reactor R-202, using a packed bed reactor.

Water Gas Shift Packed Bed Reactor			
For 10% conversion of CO2,	W/FCO2 =0.5	gcat/molCO2	
FCO2	309.17	kmol/h	
	309170	mol/h	
W=	154585	g	
Catalyst Mass=	154.585	kg	
Catalyst density =	0.9	g/cm3	
Density =	0.9	kg/L	
Density =	900	kg/m3	
Reactor Volume =	0.171761111	m3	
L/D Ratio	3		
Reactor Diameter	0.417738562		
Reactor Height	1.253215688		
A =	0.171761111		
K1 =	3.4974		
K2 =	0.4485		
K3 =	0.1074		
log10Cp =	3.217129307		

P =	15	
Fp =	1.091329147	
B1 =	1.49	
B2 =	1.52	
Fm =	3.5	
Cbm =	11227.32822	
Catalyst Cost =	2318.775	
Total Cost (Vessel+Catalyst)=	$13,546.10	
2019	19496.58717	
Conditions:		
T =	453	K
P =	15	atm
X =	0.7	

Appendix C

Cash flow table for membrane.

End of Year	2020	21	22	23	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Production, tons					8943	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885
Sales Price, $/tons					607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607
Sales Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
+Salvage																								
-Royalities																								
Net Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
-Raw Material Costs					28204	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409	56409
-Operating Costs					1430948	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896	2861896
Waste Removal					424400	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800	848800
-Depreciation					7794353	12470964	7482579	4489547	4489547	2244774														
- Amortization																								
- Depletion																								
- Loss Forward						4250702	9634365																	
- Writeoff																								
Taxable Income					(4250702)	(9634365)	(10029642)	2597755	2597755	4842528	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302	7087302
-Tax @ 25%							(2507410)	649439	649439	1210632	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825	1771825
Net Income					(4250702)	(9634365)	(7522231)	1948316	1948316	3631896	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476
+Depreciation					7794353	12470964	7482579	4489547	4489547	2244774	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+ Depletion																								
+ Loss Forward						4250702	9634365																	
+ Writeoff																								3897176
working capital	(3897176)																							
- Fixed Capital	(38971764)																							
Cash Flow	(42868940)	0	0		3543651	7087302	9594712	6437863	6437863	5876670	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	5315476	9212653
Discount Factor (P/Fi*,n)	1.00	0.93	0.86		0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21	0.20	0.18
Discounted Cash Flow	(42868940)	0	0		2813064	5209378	6530000	4056946	3756431	3174982	2659062	2462094	2279717	2110849	1954490	1809713	1675660	1551537	1436608	1330193	1231660	1140426	1055950	1694580
NPV @ i* =	7064398																							

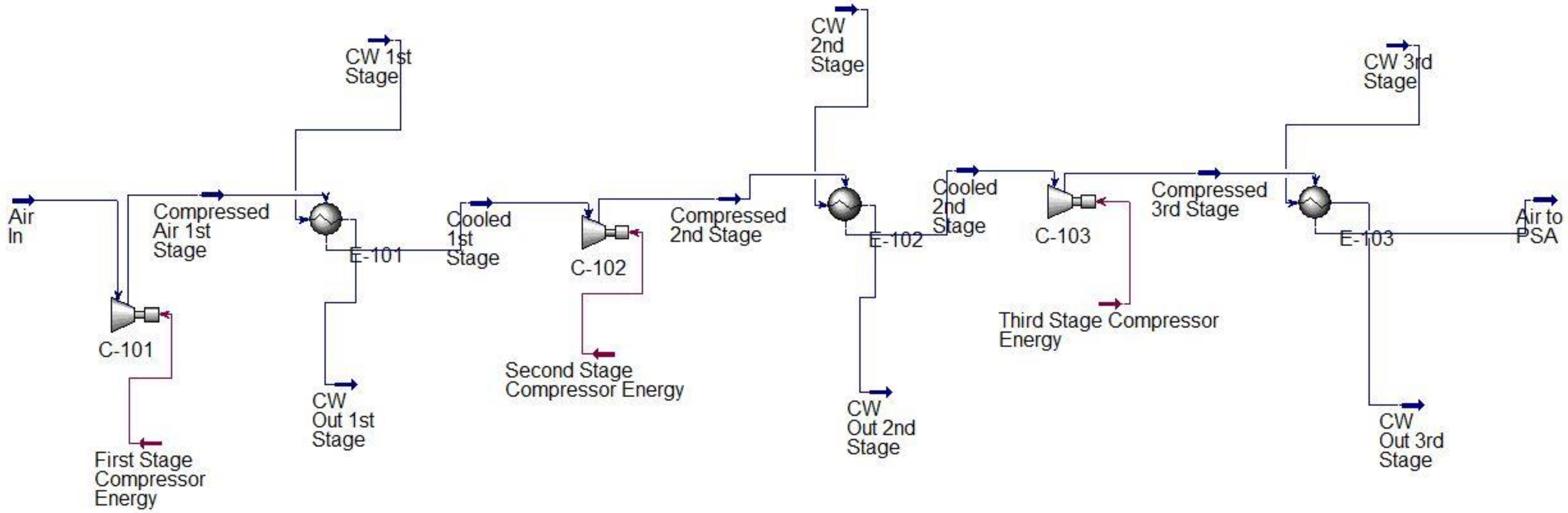
Cash flow Table for buying hydrogen and producing nitrogen.

End of Year	2020	21	22	23	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Production, tons					8943	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885
Sales Price, $/tons					607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607
Sales Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
+Salvage																								
-Royalities																								
Net Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
-Raw Material Costs					5788130	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259	11576259
-Operating Costs					1101754	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508	2203508
waste removal																								
-Depreciation					2650368	4240589	2544353	1526612	1526612	763306														
- Amortization																								
- Depletion																								
- Loss Forward																								
- Writeoff																								
Taxable Income					(4113049)	(7165950)	(5469715)	(4451973)	(4451973)	(3688667)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)
-Tax @ 25%																								
Net Income					(4113049)	(7165950)	(5469715)	(4451973)	(4451973)	(3688667)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)
+Depreciation					2650368	4240589	2544353	1526612	1526612	763306	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+ Depletion																								
+ Loss Forward						0																		
+ Writeoff																								1325184
working capital	(1325184)																							
- Fixed Capital	(13251840)																							
Cash Flow	(14577024)	0	0	0	(1462681)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(2925361)	(1600177)
Discount Factor (P/Fi*,n)	1.00	0.9	0.9	0.8	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17
Discounted Cash Flow	(14577024)	0	0	0	(1075114)	(1990952)	(1843474)	(1706920)	(1580482)	(1463409)	(1355008)	(1254637)	(1161701)	(1075649)	(995972)	(922196)	(853885)	(790634)	(732069)	(677842)	(627631)	(581140)	(538092)	(272535)
NPV @ i* =	(36076366)																							

Cash flow table for buying nitrogen and producing hydrogen.

End of Year	2020	21	22	23	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Production, tons					8943	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885	17885
Sales Price, $/tons					607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607	607
Sales Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
+Salvage																								
-Royalities																								
Net Revenue					5427203	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407	10854407
-Raw Material Costs					373083	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287	401287
-Operating Costs					1843744	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487	3687487
Waste Removal	0	0	0		424382	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764	848764
-Depreciation					4357550	6972081	4183248	2509949	2509949	1254975														
- Amortization																								
- Depletion																								
- Loss Forward						1571556	2626768	893148																
- Writeoff																								
Taxable Income					(1571556)	(2626768)	(893148)	2513771	3406919	4661894	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868	5916868
-Tax @ 25%								628443	851730	1165473	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217	1479217
Net Income					(1571556)	(2626768)	(893148)	1885328	2555189	3496420	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651
+Depreciation					4357550	6972081	4183248	2509949	2509949	1254975	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+ Depletion																								
+ Loss Forward						1571556	2626768	893148																
+ Writeoff																								2178775
working capital	(2178775)																							
- Fixed Capital	(21787752)																							
Cash Flow	(23966527)	0	0	0	2785995	5916868	5916868	5288425	5065138	4751395	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	4437651	6616426
Discount Factor (P/Fi*,n)	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17
Discounted Cash Flow	(23966527)	0	0	0	2047789	4026921	3728631	3085745	2736537	2376880	2055491	1903232	1762252	1631715	1510847	1398933	1295308	1199359	1110518	1028257	952090	881565	816264	1126879
NPV @ i* =	12708687																							

Appendix D



CW 1st Stage
CW 2nd Stage
CW 3rd Stage
Air In
Compressed Air 1st Stage
Cooled 1st Stage
Compressed 2nd Stage
Cooled 2nd Stage
Compressed 3rd Stage
Air to PSA
E-101
E-102
E-103
C-101
C-102
C-103
Third Stage Compressor Energy
Second Stage Compressor Energy
First Stage Compressor Energy
CW Out 1st Stage
CW Out 2nd Stage
CW Out 3rd Stage

****

INPUT SUMMARY

****

FLUID PACKAGE: Basis-1(Peng-Robinson)

Property Package Type: PengRob
Component List - 1: Nitrogen /Oxygen /CO2 /Argon /H2O /CO /Methane /

FLOWSHEET: Main

Fluid Package: Basis-1
STREAM: Air In (Material Stream)
  Temperature = 5 C
  Pressure = 101.324997 kPa
  Molar Flow = 113.6 kgmole/h
  Composition Basis (In Mole Flows):Nitrogen = 88.608/ Oxygen = 23.856/ CO2 = 0.4544/ Argon = 0.6816/ H2O = 0/ CO = 0/ Methane = 0/
STREAM: First Stage Compressor Energy (Energy Stream)
STREAM: Compressed Air 1st Stage (Material Stream)
  Temperature = 148.9 C
UNIT OPERATION: C-102 (Compressor)
  Feed Stream = Cooled 1st Stage
  Product Stream = Compressed 2nd Stage
  Energy Stream = Second Stage Compressor Energy
  AdiabaticEfficiency = 75
  CurveCollectionName = CC-0
  SelectedCurveCollection = True
  NumberOfCurves = 0
  NumberOfCurves = 0
  NumberOfCurves = 0
  EffCurveType = 0
  NumberOfCurves = 0
STREAM: Cooled 1st Stage (Material Stream)
  Temperature = 50 C
STREAM: Compressed 2nd Stage (Material Stream)
  Temperature = 148.888889 C
STREAM: Second Stage Compressor Energy (Energy Stream)
UNIT OPERATION: E-103 (Heat Exchanger)
  TubeInletStream = CW 3rd Stage
  TubeOutletStream = CW Out 3rd Stage
  ShellInletStream = Compressed 3rd Stage
  ShellOutletStream = Air to PSA
  TubeOuterDiameter = 20 mm
  TubeInnerDiameter = 16 mm
  TubeThickness = FEMPTY mm
  HCurveName = CW 3rd Stage-CW Out 3rd Stage
  HCurveName = Compressed 3rd Stage-Air to PSA
  ShellPressureDrop = 62 kPa
  TubePressureDrop = 0 kPa
STREAM: Air to PSA (Material Stream)
  Temperature = 90 C
STREAM: CW 3rd Stage (Material Stream)
  Temperature = 32 C
  Pressure = 101.3 kPa
  Composition Basis (In Mole Fractions):Nitrogen = 0/ Oxygen = 0/ CO2 = 0/ Argon = 0/ H2O = 1/ CO = 0/ Methane = 0/
STREAM: CW Out 3rd Stage (Material Stream)
  Temperature = 49 C
UNIT OPERATION: E-101 (Heat Exchanger)
  TubeInletStream = CW 1st Stage
  TubeOutletStream = CW Out 1st Stage
  ShellInletStream = Compressed Air 1st Stage
  ShellOutletStream = Cooled 1st Stage
  TubeOuterDiameter = 20 mm
  TubeInnerDiameter = 16 mm
  TubeThickness = FEMPTY mm
  HCurveName = CW 1st Stage-CW Out 1st Stage
  HCurveName = Compressed Air 1st Stage-Cooled 1st Stage
  ShellPressureDrop = 62 kPa
UNIT OPERATION: C-103 (Compressor)
  Feed Stream = Cooled 2nd Stage
  Product Stream = Compressed 3rd Stage
  Energy Stream = Third Stage Compressor Energy
  AdiabaticEfficiency = FEMPTY
  CurveCollectionName = CC-0
  SelectedCurveCollection = True
  NumberOfCurves = 0

NumberOfCurves = 0
NumberOfCurves = 0
EffCurveType = 0
NumberOfCurves = 0
STREAM: Compressed 3rd Stage (Material Stream)
Temperature = 148.888889 C
Pressure = 1062 kPa
STREAM: Third Stage Compressor Energy (Energy Stream)
STREAM: CW 1st Stage (Material Stream)
Temperature = 32 C
Pressure = 101.3 kPa
Composition Basis (In Mole Fractions):Nitrogen = 0/ Oxygen = 0/ CO2 = 0/
Argon = 0/ H2O = 1/ CO = 0/ Methane = 0/
STREAM: CW 2nd Stage (Material Stream)
Temperature = 32 C
Pressure = 101.3 kPa
Composition Basis (In Mole Fractions):Nitrogen = 0/ Oxygen = 0/ CO2 = 0/
Argon = 0/ H2O = 1/ CO = 0/ Methane = 0/
STREAM: Cooled 2nd Stage (Material Stream)
Temperature = 50 C
UNIT OPERATION: E-102 (Heat Exchanger)
TubeInletStream = CW 2nd Stage
TubeOutletStream = CW Out 2nd Stage
ShellInletStream = Compressed 2nd Stage
ShellOutletStream = Cooled 2nd Stage
TubeOuterDiameter = 20 mm
TubeInnerDiameter = 16 mm
TubeThickness = FEMPTY mm
HCurveName = CW 2nd Stage-CW Out 2nd Stage
HCurveName = Compressed 2nd Stage-Cooled 2nd Stage
ShellPressureDrop = 62 kPa
STREAM: CW Out 1st Stage (Material Stream)
Temperature = 49 C
Pressure = 101.3 kPa
STREAM: CW Out 2nd Stage (Material Stream)
Temperature = 49 C
Pressure = 101.3 kPa
##
OUTPUT SUMMARY
##
OKLAHOMA STATE UNIVERSIT Case Name: Nitrogen Final.hsc
Bedford, MA
USA Unit Set: SI

Date/Time: Wed Apr 01 18:48:17 2020

Basis-1 (Fluid Package): Component List

Fluid Package: Basis-1
COMPONENT LIST
Component List - 1 [HYSYS Databanks]

COMPONENT	TYPE	MOLECULAR WEIGHT	BOILING PT (C)	IDEAL LIQ DENSITY (kg/m3)	CRITICAL TEMP (C)
Nitrogen	Pure	28.01	-195.8	806.4	-147.0
Oxygen	Pure	32.00	-183.0	1138	-118.4
CO2	Pure	44.01	-78.55	825.3	30.95
Argon	Pure	39.95	-185.9	1370	-122.4
H2O	Pure	18.02	100.0	998.0	374.1
CO	Pure	28.01	-191.5	799.4	-140.2
Methane	Pure	16.04	-161.5	299.4	-82.45

(Continued..) Component List - 1 [HYSYS Databanks]

COMPONENT	CRITICAL PRES (kPa)	CRITICAL VOL (m3/kgmole)	ACENTRICITY	HEAT OF FORM (kJ/kgmole)
Nitrogen	3394	9.000e-002	4.000e-002	0.0000
Oxygen	5080	7.320e-002	1.900e-002	0.0000
CO2	7370	9.390e-002	0.2389	-3.938e+005
Argon	4864	7.490e-002	-4.000e-003	0.0000
H2O	2.212e+004	5.710e-002	0.3440	-2.418e+005
CO	3499	8.930e-002	9.300e-002	-1.106e+005
Methane	4641	9.900e-002	1.150e-002	-7.490e+004

Case (Simulation Case): Mass and Energy Balance, Utility Balance, Process CO2 Emissions
----
Simulation Case: Case

OVERALL MASS BALANCE

In Stream Count Mass Flow Out Stream Count Mass Flow
(kg/h) (kg/h)
Air In Yes 3293 CW Out 3rd Stage Yes 2734
CW 3rd Stage Yes 2734 Air to PSA Yes 3293
CW 1st Stage Yes 4543 CW Out 1st Stage Yes 4543
CW 2nd Stage Yes 4554 CW Out 2nd Stage Yes 4554
Total In MassFlow (kg/h) 1.512e+004 Total Out MassFlow (kg/h) 1.512e+004
Mass Imbalance (kg/h) 0.0000 Rel Mass Imbalance Pct (%) 0.00
OVERALL ENERGY BALANCE

InStream Count Energy Flow OutStream Count Energy Flow
(kJ/h) (kJ/h)
Air In Yes -2.461e+05 CW Out 3rd Stage Yes -4.315e+07
First Stage Compressor Energy Yes 4.814e+05 Air to PSA Yes 3.175e+04
Second Stage Compressor Energy Yes 3.324e+05 CW Out 1st Stage Yes -7.170e+07
CW 3rd Stage Yes -4.335e+07 CW Out 2nd Stage Yes -7.188e+07
CW 1st Stage Yes -7.204e+07
Third Stage Compressor Energy Yes 3.321e+05
CW 2nd Stage Yes -7.221e+07
Total In EnergyFlow (kJ/h) -1.867e+008 Total Out EnergyFlow (kJ/h) -1.867e+008
Energy Imbalance (kJ/h) -2.619e-008 Rel Energy Imbalance Pct (%) 0.00
OVERALL UTILITY BALANCE

Utility Name Usage Info Energy Flow Mass Flow Cost

Hot Utility Summary Cold Utility Summary

Utility Flow --- Utility Flow ---
Utility Cost --- Utility Cost ---
Carbon Emiss. --- Carbon Emiss. ---
Carbon Fees --- Carbon Fees ---
PROCESS CO2 EMISSIONS

Inlet Stream Count IFPP (1995) IFPP (2007) EPA (2009)
(kg/h) (kg/h) (kg/h)
Air In Yes 2.000e+01 2.000e+01 2.000e+01
CW 3rd Stage Yes 0.000e-01 0.000e-01 0.000e-01
CW 1st Stage Yes 0.000e-01 0.000e-01 0.000e-01
CW 2nd Stage Yes 0.000e-01 0.000e-01 0.000e-01
Total from Inlets 2.000e+01 2.000e+01 2.000e+01
Total Carbon Fees 0.000e-01 0.000e-01 0.000e-01
from Inlets (Cost/hr)
Outlet Stream Count IFPP (1995) IFPP (2007) EPA (2009)
(kg/h) (kg/h) (kg/h)
CW Out 3rd Stage Yes 0.000e-01 0.000e-01 0.000e-01
Air to PSA Yes 2.000e+01 2.000e+01 2.000e+01
CW Out 1st Stage Yes 0.000e-01 0.000e-01 0.000e-01
CW Out 2nd Stage Yes 0.000e-01 0.000e-01 0.000e-01
Total from Outlets 2.000e+01 2.000e+01 2.000e+01
Total Carbon Fees 0.000e-01 0.000e-01 0.000e-01
from Outlets (Cost/hr)

Air In (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Air In Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS

OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (C) 5.000 5.000
Pressure: (kPa) 101.3 101.3
Molar Flow (kgmole/h) 113.6 113.6
Mass Flow (kg/h) 3293 3293
Std Ideal Liq VolFlow (m3/h) 3.793 3.793
Molar Enthalpy (kJ/kgmole) -2.166e+03 -2.166e+03
Molar Entropy (kJ/kgmole-C) 1.501e+02 1.501e+02
Heat Flow (kJ/h) -2.461e+05 -2.461e+05
Liq VolFlow @Std Cond (m3/h) 2684 2684
COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Nitrogen 88.61 0.7800 2482 0.7538 3.078 0.8115

Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Compressed Air 1st Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Compressed Air 1st Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	148.9	148.9
Pressure: (kPa)	323.3	323.3
Molar Flow (kgmole/h)	113.6	113.6
Mass Flow (kg/h)	3293	3293
Std Ideal Liq VolFlow (m3/h)	3.793	3.793
Molar Enthalpy (kJ/kgmole)	2.071e+03	2.071e+03
Molar Entropy (kJ/kgmole-C)	1.527e+02	1.527e+02
Heat Flow (kJ/h)	2.353e+05	2.353e+05
Liq VolFlow @Std Cond (m3/h)	2684	2684

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Cooled 1st Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Cooled 1st Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	50.00	50.00
Pressure: (kPa)	261.3	261.3
Molar Flow (kgmole/h)	113.6	113.6
Mass Flow (kg/h)	3293	3293
Std Ideal Liq VolFlow (m3/h)	3.793	3.793
Molar Enthalpy (kJ/kgmole)	-8.629e+02	-8.629e+02

Molar Entropy (kJ/kgmole-C) 1.466e+02 1.466e+02
Heat Flow (kJ/h) -9.803e+04 -9.803e+04
Liq VolFlow @Std Cond (m3/h) 2684 2684
COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(kgmole/h)		(kg/h)		(m3/h)	
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(kgmole/h)		(kg/h)		(m3/h)	
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

K VALUE

Compressed 2nd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Compressed 2nd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	148.9	148.9
Pressure: (kPa)	544.9	544.9
Molar Flow (kgmole/h)	113.6	113.6
Mass Flow (kg/h)	3293	3293
Std Ideal Liq VolFlow (m3/h)	3.793	3.793
Molar Enthalpy (kJ/kgmole)	2.063e+03	2.063e+03
Molar Entropy (kJ/kgmole-C)	1.484e+02	1.484e+02
Heat Flow (kJ/h)	2.344e+05	2.344e+05
Liq VolFlow @Std Cond (m3/h)	2684	2684

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(kgmole/h)		(kg/h)		(m3/h)	
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(kgmole/h)		(kg/h)		(m3/h)	
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

K VALUE

Air to PSA (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Air to PSA Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	90.00	90.00
Pressure: (kPa)	1000	1000
Molar Flow (kgmole/h)	113.6	113.6
Mass Flow (kg/h)	3293	3293
Std Ideal Liq VolFlow (m3/h)	3.793	3.793
Molar Enthalpy (kJ/kgmole)	2.794e+02	2.794e+02
Molar Entropy (kJ/kgmole-C)	1.388e+02	1.388e+02
Heat Flow (kJ/h)	3.175e+04	3.175e+04
Liq VolFlow @Std Cond (m3/h)	2684	2684

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

CW 3rd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: CW 3rd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	AQUEOUS PH.
Vapour / Phase Fraction	0.0000	1.0000
Temperature: (C)	32.00	32.00
Pressure: (kPa)	101.3	101.3
Molar Flow (kgmole/h)	151.7	151.7
Mass Flow (kg/h)	2734	2734
Std Ideal Liq VolFlow (m3/h)	2.739	2.739
Molar Enthalpy (kJ/kgmole)	-2.857e+05	-2.857e+05
Molar Entropy (kJ/kgmole-C)	5.551e+01	5.551e+01
Heat Flow (kJ/h)	-4.335e+07	-4.335e+07
Liq VolFlow @Std Cond (m3/h)	2.694	2.694

COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	151.7	1.0000	2734	1.0000	2.739	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	151.7	1.0000	2734	1.0000	2.739	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC

Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	151.7	1.0000	2734	1.0000	2.739	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	151.7	1.0000	2734	1.0000	2.739	1.0000

CW Out 3rd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: CW Out 3rd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	AQUEOUS PH.
Vapour / Phase Fraction	0.0000	1.0000
Temperature: (C)	49.00	49.00
Pressure: (kPa)	101.3	101.3
Molar Flow (kgmole/h)	151.7	151.7
Mass Flow (kg/h)	2734	2734
Std Ideal Liq VolFlow (m3/h)	2.739	2.739
Molar Enthalpy (kJ/kgmole)	-2.844e+05	-2.844e+05
Molar Entropy (kJ/kgmole-C)	5.972e+01	5.972e+01
Heat Flow (kJ/h)	-4.315e+07	-4.315e+07
Liq VolFlow @Std Cond (m3/h)	2.694	2.694

COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	151.7	1.0000	2734	1.0000	2.739	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	151.7	1.0000	2734	1.0000	2.739	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	151.7	1.0000	2734	1.0000	2.739	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	151.7	1.0000	2734	1.0000	2.739	1.0000

Compressed 3rd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Compressed 3rd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	148.9	148.9
Pressure: (kPa)	1062	1062
Molar Flow (kgmole/h)	113.6	113.6
Mass Flow (kg/h)	3293	3293
Std Ideal Liq VolFlow (m3/h)	3.793	3.793
Molar Enthalpy (kJ/kgmole)	2.045e+03	2.045e+03
Molar Entropy (kJ/kgmole-C)	1.428e+02	1.428e+02
Heat Flow (kJ/h)	2.323e+05	2.323e+05
Liq VolFlow @Std Cond (m3/h)	2684	2684

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115

Oxygen 23.86 0.2100 763.4 0.2318 0.6710 0.1769
CO2 0.4544 0.0040 20.00 0.0061 2.423e-002 0.0064
Argon 0.6816 0.0060 27.23 0.0083 1.987e-002 0.0052
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 113.6 1.0000 3293 1.0000 3.793 1.0000
Vapour Phase Phase Fraction 1.000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Nitrogen 88.61 0.7800 2482 0.7538 3.078 0.8115
Oxygen 23.86 0.2100 763.4 0.2318 0.6710 0.1769
CO2 0.4544 0.0040 20.00 0.0061 2.423e-002 0.0064
Argon 0.6816 0.0060 27.23 0.0083 1.987e-002 0.0052
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 113.6 1.0000 3293 1.0000 3.793 1.0000

CW 1st Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: CW 1st Stage Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS

OVERALL AQUEOUS PH.
Vapour / Phase Fraction 0.0000 1.0000
Temperature: (C) 32.00 32.00
Pressure: (kPa) 101.3 101.3
Molar Flow (kgmole/h) 252.2 252.2
Mass Flow (kg/h) 4543 4543
Std Ideal Liq VolFlow (m3/h) 4.552 4.552
Molar Enthalpy (kJ/kgmole) -2.857e+05 -2.857e+05
Molar Entropy (kJ/kgmole-C) 5.551e+01 5.551e+01
Heat Flow (kJ/h) -7.204e+07 -7.204e+07
Liq VolFlow @Std Cond (m3/h) 4.477 4.477
COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Argon 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 252.2 1.0000 4543 1.0000 4.552 1.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 252.2 1.0000 4543 1.0000 4.552 1.0000
Aqueous Phase Phase Fraction 1.000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Argon 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 252.2 1.0000 4543 1.0000 4.552 1.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 252.2 1.0000 4543 1.0000 4.552 1.0000

CW 2nd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: CW 2nd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS

OVERALL AQUEOUS PH.
Vapour / Phase Fraction 0.0000 1.0000
Temperature: (C) 32.00 32.00
Pressure: (kPa) 101.3 101.3
Molar Flow (kgmole/h) 252.8 252.8
Mass Flow (kg/h) 4554 4554
Std Ideal Liq VolFlow (m3/h) 4.563 4.563
Molar Enthalpy (kJ/kgmole) -2.857e+05 -2.857e+05

Molar Entropy (kJ/kgmole-C) 5.551e+01 5.551e+01
Heat Flow (kJ/h) -7.221e+07 -7.221e+07
Liq VolFlow @Std Cond (m3/h) 4.487 4.487
COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	252.8	1.0000	4554	1.0000	4.563	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	252.8	1.0000	4554	1.0000	4.563	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	252.8	1.0000	4554	1.0000	4.563	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	252.8	1.0000	4554	1.0000	4.563	1.0000

Cooled 2nd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Cooled 2nd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	50.00	50.00
Pressure: (kPa)	482.9	482.9
Molar Flow (kgmole/h)	113.6	113.6
Mass Flow (kg/h)	3293	3293
Std Ideal Liq VolFlow (m3/h)	3.793	3.793
Molar Enthalpy (kJ/kgmole)	-8.781e+02	-8.781e+02
Molar Entropy (kJ/kgmole-C)	1.414e+02	1.414e+02
Heat Flow (kJ/h)	-9.975e+04	-9.975e+04
Liq VolFlow @Std Cond (m3/h)	2684	2684

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	88.61	0.7800	2482	0.7538	3.078	0.8115
Oxygen	23.86	0.2100	763.4	0.2318	0.6710	0.1769
CO2	0.4544	0.0040	20.00	0.0061	2.423e-002	0.0064
Argon	0.6816	0.0060	27.23	0.0083	1.987e-002	0.0052
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	113.6	1.0000	3293	1.0000	3.793	1.0000

CW Out 1st Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: CW Out 1st Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	AQUEOUS PH.
Vapour / Phase Fraction	0.0000	1.0000
Temperature: (C)	49.00	49.00
Pressure: (kPa)	101.3	101.3
Molar Flow (kgmole/h)	252.2	252.2
Mass Flow (kg/h)	4543	4543
Std Ideal Liq VolFlow (m3/h)	4.552	4.552
Molar Enthalpy (kJ/kgmole)	-2.844e+05	-2.844e+05
Molar Entropy (kJ/kgmole-C)	5.972e+01	5.972e+01
Heat Flow (kJ/h)	-7.170e+07	-7.170e+07
Liq VolFlow @Std Cond (m3/h)	4.477	4.477

COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	252.2	1.0000	4543	1.0000	4.552	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	252.2	1.0000	4543	1.0000	4.552	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	252.2	1.0000	4543	1.0000	4.552	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	252.2	1.0000	4543	1.0000	4.552	1.0000

CW Out 2nd Stage (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: CW Out 2nd Stage Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	AQUEOUS PH.
Vapour / Phase Fraction	0.0000	1.0000
Temperature: (C)	49.00	49.00
Pressure: (kPa)	101.3	101.3
Molar Flow (kgmole/h)	252.8	252.8
Mass Flow (kg/h)	4554	4554
Std Ideal Liq VolFlow (m3/h)	4.563	4.563
Molar Enthalpy (kJ/kgmole)	-2.844e+05	-2.844e+05
Molar Entropy (kJ/kgmole-C)	5.972e+01	5.972e+01
Heat Flow (kJ/h)	-7.188e+07	-7.188e+07
Liq VolFlow @Std Cond (m3/h)	4.487	4.487

COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	252.8	1.0000	4554	1.0000	4.563	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	252.8	1.0000	4554	1.0000	4.563	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

H_2O	252.8	1.0000	4554	1.0000	4.563	1.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	252.8	1.0000	4554	1.0000	4.563	1.0000

C-101 (Compressor): Design, Rating, Performance

Compressor: C-101

DESIGN

Connections

Inlet Stream

STREAM NAME FROM UNIT OPERATION
Air In

Outlet Stream

STREAM NAME TO UNIT OPERATION
Compressed Air 1st Stage E-101 Heat Exchanger

Energy Stream

STREAM NAME FROM UNIT OPERATION
First Stage Compressor Energy

Parameters

Speed: --- Duty: 1.3371e+02 kW
Adiabatic Eff.: 75.00 PolyTropic Eff.: 78.59
Adiabatic Head: 1.118e+004 m Polytropic Head: 1.172e+004 m
Adiabatic Fluid Head: 109.6 kJ/kg Polytropic Fluid Head: 114.9 kJ/kg
Polytropic Exp. 1.564 Isentropic Exp. 1.398 Poly Head Factor 1.001
User Variables

RATING

Curves

Compressor Speed: --- Efficiency: Adiabatic Curves Enabled: Yes
Head Offset: 0.0000 m Efficiency Offset: 0.00 %
Speed:
Flow Head Efficiency (%)
Flow Limits

Surge Curve: Inactive
Speed Flow
Stone Wall Curve: Inactive
Speed Flow
Surge Flow Rate --- Field Flow Rate 2591 ACT_m3/h Stone Wall Flow --- Compressor Volume 0.0000 m3
Nozzle Paramaters

Base Elevation Relative to Ground Level 0.0000 m

	Air In	Compressed Air 1st Stage
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

Inertia

Rotational inertia (kg-m2) 6.000 Radius of gyration (m) 0.2000
Mass (kg) 150.0 Friction loss factor (rad/min) (kg-m2/s) 6.000e-003
PERFORMANCE

Results

Adiabatic Head (m) 1.118e+004 Power Consumed (kW) 133.7
Polytropic Head (m) 1.172e+004 Polytropic Head Factor 1.001
Adiabatic Fluid Head (kJ/kg) 109.6 Polytropic Exponent 1.564
Polytropic Fluid Head (kJ/kg) 114.9 Isentropic Exponent 1.398
Adiabatic Efficiency 75 Speed (rpm) ---
Polytropic Efficiency 79 ---
Power/Torque

Total Rotor Power (kW) 133.7 Total Rotor Torque (N-m) ---
Transient Rotor Power (kW) 0.0000 Transient Rotor Torque (N-m) ---
Friction Power Loss (kW) 0.0000 Friction Torque Loss (N-m) ---
Fluid Power (kW) 133.7 Fluid Torque (N-m) ---

C-102 (Compressor): Design, Rating, Performance

Compressor: C-102

DESIGN

Connections

Inlet Stream

STREAM NAME FROM UNIT OPERATION
Cooled 1st Stage E-101 Heat Exchanger
Outlet Stream

STREAM NAME TO UNIT OPERATION
Compressed 2nd Stage E-102 Heat Exchanger
Energy Stream

STREAM NAME FROM UNIT OPERATION
Second Stage Compressor Energy
Parameters

Speed: --- Duty: 9.2337e+01 kW
Adiabatic Eff.: 75.00 PolyTropic Eff.: 77.37
Adiabatic Head: 7721 m Polytropic Head: 7965 m
Adiabatic Fluid Head: 75.71 kJ/kg Polytropic Fluid Head: 78.11 kJ/kg
Polytropic Exp. 1.576 Isentropic Exp. 1.396 Poly Head Factor 1.000
User Variables

RATING

Curves

Compressor Speed: --- Efficiency: Adiabatic Curves Enabled: Yes
Head Offset: 0.0000 m Efficiency Offset: 0.00 %
Speed:
Flow Head Efficiency (%)
Flow Limits

Surge Curve: Inactive
Speed Flow
Stone Wall Curve: Inactive
Speed Flow
Surge Flow Rate --- Field Flow Rate 1167 ACT_m3/h Stone Wall Flow --- Compressor Volume 0.0000 m3
Nozzle Paramaters

Base Elevation Relative to Ground Level 0.0000 m

	Cooled 1st Stage	Compressed 2nd Stage
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

Inertia

Rotational inertia (kg-m2) 6.000 Radius of gyration (m) 0.2000
Mass (kg) 150.0 Friction loss factor (rad/min) (kg-m2/s) 6.000e-003
PERFORMANCE

Results

Adiabatic Head (m) 7721 Power Consumed (kW) 92.34
Polytropic Head (m) 7965 Polytropic Head Factor 1.000
Adiabatic Fluid Head (kJ/kg) 75.71 Polytropic Exponent 1.576
Polytropic Fluid Head (kJ/kg) 78.11 Isentropic Exponent 1.396
Adiabatic Efficiency 75 Speed (rpm) ---
Polytropic Efficiency 77 ---
Power/Torque

Total Rotor Power (kW) 92.34 Total Rotor Torque (N-m) ---
Transient Rotor Power (kW) 0.0000 Transient Rotor Torque (N-m) ---
Friction Power Loss (kW) 0.0000 Friction Torque Loss (N-m) ---
Fluid Power (kW) 92.34 Fluid Torque (N-m) ---

C-103 (Compressor): Design, Rating, Performance

Compressor: C-103

DESIGN

Connections

Inlet Stream

STREAM NAME FROM UNIT OPERATION
Cooled 2nd Stage E-102 Heat Exchanger
Outlet Stream

STREAM NAME TO UNIT OPERATION
Compressed 3rd Stage E-103 Heat Exchanger
Energy Stream

STREAM NAME FROM UNIT OPERATION
Third Stage Compressor Energy
Parameters

Speed: --- Duty: 9.2248e+01 kW
Adiabatic Eff.: 81.12 PolyTropic Eff.: 83.04
Adiabatic Head: 8343 m Polytropic Head: 8540 m
Adiabatic Fluid Head: 81.81 kJ/kg Polytropic Fluid Head: 83.75 kJ/kg
Polytropic Exp. 1.521 Isentropic Exp. 1.400 Poly Head Factor 1.000
User Variables

RATING

Curves

Compressor Speed: --- Efficiency: Adiabatic Curves Enabled: Yes
Head Offset: 0.0000 m Efficiency Offset: 0.00 %
Speed:
Flow Head Efficiency (%)
Flow Limits

Surge Curve: Inactive
Speed Flow
Stone Wall Curve: Inactive
Speed Flow
Surge Flow Rate --- Field Flow Rate 631.1 ACT_m3/h Stone Wall Flow --- Compressor Volume 0.0000 m3
Nozzle Paramaters

Base Elevation Relative to Ground Level 0.0000 m

	Cooled 2nd Stage	Compressed 3rd Stage
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

Inertia

Rotational inertia (kg-m2) 6.000 Radius of gyration (m) 0.2000
Mass (kg) 150.0 Friction loss factor (rad/min) (kg-m2/s) 6.000e-003
PERFORMANCE

Results

Adiabatic Head (m) 8343 Power Consumed (kW) 92.25
Polytropic Head (m) 8540 Polytropic Head Factor 1.000
Adiabatic Fluid Head (kJ/kg) 81.81 Polytropic Exponent 1.521
Polytropic Fluid Head (kJ/kg) 83.75 Isentropic Exponent 1.400
Adiabatic Efficiency 81 Speed (rpm) ---
Polytropic Efficiency 83 ---
Power/Torque

Total Rotor Power (kW) 92.25 Total Rotor Torque (N-m) ---
Transient Rotor Power (kW) 0.0000 Transient Rotor Torque (N-m) ---
Friction Power Loss (kW) 0.0000 Friction Torque Loss (N-m) ---
Fluid Power (kW) 92.25 Fluid Torque (N-m) ---

E-103 (Heat Exchanger): Design, Rating, Details, Tables, HTFS Results, Exchanger Design and Rating
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Heat Exchanger: E-103

CONNECTIONS

Tube Side Shell Side

Inlet Outlet Inlet Outlet

Name CW 3rd Stage Name CW Out 3rd Stage Name Compressed 3rd Stage Name Air to PSA
From Op. To Op. From Op. C-103 To Op.
Op. Type Op. Type Op. Type Compressor Op. Type
Temp 32.00 C Temp 49.00 C Temp 148.89 C Temp 90.00 C
PARAMETERS

Heat Exchanger Model: Simple End Point

Tube Side DeltaP: 0.0000 kPa Shell Side DeltaP: 62.00 kPa Passes: ---
UA: 2682 kJ/C-h Tolerance: 1.0000e-04
Tube Side Data Shell Side Data
Heat Transfer Coeff --- Heat Transfer Coeff ---
Tube Pressure Drop 0.00 kPa Shell Pressure Drop 62.00 kPa
Fouling 0.00000 C-h-m2/kJ Fouling 0.00000 C-h-m2/kJ
Tube Length 6.00 m Shell Passes 1
Tube O.D. 20.00 mm Shell Series 1
Tube Thickness 2.0000 mm Shell Parallel 1
Tube Pitch 50.0000 mm Baffle Type Single
Orientation Horizontal Baffle Cut(%Area) 20.00
Passes Per Shell 2 Baffle Orientation Horizontal
Tubes Per Shell 160 Spacing 800.0000 mm
Layout Angle Triangular (30 degrees) Diameter 739.0488 mm
TEMA Type A E L Area 60.32 m2
SPECS

	Spec Value	Curr Value	Rel Error	Active	Estimate
E-101 Heat Balance	0.0000 kJ/h	8.851e-009 kJ/h	4.412e-014	On	Off
E-101 UA	---	2682 kJ/C-h	---	On	Off

Detailed Specifications

E-101 Heat Balance
Type: Duty Pass: Error Spec Value: 0.0000 kJ/h
E-101 UA
Type: UA Pass: Overall Spec Value: ---
User Variables

RATING

Sizing

Overall Data
Configuration
# of Shells in Series 1 Tube Passes per Shell 2 Elevation (Base) 0.0000 m
# of Shells in Parallel 1 Exchange Orientation Horizontal First Tube Pass Flow Direction Counter
TEMA Type: A E L
Calculated Information
Shell HT Coeff --- Tube HT Coeff ---
Overall U 44.46 kJ/h-m2-C Overall UA 2682 kJ/C-h
Shell DP 62.00 kPa Tube DP 0.0000 kPa
Shell Vol per Shell 2.272 m3 Tube Vol per Shell 0.1930 m3
HT Area per Shell 60.32 m2
Shell Data
Shell and Tube Bundle
Shell Diameter 739.0 (mm) Tube Pitch 50.00 (mm) Shell Fouling 0.0000 (C-h-m2/kJ)
# of Tubes per Shell 160 Tube Layout Angle Triangular (30 degrees)
Shell Baffles
Shell Baffle Type Single Shell Baffle Orientation Horizontal
Baffle Cut (%Area) 20.00 Baffle Spacing 800.0 mm
Tube Data
Dimensions
OD 20.00 (mm) ID 16.00 (mm) Tube Thickness 2.000 (mm) Tube Length 6.000 (m)
Tube Properties
Tube Fouling 0.0000 (C-h-m2/kJ) Thermal Cond. 45.00 (W/m-K) Wall Cp --- (kJ/kg-C) Wall Density --- (kg/m3)
Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 m

	CW 3rd Stage	Compressed 3rd Stage	CW Out 3rd Stage
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000
Elevation (% of Height) (%)	0.00	0.00	0.00

	Air to PSA
Diameter (m)	5.000e-002
Elevation (Base) (m)	0.0000
Elevation (Ground) (m)	0.0000
Elevation (% of Height) (%)	0.00

DETAILS

Overall/Detailed Performance

Duty: 2.006e+05 kJ/h
Heat Leak: 0.000e-01 kJ/h
Heat Loss: 0.000e-01 kJ/h
UA: 2.682e+03 kJ/C-h
Min. Approach: 58.00 C
Lmtd: 74.81 C

UA Curv. Error: 0.00e-01 kJ/C-h
Hot Pinch Temp: 90.00 C
Cold Pinch Temp: 32.00 C
Ft Factor: ---
Uncorrected Lmtd: 77.06 C

TABLES

Shell Side - Overall Phase

Temperature (C)	Pressure (kPa)	Heat Flow (kJ/h)	Enthalpy (kJ/kgmole)
90.00	1000.00	0.00	279.45
148.89	1062.00	200593.27	2045.23

UA (kJ/C-h)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (kJ/kgmole)
0.00	1.0000	1.0000	---
0.00	1.0000	1.0000	---

Shell Side - Vapour Phase

Mass Flow (kg/h)	Molecular Wt	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)
3292.79	28.99	9.61	1.03	0.02	0.03
3292.79	28.99	8.76	1.04	0.02	0.03

Std Gas Flow (STD_m3/h)	Z Factor	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
2686.01	1.00	3773.07	-140.10	0.29	0.04
2686.01	1.00	3773.07	-140.10	0.29	0.04

Shell Side - Light Liquid Phase

Tube Side - Overall Phase

Temperature (C)	Pressure (kPa)	Heat Flow (kJ/h)	Enthalpy (kJ/kgmole)
32.00	101.30	0.00	-285676.72
49.00	101.30	200593.27	-284354.80

UA (kJ/C-h)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (kJ/kgmole)
0.00	0.0000	0.0000	---
0.00	0.0000	0.0000	---

Tube Side - Vapour Phase

Tube Side - Heavy Liquid Phase

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
2733.70	1002.05	4.31	0.76	0.62	70.89
2733.70	989.02	4.32	0.55	0.64	67.91

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
18.02	1.00	22120.00	374.15	0.26	0.34
18.02	0.99	22120.00	374.15	0.26	0.34

Tube Side - Mixed Liquid

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
2733.70	1002.05	4.31	0.76	0.62	---
2733.70	989.02	4.32	0.55	0.64	---

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
18.02	1.00	22120.00	374.15	0.26	0.34
18.02	0.99	22120.00	374.15	0.26	0.34

HTFS

Exchanger Design and Rating

E-101 (Heat Exchanger): Design, Rating, Details, Tables, HTFS Results, Exchanger Design and Rating
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Heat Exchanger: E-101

CONNECTIONS

Tube Side Shell Side

Inlet Outlet Inlet Outlet
Name CW 1st Stage Name CW Out 1st Stage Name Compressed Air 1st Stage Name Cooled 1st Stage
From Op. To Op. From Op. C-101 To Op. C-102
Op. Type Op. Type Op. Type Compressor Op. Type Compressor
Temp 32.00 C Temp 49.00 C Temp 148.90 C Temp 50.00 C
PARAMETERS

Heat Exchanger Model: Simple End Point

Tube Side DeltaP: 0.0000 kPa Shell Side DeltaP: 62.00 kPa Passes: ---
UA: 8368 kJ/C-h Tolerance: 1.0000e-04

Tube Side Data		Shell Side Data	
Heat Transfer Coeff	---	Heat Transfer Coeff	---
Tube Pressure Drop	0.00 kPa	Shell Pressure Drop	62.00 kPa
Fouling	0.00000 C-h-m2/kJ	Fouling	0.00000 C-h-m2/kJ
Tube Length	6.00 m	Shell Passes	1
Tube O.D.	20.00 mm	Shell Series	1
Tube Thickness	2.0000 mm	Shell Parallel	1
Tube Pitch	50.0000 mm	Baffle Type	Single
Orientation	Horizontal	Baffle Cut(%Area)	20.00
Passes Per Shell	2	Baffle Orientation	Horizontal
Tubes Per Shell	160	Spacing	800.0000 mm
Layout Angle	Triangular (30 degrees)	Diameter	739.0488 mm
TEMA Type	A E L	Area	60.32 m2

SPECS

	Spec Value	Curr Value	Rel Error	Active	Estimate
E-100 Heat Balance	0.0000 kJ/h	-2.599e-008 kJ/h	-7.796e-014	On	Off
E-100 UA	---	8368 kJ/C-h	---	On	Off

Detailed Specifications

E-100 Heat Balance
Type: Duty Pass: Error Spec Value: 0.0000 kJ/h
E-100 UA
Type: UA Pass: Overall Spec Value: ---
User Variables

RATING

Sizing

Overall Data
Configuration
# of Shells in Series 1 Tube Passes per Shell 2 Elevation (Base) 0.0000 m
# of Shells in Parallel 1 Exchange Orientation Horizontal First Tube Pass Flow Direction Counter
TEMA Type: A E L
Calculated Information
Shell HT Coeff --- Tube HT Coeff ---
Overall U 138.7 kJ/h-m2-C Overall UA 8368 kJ/C-h
Shell DP 62.00 kPa Tube DP 0.0000 kPa
Shell Vol per Shell 2.272 m3 Tube Vol per Shell 0.1930 m3
HT Area per Shell 60.32 m2
Shell Data
Shell and Tube Bundle
Shell Diameter 739.0 (mm) Tube Pitch 50.00 (mm) Shell Fouling 0.0000 (C-h-m2/kJ)
# of Tubes per Shell 160 Tube Layout Angle Triangular (30 degrees)
Shell Baffles
Shell Baffle Type Single Shell Baffle Orientation Horizontal
Baffle Cut (%Area) 20.00 Baffle Spacing 800.0 mm
Tube Data
Dimensions
OD 20.00 (mm) ID 16.00 (mm) Tube Thickness 2.000 (mm) Tube Length 6.000 (m)
Tube Properties
Tube Fouling 0.0000 (C-h-m2/kJ) Thermal Cond. 45.00 (W/m-K) Wall Cp --- (kJ/kg-C) Wall Density --- (kg/m3)
Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 m

	CW 1st Stage	Compressed Air 1st Stage	CW Out 1st Stage
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000
Elevation (% of Height) (%)	0.00	0.00	0.00

	Cooled 1st Stage
Diameter (m)	5.000e-002

Elevation (Base) (m) 0.0000
Elevation (Ground) (m) 0.0000
Elevation (% of Height) (%) 0.00
DETAILS

Overall/Detailed Performance

Duty: 3.333e+05 kJ/h UA Curv. Error: 0.00e-01 kJ/C-h
Heat Leak: 0.000e-01 kJ/h Hot Pinch Temp: 50.00 C
Heat Loss: 0.000e-01 kJ/h Cold Pinch Temp: 32.00 C
UA: 8.368e+03 kJ/C-h Ft Factor: ---
Min. Approach: 18.00 C Uncorrected Lmtd: 47.82 C
Lmtd: 39.84 C
TABLES

Shell Side - Overall Phase

Temperature (C)	Pressure (kPa)	Heat Flow (kJ/h)	Enthalpy (kJ/kgmole)
50.00	261.27	0.00	-862.93
148.90	323.27	333341.13	2071.41

UA (kJ/C-h)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (kJ/kgmole)
0.00	1.0000	1.0000	---
0.00	1.0000	1.0000	---

Shell Side - Vapour Phase

Mass Flow (kg/h)	Molecular Wt	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)
3292.79	28.99	2.82	1.01	0.02	0.03
3292.79	28.99	2.67	1.03	0.02	0.03

Std Gas Flow (STD_m3/h)	Z Factor	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
2686.01	1.00	3773.07	-140.10	0.29	0.04
2686.01	1.00	3773.07	-140.10	0.29	0.04

Tube Side - Overall Phase

Temperature (C)	Pressure (kPa)	Heat Flow (kJ/h)	Enthalpy (kJ/kgmole)
32.00	101.30	0.00	-285676.72
49.00	101.30	333341.13	-284354.80

UA (kJ/C-h)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (kJ/kgmole)
0.00	0.0000	0.0000	---
0.00	0.0000	0.0000	---

Tube Side - Heavy Liquid Phase

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
4542.79	1002.05	4.31	0.76	0.62	70.89
4542.79	989.02	4.32	0.55	0.64	67.91

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
18.02	1.00	22120.00	374.15	0.26	0.34
18.02	0.99	22120.00	374.15	0.26	0.34

Tube Side - Mixed Liquid

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
4542.79	1002.05	4.31	0.76	0.62	---
4542.79	989.02	4.32	0.55	0.64	---

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
18.02	1.00	22120.00	374.15	0.26	0.34
18.02	0.99	22120.00	374.15	0.26	0.34

HTFS

Exchanger Design and Rating

E-102 (Heat Exchanger): Design, Rating, Details, Tables, HTFS Results, Exchanger Design and Rating
----
Heat Exchanger: E-102

CONNECTIONS

Tube Side Shell Side

Inlet Outlet Inlet Outlet
Name CW 2nd Stage Name CW Out 2nd Stage Name Compressed 2nd Stage Name Cooled 2nd Stage
From Op. To Op. From Op. C-102 To Op. C-103
Op. Type Op. Type Op. Type Compressor Op. Type Compressor
Temp 32.00 C Temp 49.00 C Temp 148.89 C Temp 50.00 C
PARAMETERS

Heat Exchanger Model: Simple End Point

Tube Side DeltaP: 0.0000 kPa Shell Side DeltaP: 62.00 kPa Passes: ---
UA: 8388 kJ/C-h Tolerance: 1.0000e-04
Tube Side Data Shell Side Data
Heat Transfer Coeff --- Heat Transfer Coeff ---
Tube Pressure Drop 0.00 kPa Shell Pressure Drop 62.00 kPa
Fouling 0.00000 C-h-m2/kJ Fouling 0.00000 C-h-m2/kJ
Tube Length 6.00 m Shell Passes 1
Tube O.D. 20.00 mm Shell Series 1
Tube Thickness 2.0000 mm Shell Parallel 1
Tube Pitch 50.0000 mm Baffle Type Single
Orientation Horizontal Baffle Cut(%Area) 20.00
Passes Per Shell 2 Baffle Orientation Horizontal
Tubes Per Shell 160 Spacing 800.0000 mm
Layout Angle Triangular (30 degrees) Diameter 739.0488 mm
TEMA Type A E L Area 60.32 m2
SPECS

	Spec Value	Curr Value	Rel Error	Active	Estimate
E-102 Heat Balance	0.0000 kJ/h	-2.604e-008 kJ/h	-7.793e-014	On	Off
E-102 UA	---	8388 kJ/C-h	---	On	Off

Detailed Specifications

E-102 Heat Balance
Type: Duty Pass: Error Spec Value: 0.0000 kJ/h
E-102 UA
Type: UA Pass: Overall Spec Value: ---
User Variables

RATING

Sizing

Overall Data
Configuration
# of Shells in Series 1 Tube Passes per Shell 2 Elevation (Base) 0.0000 m
# of Shells in Parallel 1 Exchange Orientation Horizontal First Tube Pass Flow Direction Counter
TEMA Type: A E L
Calculated Information
Shell HT Coeff --- Tube HT Coeff ---
Overall U 139.1 kJ/h-m2-C Overall UA 8388 kJ/C-h
Shell DP 62.00 kPa Tube DP 0.0000 kPa
Shell Vol per Shell 2.272 m3 Tube Vol per Shell 0.1930 m3
HT Area per Shell 60.32 m2
Shell Data
Shell and Tube Bundle
Shell Diameter 739.0 (mm) Tube Pitch 50.00 (mm) Shell Fouling 0.0000 (C-h-m2/kJ)
# of Tubes per Shell 160 Tube Layout Angle Triangular (30 degrees)
Shell Baffles
Shell Baffle Type Single Shell Baffle Orientation Horizontal
Baffle Cut (%Area) 20.00 Baffle Spacing 800.0 mm
Tube Data
Dimensions
OD 20.00 (mm) ID 16.00 (mm) Tube Thickness 2.000 (mm) Tube Length 6.000 (m)
Tube Properties
Tube Fouling 0.0000 (C-h-m2/kJ) Thermal Cond. 45.00 (W/m-K) Wall Cp --- (kJ/kg-C) Wall Density --- (kg/m3)
Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 m

	CW 2nd Stage	Compressed 2nd Stage	CW Out 2nd Stage
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000
Elevation (% of Height) (%)	0.00	0.00	0.00

	Cooled 2nd Stage
Diameter (m)	5.000e-002

Elevation (Base) (m) 0.0000
Elevation (Ground) (m) 0.0000
Elevation (% of Height) (%) 0.00
DETAILS

Overall/Detailed Performance

Duty: 3.341e+05 kJ/h UA Curv. Error: 0.00e-01 kJ/C-h
Heat Leak: 0.000e-01 kJ/h Hot Pinch Temp: 50.00 C
Heat Loss: 0.000e-01 kJ/h Cold Pinch Temp: 32.00 C
UA: 8.388e+03 kJ/C-h Ft Factor: ---
Min. Approach: 18.00 C Uncorrected Lmtd: 47.81 C
Lmtd: 39.83 C
TABLES

Shell Side - Overall Phase

Temperature	Pressure	Heat Flow	Enthalpy
(C)	(kPa)	(kJ/h)	(kJ/kgmole)
50.00	482.90	0.00	-878.12
148.89	544.90	334138.74	2063.24

UA	Molar Vap Frac	Mass Vap Frac	Heat of Vap.
(kJ/C-h)			(kJ/kgmole)
0.00	1.0000	1.0000	---
0.00	1.0000	1.0000	---

Shell Side - Vapour Phase

Mass Flow	Molecular Wt	Density	Mass Sp Heat	Viscosity	Thermal Cond
(kg/h)		(kg/m3)	(kJ/kg-C)	(cP)	(W/m-K)
3292.79	28.99	5.22	1.02	0.02	0.03
3292.79	28.99	4.50	1.04	0.02	0.03

Std Gas Flow	Z Factor	Pseudo Pc	Pseudo Tc	Pseudo Zc	Pseudo Omega
(STD_m3/h)		(kPa)	(C)		
2686.01	1.00	3773.07	-140.10	0.29	0.04
2686.01	1.00	3773.07	-140.10	0.29	0.04

Tube Side - Overall Phase

Temperature	Pressure	Heat Flow	Enthalpy
(C)	(kPa)	(kJ/h)	(kJ/kgmole)
32.00	101.30	0.00	-285676.72
49.00	101.30	334138.74	-284354.80

UA	Molar Vap Frac	Mass Vap Frac	Heat of Vap.
(kJ/C-h)			(kJ/kgmole)
0.00	0.0000	0.0000	---
0.00	0.0000	0.0000	---

Tube Side - Heavy Liquid Phase

Mass Flow	Density	Mass Sp Heat	Viscosity	Thermal Cond	Surface Tens
(kg/h)	(kg/m3)	(kJ/kg-C)	(cP)	(W/m-K)	(dyne/cm)
4553.66	1002.05	4.31	0.76	0.62	70.89
4553.66	989.02	4.32	0.55	0.64	67.91

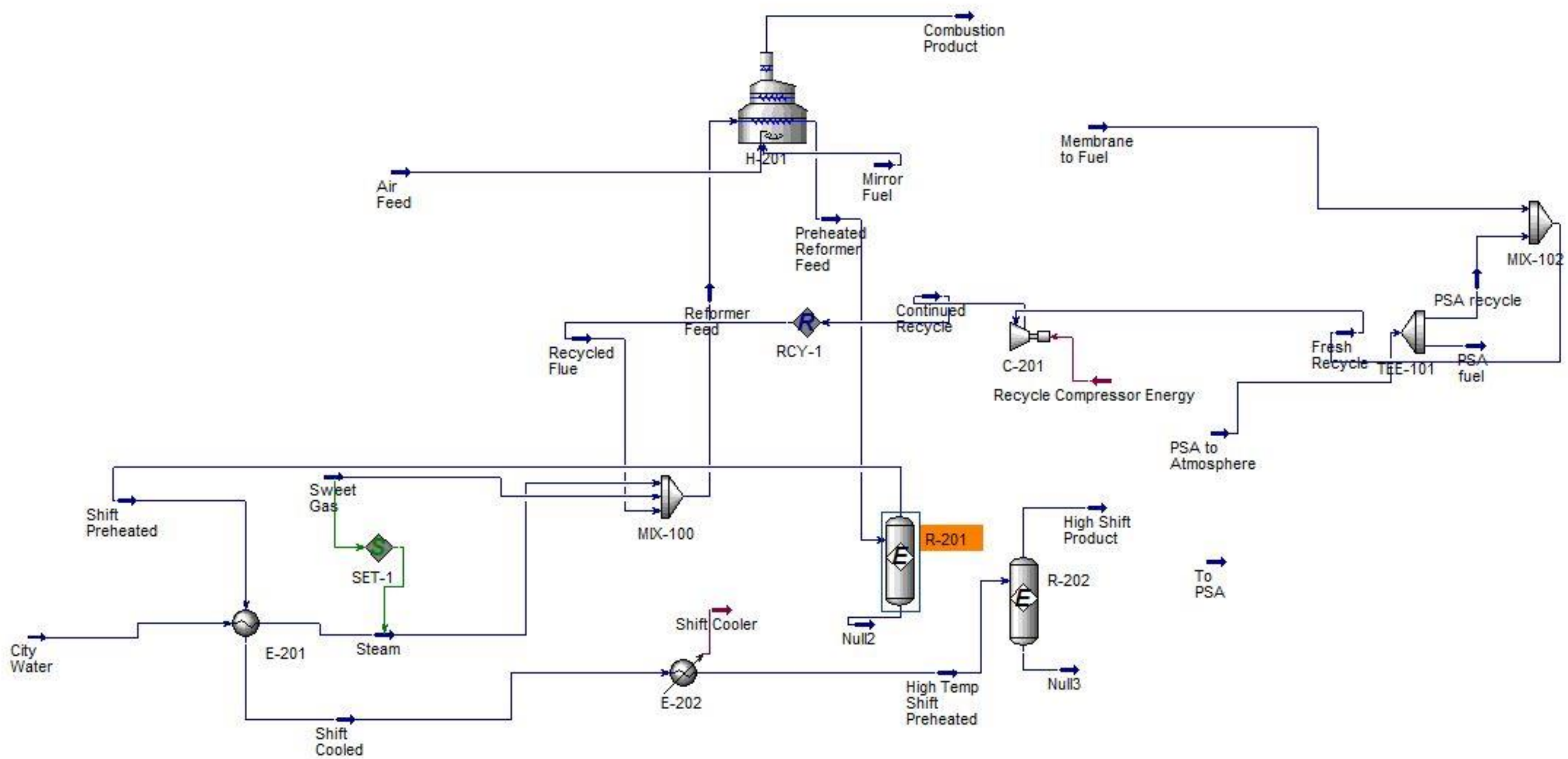
Molecular Wt	Sp Gravity	Pseudo Pc	Pseudo Tc	Pseudo Zc	Pseudo Omega
		(kPa)	(C)		
18.02	1.00	22120.00	374.15	0.26	0.34
18.02	0.99	22120.00	374.15	0.26	0.34

Tube Side - Mixed Liquid

Mass Flow	Density	Mass Sp Heat	Viscosity	Thermal Cond	Surface Tens
(kg/h)	(kg/m3)	(kJ/kg-C)	(cP)	(W/m-K)	(dyne/cm)
4553.66	1002.05	4.31	0.76	0.62	---
4553.66	989.02	4.32	0.55	0.64	---

Molecular Wt	Sp Gravity	Pseudo Pc	Pseudo Tc	Pseudo Zc	Pseudo Omega
		(kPa)	(C)		
18.02	1.00	22120.00	374.15	0.26	0.34
18.02	0.99	22120.00	374.15	0.26	0.34

HTFS



Combustion Product
Membrane to Fuel
H-201
Air Feed
Mirror Fuel
Preheated Reformer Feed
MIX-102
PSA recycle
Reformer Feed
Continued Recycle
Recycled Flue
RCY-1
C-201
Fresh Recycle
TEE-101
PSA fuel
Recycle Compressor Energy
PSA to Atmosphere
Sweet Gas
Shift Preheated
MIX-100
R-201
High Shift Product
SET-1
R-202
To PSA
Shift Cooler
City Water
E-201
Steam
Null2
Null3
E-202
High Temp Shift Preheated
Shift Cooled

****

INPUT SUMMARY

****

FLUID PACKAGE: Basis-1(Peng-Robinson)

Property Package Type: PengRob
Component List - 1: Methane /Hydrogen /H2O /CO2 /CO /S_Rhombic /H2S /Propane /Ethane /Oxygen /Nitrogen /
Reaction Set: Reforming Set
Reaction 'Methane to Hydrogen':
Reactants: Methane, Stoich Coeff -1 / H2O, Stoich Coeff -1 / CO, Stoich Coeff 1 / Hydrogen, Stoich Coeff 3 /
Basis Data: Basis = Activity / Phase = VapourPhase /
Reaction 'Water Gas Shift':
Reactants: CO, Stoich Coeff -1 / H2O, Stoich Coeff -1 / CO2, Stoich Coeff 1 / Hydrogen, Stoich Coeff 1 /
Basis Data: Basis = Activity / Phase = VapourPhase /
Reaction Set: Water Gas Shift Set
Reaction 'Rxn-1':
Reactants: CO, Stoich Coeff -1 / H2O, Stoich Coeff -1 / CO2, Stoich Coeff 1 / Hydrogen, Stoich Coeff 1 /
Basis Data: Basis = Activity / Phase = VapourPhase /
Reaction Set: Hydrodesulfurization Set
Reaction 'S to H2S':
Reactants: Hydrogen, Stoich Coeff -1 / S_Rhombic, Stoich Coeff -1 / H2S, Stoich Coeff 1 /
Basis Data: Component = Hydrogen / Phase = Overall /

FLOWSHEET: Main

Fluid Package: Basis-1
STREAM: Sweet Gas (Material Stream)
Vapour Fraction = 1
Pressure = 435.1131 psia
Molar Flow = 178.5726 lbmole/hr
Composition Basis (In Mole Fractions):Methane = 0.9/ Hydrogen = 0/ H2O = 0/ CO2 = 0/ CO = 0/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 0.1/ Oxygen = 0/ Nitrogen = 0/
UNIT OPERATION: R-201 (Equilibrium Reactor)
Feed Stream = Preheated Reformer Feed
Vapour Product = Shift Preheated
Liquid Product = Null2
Reaction Set=Reforming Set
Delta P = 127.053025 psi
UNIT OPERATION: R-202 (Equilibrium Reactor)
Feed Stream = High Temp Shift Preheated
Vapour Product = High Shift Product
Liquid Product = Null3
Reaction Set=Water Gas Shift Set
STREAM: City Water (Material Stream)
Temperature = 90 F
Pressure = 14.692319 psia
Composition Basis (In Mole Fractions):Methane = 0/ Hydrogen = 0/ H2O = 1/ CO2 = 0/ CO = 0/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 0/ Oxygen = 0/ Nitrogen = 0/
STREAM: Steam (Material Stream)
Vapour Fraction = 1
Pressure = 435.1131 psia
UNIT OPERATION: SET-1 (Set)
Target Object = Steam
Source Object = Sweet Gas
Target Variable = Molar Flow
Multiplier = 2
STREAM: Null2 (Material Stream)
STREAM: Null3 (Material Stream)
UNIT OPERATION: RCY-1 (Recycle)
Inlet Stream = Continued Recycle
Output Stream = Recycled Flue
STREAM: Recycled Flue (Material Stream)
Temperature = 643.613778 F
Pressure = 435.1131 psia
Molar Flow = 437.385365 lbmole/hr
Composition Basis (In Mole Fractions):Methane = 0.107687957/ Hydrogen =

0.174322542/ H2O = 0.199147419/ CO2 = 0.428045573/ CO = 0.00936779342/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 0.0814287157/ Oxygen = 0/ Nitrogen = 0/
STREAM: High Shift Product (Material Stream)
STREAM: High Temp Shift Preheated (Material Stream)
  Temperature = 482 F
STREAM: Continued Recycle (Material Stream)
  Pressure = 435.1131 psia
UNIT OPERATION: MIX-100 (Mixer)
  Feed Stream = Steam
  Feed Stream = Sweet Gas
  Feed Stream = Recycled Flue
  Product Stream = Reformer Feed
  UseTrivialSolution = True
STREAM: Reformer Feed (Material Stream)
STREAM: Preheated Reformer Feed (Material Stream)
  Temperature = 1472 F
STREAM: Shift Preheated (Material Stream)
UNIT OPERATION: E-201 (Heat Exchanger)
  TubeInletStream = City Water
  TubeOutletStream = Steam
  ShellInletStream = Shift Preheated
  ShellOutletStream = Shift Cooled
  TubeOuterDiameter = 0.787401575 in
  TubeInnerDiameter = 0.62992126 in
  TubeThickness = FEMPTY in
  HCurveName = City Water-Steam
  HCurveName = Shift Preheated-Shift Cooled
  ShellPressureDrop = 8.9923374 psi
STREAM: Shift Cooled (Material Stream)
UNIT OPERATION: H-201 (Fired Heater)
  Radiant Zone Inlet = Reformer Feed
  Radiant Zone Outlet = Preheated Reformer Feed
  Fuel Feed = Mirror Fuel
  Air Feed = Air Feed
  Combustion Product = Combustion Product
  CombustionEfficiency = 75 %
  ExcessAirPercent = 15 %
  ConvZoneNumberOfExternalPasses = 0
  EconZoneNumberOfExternalPasses = 0
  SSModel = Simple fired heater
STREAM: Air Feed (Material Stream)
  Temperature = 77 F
  Pressure = 14.692319 psia
  Composition Basis (In Mole Fractions):Methane = 0/ Hydrogen = 0/ H2O = 0/ CO2 = 0/ CO = 0/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 0/ Oxygen = 0.79/ Nitrogen = 0.21/
STREAM: Combustion Product (Material Stream)
UNIT OPERATION: E-202 (Cooler)
  Feed Stream = Shift Cooled
  Product Stream = High Temp Shift Preheated
  Energy Stream = Shift Cooler
  Pressure Drop = 8.9923374 psi
STREAM: Shift Cooler (Energy Stream)
STREAM: PSA to Atmosphere (Material Stream)
  Temperature = 527 F
  Pressure = 275.57163 psia
  Molar Flow = 390.2142 lbmole/hr
  Composition Basis (In Mole Fractions):Methane = 0.1387874/ Hydrogen = 0.06803645/ H2O = 0.40710572/ CO2 = 0.30769957/ CO = 0.0258849485/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 0.0524859119/ Oxygen = 0/ Nitrogen = 0/
UNIT OPERATION: C-201 (Compressor)
  Feed Stream = Fresh Recycle
  Product Stream = Continued Recycle
  Energy Stream = Recycle Compressor Energy
  CurveCollectionName = CC-0
  SelectedCurveCollection = True
  NumberOfCurves = 0
  NumberOfCurves = 0
  NumberOfCurves = 0
  EffCurveType = 0
  NumberOfCurves = 0
STREAM: Fresh Recycle (Material Stream)

STREAM: Recycle Compressor Energy (Energy Stream)
Vapour Fraction = 1
Temperature = 527 F
Pressure = 290.0754 psia
Molar Flow = 279.095085 lbmole/hr
Composition Basis (In Mole Flows):Methane = 25.13244/ Hydrogen = 65.47662/ H2O = 22.663288/ CO2 = 138.515018/ CO = 0/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 27.3077188/ Oxygen = 0/ Nitrogen = 0/
STREAM: To PSA (Material Stream)
Temperature = 543.5 F
Pressure = 290.0754 psia
Molar Flow = 798.17543 lbmole/hr
Composition Basis (In Mole Flows):Methane = 3.990326/ Hydrogen = 582.67578/ H2O = 207.518998/ CO2 = 3.990326/ CO = 0/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 0/ Oxygen = 0/ Nitrogen = 0/
STREAM: Mirror Fuel (Material Stream)
Temperature = 527 F
Pressure = 275.57163 psia
Composition Basis (In Mole Flows):Methane = 26.0667734/ Hydrogen = 46.9046709/ H2O = 43.4934221/ CO2 = 111.149856/ CO = 1.83354623/ S_Rhombic = 0/ H2S = 0/ Propane = 0/ Ethane = 3.72963201/ Oxygen = 0/ Nitrogen = 0/
UNIT OPERATION: MIX-102 (Mixer)
Feed Stream = Membrane to Fuel
Feed Stream = PSA recycle
Product Stream = Fresh Recycle
UseTrivialSolution = True
UNIT OPERATION: TEE-101 (Tee)
Feed Stream = PSA to Atmosphere
Product Stream = PSA recycleProduct Stream = PSA fuel
STREAM: PSA recycle (Material Stream)
STREAM: PSA fuel (Material Stream)
Molar Flow = 233.24668 lbmole/hr
###
OUTPUT SUMMARY
###
OKLAHOMA STATE UNIVERSIT Case Name: Hydrogen Production Final.hsc
Bedford, MA
USA Unit Set: Field

Date/Time: Wed Apr 01 17:55:20 2020

Basis-1 (Fluid Package): Component List

Fluid Package: Basis-1
COMPONENT LIST
Component List - 1 [HYSYS Databanks]

COMPONENT	TYPE	MOLECULAR WEIGHT	BOILING PT (F)	IDEAL LIQ DENSITY (lb/ft3)	CRITICAL TEMP (F)
Methane	Pure	16.04	-258.7	18.69	-116.4
Hydrogen	Pure	2.016	-422.7	4.361	-399.5
H2O	Pure	18.02	212.0	62.30	705.5
CO2	Pure	44.01	-109.4	51.52	87.71
CO	Pure	28.01	-312.6	49.90	-220.4
S_Rhombic	Pure	32.07	---	129.2	---
H2S	Pure	34.08	-75.37	49.22	212.8
Propane	Pure	44.10	-43.78	31.63	206.1
Ethane	Pure	30.07	-127.5	22.20	90.10
Oxygen	Pure	32.00	-297.3	71.02	-181.1
Nitrogen	Pure	28.01	-320.4	50.34	-232.5

(Continued..) Component List - 1 [HYSYS Databanks]

COMPONENT	CRITICAL PRES (psia)	CRITICAL VOL (ft3/lbmole)	ACENTRICITY	HEAT OF FORM (Btu/lbmole)
Methane	673.1	1.586	1.150e-002	-3.220e+004
Hydrogen	190.8	0.8250	-0.1201	0.0000
H2O	3208	0.9147	0.3440	-1.040e+005
CO2	1069	1.504	0.2389	-1.693e+005
CO	507.5	1.430	9.300e-002	-4.755e+004
S_Rhombic	---	---	---	1.192e+005
H2S	1306	1.570	8.100e-002	-8675
Propane	617.4	3.204	0.1524	-4.466e+004
Ethane	708.3	2.371	9.860e-002	-3.643e+004
Oxygen	736.8	1.173	1.900e-002	0.0000
Nitrogen	492.3	1.442	4.000e-002	0.0000

Case (Simulation Case): Mass and Energy Balance, Utility Balance, Process CO2 Emissions
----
Simulation Case: Case
OVERALL MASS BALANCE
In Stream Count Mass Flow Out Stream Count Mass Flow
(lb/hr) (lb/hr)
Sweet Gas Yes 3115 Null2 Yes 0.0000
City Water Yes 6434 Null3 Yes 0.0000
Air Feed Yes 4063 High Shift Product Yes 2.145e+004
Mirror Fuel Yes 6351 Combustion Product Yes 1.041e+004
Membrane to Fuel Yes 7861 PSA fuel Yes 5958
PSA to Atmosphere Yes 9967
Total In MassFlow (lb/hr) 3.779e+004 Total Out MassFlow (lb/hr) 3.782e+004
Mass Imbalance (lb/hr) 33.81 Rel Mass Imbalance Pct (%) 0.09
OVERALL ENERGY BALANCE
InStream Count Energy Flow OutStream Count Energy Flow
(Btu/hr) (Btu/hr)
Sweet Gas Yes -6.186e+06 Null2 Yes 0.000e-01
City Water Yes -4.386e+07 Null3 Yes 0.000e-01
Air Feed Yes -5.161e+02 High Shift Product Yes -7.970e+07
Mirror Fuel Yes -2.346e+07 Combustion Product Yes -3.545e+07
Recycle Compressor Energy Yes 5.396e+05 Shift Cooler Yes 2.734e+05
Membrane to Fuel Yes -2.641e+07 PSA fuel Yes -2.285e+07
PSA to Atmosphere Yes -3.823e+07
Total In EnergyFlow (Btu/hr) -1.376e+008 Total Out EnergyFlow (Btu/hr) -1.377e+008
Energy Imbalance (Btu/hr) -1.274e+005 Rel Energy Imbalance Pct (%) 0.09
OVERALL UTILITY BALANCE
PROCESS CO2 EMISSIONS
Inlet Stream Count IFPP (1995) IFPP (2007) EPA (2009)
(lb/hr) (lb/hr) (lb/hr)
Sweet Gas Yes 5.415e+04 6.446e+04 5.415e+04
City Water Yes 0.000e-01 0.000e-01 0.000e-01
Air Feed Yes 0.000e-01 0.000e-01 0.000e-01
Mirror Fuel Yes 1.367e+04 1.535e+04 1.367e+04
Membrane to Fuel Yes 1.456e+04 1.618e+04 1.456e+04
PSA to Atmosphere Yes 2.353e+04 2.700e+04 2.353e+04
Total from Inlets 1.059e+05 1.230e+05 1.059e+05
Total Carbon Fees 0.000e-01 0.000e-01 0.000e-01
from Inlets (Cost/hr)
Outlet Stream Count IFPP (1995) IFPP (2007) EPA (2009)
(lb/hr) (lb/hr) (lb/hr)
Null2 Yes 0.000e-01 0.000e-01 0.000e-01
Null3 Yes 0.000e-01 0.000e-01 0.000e-01
High Shift Product Yes 6.711e+04 7.799e+04 6.711e+04
Combustion Product Yes 6.448e+03 6.448e+03 6.448e+03
PSA fuel Yes 1.406e+04 1.614e+04 1.406e+04
Total from Outlets 8.762e+04 1.006e+05 8.762e+04
Total Carbon Fees 0.000e-01 0.000e-01 0.000e-01
from Outlets (Cost/hr)

Sweet Gas (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Sweet Gas Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS OVERALL VAPOUR PH. LIQUID PH.
Vapour / Phase Fraction 1.0000 1.0000 0.0000
Temperature: (F) -90.05 -90.05 -90.05
Pressure: (psia) 435.1 435.1 435.1
Molar Flow (lbmole/hr) 178.6 178.6 0.0000
Mass Flow (lb/hr) 3115 3115 0.0000
Std Ideal Liq VolFlow (barrel/day) 693.1 693.1 0.0000
Molar Enthalpy (Btu/lbmole) -3.464e+04 -3.464e+04 -4.016e+04
Molar Entropy (Btu/lbmole-F) 3.377e+01 3.377e+01 2.674e+01
Heat Flow (Btu/hr) -6.186e+06 -6.186e+06 0.000e-01
Liq VolFlow @Std Cond (barrel/day) 2.882e+005 2.882e+005 0.0000
COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)

Methane 160.7 0.9000 2578 0.8276 589.7 0.8508
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 17.86 0.1000 537.0 0.1724 103.4 0.1492
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 178.6 1.0000 3115 1.0000 693.1 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 160.7 0.9000 2578 0.8276 589.7 0.8508
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 17.86 0.1000 537.0 0.1724 103.4 0.1492
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 178.6 1.0000 3115 1.0000 693.1 1.0000
Liquid Phase Phase Fraction 0.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.5001 0.0000 0.3480 0.0000 0.3881
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.4999 0.0000 0.6520 0.0000 0.6119
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000

City Water (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: City Water Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS
OVERALL AQUEOUS PH.
Vapour / Phase Fraction 0.0000 1.0000
Temperature: (F) 90.00 90.00
Pressure: (psia) 14.69 14.69
Molar Flow (lbmole/hr) 357.1 357.1
Mass Flow (lb/hr) 6434 6434
Std Ideal Liq VolFlow (barrel/day) 441.4 441.4
Molar Enthalpy (Btu/lbmole) -1.228e+05 -1.228e+05
Molar Entropy (Btu/lbmole-F) 1.327e+01 1.327e+01
Heat Flow (Btu/hr) -4.386e+07 -4.386e+07
Liq VolFlow @Std Cond (barrel/day) 434.1 434.1
COMPOSITION
Overall Phase Vapour Fraction 0.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 357.1 1.0000 6434 1.0000 441.4 1.0000
CO2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	357.1	1.0000	6434	1.0000	441.4	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(lbmole/hr)		(lb/hr)		(barrel/day)	
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	357.1	1.0000	6434	1.0000	441.4	1.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	357.1	1.0000	6434	1.0000	441.4	1.0000

Steam (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Steam Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.	AQUEOUS PH.
Vapour / Phase Fraction	1.0000	1.0000	0.0000
Temperature: (F)	454.2	454.2	454.2
Pressure: (psia)	435.1	435.1	435.1
Molar Flow (lbmole/hr)	357.1	357.1	0.0000
Mass Flow (lb/hr)	6434	6434	0.0000
Std Ideal Liq VolFlow (barrel/day)	441.4	441.4	0.0000
Molar Enthalpy (Btu/lbmole)	-1.015e+05	-1.015e+05	-1.156e+05
Molar Entropy (Btu/lbmole-F)	3.866e+01	3.866e+01	2.321e+01
Heat Flow (Btu/hr)	-3.625e+07	-3.625e+07	0.000e-01
Liq VolFlow @Std Cond (barrel/day)	434.1	434.1	0.0000

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(lbmole/hr)		(lb/hr)		(barrel/day)	
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	357.1	1.0000	6434	1.0000	441.4	1.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	357.1	1.0000	6434	1.0000	441.4	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(lbmole/hr)		(lb/hr)		(barrel/day)	
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	357.1	1.0000	6434	1.0000	441.4	1.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	357.1	1.0000	6434	1.0000	441.4	1.0000

Aqueous Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW	MOLE FRAC	MASS FLOW	MASS FRAC	LIQVOL FLOW	LIQVOL FRAC
	(lbmole/hr)		(lb/hr)		(barrel/day)	
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Null2 (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Null2 Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.	AQUEOUS PH.
Vapour / Phase Fraction	0.0000	0.0000	1.0000
Temperature: (F)	1178	1178	1178
Pressure: (psia)	308.1	308.1	308.1
Molar Flow (lbmole/hr)	0.0000	0.0000	0.0000
Mass Flow (lb/hr)	0.0000	0.0000	0.0000
Std Ideal Liq VolFlow (barrel/day)	0.0000	0.0000	0.0000
Molar Enthalpy (Btu/lbmole)	-6.842e+04	-6.842e+04	-6.842e+04
Molar Entropy (Btu/lbmole-F)	4.757e+01	4.757e+01	4.757e+01
Heat Flow (Btu/hr)	0.000e-01	0.000e-01	0.000e-01
Liq VolFlow @Std Cond (barrel/day)	0.0000	0.0000	0.0000

COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.1615	0.0000	0.1268	0.0000	0.2393
Hydrogen	0.0000	0.1836	0.0000	0.0181	0.0000	0.1465
H2O	0.0000	0.3851	0.0000	0.3395	0.0000	0.1922
CO2	0.0000	0.1800	0.0000	0.3876	0.0000	0.2654
CO	0.0000	0.0387	0.0000	0.0531	0.0000	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0509	0.0000	0.0750	0.0000	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Vapour Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.1615	0.0000	0.1268	0.0000	0.2393
Hydrogen	0.0000	0.1836	0.0000	0.0181	0.0000	0.1465
H2O	0.0000	0.3852	0.0000	0.3395	0.0000	0.1922
CO2	0.0000	0.1800	0.0000	0.3876	0.0000	0.2654
CO	0.0000	0.0387	0.0000	0.0531	0.0000	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0509	0.0000	0.0750	0.0000	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Aqueous Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.1615	0.0000	0.1268	0.0000	0.2393
Hydrogen	0.0000	0.1836	0.0000	0.0181	0.0000	0.1465
H2O	0.0000	0.3851	0.0000	0.3395	0.0000	0.1922
CO2	0.0000	0.1800	0.0000	0.3876	0.0000	0.2654
CO	0.0000	0.0387	0.0000	0.0531	0.0000	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0509	0.0000	0.0750	0.0000	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Null3 (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Null3 Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH. AQUEOUS PH.
Vapour / Phase Fraction 0.0000 0.0000 1.0000
Temperature: (F) 543.5 543.5 543.5
Pressure: (psia) 290.1 290.1 290.1
Molar Flow (lbmole/hr) 0.0000 0.0000 0.0000
Mass Flow (lb/hr) 0.0000 0.0000 0.0000
Std Ideal Liq VolFlow (barrel/day) 0.0000 0.0000 0.0000
Molar Enthalpy (Btu/lbmole) -1.132e+05 -7.593e+04 -1.132e+05
Molar Entropy (Btu/lbmole-F) 2.584e+01 4.197e+01 2.584e+01
Heat Flow (Btu/hr) 0.000e-01 0.000e-01 0.000e-01
Liq VolFlow @Std Cond (barrel/day) 0.0000 0.0000 0.0000
COMPOSITION
Overall Phase Vapour Fraction 0.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.0012 0.0000 0.0010 0.0000 0.0034
Hydrogen 0.0000 0.0043 0.0000 0.0005 0.0000 0.0067
H2O 0.0000 0.9839 0.0000 0.9729 0.0000 0.9590
CO2 0.0000 0.0104 0.0000 0.0252 0.0000 0.0300
CO 0.0000 0.0000 0.0000 0.0001 0.0000 0.0001
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0002 0.0000 0.0003 0.0000 0.0009
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000
Vapour Phase Phase Fraction 0.0000 COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.1615 0.0000 0.1268 0.0000 0.2325
Hydrogen 0.0000 0.2198 0.0000 0.0217 0.0000 0.1704
H2O 0.0000 0.3490 0.0000 0.3076 0.0000 0.1693
CO2 0.0000 0.2162 0.0000 0.4654 0.0000 0.3097
CO 0.0000 0.0026 0.0000 0.0035 0.0000 0.0024
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0509 0.0000 0.0750 0.0000 0.1157
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000
Aqueous Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.0012 0.0000 0.0010 0.0000 0.0034
Hydrogen 0.0000 0.0043 0.0000 0.0005 0.0000 0.0067
H2O 0.0000 0.9839 0.0000 0.9729 0.0000 0.9590
CO2 0.0000 0.0104 0.0000 0.0252 0.0000 0.0300
CO 0.0000 0.0000 0.0000 0.0001 0.0000 0.0001
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0002 0.0000 0.0003 0.0000 0.0009
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000

Recycled Flue (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
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Material Stream: Recycled Flue Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (F) 643.6 643.6
Pressure: (psia) 435.1 435.1
Molar Flow (lbmole/hr) 437.4 437.4
Mass Flow (lb/hr) 1.190e+004 1.190e+004
Std Ideal Liq VolFlow (barrel/day) 1331 1331

Molar Enthalpy (Btu/lbmole) -9.459e+04 -9.459e+04
Molar Entropy (Btu/lbmole-F) 4.300e+01 4.300e+01
Heat Flow (Btu/hr) -4.137e+07 -4.137e+07
Liq VolFlow @Std Cond (barrel/day) 7.044e+005 7.044e+005
COMPOSITION
Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	47.10	0.1077	755.6	0.0635	172.8	0.1299
Hydrogen	76.25	0.1743	153.7	0.0129	150.7	0.1132
H2O	87.10	0.1991	1569	0.1318	107.7	0.0809
CO2	187.2	0.4280	8240	0.6922	683.6	0.5137
CO	4.097	0.0094	114.8	0.0096	9.831	0.0074
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	35.62	0.0814	1071	0.0900	206.2	0.1549
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	437.4	1.0000	1.190e+004	1.0000	1331	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	47.10	0.1077	755.6	0.0635	172.8	0.1299
Hydrogen	76.25	0.1743	153.7	0.0129	150.7	0.1132
H2O	87.10	0.1991	1569	0.1318	107.7	0.0809
CO2	187.2	0.4280	8240	0.6922	683.6	0.5137
CO	4.097	0.0094	114.8	0.0096	9.831	0.0074
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	35.62	0.0814	1071	0.0900	206.2	0.1549
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	437.4	1.0000	1.190e+004	1.0000	1331	1.0000

High Shift Product (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
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Material Stream: High Shift Product Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS

	OVERALL	VAPOUR PH.	AQUEOUS PH.
Vapour / Phase Fraction	1.0000	1.0000	0.0000
Temperature: (F)	543.5	543.5	543.5
Pressure: (psia)	290.1	290.1	290.1
Molar Flow (lbmole/hr)	1050	1050	0.0000
Mass Flow (lb/hr)	2.145e+004	2.145e+004	0.0000
Std Ideal Liq VolFlow (barrel/day)	2675	2675	0.0000
Molar Enthalpy (Btu/lbmole)	-7.593e+04	-7.593e+04	-1.132e+05
Molar Entropy (Btu/lbmole-F)	4.197e+01	4.197e+01	2.584e+01
Heat Flow (Btu/hr)	-7.970e+07	-7.970e+07	0.000e-01
Liq VolFlow @Std Cond (barrel/day)	3289	3289	0.0000

COMPOSITION
Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2325
Hydrogen	230.7	0.2198	465.1	0.0217	455.9	0.1704
H2O	366.3	0.3490	6599	0.3076	452.8	0.1693
CO2	226.9	0.2162	9985	0.4654	828.4	0.3097
CO	2.693	0.0026	75.44	0.0035	6.462	0.0024
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1157
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2675	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2325
Hydrogen	230.7	0.2198	465.1	0.0217	455.9	0.1704
H2O	366.3	0.3490	6599	0.3076	452.8	0.1693

CO2	226.9	0.2162	9985	0.4654	828.4	0.3097
CO	2.693	0.0026	75.44	0.0035	6.462	0.0024
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1157
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2675	1.0000

Aqueous Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.0012	0.0000	0.0010	0.0000	0.0034
Hydrogen	0.0000	0.0043	0.0000	0.0005	0.0000	0.0067
H2O	0.0000	0.9839	0.0000	0.9729	0.0000	0.9590
CO2	0.0000	0.0104	0.0000	0.0252	0.0000	0.0300
CO	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0002	0.0000	0.0003	0.0000	0.0009
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

High Temp Shift Preheated (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: High Temp Shift Preheated Fluid Package: Basis-1
Property Package: Peng-Robinson

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	482.0	482.0
Pressure: (psia)	290.1	290.1
Molar Flow (lbmole/hr)	1050	1050
Mass Flow (lb/hr)	2.145e+004	2.145e+004
Std Ideal Liq VolFlow (barrel/day)	2600	2600
Molar Enthalpy (Btu/lbmole)	-7.593e+04	-7.593e+04
Molar Entropy (Btu/lbmole-F)	4.176e+01	4.176e+01
Heat Flow (Btu/hr)	-7.970e+07	-7.970e+07
Liq VolFlow @Std Cond (barrel/day)	2821	2821

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2393
Hydrogen	192.7	0.1836	388.6	0.0181	380.9	0.1465
H2O	404.3	0.3852	7283	0.3395	499.7	0.1922
CO2	188.9	0.1800	8315	0.3876	689.8	0.2654
CO	40.65	0.0387	1139	0.0531	97.54	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2600	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2393
Hydrogen	192.7	0.1836	388.6	0.0181	380.9	0.1465
H2O	404.3	0.3852	7283	0.3395	499.7	0.1922
CO2	188.9	0.1800	8315	0.3876	689.8	0.2654
CO	40.65	0.0387	1139	0.0531	97.54	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2600	1.0000

Continued Recycle (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Continued Recycle Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	643.6	643.6
Pressure: (psia)	435.1	435.1
Molar Flow (lbmole/hr)	436.1	436.1
Mass Flow (lb/hr)	1.187e+004	1.187e+004
Std Ideal Liq VolFlow (barrel/day)	1327	1327
Molar Enthalpy (Btu/lbmole)	-9.458e+04	-9.458e+04
Molar Entropy (Btu/lbmole-F)	4.300e+01	4.300e+01
Heat Flow (Btu/hr)	-4.124e+07	-4.124e+07
Liq VolFlow @Std Cond (barrel/day)	7.023e+005	7.023e+005

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	46.92	0.1076	752.7	0.0634	172.1	0.1297
Hydrogen	76.16	0.1746	153.5	0.0129	150.5	0.1134
H2O	86.57	0.1985	1559	0.1314	107.0	0.0806
CO2	186.8	0.4284	8222	0.6926	682.1	0.5139
CO	4.063	0.0093	113.8	0.0096	9.749	0.0073
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	35.55	0.0815	1069	0.0900	205.8	0.1550
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	436.1	1.0000	1.187e+004	1.0000	1327	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	46.92	0.1076	752.7	0.0634	172.1	0.1297
Hydrogen	76.16	0.1746	153.5	0.0129	150.5	0.1134
H2O	86.57	0.1985	1559	0.1314	107.0	0.0806
CO2	186.8	0.4284	8222	0.6926	682.1	0.5139
CO	4.063	0.0093	113.8	0.0096	9.749	0.0073
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	35.55	0.0815	1069	0.0900	205.8	0.1550
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	436.1	1.0000	1.187e+004	1.0000	1327	1.0000

Reformer Feed (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Reformer Feed Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	432.9	432.9
Pressure: (psia)	435.1	435.1
Molar Flow (lbmole/hr)	973.1	973.1
Mass Flow (lb/hr)	2.145e+004	2.145e+004
Std Ideal Liq VolFlow (barrel/day)	2465	2465
Molar Enthalpy (Btu/lbmole)	-8.612e+04	-8.612e+04
Molar Entropy (Btu/lbmole-F)	4.169e+01	4.169e+01
Heat Flow (Btu/hr)	-8.380e+07	-8.380e+07
Liq VolFlow @Std Cond (barrel/day)	2416	2416

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	207.8	0.2136	3334	0.1554	762.5	0.3093
Hydrogen	76.25	0.0784	153.7	0.0072	150.7	0.0611
H2O	444.2	0.4565	8003	0.3731	549.1	0.2227
CO2	187.2	0.1924	8240	0.3841	683.6	0.2773
CO	4.097	0.0042	114.8	0.0053	9.831	0.0040
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 53.47 0.0550 1608 0.0750 309.5 0.1256
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 973.1 1.0000 2.145e+004 1.0000 2465 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 207.8 0.2136 3334 0.1554 762.5 0.3093
Hydrogen 76.25 0.0784 153.7 0.0072 150.7 0.0611
H2O 444.2 0.4565 8003 0.3731 549.1 0.2227
CO2 187.2 0.1924 8240 0.3841 683.6 0.2773
CO 4.097 0.0042 114.8 0.0053 9.831 0.0040
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 53.47 0.0550 1608 0.0750 309.5 0.1256
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 973.1 1.0000 2.145e+004 1.0000 2465 1.0000

Preheated Reformer Feed (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Preheated Reformer Feed Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (F) 1472 1472
Pressure: (psia) 435.1 435.1
Molar Flow (lbmole/hr) 973.1 973.1
Mass Flow (lb/hr) 2.145e+004 2.145e+004
Std Ideal Liq VolFlow (barrel/day) 2465 2465
Molar Enthalpy (Btu/lbmole) -7.380e+04 -7.380e+04
Molar Entropy (Btu/lbmole-F) 5.069e+01 5.069e+01
Heat Flow (Btu/hr) -7.181e+07 -7.181e+07
Liq VolFlow @Std Cond (barrel/day) 2416 2416
COMPOSITION
Overall Phase Vapour Fraction 1.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 207.8 0.2136 3334 0.1554 762.5 0.3093
Hydrogen 76.25 0.0784 153.7 0.0072 150.7 0.0611
H2O 444.2 0.4565 8003 0.3731 549.1 0.2227
CO2 187.2 0.1924 8240 0.3841 683.6 0.2773
CO 4.097 0.0042 114.8 0.0053 9.831 0.0040
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 53.47 0.0550 1608 0.0750 309.5 0.1256
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 973.1 1.0000 2.145e+004 1.0000 2465 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 207.8 0.2136 3334 0.1554 762.5 0.3093
Hydrogen 76.25 0.0784 153.7 0.0072 150.7 0.0611
H2O 444.2 0.4565 8003 0.3731 549.1 0.2227
CO2 187.2 0.1924 8240 0.3841 683.6 0.2773
CO 4.097 0.0042 114.8 0.0053 9.831 0.0040
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 53.47 0.0550 1608 0.0750 309.5 0.1256
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 973.1 1.0000 2.145e+004 1.0000 2465 1.0000

Shift Preheated (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Shift Preheated Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.	AQUEOUS PH.
Vapour / Phase Fraction	1.0000	1.0000	0.0000
Temperature: (F)	1178	1178	1178
Pressure: (psia)	308.1	308.1	308.1
Molar Flow (lbmole/hr)	1050	1050	0.0000
Mass Flow (lb/hr)	2.145e+004	2.145e+004	0.0000
Std Ideal Liq VolFlow (barrel/day)	2600	2600	0.0000
Molar Enthalpy (Btu/lbmole)	-6.842e+04	-6.842e+04	-6.842e+04
Molar Entropy (Btu/lbmole-F)	4.757e+01	4.757e+01	4.757e+01
Heat Flow (Btu/hr)	-7.181e+07	-7.181e+07	0.000e-01
Liq VolFlow @Std Cond (barrel/day)	2821	2821	0.0000

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2393
Hydrogen	192.7	0.1836	388.6	0.0181	380.9	0.1465
H2O	404.3	0.3852	7283	0.3395	499.7	0.1922
CO2	188.9	0.1800	8315	0.3876	689.8	0.2654
CO	40.65	0.0387	1139	0.0531	97.54	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2600	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2393
Hydrogen	192.7	0.1836	388.6	0.0181	380.9	0.1465
H2O	404.3	0.3852	7283	0.3395	499.7	0.1922
CO2	188.9	0.1800	8315	0.3876	689.8	0.2654
CO	40.65	0.0387	1139	0.0531	97.54	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2600	1.0000

Aqueous Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.1615	0.0000	0.1268	0.0000	0.2393
Hydrogen	0.0000	0.1836	0.0000	0.0181	0.0000	0.1465
H2O	0.0000	0.3851	0.0000	0.3395	0.0000	0.1922
CO2	0.0000	0.1800	0.0000	0.3876	0.0000	0.2654
CO	0.0000	0.0387	0.0000	0.0531	0.0000	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0509	0.0000	0.0750	0.0000	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Shift Cooled (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Shift Cooled Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	508.8	508.8
Pressure: (psia)	299.1	299.1
Molar Flow (lbmole/hr)	1050	1050
Mass Flow (lb/hr)	2.145e+004	2.145e+004
Std Ideal Liq VolFlow (barrel/day)	2600	2600
Molar Enthalpy (Btu/lbmole)	-7.567e+04	-7.567e+04
Molar Entropy (Btu/lbmole-F)	4.198e+01	4.198e+01
Heat Flow (Btu/hr)	-7.943e+07	-7.943e+07

Liq VolFlow @Std Cond (barrel/day) 2821 2821

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2393
Hydrogen	192.7	0.1836	388.6	0.0181	380.9	0.1465
H2O	404.3	0.3852	7283	0.3395	499.7	0.1922
CO2	188.9	0.1800	8315	0.3876	689.8	0.2654
CO	40.65	0.0387	1139	0.0531	97.54	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2600	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	169.6	0.1615	2720	0.1268	622.1	0.2393
Hydrogen	192.7	0.1836	388.6	0.0181	380.9	0.1465
H2O	404.3	0.3852	7283	0.3395	499.7	0.1922
CO2	188.9	0.1800	8315	0.3876	689.8	0.2654
CO	40.65	0.0387	1139	0.0531	97.54	0.0375
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	53.47	0.0509	1608	0.0750	309.5	0.1191
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1050	1.0000	2.145e+004	1.0000	2600	1.0000

Air Feed (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Air Feed Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	77.00	77.00
Pressure: (psia)	14.69	14.69
Molar Flow (lbmole/hr)	130.4	130.4
Mass Flow (lb/hr)	4063	4063
Std Ideal Liq VolFlow (barrel/day)	263.5	263.5
Molar Enthalpy (Btu/lbmole)	-3.959e+00	-3.959e+00
Molar Entropy (Btu/lbmole-F)	3.581e+01	3.581e+01
Heat Flow (Btu/hr)	-5.161e+02	-5.161e+02
Liq VolFlow @Std Cond (barrel/day)	2.109e+005	2.109e+005

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	103.0	0.7900	3296	0.8112	198.4	0.7528
Nitrogen	27.38	0.2100	766.9	0.1888	65.12	0.2472
Total	130.4	1.0000	4063	1.0000	263.5	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 103.0 0.7900 3296 0.8112 198.4 0.7528
Nitrogen 27.38 0.2100 766.9 0.1888 65.12 0.2472
Total 130.4 1.0000 4063 1.0000 263.5 1.0000

Combustion Product (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Combustion Product Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (F) 1640 1640
Pressure: (psia) 14.69 14.69
Molar Flow (lbmole/hr) 341.0 341.0
Mass Flow (lb/hr) 1.041e+004 1.041e+004
Std Ideal Liq VolFlow (barrel/day) 815.9 815.9
Molar Enthalpy (Btu/lbmole) -1.040e+05 -1.040e+05
Molar Entropy (Btu/lbmole-F) 5.587e+01 5.587e+01
Heat Flow (Btu/hr) -3.545e+07 -3.545e+07
Liq VolFlow @Std Cond (barrel/day) 731.3 731.3
COMPOSITION
Overall Phase Vapour Fraction 1.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 153.7 0.4507 2769 0.2659 190.0 0.2329
CO2 146.5 0.4296 6448 0.6192 534.9 0.6556
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 13.43 0.0394 429.9 0.0413 25.87 0.0317
Nitrogen 27.38 0.0803 766.9 0.0736 65.12 0.0798
Total 341.0 1.0000 1.041e+004 1.0000 815.9 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 153.7 0.4507 2769 0.2659 190.0 0.2329
CO2 146.5 0.4296 6448 0.6192 534.9 0.6556
CO 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 13.43 0.0394 429.9 0.0413 25.87 0.0317
Nitrogen 27.38 0.0803 766.9 0.0736 65.12 0.0798
Total 341.0 1.0000 1.041e+004 1.0000 815.9 1.0000

PSA to Atmosphere (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: PSA to Atmosphere Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (F) 527.0 527.0
Pressure: (psia) 275.6 275.6
Molar Flow (lbmole/hr) 390.2 390.2
Mass Flow (lb/hr) 9967 9967
Std Ideal Liq VolFlow (barrel/day) 1029 1029
Molar Enthalpy (Btu/lbmole) -9.796e+04 -9.796e+04
Molar Entropy (Btu/lbmole-F) 4.365e+01 4.365e+01
Heat Flow (Btu/hr) -3.823e+07 -3.823e+07
Liq VolFlow @Std Cond (barrel/day) 993.2 993.2
COMPOSITION
Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	54.16	0.1388	868.8	0.0872	198.7	0.1932
Hydrogen	26.55	0.0680	53.52	0.0054	52.46	0.0510
H2O	158.9	0.4071	2862	0.2871	196.4	0.1909
CO2	120.1	0.3077	5284	0.5302	438.4	0.4262
CO	10.10	0.0259	282.9	0.0284	24.23	0.0236
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	20.48	0.0525	615.9	0.0618	118.6	0.1152
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	390.2	1.0000	9967	1.0000	1029	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	54.16	0.1388	868.8	0.0872	198.7	0.1932
Hydrogen	26.55	0.0680	53.52	0.0054	52.46	0.0510
H2O	158.9	0.4071	2862	0.2871	196.4	0.1909
CO2	120.1	0.3077	5284	0.5302	438.4	0.4262
CO	10.10	0.0259	282.9	0.0284	24.23	0.0236
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	20.48	0.0525	615.9	0.0618	118.6	0.1152
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	390.2	1.0000	9967	1.0000	1029	1.0000

Fresh Recycle (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Fresh Recycle Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	526.5	526.5
Pressure: (psia)	275.6	275.6
Molar Flow (lbmole/hr)	436.1	436.1
Mass Flow (lb/hr)	1.187e+004	1.187e+004
Std Ideal Liq VolFlow (barrel/day)	1327	1327
Molar Enthalpy (Btu/lbmole)	-9.582e+04	-9.582e+04
Molar Entropy (Btu/lbmole-F)	4.271e+01	4.271e+01
Heat Flow (Btu/hr)	-4.178e+07	-4.178e+07
Liq VolFlow @Std Cond (barrel/day)	7.023e+005	7.023e+005

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	46.92	0.1076	752.7	0.0634	172.1	0.1297
Hydrogen	76.16	0.1746	153.5	0.0129	150.5	0.1134
H2O	86.57	0.1985	1559	0.1314	107.0	0.0806
CO2	186.8	0.4284	8222	0.6926	682.1	0.5139
CO	4.063	0.0093	113.8	0.0096	9.749	0.0073
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	35.55	0.0815	1069	0.0900	205.8	0.1550
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	436.1	1.0000	1.187e+004	1.0000	1327	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	46.92	0.1076	752.7	0.0634	172.1	0.1297
Hydrogen	76.16	0.1746	153.5	0.0129	150.5	0.1134
H2O	86.57	0.1985	1559	0.1314	107.0	0.0806
CO2	186.8	0.4284	8222	0.6926	682.1	0.5139
CO	4.063	0.0093	113.8	0.0096	9.749	0.0073
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Ethane	35.55	0.0815	1069	0.0900	205.8	0.1550
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	436.1	1.0000	1.187e+004	1.0000	1327	1.0000

Membrane to Fuel (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Membrane to Fuel Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	527.0	527.0
Pressure: (psia)	290.1	290.1
Molar Flow (lbmole/hr)	279.1	279.1
Mass Flow (lb/hr)	7861	7861
Std Ideal Liq VolFlow (barrel/day)	913.4	913.4
Molar Enthalpy (Btu/lbmole)	-9.461e+04	-9.461e+04
Molar Entropy (Btu/lbmole-F)	4.176e+01	4.176e+01
Heat Flow (Btu/hr)	-2.641e+07	-2.641e+07
Liq VolFlow @Std Cond (barrel/day)	4.501e+005	4.501e+005

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	25.13	0.0900	403.2	0.0513	92.21	0.1010
Hydrogen	65.48	0.2346	132.0	0.0168	129.4	0.1416
H2O	22.66	0.0812	408.3	0.0519	28.01	0.0307
CO2	138.5	0.4963	6096	0.7755	505.7	0.5537
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	27.31	0.0978	821.1	0.1045	158.1	0.1731
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	279.1	1.0000	7861	1.0000	913.4	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	25.13	0.0900	403.2	0.0513	92.21	0.1010
Hydrogen	65.48	0.2346	132.0	0.0168	129.4	0.1416
H2O	22.66	0.0812	408.3	0.0519	28.01	0.0307
CO2	138.5	0.4963	6096	0.7755	505.7	0.5537
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	27.31	0.0978	821.1	0.1045	158.1	0.1731
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	279.1	1.0000	7861	1.0000	913.4	1.0000

To PSA (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: To PSA Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	543.5	543.5
Pressure: (psia)	290.1	290.1
Molar Flow (lbmole/hr)	798.2	798.2
Mass Flow (lb/hr)	5153	5153
Std Ideal Liq VolFlow (barrel/day)	1437	1437
Molar Enthalpy (Btu/lbmole)	-2.468e+04	-2.468e+04
Molar Entropy (Btu/lbmole-F)	3.250e+01	3.250e+01
Heat Flow (Btu/hr)	-1.970e+07	-1.970e+07
Liq VolFlow @Std Cond (barrel/day)	1.290e+006	1.290e+006

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	3.990	0.0050	64.02	0.0124	14.64	0.0102

Hydrogen	582.7	0.7300	1175	0.2280	1151	0.8012
H2O	207.5	0.2600	3738	0.7255	256.5	0.1785
CO2	3.990	0.0050	175.6	0.0341	14.57	0.0101
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	798.2	1.0000	5153	1.0000	1437	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	3.990	0.0050	64.02	0.0124	14.64	0.0102
Hydrogen	582.7	0.7300	1175	0.2280	1151	0.8012
H2O	207.5	0.2600	3738	0.7255	256.5	0.1785
CO2	3.990	0.0050	175.6	0.0341	14.57	0.0101
CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	798.2	1.0000	5153	1.0000	1437	1.0000

Mirror Fuel (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Mirror Fuel Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	527.0	527.0
Pressure: (psia)	275.6	275.6
Molar Flow (lbmole/hr)	233.2	233.2
Mass Flow (lb/hr)	6351	6351
Std Ideal Liq VolFlow (barrel/day)	673.9	673.9
Molar Enthalpy (Btu/lbmole)	-1.006e+05	-1.006e+05
Molar Entropy (Btu/lbmole-F)	4.152e+01	4.152e+01
Heat Flow (Btu/hr)	-2.346e+07	-2.346e+07
Liq VolFlow @Std Cond (barrel/day)	3.756e+005	3.756e+005

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	26.07	0.1118	418.2	0.0658	95.64	0.1419
Hydrogen	46.90	0.2012	94.56	0.0149	92.68	0.1375
H2O	43.49	0.1865	783.5	0.1234	53.76	0.0798
CO2	111.1	0.4767	4892	0.7702	405.8	0.6022
CO	1.834	0.0079	51.36	0.0081	4.399	0.0065
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	3.730	0.0160	112.1	0.0177	21.59	0.0320
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	233.2	1.0000	6351	1.0000	673.9	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	26.07	0.1118	418.2	0.0658	95.64	0.1419
Hydrogen	46.90	0.2012	94.56	0.0149	92.68	0.1375
H2O	43.49	0.1865	783.5	0.1234	53.76	0.0798
CO2	111.1	0.4767	4892	0.7702	405.8	0.6022
CO	1.834	0.0079	51.36	0.0081	4.399	0.0065
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	3.730	0.0160	112.1	0.0177	21.59	0.0320
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	233.2	1.0000	6351	1.0000	673.9	1.0000

PSA recycle (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: PSA recycle Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	527.0	527.0
Pressure: (psia)	275.6	275.6
Molar Flow (lbmole/hr)	157.0	157.0
Mass Flow (lb/hr)	4009	4009
Std Ideal Liq VolFlow (barrel/day)	413.8	413.8
Molar Enthalpy (Btu/lbmole)	-9.796e+04	-9.796e+04
Molar Entropy (Btu/lbmole-F)	4.365e+01	4.365e+01
Heat Flow (Btu/hr)	-1.538e+07	-1.538e+07
Liq VolFlow @Std Cond (barrel/day)	399.5	399.5

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	21.79	0.1388	349.5	0.0872	79.93	0.1932
Hydrogen	10.68	0.0680	21.53	0.0054	21.10	0.0510
H2O	63.90	0.4071	1151	0.2871	78.99	0.1909
CO2	48.30	0.3077	2126	0.5302	176.3	0.4262
CO	4.063	0.0259	113.8	0.0284	9.749	0.0236
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	8.239	0.0525	247.7	0.0618	47.69	0.1152
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	157.0	1.0000	4009	1.0000	413.8	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	21.79	0.1388	349.5	0.0872	79.93	0.1932
Hydrogen	10.68	0.0680	21.53	0.0054	21.10	0.0510
H2O	63.90	0.4071	1151	0.2871	78.99	0.1909
CO2	48.30	0.3077	2126	0.5302	176.3	0.4262
CO	4.063	0.0259	113.8	0.0284	9.749	0.0236
S_Rhombic	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	8.239	0.0525	247.7	0.0618	47.69	0.1152
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	157.0	1.0000	4009	1.0000	413.8	1.0000

PSA fuel (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: PSA fuel Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (F)	527.0	527.0
Pressure: (psia)	275.6	275.6
Molar Flow (lbmole/hr)	233.2	233.2
Mass Flow (lb/hr)	5958	5958
Std Ideal Liq VolFlow (barrel/day)	614.9	614.9
Molar Enthalpy (Btu/lbmole)	-9.796e+04	-9.796e+04
Molar Entropy (Btu/lbmole-F)	4.365e+01	4.365e+01
Heat Flow (Btu/hr)	-2.285e+07	-2.285e+07
Liq VolFlow @Std Cond (barrel/day)	593.7	593.7

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (lbmole/hr)	MOLE FRAC	MASS FLOW (lb/hr)	MASS FRAC	LIQVOL FLOW (barrel/day)	LIQVOL FRAC
Methane	32.37	0.1388	519.3	0.0872	118.8	0.1932
Hydrogen	15.87	0.0680	31.99	0.0054	31.36	0.0510
H2O	94.96	0.4071	1711	0.2871	117.4	0.1909
CO2	71.77	0.3077	3159	0.5302	262.0	0.4262
CO	6.038	0.0259	169.1	0.0284	14.49	0.0236

S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 12.24 0.0525 368.1 0.0618 70.87 0.1152
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 233.2 1.0000 5958 1.0000 614.9 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(lbmole/hr) (lb/hr) (barrel/day)
Methane 32.37 0.1388 519.3 0.0872 118.8 0.1932
Hydrogen 15.87 0.0680 31.99 0.0054 31.36 0.0510
H2O 94.96 0.4071 1711 0.2871 117.4 0.1909
CO2 71.77 0.3077 3159 0.5302 262.0 0.4262
CO 6.038 0.0259 169.1 0.0284 14.49 0.0236
S_Rhombic 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ethane 12.24 0.0525 368.1 0.0618 70.87 0.1152
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 233.2 1.0000 5958 1.0000 614.9 1.0000
R-201 (Equilibrium Reactor): Design, Reactions, Rating

Equilibrium Reactor: R-201
CONNECTIONS
Inlet Stream Connections
Stream Name From Unit Operation
Preheated Reformer Feed H-201 Fired Heater
Outlet Stream Connections
Stream Name To Unit Operation
Shift Preheated Heat Exchanger: E-201
Null2
Energy Stream Connections
Stream Name From Unit Operation
PARAMETERS
Physical Parameters Optional Heat Transfer
Delta P Vessel Volume Duty Energy Stream
127.1 psi --- 0.0000 Btu/hr
User Variables
REACTION DETAILS
Component Molecular Weight Stoichiometric Coefficient
Methane 16.04 -1
H2O 18.02 -1
CO 28.01 1
Hydrogen 2.016 3
Component Molecular Weight Stoichiometric Coefficient
CO 28.01 -1
H2O 18.02 -1
CO2 44.01 1
Hydrogen 2.016 1
REACTION RESULTS FOR : Reforming Set
Extents
Act. % Conv. Base Comp. Eqm Constant Rxn Extent
Methane to Hydrogen 18.41 Methane 1.742 4.821e-003
Water Gas Shift 41.66 CO 2.234 2.151e-004
Balance
Total Inflow Total Rxn Total Outflow
Methane 2.618e-002 -4.821e-003 2.136e-002
Hydrogen 9.607e-003 1.468e-002 2.429e-002
H2O 5.598e-002 -5.036e-003 5.094e-002
CO2 2.359e-002 2.151e-004 2.380e-002
CO 5.163e-004 4.606e-003 5.122e-003
S_Rhombic 0.0000 0.0000 0.0000
H2S 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000
Ethane 6.738e-003 8.674e-019 6.738e-003
Oxygen 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000
RATING

R-202 (Equilibrium Reactor): Design, Reactions, Rating

Equilibrium Reactor: R-202
CONNECTIONS
Inlet Stream Connections

Stream Name	From Unit Operation
High Temp Shift Preheated	E-202 Cooler

Outlet Stream Connections

Stream Name	To Unit Operation
High Shift Product	
Null3	

Energy Stream Connections

Stream Name	From Unit Operation

PARAMETERS

Physical Parameters		Optional Heat Transfer	
Delta P	Vessel Volume	Duty	Energy Stream
0.0000 psi	---	0.0000 Btu/hr	

User Variables
REACTION DETAILS

Component	Molecular Weight	Stoichiometric Coefficient
CO	28.01	-1
H2O	18.02	-1
CO2	44.01	1
Hydrogen	2.016	1

REACTION RESULTS FOR : Water Gas Shift Set
Extents

	Act. % Conv.	Base Comp.	Eqm Constant	Rxn Extent
Rxn-1	93.38	CO	55.07	4.783e-003

Balance

	Total Inflow	Total Rxn	Total Outflow
Methane	2.136e-002	0.0000	2.136e-002
Hydrogen	2.429e-002	4.783e-003	2.907e-002
H2O	5.094e-002	-4.783e-003	4.616e-002
CO2	2.380e-002	4.783e-003	2.859e-002
CO	5.122e-003	-4.783e-003	3.393e-004
S_Rhombic	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000
Ethane	6.738e-003	0.0000	6.738e-003
Oxygen	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000

RATING

SET-1 (Set): Design

Set: SET-1

Target		OBJECT	VARIABLE
Steam	Molar Flow		
Source		OBJECT	VARIABLE
Sweet Gas	Molar Flow		

Equation Parameters

MULTIPLIER	OFFSET
2.000	0.0000 lbmole/hr

User Variables

RCY-1 (Recycle): Design

Recycle: RCY-1
CONNECTIONS
Inlet Stream

Stream Name	From Unit Operation
Continued Recycle	C-201 Compressor

Outlet Stream

Stream Name	To Unit Operation
Recycled Flue	MIX-100 Mixer

TOLERANCE
Vapour Fraction: 10.00 Temperature: 10.00 Pressure: 10.00
Flow: 10.00 Enthalpy: 10.00 Composition: 10.00
NUMERICAL
Acceleration Type: Wegstein Iteration Type: Nested
Maximum Iterations: 10 Iteration Count: 0
Wegstein Count: 3 Q Minimum: -20.00 Q Maximum: 0.0000
Iteration History

Iteration	Variable	Outlet Value	Inlet Value

0 Converged --- ---
User Variables
MIX-100 (Mixer): Design, Rating

Mixer: MIX-100
CONNECTIONS
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Steam E-201 Heat Exchanger
Sweet Gas
Recycled Flue RCY-1 Recycle
Outlet Stream
STREAM NAME TO UNIT OPERATION
Reformer Feed H-201 Fired Heater
PARAMETERS

MIX-102 (Mixer): Design, Rating

Mixer: MIX-102
CONNECTIONS
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Membrane to Fuel
PSA recycle TEE-101 Tee
Outlet Stream
STREAM NAME TO UNIT OPERATION
Fresh Recycle C-201 Compressor
PARAMETERS
User Variables

E-201 (Heat Exchanger): Design, Rating, Details, Tables, HTFS Results, Exchanger Design and Rating
----
Heat Exchanger: E-201
CONNECTIONS
Tube Side Shell Side
Inlet Outlet Inlet Outlet
Name City Water Name Steam Name Shift Preheated Name Shift Cooled
From Op. To Op. MIX-100 From Op. R-201 To Op. E-202
Op. Type Op. Type Mixer Op. Type Equilibrium Reactor Op. Type Cooler
Temp 90.00 F Temp 454.24 F Temp 1178.25 F Temp 508.81 F
PARAMETERS
Heat Exchanger Model: Simple End Point
Tube Side DeltaP: -420.4 psi Shell Side DeltaP: 8.992 psi Passes: ---
UA: 1.609e+004 Btu/F-hr Tolerance: 1.0000e-04
Tube Side Data Shell Side Data
Heat Transfer Coeff --- Heat Transfer Coeff ---
Tube Pressure Drop -420.42 psi Shell Pressure Drop 8.99 psi
Fouling 0.00000 F-hr-ft2/Btu Fouling 0.00000 F-hr-ft2/Btu
Tube Length 19.69 ft Shell Passes 1
Tube O.D. 0.79 in Shell Series 1
Tube Thickness 0.0787 in Shell Parallel 1
Tube Pitch 1.9685 in Baffle Type Single
Orientation Horizontal Baffle Cut(%Area) 20.00
Passes Per Shell 2 Baffle Orientation Horizontal
Tubes Per Shell 160 Spacing 31.4961 in
Layout Angle Triangular (30 degrees) Diameter 29.0964 in
TEMA Type A E L Area 649.26 ft2
SPECS
Spec Value Curr Value Rel Error Active Estimate
E-103 Heat Balance 0.0000 Btu/hr -3.103e-009 Btu/hr -4.076e-016 On Off
E-103 UA --- 1.609e+004 Btu/F-hr --- On Off
Detailed Specifications
E-103 Heat Balance
Type: Duty Pass: Error Spec Value: 0.0000 Btu/hr
E-103 UA
Type: UA Pass: Overall Spec Value: ---
User Variables
RATING
Sizing
Overall Data
Configuration
# of Shells in Series 1 Tube Passes per Shell 2 Elevation (Base) 0.0000 ft
# of Shells in Parallel 1 Exchange Orientation Horizontal First Tube Pass Flow Direction Counter
TEMA Type: A E L

Calculated Information
Shell HT Coeff --- Tube HT Coeff ---
Overall U 24.78 Btu/hr-ft2-F Overall UA 1.609e+004 Btu/F-hr
Shell DP 8.992 psi Tube DP -420.4 psi
Shell Vol per Shell 80.24 ft3 Tube Vol per Shell 6.816 ft3
HT Area per Shell 649.3 ft2
Shell Data
Shell and Tube Bundle

Shell Diameter 29.10	Tube Pitch 1.969	Shell Fouling 0.0000
(in)	(in)	(F-hr-ft2/Btu)

# of Tubes per Shell 160 Tube Layout Angle Triangular (30 degrees)
Shell Baffles
Shell Baffle Type Single Shell Baffle Orientation Horizontal
Baffle Cut (%Area) 20.00 Baffle Spacing 31.50 in
Tube Data
Dimensions

OD 0.7874	ID 0.6299	Tube Thickness 7.874e-002	Tube Length 19.69
(in)	(in)	(in)	(ft)

Tube Properties

Tube Fouling 0.0000	Thermal Cond. 26.00	Wall Cp ---	Wall Density ---
(F-hr-ft2/Btu)	(Btu/hr-ft-F)	(Btu/lb-F)	(lb/ft3)

Nozzle Parameters
Overall/Detailed Performance
Duty: 7.614e+06 Btu/hr UA Curv. Error: 0.00e-01 Btu/F-hr
Heat Leak: 0.000e-01 Btu/hr Hot Pinch Temp: 508.8 F
Heat Loss: 0.000e-01 Btu/hr Cold Pinch Temp: 90.00 F
UA: 1.609e+04 Btu/F-hr Ft Factor: ---
Min. Approach: 418.8 F Uncorrected Lmtd: 557.6 F
Lmtd: 473.3 F
TABLES
Shell Side - Overall Phase

Temperature (F)	Pressure (psia)	Heat Flow (Btu/hr)	Enthalpy (Btu/lbmole)
508.81	299.07	0.00	-75671.24
1178.25	308.06	7614173.82	-68417.17

UA (Btu/F-hr)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
0.00	1.0000	1.0000	---
0.00	1.0000	1.0000	---

Shell Side - Vapour Phase

Mass Flow (lb/hr)	Molecular Wt	Density (lb/ft3)	Mass Sp Heat (Btu/lb-F)	Viscosity (cP)	Thermal Cond (Btu/hr-ft-F)
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.36	0.57	0.03	0.07

Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psia)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
9.54	0.99	1627.59	191.40	0.28	0.16
9.54	1.00	1627.59	191.40	0.28	0.16

Shell Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	Mass Sp Heat (Btu/lb-F)	Viscosity (cP)	Thermal Cond (Btu/hr-ft-F)	Surface Tens (dyne/cm)
---	---	---	---	---	---
0.00	0.36	0.57	0.00	0.08	0.00

Molecular Wt	Sp Gravity	Pseudo Pc (psia)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---
20.44	0.01	1627.54	191.38	0.28	0.16

Shell Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	Mass Sp Heat (Btu/lb-F)	Viscosity (cP)	Thermal Cond (Btu/hr-ft-F)	Surface Tens (dyne/cm)
---	---	---	---	---	---
0.00	0.36	0.57	0.00	0.08	---

Molecular Wt	Sp Gravity	Pseudo Pc (psia)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---
20.44	0.01	1627.54	191.38	0.28	0.16

Tube Side - Overall Phase

Temperature (F)	Pressure (psia)	Heat Flow (Btu/hr)	Enthalpy (Btu/lbmole)
90.00	14.69	0.00	-122811.45
331.92	105.60	1646365.88	-118201.70
454.24	435.11	7614173.82	-101492.12

UA Molar Vap Frac Mass Vap Frac Heat of Vap.
(Btu/F-hr) (Btu/lbmole)
0.00 0.0000 0.0000 ---
0.00 0.0000 0.0000 ---
0.00 1.0000 1.0000 ---
Tube Side - Vapour Phase
Mass Flow Molecular Wt Density Mass Sp Heat Viscosity Thermal Cond
(lb/hr) (lb/ft3) (Btu/lb-F) (cP) (Btu/hr-ft-F)
--- --- --- --- --- ---
0.00 18.02 0.23 0.48 0.01 0.02
6434.01 18.02 0.91 0.54 0.02 0.03
Std Gas Flow Z Factor Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(MMSCFD) (psia) (F)
--- --- --- --- --- ---
0.00 0.96 3208.23 705.47 0.26 0.34
3.25 0.88 3208.23 705.47 0.26 0.34
Tube Side - Light Liquid Phase
Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(lb/hr) (lb/ft3) (Btu/lb-F) (cP) (Btu/hr-ft-F) (dyne/cm)
6434.01 62.55 1.03 0.76 0.36 70.85
6434.01 55.43 1.11 0.16 0.39 45.17
0.00 50.85 1.26 0.11 0.37 29.80
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(psia) (F)
18.02 1.00 3208.23 705.47 0.26 0.34
18.02 0.89 3208.23 705.47 0.26 0.34
18.02 0.81 3208.23 705.47 0.26 0.34
Tube Side - Mixed Liquid
Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(lb/hr) (lb/ft3) (Btu/lb-F) (cP) (Btu/hr-ft-F) (dyne/cm)
6434.01 62.55 1.03 0.76 0.36 ---
6434.01 55.43 1.11 0.16 0.39 ---
0.00 50.85 1.26 0.11 0.37 ---
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(psia) (F)
18.02 1.00 3208.23 705.47 0.26 0.34
18.02 0.89 3208.23 705.47 0.26 0.34
18.02 0.81 3208.23 705.47 0.26 0.34
HTFS
H-201 (Fired Heater): Design, Rating, Performance

Fired Heater: H-201
CONNECTIONS
Combustion Product Combustion Product Fuel Gas Feed Air Feed
Economizer Zone Connections
Econ Zone Inlet Econ Zone Outlet # of Tubes 0
Convective Zone
Conv Zone Inlet Conv Zone Outlet # of Tubes 0
Radiative Zone
Radiant Zone Inlet Radiant Zone Oulet # of Tubes 1
Reformer Feed Preheated Reformer Feed
PARAMETERS
Min Air Fuel Ratio --- Flame Temp --- Heater SS Efficiency 75.00
Air Fuel Ratio --- Lean Factor 1.000 Heater SS Excess Air Percent 15.00
Max Air Fuel Ratio --- Rich Factor 40.00
User Variables
RATING
Sizing
Radiant Tube Inner Diameters (ft) --- Radiant Zone Inner Diameters (ft) 5.577
Radiant Tube Outer Diameters (ft) --- Radiant Zone Outer Diameters (ft) 6.562
Number of Radiant Tubes --- Radiant Zone Height (ft) 14.04
Radiant Tube Lengths (ft) ---
Tube Inner Area (ft2) --- Tube Outer Area (ft2) --- Wall Inner Area (ft2) 246.0 Wall Outer Area (ft2) 289.5
Convective Zone
Convective Tube Inner Diameters (ft) --- Convective Zone Inner Diameter (ft) 3.714
Convective Tube Outer Diameters (ft) --- Convective Zone Outer Diameter (ft) 4.698
Number of Convective Tubes --- Convective Zone Height (ft) 5.577
Convective Tube Lengths (ft) ---
Tube Inner Area (ft2) --- Tube Outer Area (ft2) ---
Economizer Zone
Economizer Tube Inner Diameters (ft) --- Economizer Zone Inner Diameter (ft) 1.280
Economizer Tube Outer Diameters (ft) --- Economizer Zone Outer Diameter (ft) 1.608
Number of Economizer Tubes --- Economizer Zone Height (ft) 38.12
Economizer Tube Lengths (ft) ---

Tube Inner Area (ft2) --- Tube Outer Area (ft2) ---
Heat Transfer
Reformer Feed 432.9 1472 --- ---
Temp Profile
Top Temp --- --- --- --- Bottom Temp ---
Wall Inner Temp --- Wall Outer Temp ---

PERFORMANCE TABLE

Reformer Feed

Overall Phase

Temperature (F)	Pressure (psia)	Heat Flow (Btu/hr)	Enthalpy (Btu/lbmole)
432.91	435.11	0.00	-86120.47
536.82	435.11	1057955.84	-85033.28
640.73	435.11	2147781.90	-83913.34
744.64	435.11	3269987.72	-82760.13
848.55	435.11	4425476.79	-81572.71
952.46	435.11	5613800.40	-80351.56
1056.37	435.11	6833664.23	-79097.99
1160.27	435.11	8083279.88	-77813.85
1264.18	435.11	9360639.38	-76501.19
1368.09	435.11	10663748.74	-75162.08
1472.00	435.11	11990838.06	-73798.32

Vapour Phase

Mass Flow (lb/hr)	Molecular Wt	Density (lb/ft3)	Mass Sp Heat (Btu/lb-F)	Viscosity (cP)	Thermal Cond (Btu/hr-ft-F)
21453.12	22.05	1.04	0.47	0.02	0.03
21453.12	22.05	0.92	0.48	0.02	0.03
21453.12	22.05	0.83	0.50	0.02	0.04
21453.12	22.05	0.75	0.51	0.02	0.04
21453.12	22.05	0.69	0.53	0.03	0.05
21453.12	22.05	0.64	0.54	0.03	0.05
21453.12	22.05	0.59	0.55	0.03	0.05
21453.12	22.05	0.55	0.57	0.03	0.06
21453.12	22.05	0.52	0.58	0.03	0.06
21453.12	22.05	0.49	0.59	0.03	0.07
21453.12	22.05	0.46	0.60	0.03	0.07

Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psia)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
8.85	0.96	1870.06	286.80	0.27	0.20
8.85	0.97	1870.06	286.80	0.27	0.20
8.85	0.98	1870.06	286.80	0.27	0.20
8.85	0.99	1870.06	286.80	0.27	0.20
8.85	0.99	1870.06	286.80	0.27	0.20
8.85	1.00	1870.06	286.80	0.27	0.20
8.85	1.00	1870.06	286.80	0.27	0.20
8.85	1.00	1870.06	286.80	0.27	0.20
8.85	1.00	1870.06	286.80	0.27	0.20
8.85	1.00	1870.06	286.80	0.27	0.20
8.85	1.00	1870.06	286.80	0.27	0.20

Light Liquid Phase

E-202 (Cooler): Design, Rating, Profiles, Tables

Cooler: E-202

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION
Shift Cooled	E-201 Heat Exchanger

Outlet Stream

STREAM NAME	TO UNIT OPERATION
High Temp Shift Preheated	R-202 Equilibrium Reactor

Energy Stream

STREAM NAME	TO UNIT OPERATION
Shift Cooler	

PARAMETERS

Pressure Drop: 8.992 psi Duty: 2.734e+005 Btu/hr Volume: 3.531 ft3
Function: Not Selected Zones: 1

User Variables

Zone	Pressure (psia)	Temperature (F)	Vapour Fraction	Enthalpy (Btu/lbmole)
Inlet	299.07	508.81	1.0000	-75671.24
0	290.08	482.00	1.0000	-75931.68

PERFORMANCE TABLE

Overall Phase

Temperature (F)	Pressure (psia)	Heat Flow (Btu/hr)	Enthalpy (Btu/lbmole)
508.81	299.07	0.00	-75671.24
506.13	298.17	-27449.54	-75697.39
503.44	297.27	-54874.17	-75723.52
500.76	296.37	-82273.89	-75749.62
498.08	295.47	-109648.70	-75775.70
495.40	294.57	-136998.59	-75801.76
492.72	293.67	-164323.57	-75827.79
490.04	292.77	-191623.65	-75853.80
487.36	291.87	-218898.81	-75879.79
484.68	290.97	-246149.08	-75905.75
482.00	290.08	-273374.43	-75931.68

Mass Flow (lb/hr)	Molecular Wt	Density (lb/ft3)	Mass Sp Heat (Btu/lb-F)	Viscosity (cP)	Thermal Cond (Btu/hr-ft-F)
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04
21453.15	20.44	0.60	0.48	0.02	0.04

Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psia)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
9.54	0.99	1627.59	191.40	0.28	0.16
9.54	0.99	1627.59	191.40	0.28	0.16
9.54	0.99	1627.59	191.40	0.28	0.16
9.54	0.99	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16
9.54	0.98	1627.59	191.40	0.28	0.16

Light Liquid Phase

C-201 (Compressor): Design, Rating, Performance

Compressor: C-201
DESIGN
Connections
Inlet Stream

STREAM NAME	FROM UNIT OPERATION
Fresh Recycle	MIX-102 Mixer

Outlet Stream

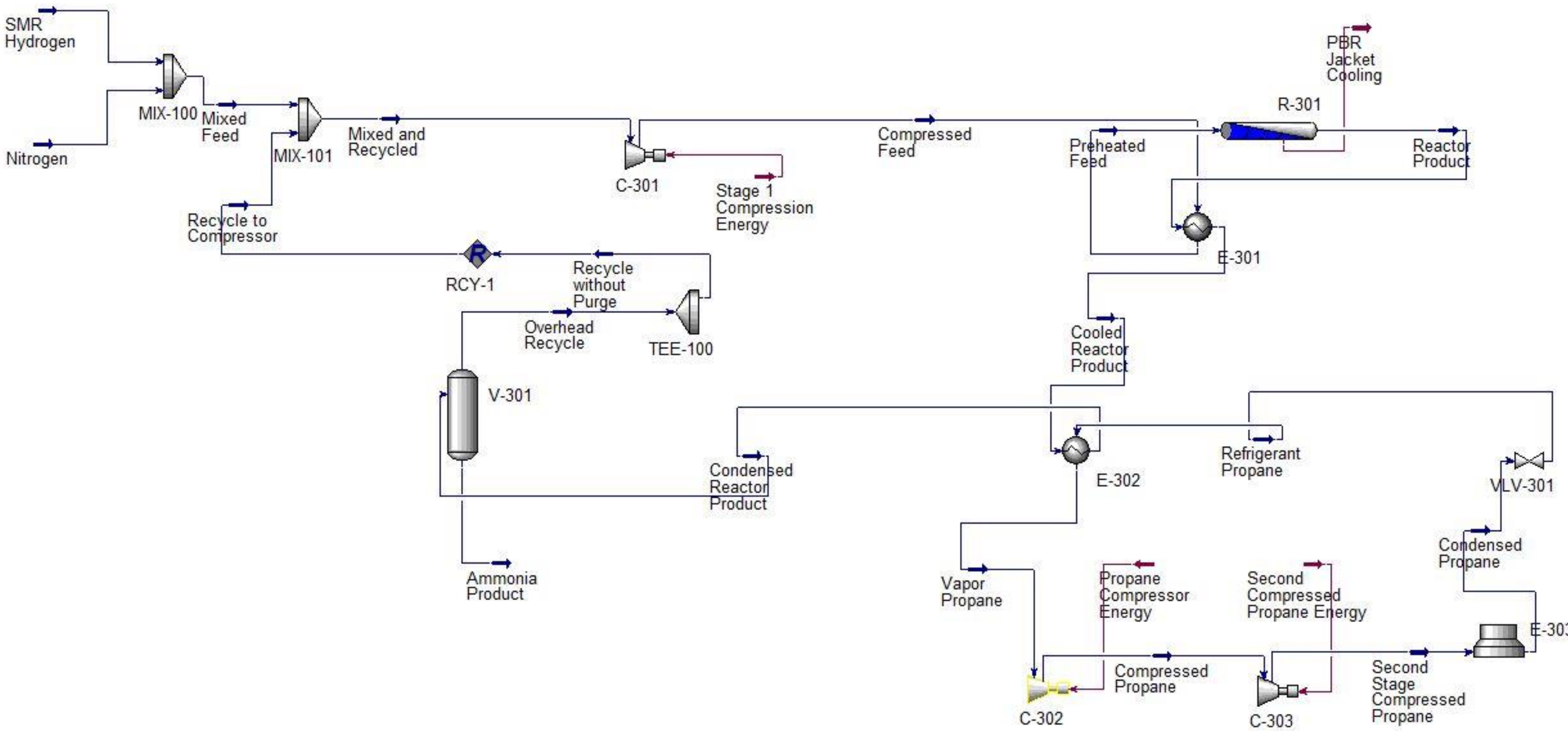
STREAM NAME	TO UNIT OPERATION
Continued Recycle	RCY-1 Recycle

Energy Stream

STREAM NAME	FROM UNIT OPERATION
Recycle Compressor Energy	

Parameters
Speed: --- Duty: 2.1206e+02 hp
Adiabatic Eff.: 75.00 PolyTropic Eff.: 76.03
Adiabatic Head: 2.653e+004 ft Polytropic Head: 2.689e+004 ft

Adiabatic Fluid Head: 2.653e+004 lbf-ft/lbm Polytropic Fluid Head: 2.689e+004 lbf-ft/lbm
Polytropic Exp. 1.336 Isentropic Exp. 1.239 Poly Head Factor 1.001
User Variables
RATING
Rotational inertia (lb-ft2) 142.4 Radius of gyration (ft) 0.6562
Mass (lb) 330.7 Friction loss factor (rad/min) (lb-ft2/s) 0.1424
PERFORMANCE
Results
Adiabatic Head (ft) 2.653e+004 Power Consumed (hp) 212.1
Polytropic Head (ft) 2.689e+004 Polytropic Head Factor 1.001
Adiabatic Fluid Head (lbf-ft/lbm) 2.653e+004 Polytropic Exponent 1.336
Polytropic Fluid Head (lbf-ft/lbm) 2.689e+004 Isentropic Exponent 1.239
Adiabatic Efficiency 75 Speed (rpm) ---
Polytropic Efficiency 76 ---
Total Rotor Power (hp) 212.1 Total Rotor Torque (lbf-ft) ---
Transient Rotor Power (hp) 0.0000 Transient Rotor Torque (lbf-ft) ---
Friction Power Loss (hp) 0.0000 Friction Torque Loss (lbf-ft) ---
Fluid Power (hp) 212.1 Fluid Torque (lbf-ft) ---



SMR Hydrogen
Nitrogen
MIX-100
Mixed Feed
MIX-101
Mixed and Recycled
C-301
Stage 1 Compression Energy
Compressed Feed
Preheated Feed
R-301
PBR Jacket Cooling
Reactor Product
E-301
Cooled Reactor Product
Recycle to Compressor
RCY-1
Recycle without Purge
Overhead Recycle
TEE-100
V-301
Condensed Reactor Product
Ammonia Product
E-302
Refrigerant Propane
VLV-301
Condensed Propane
Vapor Propane
Propane Compressor Energy
Second Compressed Propane Energy
E-303
Compressed Propane
Second Stage Compressed Propane
C-302
C-303

****

INPUT SUMMARY

****

FLUID PACKAGE: Basis-1(Peng-Robinson)

Property Package Type: PengRob
Component List - 1: Hydrogen /Nitrogen /Ammonia /Oxygen /H2O /Propane /
Reaction Set: Set-1
  Reaction 'Rxn-1':
    Reactants: Hydrogen, Stoich Coeff -3 / Nitrogen, Stoich Coeff -1 / Ammonia, Stoich Coeff 2 /
    Basis Data: Basis = Partial Pres / Component = Nitrogen / Phase = VapourPhase / RateUnits = kgmole/m3-s /
    Kinetic Coefficients: Fwd Freq Factor = 1120000 / Fwd Activation Energy = 136000 /

FLOWSHEET: Main

Fluid Package: Basis-1
STREAM: SMR Hydrogen (Material Stream)
  Temperature = 275 C
  Pressure = 1500 kPa
  Molar Flow = 185 kgmole/h
  Composition Basis (In Mole Flows):Hydrogen = 184.445/ Nitrogen = 0/ Ammonia = 0/ Oxygen = 0/ H2O = 0.555/ Propane = 0/
STREAM: Nitrogen (Material Stream)
  Vapour Fraction = 1
  Temperature = 80.2 C
  Pressure = 900 kPa
  Molar Flow = 62 kgmole/h
  Composition Basis (In Mole Fractions):Hydrogen = 0/ Nitrogen = 0.999/ Ammonia = 0/ Oxygen = 0.001/ H2O = 0/ Propane = 0/
UNIT OPERATION: MIX-100 (Mixer)
  Feed Stream = Nitrogen
  Feed Stream = SMR Hydrogen
  Product Stream = Mixed Feed
  UseTrivialSolution = True
UNIT OPERATION: K-100 (Compressor)
  Feed Stream = Mixed and Recycled
  Product Stream = Compressed Feed
  Energy Stream = Stage 1 Compression Energy
  AdiabaticEfficiency = 85
  CylinderType = Single-acting, Outer End
   = 1
  CurveCollectionName = CC-0
  SelectedCurveCollection = True
  NumberOfCurves = 0
  NumberOfCurves = 0
  NumberOfCurves = 0
  EffCurveType = 0
  NumberOfCurves = 0
  UseDutySpec = 0
  UseAdiabaticEfficiencySpec = 1
  UsePolytropicEfficiencySpec = 0
  UseSpeedSpec = 1
STREAM: Mixed Feed (Material Stream)
STREAM: Compressed Feed (Material Stream)
  Pressure = 1100 kPa
STREAM: Preheated Feed (Material Stream)
  Temperature = 450 C
STREAM: Reactor Product (Material Stream)
  Temperature = 550 C
STREAM: Condensed Reactor Product (Material Stream)
  Temperature = -30 C
UNIT OPERATION: V-100 (Separator)
  Feed Stream = Condensed Reactor Product
  Vapour Product = Overhead Recycle
  Liquid Product = Ammonia Product
  Delta P = FEMPTY kPa
STREAM: Ammonia Product (Material Stream)
  Pressure = 800 kPa

STREAM: Stage 1 Compression Energy (Energy Stream)
STREAM: Cooled Reactor Product (Material Stream)
UNIT OPERATION: MIX-101 (Mixer)
  Feed Stream = Mixed Feed
  Feed Stream = Recycle to Compressor
  Product Stream = Mixed and Recycled
  UseTrivialSolution = True
STREAM: Mixed and Recycled (Material Stream)
STREAM: Overhead Recycle (Material Stream)
STREAM: Recycle to Compressor (Material Stream)
  Temperature = -32.0310422 C
  Pressure = 800 kPa
  Molar Flow = 399.351699 kgmole/h
  Composition Basis (In Mole Fractions):Hydrogen = 0.564486814/ Nitrogen = 0.284575368/ Ammonia = 0.139272636/ Oxygen = 0.0116651543/ H2O = 2.69335854e-008/ Propane = 0/
UNIT OPERATION: Named E-106 (Heat Exchanger)
  TubeInletStream = Reactor Product
  TubeOutletStream = Cooled Reactor Product
  ShellInletStream = Compressed Feed
  ShellOutletStream = Preheated Feed
  TubeOuterDiameter = 20 mm
  TubeInnerDiameter = 16 mm
  TubeThickness = FEMPTY mm
  HCurveName = Reactor Product-Cooled Reactor Product
  HCurveName = Compressed Feed-Preheated Feed
  ShellPressureDrop = 62 kPa
  TubePressureDrop = 62 kPa
  calcFTMoniker = False
UNIT OPERATION: RCY-1 (Recycle)
  Inlet Stream = Recycle without Purge
  Output Stream = Recycle to Compressor
UNIT OPERATION: PFR-100 (Plug Flow Reactor)
  Feed Stream = Preheated Feed
  Product Stream = Reactor Product
  Energy Stream = PBR Jacket Cooling
  Reaction Set=Set-1
  DeltaPType = 1
  SinglePhase = True
  TubeTotalVolume = 538.4 m3
  TubeDiameter = 6.1 m
  VoidFraction = 0.9
UNIT OPERATION: TEE-100 (Tee)
  Feed Stream = Overhead Recycle
  Product Stream = Recycle without Purge
STREAM: Recycle without Purge (Material Stream)
UNIT OPERATION: K-101 (Compressor)
  Feed Stream = Vapor Propane
  Product Stream = Compressed Propane
  Energy Stream = Propane Compressor Energy
  AdiabaticEfficiency = FEMPTY
  PressureRatio = 4
  CylinderType = Single-acting, Outer End
   = 1
  CurveCollectionName = CC-0
  SelectedCurveCollection = True
  NumberOfCurves = 0
  NumberOfCurves = 0
  NumberOfCurves = 0
  EffCurveType = 0
  NumberOfCurves = 0
  UseDutySpec = 0
  UseAdiabaticEfficiencySpec = 1
  UsePolytropicEfficiencySpec = 0
  UseSpeedSpec = 1
UNIT OPERATION: VLV-100 (Valve)
  Feed Stream = Condensed Propane
  Product Stream = Refrigerant Propane
  ValveManufacturer = FISHER
  ValveManufacturerType = 0
  C1 = 33.4664011
  RigorousSizingMethod = True
  UseXtTable = False
  RigorousFlowCalc = True

UNIT OPERATION: Named E-107 (Heat Exchanger)
TubeInletStream = Cooled Reactor Product
TubeOutletStream = Condensed Reactor Product
ShellInletStream = Refrigerant Propane
ShellOutletStream = Vapor Propane
TubeOuterDiameter = 20 mm
TubeInnerDiameter = 16 mm
TubeThickness = FEMPTY mm
HCurveName = Cooled Reactor Product-Condensed Reactor Product
HCurveName = Refrigerant Propane-Vapor Propane
ShellPressureDrop = 62 kPa
TubePressureDrop = 62 kPa
STREAM: Refrigerant Propane (Material Stream)
STREAM: Vapor Propane (Material Stream)
Vapour Fraction = 1
Pressure = 101.3 kPa
STREAM: Compressed Propane (Material Stream)
Vapour Fraction = 1
STREAM: Propane Compressor Energy (Energy Stream)
STREAM: Condensed Propane (Material Stream)
Vapour Fraction = 0
Composition Basis (In Mole Fractions):Hydrogen = 0/ Nitrogen = 0/ Ammonia = 0/
Oxygen = 0/ H2O = 0/ Propane = 1/
STREAM: PBR Jacket Cooling (Energy Stream)
UNIT OPERATION: K-102 (Compressor)
Feed Stream = Compressed Propane
Product Stream = Second Stage Compressed Propane
Energy Stream = Second Compressed Propane Energy
PressureRatio = 4
CurveCollectionName = CC-0
SelectedCurveCollection = True
NumberOfCurves = 0
NumberOfCurves = 0
NumberOfCurves = 0
EffCurveType = 0
NumberOfCurves = 0
STREAM: Second Stage Compressed Propane (Material Stream)
STREAM: Second Compressed Propane Energy (Energy Stream)
UNIT OPERATION: AC-100 (Air cooler)
Feed Stream = Second Stage Compressed Propane
Product Stream = Condensed Propane
Pressure Drop = 2 kPa
UA = 645329.254 kJ/C-h
NumberOfFans = 1
Fan_Name = Fan 0
Tolerance = 1e-005

##

OUTPUT SUMMARY

##

OKLAHOMA STATE UNIVERSIT Case Name: Haber Process Final.hsc
Bedford, MA
USA Unit Set: SI

Date/Time: Wed Apr 01 18:35:41 2020

Basis-1 (Fluid Package): Component List

Fluid Package: Basis-1
COMPONENT LIST
Component List - 1 [HYSYS Databanks]

COMPONENT	TYPE	MOLECULAR WEIGHT	BOILING PT (C)	IDEAL LIQ DENSITY (kg/m3)	CRITICAL TEMP (C)
Hydrogen	Pure	2.016	-252.6	69.86	-239.7
Nitrogen	Pure	28.01	-195.8	806.4	-147.0
Ammonia	Pure	17.03	-33.45	616.1	132.4
Oxygen	Pure	32.00	-183.0	1138	-118.4
H2O	Pure	18.02	100.0	998.0	374.1
Propane	Pure	44.10	-42.10	506.7	96.75

(Continued..) Component List - 1 [HYSYS Databanks]

COMPONENT	CRITICAL PRES (kPa)	CRITICAL VOL (m3/kgmole)	ACENTRICITY	HEAT OF FORM (kJ/kgmole)
Hydrogen	1316	5.150e-002	-0.1201	0.0000

Nitrogen 3394 9.000e-002 4.000e-002 0.0000
Ammonia 1.128e+004 8.040e-002 0.2550 -4.571e+004
Oxygen 5080 7.320e-002 1.900e-002 0.0000
H2O 2.212e+004 5.710e-002 0.3440 -2.418e+005
Propane 4257 0.2000 0.1524 -1.039e+005

Case (Simulation Case): Mass and Energy Balance, Utility Balance, Process CO2 Emissions
----
Simulation Case: Case
OVERALL MASS BALANCE
In Stream Count Mass Flow Out Stream Count Mass Flow
(kg/h) (kg/h)
Nitrogen Yes 1737 Ammonia Product Yes 2084
SMR Hydrogen Yes 381.8
Total In MassFlow (kg/h) 2119 Total Out MassFlow (kg/h) 2084
Mass Imbalance (kg/h) -35.10 Rel Mass Imbalance Pct (%) -1.66
OVERALL ENERGY BALANCE
InStream Count Energy Flow OutStream Count Energy Flow
(kJ/h) (kJ/h)
Nitrogen Yes 9.735e+04 Ammonia Product Yes -8.864e+06
SMR Hydrogen Yes 1.198e+06 PBR Jacket Cooling Yes 4.512e+06
Stage 1 Compression Energy Yes 7.119e+05
Propane Compressor Energy Yes 1.541e+06
Second Compressed Propane Energy Yes 2.876e+06
Total In EnergyFlow (kJ/h) 6.424e+006 Total Out EnergyFlow (kJ/h) -4.352e+006
Energy Imbalance (kJ/h) -1.078e+007 Rel Energy Imbalance Pct (%) -167.74
OVERALL UTILITY BALANCE
Utility Name Usage Info Energy Flow Mass Flow Cost
Hot Utility Summary Cold Utility Summary
Utility Flow --- Utility Flow ---
Utility Cost --- Utility Cost ---
Carbon Emiss. --- Carbon Emiss. ---
Carbon Fees --- Carbon Fees ---
PROCESS CO2 EMISSIONS
Inlet Stream Count IFPP (1995) IFPP (2007) EPA (2009)
(kg/h) (kg/h) (kg/h)
Nitrogen Yes 0.000e-01 0.000e-01 0.000e-01
SMR Hydrogen Yes 0.000e-01 0.000e-01 0.000e-01
Total from Inlets --- --- ---
Total Carbon Fees --- --- ---
from Inlets (Cost/hr)
Outlet Stream Count IFPP (1995) IFPP (2007) EPA (2009)
(kg/h) (kg/h) (kg/h)
Ammonia Product Yes 0.000e-01 0.000e-01 0.000e-01
Total from Outlets --- --- ---
Total Carbon Fees --- --- ---
from Outlets (Cost/hr)

SMR Hydrogen (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: SMR Hydrogen Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (C) 275.0 275.0
Pressure: (kPa) 1500 1500
Molar Flow (kgmole/h) 185.0 185.0
Mass Flow (kg/h) 381.8 381.8
Std Ideal Liq VolFlow (m3/h) 5.333 5.333
Molar Enthalpy (kJ/kgmole) 6.474e+03 6.474e+03
Molar Entropy (kJ/kgmole-C) 1.184e+02 1.184e+02
Heat Flow (kJ/h) 1.198e+06 1.198e+06
Liq VolFlow @Std Cond (m3/h) 4376 4376
COMPOSITION
Overall Phase Vapour Fraction 1.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 184.4 0.9970 371.8 0.9738 5.323 0.9981
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.5550 0.0030 9.998 0.0262 1.002e-002 0.0019
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

Total 185.0 1.0000 381.8 1.0000 5.333 1.0000
Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	184.4	0.9970	371.8	0.9738	5.323	0.9981
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.5550	0.0030	9.998	0.0262	1.002e-002	0.0019
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	185.0	1.0000	381.8	1.0000	5.333	1.0000

Nitrogen (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Nitrogen Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	80.20	80.20
Pressure: (kPa)	900.0	900.0
Molar Flow (kgmole/h)	62.00	62.00
Mass Flow (kg/h)	1737	1737
Std Ideal Liq VolFlow (m3/h)	2.153	2.153
Molar Enthalpy (kJ/kgmole)	1.570e+03	1.570e+03
Molar Entropy (kJ/kgmole-C)	1.348e+02	1.348e+02
Heat Flow (kJ/h)	9.735e+04	9.735e+04
Liq VolFlow @Std Cond (m3/h)	1465	1465

COMPOSITION
Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	61.94	0.9990	1735	0.9989	2.152	0.9992
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	6.200e-002	0.0010	1.984	0.0011	1.744e-003	0.0008
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	62.00	1.0000	1737	1.0000	2.153	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	61.94	0.9990	1735	0.9989	2.152	0.9992
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	6.200e-002	0.0010	1.984	0.0011	1.744e-003	0.0008
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	62.00	1.0000	1737	1.0000	2.153	1.0000

Mixed Feed (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Mixed Feed Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	224.9	224.9
Pressure: (kPa)	900.0	900.0
Molar Flow (kgmole/h)	247.0	247.0
Mass Flow (kg/h)	2119	2119
Std Ideal Liq VolFlow (m3/h)	7.486	7.486
Molar Enthalpy (kJ/kgmole)	5.243e+03	5.243e+03
Molar Entropy (kJ/kgmole-C)	1.309e+02	1.309e+02
Heat Flow (kJ/h)	1.295e+06	1.295e+06
Liq VolFlow @Std Cond (m3/h)	5841	5841

COMPOSITION
Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	184.4	0.7467	371.8	0.1755	5.323	0.7110
Nitrogen	61.94	0.2508	1735	0.8189	2.152	0.2874
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	6.200e-002	0.0003	1.984	0.0009	1.744e-003	0.0002

H2O 0.5550 0.0022 9.998 0.0047 1.002e-002 0.0013
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 247.0 1.0000 2119 1.0000 7.486 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 184.4 0.7467 371.8 0.1755 5.323 0.7110
Nitrogen 61.94 0.2508 1735 0.8189 2.152 0.2874
Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 6.200e-002 0.0003 1.984 0.0009 1.744e-003 0.0002
H2O 0.5550 0.0022 9.998 0.0047 1.002e-002 0.0013
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 247.0 1.0000 2119 1.0000 7.486 1.0000

Compressed Feed (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

----

Material Stream: Compressed Feed Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (C) 101.7 101.7
Pressure: (kPa) 1100 1100
Molar Flow (kgmole/h) 646.4 646.4
Mass Flow (kg/h) 6853 6853
Std Ideal Liq VolFlow (m3/h) 19.61 19.61
Molar Enthalpy (kJ/kgmole) -1.905e+03 -1.905e+03
Molar Entropy (kJ/kgmole-C) 1.284e+02 1.284e+02
Heat Flow (kJ/h) -1.231e+06 -1.231e+06
Liq VolFlow @Std Cond (m3/h) 1.528e+004 1.528e+004
COMPOSITION
Overall Phase Vapour Fraction 1.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 409.9 0.6341 826.3 0.1206 11.83 0.6032
Nitrogen 175.6 0.2717 4919 0.7177 6.100 0.3111
Ammonia 55.62 0.0861 947.2 0.1382 1.537 0.0784
Oxygen 4.720 0.0073 151.1 0.0220 0.1328 0.0068
H2O 0.5550 0.0009 9.999 0.0015 1.002e-002 0.0005
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 646.4 1.0000 6853 1.0000 19.61 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 409.9 0.6341 826.3 0.1206 11.83 0.6032
Nitrogen 175.6 0.2717 4919 0.7177 6.100 0.3111
Ammonia 55.62 0.0861 947.2 0.1382 1.537 0.0784
Oxygen 4.720 0.0073 151.1 0.0220 0.1328 0.0068
H2O 0.5550 0.0009 9.999 0.0015 1.002e-002 0.0005
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 646.4 1.0000 6853 1.0000 19.61 1.0000

Preheated Feed (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

----

Material Stream: Preheated Feed Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH.
Vapour / Phase Fraction 1.0000 1.0000
Temperature: (C) 450.0 450.0
Pressure: (kPa) 1038 1038
Molar Flow (kgmole/h) 646.4 646.4
Mass Flow (kg/h) 6853 6853
Std Ideal Liq VolFlow (m3/h) 19.61 19.61
Molar Enthalpy (kJ/kgmole) 8.808e+03 8.808e+03
Molar Entropy (kJ/kgmole-C) 1.490e+02 1.490e+02
Heat Flow (kJ/h) 5.693e+06 5.693e+06
Liq VolFlow @Std Cond (m3/h) 1.528e+004 1.528e+004
COMPOSITION
Overall Phase Vapour Fraction 1.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 409.9 0.6341 826.3 0.1206 11.83 0.6032
Nitrogen 175.6 0.2717 4919 0.7177 6.100 0.3111

Ammonia 55.62 0.0861 947.2 0.1382 1.537 0.0784
Oxygen 4.720 0.0073 151.1 0.0220 0.1328 0.0068
H2O 0.5550 0.0009 9.999 0.0015 1.002e-002 0.0005
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 646.4 1.0000 6853 1.0000 19.61 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 409.9 0.6341 826.3 0.1206 11.83 0.6032
Nitrogen 175.6 0.2717 4919 0.7177 6.100 0.3111
Ammonia 55.62 0.0861 947.2 0.1382 1.537 0.0784
Oxygen 4.720 0.0073 151.1 0.0220 0.1328 0.0068
H2O 0.5550 0.0009 9.999 0.0015 1.002e-002 0.0005
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 646.4 1.0000 6853 1.0000 19.61 1.0000

Reactor Product (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Reactor Product Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH. LIQUID PH.
Vapour / Phase Fraction 1.0000 1.0000 0.0000
Temperature: (C) 550.0 550.0 550.0
Pressure: (kPa) 1038 1038 1038
Molar Flow (kgmole/h) 524.3 524.3 0.0000
Mass Flow (kg/h) 6853 6853 0.0000
Std Ideal Liq VolFlow (m3/h) 15.58 15.58 0.0000
Molar Enthalpy (kJ/kgmole) 2.252e+03 2.252e+03 2.252e+03
Molar Entropy (kJ/kgmole-C) 1.690e+02 1.690e+02 1.690e+02
Heat Flow (kJ/h) 1.181e+06 1.181e+06 0.000e-01
Liq VolFlow @Std Cond (m3/h) 1.238e+004 1.238e+004 0.0000
COMPOSITION
Overall Phase Vapour Fraction 1.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 226.7 0.4325 457.1 0.0667 6.543 0.4200
Nitrogen 114.5 0.2185 3208 0.4682 3.979 0.2554
Ammonia 177.7 0.3390 3026 0.4416 4.913 0.3154
Oxygen 4.720 0.0090 151.1 0.0220 0.1328 0.0085
H2O 0.5550 0.0011 9.999 0.0015 1.002e-002 0.0006
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 524.3 1.0000 6853 1.0000 15.58 1.0000
Vapour Phase Phase Fraction 1.000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 226.7 0.4325 457.1 0.0667 6.543 0.4200
Nitrogen 114.5 0.2185 3208 0.4682 3.979 0.2554
Ammonia 177.7 0.3390 3026 0.4416 4.913 0.3154
Oxygen 4.720 0.0090 151.1 0.0220 0.1328 0.0085
H2O 0.5550 0.0011 9.999 0.0015 1.002e-002 0.0006
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 524.3 1.0000 6853 1.0000 15.58 1.0000
Liquid Phase Phase Fraction 0.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 0.0000 0.4325 0.0000 0.0667 0.0000 0.4200
Nitrogen 0.0000 0.2185 0.0000 0.4682 0.0000 0.2554
Ammonia 0.0000 0.3390 0.0000 0.4416 0.0000 0.3154
Oxygen 0.0000 0.0090 0.0000 0.0220 0.0000 0.0085
H2O 0.0000 0.0011 0.0000 0.0015 0.0000 0.0006
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000

Condensed Reactor Product (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
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Material Stream: Condensed Reactor Product Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH. LIQUID PH.
Vapour / Phase Fraction 0.7633 0.7633 0.2367
Temperature: (C) -30.00 -30.00 -30.00
Pressure: (kPa) 914.0 914.0 914.0
Molar Flow (kgmole/h) 524.3 400.2 124.1

Mass Flow (kg/h) 6853 4740 2113
Std Ideal Liq VolFlow (m3/h) 15.58 12.15 3.425
Molar Enthalpy (kJ/kgmole) -2.312e+04 -7.884e+03 -7.228e+04
Molar Entropy (kJ/kgmole-C) 1.076e+02 1.207e+02 6.507e+01
Heat Flow (kJ/h) -1.212e+07 -3.155e+06 -8.968e+06
Liq VolFlow @Std Cond (m3/h) 1.238e+004 9459 3.445
COMPOSITION
Overall Phase Vapour Fraction 0.7633
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 226.7 0.4325 457.1 0.0667 6.543 0.4200
Nitrogen 114.5 0.2185 3208 0.4682 3.979 0.2554
Ammonia 177.7 0.3390 3026 0.4416 4.913 0.3154
Oxygen 4.720 0.0090 151.1 0.0220 0.1328 0.0085
H2O 0.5550 0.0011 9.999 0.0015 1.002e-002 0.0006
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 524.3 1.0000 6853 1.0000 15.58 1.0000
Vapour Phase Phase Fraction 0.7633
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 226.7 0.5665 457.0 0.0964 6.542 0.5383
Nitrogen 114.5 0.2862 3208 0.6768 3.978 0.3274
Ammonia 54.25 0.1356 923.9 0.1949 1.500 0.1234
Oxygen 4.712 0.0118 150.8 0.0318 0.1325 0.0109
H2O 1.204e-005 0.0000 2.169e-004 0.0000 2.174e-007 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 400.2 1.0000 4740 1.0000 12.15 1.0000
Liquid Phase Phase Fraction 0.2367
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 3.366e-002 0.0003 6.785e-002 0.0000 9.713e-004 0.0003
Nitrogen 1.195e-002 0.0001 0.3347 0.0002 4.150e-004 0.0001
Ammonia 123.5 0.9951 2103 0.9949 3.413 0.9966
Oxygen 8.756e-003 0.0001 0.2802 0.0001 2.463e-004 0.0001
H2O 0.5550 0.0045 9.998 0.0047 1.002e-002 0.0029
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 124.1 1.0000 2113 1.0000 3.425 1.0000

Ammonia Product (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
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Material Stream: Ammonia Product Fluid Package: Basis-1
Property Package: Peng-Robinson
CONDITIONS
OVERALL VAPOUR PH. LIQUID PH.
Vapour / Phase Fraction 0.0000 0.0000 1.0000
Temperature: (C) -32.03 -32.03 -32.03
Pressure: (kPa) 800.0 800.0 800.0
Molar Flow (kgmole/h) 122.3 0.0000 122.3
Mass Flow (kg/h) 2084 0.0000 2084
Std Ideal Liq VolFlow (m3/h) 3.377 0.0000 3.377
Molar Enthalpy (kJ/kgmole) -7.245e+04 -8.108e+03 -7.245e+04
Molar Entropy (kJ/kgmole-C) 6.443e+01 1.218e+02 6.443e+01
Heat Flow (kJ/h) -8.864e+06 0.000e-01 -8.864e+06
Liq VolFlow @Std Cond (m3/h) 3.397 0.0000 3.397
COMPOSITION
Overall Phase Vapour Fraction 0.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 2.769e-002 0.0002 5.582e-002 0.0000 7.990e-004 0.0002
Nitrogen 9.790e-003 0.0001 0.2742 0.0001 3.401e-004 0.0001
Ammonia 121.7 0.9951 2073 0.9949 3.365 0.9966
Oxygen 7.500e-003 0.0001 0.2400 0.0001 2.110e-004 0.0001
H2O 0.5550 0.0045 9.998 0.0048 1.002e-002 0.0030
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Total 122.3 1.0000 2084 1.0000 3.377 1.0000
Vapour Phase Phase Fraction 0.0000
COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 0.0000 0.5641 0.0000 0.0958 0.0000 0.5362
Nitrogen 0.0000 0.2849 0.0000 0.6727 0.0000 0.3261
Ammonia 0.0000 0.1393 0.0000 0.1999 0.0000 0.1268
Oxygen 0.0000 0.0117 0.0000 0.0316 0.0000 0.0109
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Liquid Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	2.769e-002	0.0002	5.582e-002	0.0000	7.990e-004	0.0002
Nitrogen	9.790e-003	0.0001	0.2742	0.0001	3.401e-004	0.0001
Ammonia	121.7	0.9951	2073	0.9949	3.365	0.9966
Oxygen	7.500e-003	0.0001	0.2400	0.0001	2.110e-004	0.0001
H2O	0.5550	0.0045	9.998	0.0048	1.002e-002	0.0030
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	122.3	1.0000	2084	1.0000	3.377	1.0000

Cooled Reactor Product (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Cooled Reactor Product Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	177.0	177.0
Pressure: (kPa)	976.0	976.0
Molar Flow (kgmole/h)	524.3	524.3
Mass Flow (kg/h)	6853	6853
Std Ideal Liq VolFlow (m3/h)	15.58	15.58
Molar Enthalpy (kJ/kgmole)	-1.096e+04	-1.096e+04
Molar Entropy (kJ/kgmole-C)	1.483e+02	1.483e+02
Heat Flow (kJ/h)	-5.743e+06	-5.743e+06
Liq VolFlow @Std Cond (m3/h)	1.238e+004	1.238e+004

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	226.7	0.4325	457.1	0.0667	6.543	0.4200
Nitrogen	114.5	0.2185	3208	0.4682	3.979	0.2554
Ammonia	177.7	0.3390	3026	0.4416	4.913	0.3154
Oxygen	4.720	0.0090	151.1	0.0220	0.1328	0.0085
H2O	0.5550	0.0011	9.999	0.0015	1.002e-002	0.0006
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	524.3	1.0000	6853	1.0000	15.58	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	226.7	0.4325	457.1	0.0667	6.543	0.4200
Nitrogen	114.5	0.2185	3208	0.4682	3.979	0.2554
Ammonia	177.7	0.3390	3026	0.4416	4.913	0.3154
Oxygen	4.720	0.0090	151.1	0.0220	0.1328	0.0085
H2O	0.5550	0.0011	9.999	0.0015	1.002e-002	0.0006
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	524.3	1.0000	6853	1.0000	15.58	1.0000

Mixed and Recycled (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Mixed and Recycled Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	64.37	64.37
Pressure: (kPa)	800.0	800.0
Molar Flow (kgmole/h)	646.4	646.4
Mass Flow (kg/h)	6853	6853
Std Ideal Liq VolFlow (m3/h)	19.61	19.61
Molar Enthalpy (kJ/kgmole)	-3.006e+03	-3.006e+03
Molar Entropy (kJ/kgmole-C)	1.280e+02	1.280e+02
Heat Flow (kJ/h)	-1.943e+06	-1.943e+06
Liq VolFlow @Std Cond (m3/h)	1.528e+004	1.528e+004

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	409.9	0.6341	826.3	0.1206	11.83	0.6032
Nitrogen	175.6	0.2717	4919	0.7177	6.100	0.3111
Ammonia	55.62	0.0861	947.2	0.1382	1.537	0.0784

Oxygen	4.720	0.0073	151.1	0.0220	0.1328	0.0068
H2O	0.5550	0.0009	9.999	0.0015	1.002e-002	0.0005
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	646.4	1.0000	6853	1.0000	19.61	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	409.9	0.6341	826.3	0.1206	11.83	0.6032
Nitrogen	175.6	0.2717	4919	0.7177	6.100	0.3111
Ammonia	55.62	0.0861	947.2	0.1382	1.537	0.0784
Oxygen	4.720	0.0073	151.1	0.0220	0.1328	0.0068
H2O	0.5550	0.0009	9.999	0.0015	1.002e-002	0.0005
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	646.4	1.0000	6853	1.0000	19.61	1.0000

Overhead Recycle (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Overhead Recycle Fluid Package: Basis-1

Property Package: Peng-Robinson

	OVERALL	VAPOUR PH.	LIQUID PH.
Vapour / Phase Fraction	1.0000	1.0000	0.0000
Temperature: (C)	-32.03	-32.03	-32.03
Pressure: (kPa)	800.0	800.0	800.0
Molar Flow (kgmole/h)	401.9	401.9	0.0000
Mass Flow (kg/h)	4769	4769	0.0000
Std Ideal Liq VolFlow (m3/h)	12.20	12.20	0.0000
Molar Enthalpy (kJ/kgmole)	-8.108e+03	-8.108e+03	-7.245e+04
Molar Entropy (kJ/kgmole-C)	1.218e+02	1.218e+02	6.443e+01
Heat Flow (kJ/h)	-3.259e+06	-3.259e+06	0.000e-01
Liq VolFlow @Std Cond (m3/h)	9500	9500	0.0000

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	226.7	0.5641	457.0	0.0958	6.542	0.5362
Nitrogen	114.5	0.2849	3208	0.6727	3.979	0.3261
Ammonia	55.98	0.1393	953.3	0.1999	1.547	0.1268
Oxygen	4.713	0.0117	150.8	0.0316	0.1326	0.0109
H2O	1.082e-005	0.0000	1.949e-004	0.0000	1.953e-007	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	401.9	1.0000	4769	1.0000	12.20	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	226.7	0.5641	457.0	0.0958	6.542	0.5362
Nitrogen	114.5	0.2849	3208	0.6727	3.979	0.3261
Ammonia	55.98	0.1393	953.3	0.1999	1.547	0.1268
Oxygen	4.713	0.0117	150.8	0.0316	0.1326	0.0109
H2O	1.082e-005	0.0000	1.949e-004	0.0000	1.953e-007	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	401.9	1.0000	4769	1.0000	12.20	1.0000

Liquid Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0002	0.0000	0.0000	0.0000	0.0002
Nitrogen	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001
Ammonia	0.0000	0.9951	0.0000	0.9949	0.0000	0.9966
Oxygen	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001
H2O	0.0000	0.0045	0.0000	0.0048	0.0000	0.0030
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Recycle to Compressor (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Recycle to Compressor Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	-32.03	-32.03
Pressure: (kPa)	800.0	800.0
Molar Flow (kgmole/h)	399.4	399.4
Mass Flow (kg/h)	4734	4734
Std Ideal Liq VolFlow (m3/h)	12.12	12.12

Molar Enthalpy (kJ/kgmole) -8.108e+03 -8.108e+03
Molar Entropy (kJ/kgmole-C) 1.218e+02 1.218e+02
Heat Flow (kJ/h) -3.238e+06 -3.238e+06
Liq VolFlow @Std Cond (m3/h) 9439 9439

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	225.4	0.5645	454.5	0.0960	6.505	0.5367
Nitrogen	113.6	0.2846	3184	0.6724	3.948	0.3257
Ammonia	55.62	0.1393	947.2	0.2001	1.537	0.1268
Oxygen	4.658	0.0117	149.1	0.0315	0.1310	0.0108
H2O	1.076e-005	0.0000	1.938e-004	0.0000	1.942e-007	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	399.4	1.0000	4734	1.0000	12.12	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	225.4	0.5645	454.5	0.0960	6.505	0.5367
Nitrogen	113.6	0.2846	3184	0.6724	3.948	0.3257
Ammonia	55.62	0.1393	947.2	0.2001	1.537	0.1268
Oxygen	4.658	0.0117	149.1	0.0315	0.1310	0.0108
H2O	1.076e-005	0.0000	1.938e-004	0.0000	1.942e-007	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	399.4	1.0000	4734	1.0000	12.12	1.0000

Recycle without Purge (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Recycle without Purge Fluid Package: Basis-1
Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.	LIQUID PH.
Vapour / Phase Fraction	1.0000	1.0000	0.0000
Temperature: (C)	-32.03	-32.03	-32.03
Pressure: (kPa)	800.0	800.0	800.0
Molar Flow (kgmole/h)	401.9	401.9	0.0000
Mass Flow (kg/h)	4769	4769	0.0000
Std Ideal Liq VolFlow (m3/h)	12.20	12.20	0.0000
Molar Enthalpy (kJ/kgmole)	-8.108e+03	-8.108e+03	-7.245e+04
Molar Entropy (kJ/kgmole-C)	1.218e+02	1.218e+02	6.443e+01
Heat Flow (kJ/h)	-3.259e+06	-3.259e+06	0.000e-01
Liq VolFlow @Std Cond (m3/h)	9500	9500	0.0000

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	226.7	0.5641	457.0	0.0958	6.542	0.5362
Nitrogen	114.5	0.2849	3208	0.6727	3.979	0.3261
Ammonia	55.98	0.1393	953.3	0.1999	1.547	0.1268
Oxygen	4.713	0.0117	150.8	0.0316	0.1326	0.0109
H2O	1.082e-005	0.0000	1.949e-004	0.0000	1.953e-007	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	401.9	1.0000	4769	1.0000	12.20	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	226.7	0.5641	457.0	0.0958	6.542	0.5362
Nitrogen	114.5	0.2849	3208	0.6727	3.979	0.3261
Ammonia	55.98	0.1393	953.3	0.1999	1.547	0.1268
Oxygen	4.713	0.0117	150.8	0.0316	0.1326	0.0109
H2O	1.082e-005	0.0000	1.949e-004	0.0000	1.953e-007	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	401.9	1.0000	4769	1.0000	12.20	1.0000

Liquid Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0002	0.0000	0.0000	0.0000	0.0002
Nitrogen	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001
Ammonia	0.0000	0.9951	0.0000	0.9949	0.0000	0.9966
Oxygen	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001
H2O	0.0000	0.0045	0.0000	0.0048	0.0000	0.0030
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

Refrigerant Propane (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Refrigerant Propane Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.	LIQUID PH.
Vapour / Phase Fraction	0.5021	0.5021	0.4979
Temperature: (C)	-30.70	-30.70	-30.70
Pressure: (kPa)	163.3	163.3	163.3
Molar Flow (kgmole/h)	756.5	379.8	376.7
Mass Flow (kg/h)	3.336e+004	1.675e+004	1.661e+004
Std Ideal Liq VolFlow (m3/h)	65.84	33.05	32.78
Molar Enthalpy (kJ/kgmole)	-1.171e+05	-1.080e+05	-1.262e+05
Molar Entropy (kJ/kgmole-C)	1.055e+02	1.429e+02	6.781e+01
Heat Flow (kJ/h)	-8.857e+07	-4.102e+07	-4.755e+07
Liq VolFlow @Std Cond (m3/h)	65.71	32.99	32.72

COMPOSITION

Overall Phase Vapour Fraction 0.5021

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000
Total	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000

Vapour Phase Phase Fraction 0.5021

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	379.8	1.0000	1.675e+004	1.0000	33.05	1.0000
Total	379.8	1.0000	1.675e+004	1.0000	33.05	1.0000

Liquid Phase Phase Fraction 0.4979

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	376.7	1.0000	1.661e+004	1.0000	32.78	1.0000
Total	376.7	1.0000	1.661e+004	1.0000	32.78	1.0000

Vapor Propane (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments

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Material Stream: Vapor Propane Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.	LIQUID PH.
Vapour / Phase Fraction	1.0000	1.0000	0.0000
Temperature: (C)	-42.19	-42.19	-42.19
Pressure: (kPa)	101.3	101.3	101.3
Molar Flow (kgmole/h)	756.5	756.5	0.0000
Mass Flow (kg/h)	3.336e+004	3.336e+004	0.0000
Std Ideal Liq VolFlow (m3/h)	65.84	65.84	0.0000
Molar Enthalpy (kJ/kgmole)	-1.087e+05	-1.087e+05	-1.274e+05
Molar Entropy (kJ/kgmole-C)	1.441e+02	1.441e+02	6.306e+01
Heat Flow (kJ/h)	-8.219e+07	-8.219e+07	0.000e-01
Liq VolFlow @Std Cond (m3/h)	65.71	65.71	0.0000

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Total 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Vapour Phase Phase Fraction 1.000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Total 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Liquid Phase Phase Fraction 0.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000

Compressed Propane (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Compressed Propane Fluid Package: Basis-1

Property Package: Peng-Robinson
CONDITIONS

OVERALL VAPOUR PH. LIQUID PH.
Vapour / Phase Fraction 1.0000 1.0000 0.0000
Temperature: (C) -4.998 -4.998 -4.998
Pressure: (kPa) 405.2 405.2 405.2
Molar Flow (kgmole/h) 756.5 756.5 0.0000
Mass Flow (kg/h) 3.336e+004 3.336e+004 0.0000
Std Ideal Liq VolFlow (m3/h) 65.84 65.84 0.0000
Molar Enthalpy (kJ/kgmole) -1.066e+05 -1.066e+05 -1.235e+05
Molar Entropy (kJ/kgmole-C) 1.414e+02 1.414e+02 7.828e+01
Heat Flow (kJ/h) -8.065e+07 -8.065e+07 0.000e-01
Liq VolFlow @Std Cond (m3/h) 65.71 65.71 0.0000
COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000
Nitrogen -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000
Ammonia -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000
Oxygen -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000
H2O -0.0000 -0.0000 -0.0000 -0.0000 -0.0000 -0.0000
Propane 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Total 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Vapour Phase Phase Fraction 1.000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)
Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Total 756.5 1.0000 3.336e+004 1.0000 65.84 1.0000
Liquid Phase Phase Fraction 0.0000

COMPONENTS MOLE FLOW MOLE FRAC MASS FLOW MASS FRAC LIQVOL FLOW LIQVOL FRAC
(kgmole/h) (kg/h) (m3/h)

Hydrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Nitrogen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Ammonia 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Oxygen 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
H2O 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
Propane 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000
Total 0.0000 1.0000 0.0000 1.0000 0.0000 1.0000

Condensed Propane (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Condensed Propane Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	LIQUID PH.	VAPOUR PH.
Vapour / Phase Fraction	0.0000	1.0000	0.0000
Temperature: (C)	47.24	47.24	47.24
Pressure: (kPa)	1619	1619	1619
Molar Flow (kgmole/h)	756.5	756.5	0.0000
Mass Flow (kg/h)	3.336e+004	3.336e+004	0.0000
Std Ideal Liq VolFlow (m3/h)	65.84	65.84	0.0000
Molar Enthalpy (kJ/kgmole)	-1.171e+05	-1.171e+05	-1.042e+05
Molar Entropy (kJ/kgmole-C)	9.984e+01	9.984e+01	1.400e+02
Heat Flow (kJ/h)	-8.857e+07	-8.857e+07	0.000e-01
Liq VolFlow @Std Cond (m3/h)	65.71	65.71	0.0000

COMPOSITION

Overall Phase Vapour Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000
Total	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000

Liquid Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000
Total	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000

Vapour Phase Phase Fraction 0.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

PROCESS UTILITY

Second Stage Compressed Propane (Material Stream): Conditions, Composition, K Value, Package Properties, Attachments
----
Material Stream: Second Stage Compressed Propane Fluid Package: Basis-1

Property Package: Peng-Robinson

CONDITIONS

	OVERALL	VAPOUR PH.
Vapour / Phase Fraction	1.0000	1.0000
Temperature: (C)	62.07	62.07
Pressure: (kPa)	1621	1621

Molar Flow (kgmole/h)	756.5	756.5
Mass Flow (kg/h)	3.336e+004	3.336e+004
Std Ideal Liq VolFlow (m3/h)	65.84	65.84
Molar Enthalpy (kJ/kgmole)	-1.028e+05	-1.028e+05
Molar Entropy (kJ/kgmole-C)	1.443e+02	1.443e+02
Heat Flow (kJ/h)	-7.778e+07	-7.778e+07
Liq VolFlow @Std Cond (m3/h)	65.71	65.71

COMPOSITION

Overall Phase Vapour Fraction 1.0000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
Nitrogen	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
Ammonia	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
Oxygen	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
H2O	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
Propane	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000
Total	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000

Vapour Phase Phase Fraction 1.000

COMPONENTS	MOLE FLOW (kgmole/h)	MOLE FRAC	MASS FLOW (kg/h)	MASS FRAC	LIQVOL FLOW (m3/h)	LIQVOL FRAC
Hydrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000
Total	756.5	1.0000	3.336e+004	1.0000	65.84	1.0000

MIX-100 (Mixer): Design, Rating

Mixer: MIX-100

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION
Nitrogen	
SMR Hydrogen	

Outlet Stream

STREAM NAME	TO UNIT OPERATION
Mixed Feed	MIX-101 Mixer

PARAMETERS

User Variables

NOZZLE PARAMETERS

Base Elevation Relative to Ground Level 0.0000 m

	Nitrogen	SMR Hydrogen	Mixed Feed
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000

MIX-101 (Mixer): Design, Rating

Mixer: MIX-101

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION
Mixed Feed	MIX-100 Mixer
Recycle to Compressor	RCY-1 Recycle

Outlet Stream

STREAM NAME	TO UNIT OPERATION
Mixed and Recycled	K-100 Compressor

PARAMETERS

User Variables

NOZZLE PARAMETERS

Base Elevation Relative to Ground Level 0.0000 m

	Mixed Feed	Recycle to Compressor	Mixed and Recycled
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000

K-100 (Compressor): Design, Rating, Performance

Compressor: K-100
DESIGN
Connections
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Mixed and Recycled MIX-101 Mixer
Outlet Stream
STREAM NAME TO UNIT OPERATION
Compressed Feed Named E-106 Heat Exchanger
Energy Stream

STREAM NAME FROM UNIT OPERATION
Stage 1 Compression Energy
Parameters
Speed: 1325 rpm Duty: 1.9774e+02 kW
Adiabatic Eff.: 85.00 PolyTropic Eff.: 85.65
Adiabatic Head: 9003 m Polytropic Head: 9072 m
Adiabatic Fluid Head: 88.29 kJ/kg Polytropic Fluid Head: 88.97 kJ/kg
Polytropic Exp. 1.498 Isentropic Exp. 1.399 Poly Head Factor 1.000
RECIPROCATING SETTINGS
Number of Cylinders: 1 Cylinder Type: Single-acting, Outer End
Bore: 0.2000 m Stroke: 1.000 m
Piston Rod Diameter: 2.500e-002 m Const. Vol. Efficiency Loss: 4.00 %
Default Fixed Clearance Vol.: 15.00 % Zero Speed Flow Resistance: 0.0000 kg/hr/sqrt(kPa-kg/m3)
Typical Design Speed: --- Volumetric Efficiency: 90.81 %
Speed: 1325 rpm
1
Fixed Clearance Vol. (m3) 4.712e-003
Variable Clearance Vol. (m3) 0.0000
Variable Volume Enabled Off
Cylinder is unloaded Off
User Variables
RATING
Nozzle Paramaters
Base Elevation Relative to Ground Level 0.0000 m

	Mixed and Recycled	Compressed Feed
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

Inertia
Rotational inertia (kg-m2) 6.000 Radius of gyration (m) 0.2000
Mass (kg) 150.0 Friction loss factor (rad/min) (kg-m2/s) 6.000e-003
PERFORMANCE
Results
Adiabatic Head (m) 9003 Power Consumed (kW) 197.7
Polytropic Head (m) 9072 Polytropic Head Factor 1.000
Adiabatic Fluid Head (kJ/kg) 88.29 Polytropic Exponent 1.498
Polytropic Fluid Head (kJ/kg) 88.97 Isentropic Exponent 1.399
Adiabatic Efficiency 85 Speed (rpm) 1325
Polytropic Efficiency 86 ---
Power/Torque
Total Rotor Power (kW) 197.7 Total Rotor Torque (N-m) 1425
Transient Rotor Power (kW) 0.0000 Transient Rotor Torque (N-m) 0.0000
Friction Power Loss (kW) 0.0000 Friction Torque Loss (N-m) 0.0000
Fluid Power (kW) 197.7 Fluid Torque (N-m) 1425

K-101 (Compressor): Design, Rating, Performance

Compressor: K-101
DESIGN
Connections
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Vapor Propane Named E-107 Heat Exchanger
Outlet Stream
STREAM NAME TO UNIT OPERATION
Compressed Propane K-102 Compressor
Energy Stream
STREAM NAME FROM UNIT OPERATION
Propane Compressor Energy
Parameters
Speed: 1.344e+004 rpm Duty: 4.2812e+02 kW
Adiabatic Eff.: 135.69 PolyTropic Eff.: 132.50

Adiabatic Head: --- Polytropic Head: 6242 m
Adiabatic Fluid Head: --- Polytropic Fluid Head: 61.22 kJ/kg
Polytropic Exp. 1.064 Isentropic Exp. 1.104 Poly Head Factor 1.006
RECIPROCATING SETTINGS
Number of Cylinders: 1 Cylinder Type: Single-acting, Outer End
Bore: 0.2000 m Stroke: 1.000 m
Piston Rod Diameter: 2.500e-002 m Const. Vol. Efficiency Loss: 4.00 %
Default Fixed Clearance Vol.: 15.00 % Zero Speed Flow Resistance: 0.0000 kg/hr/sqrt(kPa-kg/m3)
Typical Design Speed: --- Volumetric Efficiency: 54.72 %
Speed: 1.344e+004 rpm
1
Fixed Clearance Vol. (m3) 4.712e-003
Variable Clearance Vol. (m3) 0.0000
Variable Volume Enabled Off
Cylinder is unloaded Off
User Variables
RATING
Nozzle Paramaters
Base Elevation Relative to Ground Level 0.0000 m

	Vapor Propane	Compressed Propane
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

Inertia
Rotational inertia (kg-m2) 6.000 Radius of gyration (m) 0.2000
Mass (kg) 150.0 Friction loss factor (rad/min) (kg-m2/s) 6.000e-003
PERFORMANCE
Results
Adiabatic Head (m) --- Power Consumed (kW) 428.1
Polytropic Head (m) 6242 Polytropic Head Factor 1.006
Adiabatic Fluid Head (kJ/kg) --- Polytropic Exponent 1.064
Polytropic Fluid Head (kJ/kg) 61.22 Isentropic Exponent 1.104
Adiabatic Efficiency 136 Speed (rpm) 1.344e+004
Polytropic Efficiency 132 ---
Power/Torque
Total Rotor Power (kW) 428.1 Total Rotor Torque (N-m) 304.2
Transient Rotor Power (kW) 0.0000 Transient Rotor Torque (N-m) 0.0000
Friction Power Loss (kW) 0.0000 Friction Torque Loss (N-m) 0.0000
Fluid Power (kW) 428.1 Fluid Torque (N-m) 304.2

K-102 (Compressor): Design, Rating, Performance

Compressor: K-102
DESIGN
Connections
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Compressed Propane K-101 Compressor
Outlet Stream
STREAM NAME TO UNIT OPERATION
Second Stage Compressed Propane AC-100 Air cooler
Energy Stream
STREAM NAME FROM UNIT OPERATION
Second Compressed Propane Energy
Parameters
Speed: --- Duty: 7.9884e+02 kW
Adiabatic Eff.: 75.00 PolyTropic Eff.: 77.52
Adiabatic Head: 6593 m Polytropic Head: 6815 m
Adiabatic Fluid Head: 64.66 kJ/kg Polytropic Fluid Head: 66.83 kJ/kg
Polytropic Exp. 1.054 Isentropic Exp. 1.004 Poly Head Factor 1.017
User Variables
RATING
Curves
Compressor Speed: --- Efficiency: Adiabatic Curves Enabled: Yes
Head Offset: 0.0000 m Efficiency Offset: 0.00 %
Speed:
Flow Head Efficiency (%)
Flow Limits Surge Curve: Inactive
Speed Flow
Stone Wall Curve: Inactive
Speed Flow
Surge Flow Rate --- Field Flow Rate 3768 ACT_m3/h Stone Wall Flow --- Compressor Volume 0.0000 m3
Nozzle Paramaters
Base Elevation Relative to Ground Level 0.0000 m

Compressed Propane Second Stage Compressed Propane
Diameter (m) 5.000e-002 5.000e-002
Elevation (Base) (m) 0.0000 0.0000
Elevation (Ground) (m) 0.0000 0.0000
Inertia
Rotational inertia (kg-m2) 6.000 Radius of gyration (m) 0.2000
Mass (kg) 150.0 Friction loss factor (rad/min) (kg-m2/s) 6.000e-003
PERFORMANCE
Results
Adiabatic Head (m) 6593 Power Consumed (kW) 798.8
Polytropic Head (m) 6815 Polytropic Head Factor 1.017
Adiabatic Fluid Head (kJ/kg) 64.66 Polytropic Exponent 1.054
Polytropic Fluid Head (kJ/kg) 66.83 Isentropic Exponent 1.004
Adiabatic Efficiency 75 Speed (rpm) ---
Polytropic Efficiency 78 ---
Power/Torque
Total Rotor Power (kW) 798.8 Total Rotor Torque (N-m) ---
Transient Rotor Power (kW) 0.0000 Transient Rotor Torque (N-m) ---
Friction Power Loss (kW) 0.0000 Friction Torque Loss (N-m) ---
Fluid Power (kW) 798.8 Fluid Torque (N-m) ---

V-100 (Separator): Design, Reactions, Rating, Carry Over

Separator: V-100
CONNECTIONS
Inlet Stream
Stream Name From Unit Operation
Condensed Reactor Product Heat Exchanger: Named E-107
Outlet Stream
Stream Name To Unit Operation
Overhead Recycle Tee: TEE-100
Ammonia Product
Energy Stream
Stream Name From Unit Operation
PARAMETERS
Vessel Volume: --- Level SP: 50.00 % Liquid Volume: ---
Vessel Pressure: 800.0 kPa Pressure Drop: 114.0 kPa Duty: 0.0000 kJ/h Heat Transfer Mode: Heating
User Variables
RATING
Base Elevation Relative to Ground Level 0.0000 m Diameter --- Length ---
Condensed Reactor Product Overhead Recycle Ammonia Product
Diameter (m) 5.000e-002 5.000e-002 5.000e-002
Elevation (Base) (m) 0.0000 0.0000 0.0000
Elevation (Ground) (m) 0.0000 0.0000 0.0000
Elevation (% of Height) (%) --- --- ---
Level Taps: Level Tap Specification
Level Tap PV High PV Low OP High OP Low
Level Taps: Calculated Level Tap Values
Level Tap Liquid Level Aqueous Level
Options
PV Work Term Contribution (%) 100.00

Named E-106 (Heat Exchanger): Design, Rating, Details, Tables, HTFS Results, Exchanger Design and Rating
----
Heat Exchanger: Named E-106
CONNECTIONS
Tube Side Shell Side
Inlet Outlet Inlet Outlet
Name Reactor Product Name Cooled Reactor Product Name Compressed Feed Name Preheated Feed
From Op. PFR-100 To Op. Named E-107 From Op. K-100 To Op. PFR-100
Op. Type Plug Flow Reactor Op. Type Heat Exchanger Op. Type Compressor Op. Type Plug Flow Reactor
Temp 550.00 C Temp 177.02 C Temp 101.65 C Temp 450.00 C
PARAMETERS
Heat Exchanger Model: Simple End Point
Tube Side DeltaP: 62.00 kPa Shell Side DeltaP: 62.00 kPa Passes: ---
UA: 7.949e+004 kJ/C-h Tolerance: 1.0000e-04
Tube Side Data Shell Side Data
Heat Transfer Coeff --- Heat Transfer Coeff ---
Tube Pressure Drop 62.00 kPa Shell Pressure Drop 62.00 kPa
Fouling 0.00000 C-h-m2/kJ Fouling 0.00000 C-h-m2/kJ
Tube Length 6.00 m Shell Passes 1
Tube O.D. 20.00 mm Shell Series 1
Tube Thickness 2.0000 mm Shell Parallel 1
Tube Pitch 50.0000 mm Baffle Type Single

Orientation Horizontal Baffle Cut(%Area) 20.00
Passes Per Shell 2 Baffle Orientation Horizontal
Tubes Per Shell 160 Spacing 800.0000 mm
Layout Angle Triangular (30 degrees) Diameter 739.0488 mm
TEMA Type A E L Area 60.32 m2
SPECS

	Spec Value	Curr Value	Rel Error	Active	Estimate
E-100 Heat Balance	0.0000 kJ/h	0.0000 kJ/h	0.0000	On	Off
E-100 UA	---	7.949e+004 kJ/C-h	---	On	Off

Detailed Specifications
E-100 Heat Balance
Type: Duty Pass: Error Spec Value: 0.0000 kJ/h
E-100 UA
Type: UA Pass: Overall Spec Value: ---
User Variables
RATING
Sizing
Overall Data
Configuration
# of Shells in Series 1 Tube Passes per Shell 2 Elevation (Base) 0.0000 m
# of Shells in Parallel 1 Exchange Orientation Horizontal First Tube Pass Flow Direction Counter
TEMA Type: A E L
Calculated Information
Shell HT Coeff --- Tube HT Coeff ---
Overall U 1318 kJ/h-m2-C Overall UA 7.949e+004 kJ/C-h
Shell DP 62.00 kPa Tube DP 62.00 kPa
Shell Vol per Shell 2.272 m3 Tube Vol per Shell 0.1930 m3
HT Area per Shell 60.32 m2
Shell Data
Shell and Tube Bundle
Shell Diameter 739.0 (mm) Tube Pitch 50.00 (mm) Shell Fouling 0.0000 (C-h-m2/kJ)
# of Tubes per Shell 160 Tube Layout Angle Triangular (30 degrees)
Shell Baffles
Shell Baffle Type Single Shell Baffle Orientation Horizontal
Baffle Cut (%Area) 20.00 Baffle Spacing 800.0 mm
Tube Data
Dimensions
OD 20.00 (mm) ID 16.00 (mm) Tube Thickness 2.000 (mm) Tube Length 6.000 (m)
Tube Properties
Tube Fouling 0.0000 (C-h-m2/kJ) Thermal Cond. 45.00 (W/m-K) Wall Cp --- (kJ/kg-C) Wall Density --- (kg/m3)
Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 m

	Reactor Product	Compressed Feed	Cooled Reactor Product
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000
Elevation (% of Height) (%)	0.00	0.00	0.00

	Preheated Feed
Diameter (m)	5.000e-002
Elevation (Base) (m)	0.0000
Elevation (Ground) (m)	0.0000
Elevation (% of Height) (%)	0.00

DETAILS

Overall/Detailed Performance

Duty: 6.924e+06 kJ/h UA Curv. Error: 0.00e-01 kJ/C-h
Heat Leak: 0.000e-01 kJ/h Hot Pinch Temp: 177.0 C
Heat Loss: 0.000e-01 kJ/h Cold Pinch Temp: 101.7 C
UA: 7.949e+04 kJ/C-h Ft Factor: ---
Min. Approach: 75.37 C Uncorrected Lmtd: ---
Lmtd: 87.11 C
TABLES

Shell Side - Overall Phase

Temperature (C)	Pressure (kPa)	Heat Flow (kJ/h)	Enthalpy (kJ/kgmole)
101.65	1100.00	0.00	-1904.57
450.00	1038.00	6924087.72	8808.00

UA Molar Vap Frac Mass Vap Frac Heat of Vap.
(kJ/C-h) (kJ/kgmole)
0.00 1.0000 1.0000 ---
0.00 1.0000 1.0000 ---
Shell Side - Vapour Phase

Mass Flow Molecular Wt Density Mass Sp Heat Viscosity Thermal Cond
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K)
6853.17 10.60 3.74 2.81 0.01 0.11
6853.17 10.60 1.83 2.99 0.02 0.18
Std Gas Flow Z Factor Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(STD_m3/h) (kPa) (C)
15282.62 1.00 2782.77 -181.08 0.29 -0.04
15282.62 1.00 2782.77 -181.08 0.29 -0.04
Shell Side - Light Liquid Phase
Temperature Pressure Heat Flow Enthalpy
(C) (kPa) (kJ/h) (kJ/kgmole)
177.02 975.96 0.00 -10955.12
550.00 1037.96 6924087.72 2252.37
UA Molar Vap Frac Mass Vap Frac Heat of Vap.
(kJ/C-h) (kJ/kgmole)
0.00 1.0000 1.0000 ---
0.00 1.0000 1.0000 ---
Tube Side - Vapour Phase
Mass Flow Molecular Wt Density Mass Sp Heat Viscosity Thermal Cond
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K)
6853.11 13.07 3.41 2.53 0.02 0.09
6853.11 13.07 1.98 2.89 0.02 0.16
Std Gas Flow Z Factor Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(STD_m3/h) (kPa) (C)
12395.71 1.00 5202.39 -91.56 0.29 0.04
12395.71 1.00 5202.39 -91.56 0.29 0.04
Tube Side - Light Liquid Phase

Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K) (dyne/cm)
--- --- --- --- --- ---
0.00 1.98 2.89 0.00 0.11 0.00
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(kPa) (C)
--- --- --- --- --- ---
13.07 0.00 5202.38 -91.56 0.29 0.04
Tube Side - Heavy Liquid Phase

(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K) (dyne/cm)
--- --- --- --- --- ---
0.00 1.98 2.89 0.00 0.11 ---
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(kPa) (C)
--- --- --- --- --- ---
13.07 0.00 5202.38 -91.56 0.29 0.04
HTFS
Exchanger Design and Rating

Named E-107 (Heat Exchanger): Design, Rating, Details, Tables, HTFS Results, Exchanger Design and Rating

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Heat Exchanger: Named E-107
CONNECTIONS
Tube Side Shell Side
Inlet Outlet Inlet Outlet
Name Cooled Reactor Product Name Condensed Reactor Product Name Refrigerant Propane Name Vapor Propane
From Op. Named E-106 To Op. V-100 From Op. VLV-100 To Op. K-101
Op. Type Heat Exchanger Op. Type Separator Op. Type Valve Op. Type Compressor
Temp 177.02 C Temp -30.00 C Temp -30.70 C Temp -42.19 C
PARAMETERS
Heat Exchanger Model: Simple End Point
Tube Side DeltaP: 62.00 kPa Shell Side DeltaP: 62.00 kPa Passes: ---
UA: 1.609e+005 kJ/C-h Tolerance: 1.0000e-04
Tube Side Data Shell Side Data
Heat Transfer Coeff --- Heat Transfer Coeff ---
Tube Pressure Drop 62.00 kPa Shell Pressure Drop 62.00 kPa
Fouling 0.00000 C-h-m2/kJ Fouling 0.00000 C-h-m2/kJ
Tube Length 6.00 m Shell Passes 1
Tube O.D. 20.00 mm Shell Series 1

Tube Thickness 2.0000 mm Shell Parallel 1
Tube Pitch 50.0000 mm Baffle Type Single
Orientation Horizontal Baffle Cut(%Area) 20.00
Passes Per Shell 2 Baffle Orientation Horizontal
Tubes Per Shell 160 Spacing 800.0000 mm
Layout Angle Triangular (30 degrees) Diameter 739.0488 mm
TEMA Type A E L Area 60.32 m2
SPECS

	Spec Value	Curr Value	Rel Error	Active	Estimate
E-104 Heat Balance	0.0000 kJ/h	-2.774e-005 kJ/h	-4.348e-012	On	Off
E-104 UA	---	1.609e+005 kJ/C-h	---	On	Off

Detailed Specifications

E-104 Heat Balance
Type: Duty Pass: Error Spec Value: 0.0000 kJ/h
E-104 UA
Type: UA Pass: Overall Spec Value: ---
User Variables

RATING

Sizing

Overall Data
Configuration
# of Shells in Series 1 Tube Passes per Shell 2 Elevation (Base) 0.0000 m
# of Shells in Parallel 1 Exchange Orientation Horizontal First Tube Pass Flow Direction Counter
TEMA Type: A E L
Calculated Information
Shell HT Coeff --- Tube HT Coeff ---
Overall U 2668 kJ/h-m2-C Overall UA 1.609e+005 kJ/C-h
Shell DP 62.00 kPa Tube DP 62.00 kPa
Shell Vol per Shell 2.272 m3 Tube Vol per Shell 0.1930 m3
HT Area per Shell 60.32 m2
Shell Data
Shell and Tube Bundle
Shell Diameter 739.0 (mm) Tube Pitch 50.00 (mm) Shell Fouling 0.0000 (C-h-m2/kJ)
# of Tubes per Shell 160 Tube Layout Angle Triangular (30 degrees)
Shell Baffles
Shell Baffle Type Single Shell Baffle Orientation Horizontal
Baffle Cut (%Area) 20.00 Baffle Spacing 800.0 mm
Tube Data
Dimensions
OD 20.00 (mm) ID 16.00 (mm) Tube Thickness 2.000 (mm) Tube Length 6.000 (m)
Tube Properties
Tube Fouling 0.0000 (C-h-m2/kJ) Thermal Cond. 45.00 (W/m-K) Wall Cp --- (kJ/kg-C) Wall Density --- (kg/m3)
Nozzle Parameters
Base Elevation Relative to Ground Level 0.0000 m

	Cooled Reactor Product	Refrigerant Propane	Condensed Reactor Product
Diameter (m)	5.000e-002	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000	0.0000
Elevation (% of Height) (%)	0.00	0.00	0.00

	Vapor Propane
Diameter (m)	5.000e-002
Elevation (Base) (m)	0.0000
Elevation (Ground) (m)	0.0000
Elevation (% of Height) (%)	0.00

DETAILS
Overall/Detailed Performance
Duty: 6.379e+06 kJ/h UA Curv. Error: 0.00e-01 kJ/C-h
Heat Leak: 0.000e-01 kJ/h Hot Pinch Temp: -30.00 C
Heat Loss: 0.000e-01 kJ/h Cold Pinch Temp: -30.70 C
UA: 1.609e+05 kJ/C-h Ft Factor: ---
Min. Approach: 0.6979 C Uncorrected Lmtd: 39.65 C
Lmtd: 39.65 C
TABLES
Shell Side - Overall Phase

Temperature (C)	Pressure (kPa)	Heat Flow (kJ/h)	Enthalpy (kJ/kgmole)
-30.70	163.30	0.00	-117083.32

-42.19 101.30 6379448.55 -108650.50
UA Molar Vap Frac Mass Vap Frac Heat of Vap.
(kJ/C-h) (kJ/kgmole)
0.00 0.5021 0.5021 ---
0.00 1.0000 1.0000 ---
Shell Side - Vapour Phase

Mass Flow Molecular Wt Density Mass Sp Heat Viscosity Thermal Cond
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K)
16748.19 44.10 3.75 1.49 0.01 0.01
33359.47 44.10 2.41 1.43 0.01 0.01
Std Gas Flow Z Factor Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(STD_m3/h) (kPa) (C)
--- 0.95 4256.66 96.75 0.28 0.15
--- 0.97 4256.66 96.75 0.28 0.15
Shell Side - Light Liquid Phase

Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K) (dyne/cm)
16611.27 567.95 2.26 0.17 0.13 13.93
0.00 581.52 2.18 0.20 0.13 15.48
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(kPa) (C)
44.10 0.57 4256.66 96.75 0.28 0.15
44.10 0.58 4256.66 96.75 0.28 0.15
Shell Side - Heavy Liquid Phase

Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K) (dyne/cm)
--- --- --- --- --- ---
--- --- --- --- --- ---
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(kPa) (C)
--- --- --- --- --- ---
--- --- --- --- --- ---
Shell Side - Mixed Liquid
Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K) (dyne/cm)
16611.27 567.95 2.26 0.17 0.13 ---
0.00 581.52 2.18 0.20 0.13 ---
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(kPa) (C)
44.10 0.57 4256.66 96.75 0.28 0.15
44.10 0.58 4256.66 96.75 0.28 0.15
Tube Side - Overall Phase
Temperature Pressure Heat Flow Enthalpy
(C) (kPa) (kJ/h) (kJ/kgmole)
-30.00 913.96 0.00 -23123.73
24.11 950.79 3789108.02 -15896.12
177.02 975.96 6379448.55 -10955.12
UA Molar Vap Frac Mass Vap Frac Heat of Vap.
(kJ/C-h) (kJ/kgmole)
0.00 0.7633 0.6916 ---
0.00 1.0000 1.0000 ---
0.00 1.0000 1.0000 ---
Tube Side - Vapour Phase
Mass Flow Molecular Wt Density Mass Sp Heat Viscosity Thermal Cond
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K)
4739.86 11.84 5.39 2.52 0.01 0.07
6853.11 13.07 5.10 2.43 0.01 0.07
6853.11 13.07 3.41 2.53 0.02 0.09
Std Gas Flow Z Factor Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega
(STD_m3/h) (kPa) (C)
9462.09 0.99 3305.22 -161.29 0.29 -0.02
12395.71 0.99 5202.39 -91.56 0.29 0.04
12395.71 1.00 5202.39 -91.56 0.29 0.04
Tube Side - Light Liquid Phase

Mass Flow Density Mass Sp Heat Viscosity Thermal Cond Surface Tens
(kg/h) (kg/m3) (kJ/kg-C) (cP) (W/m-K) (dyne/cm)
2113.25 670.75 4.47 0.24 0.61 39.17
0.00 782.22 4.55 0.34 0.54 49.80
--- --- --- --- --- ---
Molecular Wt Sp Gravity Pseudo Pc Pseudo Tc Pseudo Zc Pseudo Omega

(kPa) (C)
17.03 0.67 11321.51 133.33 0.27 0.26
17.53 0.78 16827.30 256.14 0.27 0.30
--- --- --- --- --- ---
Tube Side - Heavy Liquid Phase

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	---	---	---

Tube Side - Mixed Liquid

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
2113.25	670.75	4.47	0.24	0.61	---
0.00	782.22	4.55	0.34	0.54	---
---	---	---	---	---	---

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
17.03	0.67	11321.51	133.33	0.27	0.26
17.53	0.78	16827.30	256.14	0.27	0.30
---	---	---	---	---	---

HTFS
Exchanger Design and Rating

RCY-1 (Recycle): Design

Recycle: RCY-1
CONNECTIONS
Inlet Stream

Stream Name	From Unit Operation
Recycle without Purge	TEE-100 Tee

Outlet Stream

Stream Name	To Unit Operation
Recycle to Compressor	MIX-101 Mixer

TOLERANCE
Vapour Fraction: 10.00 Temperature: 10.00 Pressure: 10.00
Flow: 10.00 Enthalpy: 10.00 Composition: 10.00
NUMERICAL
Acceleration Type: Wegstein Iteration Type: Nested
Maximum Iterations: 10 Iteration Count: 0
Wegstein Count: 3 Q Minimum: -20.00 Q Maximum: 0.0000
Iteration History

Iteration	Variable	Outlet Value	Inlet Value
0	Converged	---	---

User Variables

PFR-100 (Plug Flow Reactor): Design, Rating, Performance

Plug Flow Reactor: PFR-100
CONNECTIONS
Inlet Stream

STREAM NAME	FROM UNIT OPERATION
Preheated Feed	Named E-106 Heat Exchanger

Outlet Stream

STREAM NAME	TO UNIT OPERATION
Reactor Product	Named E-106 Heat Exchanger

Energy Stream

STREAM NAME	TO UNIT OPERATION
PBR Jacket Cooling	

PARAMETERS
Physical Parameters
Type : Ergun Equation Pressure Drop: 3.556e-002 kPa
Heat Transfer
Type : Direct Q Value Energy Stream : PBR Jacket Cooling Duty : 4.512e+006 kJ/h
Dimensions
Total Volume: 538.4 m3 Length: 18.42 m Diameter: 6.100 m Number of Tubes: 1
Wall Thickness: 5.000e-003 m Void Fraction: 0.9000 Void Volume: 484.6 m3

Reaction Info
Reaction Set: Set-1 Initialize From: Current
Integration Information
Number of Segments: 20 Minimum Step Fraction: 1.0e-06 Minimum Step Length: 1.8e-05 m
Catalyst Data
Particle Diameter: 1.000e-003 m Particle Spericity: 1.0000 Solid Density: 2500 kg/m3
Bulk Density: 250.0 kg/m3 Solid Heat Capacity: 250.0 kJ/kg-C
User Variables
RATING
Sizing
Tube Dimensions
Total Volume 538.4 m3 Length 18.42 m Diameter 6.100 m Number of Tubes 1 Wall Thickness 5.000e-003 m
Tube Packing
Void Fraction 0.9000 Void Volume 484.6 m3
Nozzle Parameters
Base Elevation Relative to Ground Level 0.0000 m Diameter 6.100 m Length 18.42

	Reactor Product	Preheated Feed
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

Conditions

Length (m)	Temperature (C)	Pressure (kPa)	Vapour Fraction	Duty (kJ/h)
0.461	455.0	1038.00	1.0000	7714838
1.382	460.0	1038.00	1.0000	-118455
2.303	465.0	1037.99	1.0000	-173385
3.224	470.0	1037.99	1.0000	-173477
4.145	475.0	1037.99	1.0000	-173236
5.066	480.0	1037.99	1.0000	-172984
5.987	485.0	1037.99	1.0000	-172724
6.909	490.0	1037.99	1.0000	-172456
7.830	495.0	1037.98	1.0000	-172179
8.751	500.0	1037.98	1.0000	-171895
9.672	505.0	1037.98	1.0000	-171603
10.593	510.0	1037.98	1.0000	-171303
11.514	515.0	1037.98	1.0000	-170997
12.435	520.0	1037.98	1.0000	-170684
13.357	525.0	1037.97	1.0000	-170365
14.278	530.0	1037.97	1.0000	-170040
15.199	535.0	1037.97	1.0000	-169709
16.120	540.0	1037.97	1.0000	-169373
17.041	545.0	1037.97	1.0000	-169032
17.962	550.0	1037.96	1.0000	-168687

Length (m)	Enthalpy (kJ/kgmole)	Entropy (kJ/kgmole-C)	Inside HTC (kJ/h-m2-C)	Overall HTC (kJ/h-m2-C)
0.461	-4054	168.06	---	---
1.382	-3813	168.26	---	---
2.303	-3455	168.30	---	---
3.224	-3100	168.34	---	---
4.145	-2747	168.38	---	---
5.066	-2396	168.42	---	---
5.987	-2048	168.47	---	---
6.909	-1703	168.51	---	---
7.830	-1360	168.55	---	---
8.751	-1020	168.59	---	---
9.672	-682	168.63	---	---
10.593	-347	168.67	---	---
11.514	-14	168.71	---	---
12.435	317	168.75	---	---
13.357	645	168.80	---	---
14.278	971	168.84	---	---
15.199	1295	168.88	---	---
16.120	1616	168.92	---	---
17.041	1935	168.96	---	---
17.962	2252	169.01	---	---

Flows

Length (m)	Molar Flow (kgmole/h)	Mass Flow (kg/h)	Volumetric Flow (m3/h)	Heat Flow (kJ/h)
0.461	498.754	6853.10	2913.296	-2.022e+006
1.382	499.204	6853.10	2936.036	-1.903e+006
2.303	500.684	6853.10	2964.947	-1.730e+006
3.224	502.159	6853.10	2993.945	-1.556e+006
4.145	503.624	6853.10	3022.993	-1.383e+006
5.066	505.077	6853.10	3052.089	-1.210e+006

5.987	506.520	6853.10	3081.231	-1.038e+006
6.909	507.952	6853.10	3110.417	-8.651e+005
7.830	509.373	6853.10	3139.646	-6.929e+005
8.751	510.782	6853.10	3168.917	-5.210e+005
9.672	512.181	6853.11	3198.227	-3.494e+005
10.593	513.568	6853.11	3227.575	-1.781e+005
11.514	514.944	6853.11	3256.960	-7077
12.435	516.308	6853.11	3286.379	1.636e+005
13.357	517.661	6853.11	3315.833	3.340e+005
14.278	519.003	6853.11	3345.318	5.040e+005
15.199	520.333	6853.11	3374.834	6.737e+005
16.120	521.652	6853.11	3404.378	8.431e+005
17.041	522.959	6853.11	3433.951	1.012e+006
17.962	524.255	6853.11	3463.550	1.181e+006

Segment Overall Reaction Rates (kgmole/m3-s)

Length (m)	Rxn-1
0.4606	8.461e-004
1.382	-2.580e-006
2.303	-8.484e-006
3.224	-8.457e-006
4.145	-8.396e-006
5.066	-8.334e-006
5.987	-8.271e-006
6.909	-8.208e-006
7.830	-8.144e-006
8.751	-8.081e-006
9.672	-8.017e-006
10.59	-7.951e-006
11.51	-7.886e-006
12.44	-7.823e-006
13.36	-7.757e-006
14.28	-7.691e-006
15.20	-7.624e-006
16.12	-7.559e-006
17.04	-7.493e-006
17.96	-7.428e-006

Component Production Rates (kgmole/m3-s)

Length (m)	Hydrogen	Nitrogen	Ammonia	Oxygen
0.4606	-2.538e-003	-8.461e-004	1.692e-003	0.0000
1.382	7.740e-006	2.580e-006	-5.160e-006	0.0000
2.303	2.545e-005	8.484e-006	-1.697e-005	0.0000
3.224	2.537e-005	8.457e-006	-1.691e-005	0.0000
4.145	2.519e-005	8.396e-006	-1.679e-005	0.0000
5.066	2.500e-005	8.334e-006	-1.667e-005	0.0000
5.987	2.481e-005	8.271e-006	-1.654e-005	0.0000
6.909	2.462e-005	8.208e-006	-1.642e-005	0.0000
7.830	2.443e-005	8.144e-006	-1.629e-005	0.0000
8.751	2.424e-005	8.081e-006	-1.616e-005	0.0000
9.672	2.405e-005	8.017e-006	-1.603e-005	0.0000
10.59	2.385e-005	7.951e-006	-1.590e-005	0.0000
11.51	2.366e-005	7.886e-006	-1.577e-005	0.0000
12.44	2.347e-005	7.823e-006	-1.565e-005	0.0000
13.36	2.327e-005	7.757e-006	-1.551e-005	0.0000
14.28	2.307e-005	7.691e-006	-1.538e-005	0.0000
15.20	2.287e-005	7.624e-006	-1.525e-005	0.0000
16.12	2.268e-005	7.559e-006	-1.512e-005	0.0000
17.04	2.248e-005	7.493e-006	-1.499e-005	0.0000
17.96	2.228e-005	7.428e-006	-1.486e-005	0.0000

Length (m)	H2O	Propane
0.4606	0.0000	0.0000
1.382	0.0000	0.0000
2.303	0.0000	0.0000
3.224	0.0000	0.0000
4.145	0.0000	0.0000
5.066	0.0000	0.0000
5.987	0.0000	0.0000
6.909	0.0000	0.0000
7.830	0.0000	0.0000
8.751	0.0000	0.0000
9.672	0.0000	0.0000
10.59	0.0000	0.0000
11.51	0.0000	0.0000
12.44	0.0000	0.0000

13.36	0.0000	0.0000
14.28	0.0000	0.0000
15.20	0.0000	0.0000
16.12	0.0000	0.0000
17.04	0.0000	0.0000
17.96	0.0000	0.0000

Transport

Length (m)	Viscosity (cP)	Moleular Weight	Mass Density (kg/m3)	Heat Capacity (kJ/kgmole-C)	Surface Tension (dyne/cm)	Z Factor
0.4606	2.219e-002	13.74	2.352	37.889	---	1.001
1.382	2.231e-002	13.73	2.334	37.935	---	1.002
2.303	2.241e-002	13.69	2.311	37.926	---	1.002
3.224	2.252e-002	13.65	2.289	37.916	---	1.002
4.145	2.263e-002	13.61	2.267	37.906	---	1.002
5.066	2.274e-002	13.57	2.245	37.895	---	1.002
5.987	2.286e-002	13.53	2.224	37.885	---	1.002
6.909	2.297e-002	13.49	2.203	37.874	---	1.002
7.830	2.309e-002	13.45	2.183	37.863	---	1.002
8.751	2.321e-002	13.42	2.163	37.852	---	1.002
9.672	2.333e-002	13.38	2.143	37.841	---	1.002
10.59	2.345e-002	13.34	2.123	37.830	---	1.002
11.51	2.357e-002	13.31	2.104	37.818	---	1.002
12.44	2.369e-002	13.27	2.085	37.807	---	1.002
13.36	2.382e-002	13.24	2.067	37.795	---	1.002
14.28	2.394e-002	13.20	2.049	37.784	---	1.002
15.20	2.407e-002	13.17	2.031	37.772	---	1.002
16.12	2.420e-002	13.14	2.013	37.760	---	1.002
17.04	2.433e-002	13.10	1.996	37.749	---	1.002
17.96	2.446e-002	13.07	1.979	37.737	---	1.002

Component Molar Flowrates (kgmole/h)

Length (m)	Hydrogen	Nitrogen	Ammonia	Oxygen
0.4606	188.4770	101.7847	203.2166	4.7205
1.382	189.1521	102.0098	202.7665	4.7205
2.303	191.3719	102.7497	201.2867	4.7205
3.224	193.5849	103.4874	199.8113	4.7205
4.145	195.7818	104.2197	198.3468	4.7205
5.066	197.9623	104.9465	196.8931	4.7205
5.987	200.1265	105.6679	195.4503	4.7205
6.909	202.2742	106.3838	194.0185	4.7205
7.830	204.4053	107.0942	192.5978	4.7205
8.751	206.5196	107.7989	191.1882	4.7205
9.672	208.6171	108.4981	189.7898	4.7205
10.59	210.6978	109.1917	188.4027	4.7205
11.51	212.7615	109.8796	187.0269	4.7205
12.44	214.8082	110.5618	185.6625	4.7205
13.36	216.8378	111.2383	184.3094	4.7205
14.28	218.8503	111.9092	182.9678	4.7205
15.20	220.8456	112.5743	181.6376	4.7205
16.12	222.8237	113.2336	180.3188	4.7205
17.04	224.7846	113.8873	179.0115	4.7205
17.96	226.7283	114.5352	177.7157	4.7205

Length (m)	H2O	Propane
0.4606	0.5550	0.0000
1.382	0.5550	0.0000
2.303	0.5550	0.0000
3.224	0.5550	0.0000
4.145	0.5550	0.0000
5.066	0.5550	0.0000
5.987	0.5550	0.0000
6.909	0.5550	0.0000
7.830	0.5550	0.0000
8.751	0.5550	0.0000
9.672	0.5550	0.0000
10.59	0.5550	0.0000
11.51	0.5550	0.0000
12.44	0.5550	0.0000
13.36	0.5550	0.0000
14.28	0.5550	0.0000
15.20	0.5550	0.0000
16.12	0.5550	0.0000
17.04	0.5550	0.0000
17.96	0.5550	0.0000

Component Mole Fractions

Length (m)	Hydrogen	Nitrogen	Ammonia	Oxygen
0.4606	0.3779	0.2041	0.4074	0.0095
1.382	0.3789	0.2043	0.4062	0.0095
2.303	0.3822	0.2052	0.4020	0.0094
3.224	0.3855	0.2061	0.3979	0.0094
4.145	0.3887	0.2069	0.3938	0.0094
5.066	0.3919	0.2078	0.3898	0.0093
5.987	0.3951	0.2086	0.3859	0.0093
6.909	0.3982	0.2094	0.3820	0.0093
7.830	0.4013	0.2102	0.3781	0.0093
8.751	0.4043	0.2110	0.3743	0.0092
9.672	0.4073	0.2118	0.3706	0.0092
10.59	0.4103	0.2126	0.3669	0.0092
11.51	0.4132	0.2134	0.3632	0.0092
12.44	0.4160	0.2141	0.3596	0.0091
13.36	0.4189	0.2149	0.3560	0.0091
14.28	0.4217	0.2156	0.3525	0.0091
15.20	0.4244	0.2164	0.3491	0.0091
16.12	0.4272	0.2171	0.3457	0.0090
17.04	0.4298	0.2178	0.3423	0.0090
17.96	0.4325	0.2185	0.3390	0.0090

Length (m)	H2O	Propane
0.4606	0.0011	0.0000
1.382	0.0011	0.0000
2.303	0.0011	0.0000
3.224	0.0011	0.0000
4.145	0.0011	0.0000
5.066	0.0011	0.0000
5.987	0.0011	0.0000
6.909	0.0011	0.0000
7.830	0.0011	0.0000
8.751	0.0011	0.0000
9.672	0.0011	0.0000
10.59	0.0011	0.0000
11.51	0.0011	0.0000
12.44	0.0011	0.0000
13.36	0.0011	0.0000
14.28	0.0011	0.0000
15.20	0.0011	0.0000
16.12	0.0011	0.0000
17.04	0.0011	0.0000
17.96	0.0011	0.0000

TEE-100 (Tee): Design, Rating

Tee: TEE-100

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION
Overhead Recycle	V-100 Separator

Outlet Stream

STREAM NAME	TO UNIT OPERATION
Recycle without Purge	RCY-1 Recycle

PARAMETERS

	Flow Ratios	Dynamic Valve Openings
Recycle without Purge	1.000	100.0

Valve Control: Multiple Stream

User Variables

RATING

Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 m

	Overhead Recycle	Recycle without Purge
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

VLV-100 (Valve): Design, Rating

Valve: VLV-100

CONNECTIONS
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Condensed Propane AC-100 Air cooler
Outlet Stream
STREAM NAME TO UNIT OPERATION
Refrigerant Propane Named E-107 Heat Exchanger
PARAMETERS
Physical Properties
Pressure Drop: 1456 kPa
User Variables
RATING
Sizing
Sizing Conditions
Inlet Pressure 1619 kPa Molecular Weight 44.10 Current
Valve Opening 50.00 % Delta P 1456 kPa Flow Rate 3.336e+004 kg/h
Valve Sizing Method and Type
Sizing Method: ANSI/ISA
Valve Operating Characteristic and Sizing Information
Linear Sized Coefficient: Cv (standard) cal/min.sqrt(psi)
Fl 0.9000 Cv 30.01 USGPM(60F,1psi) Cg 1004 Fp 1.000 Xt 0.7000 Rigorous Cp/Cv Method
Nozzle Parameters
Base Elevation Relative to Ground Level 0.0000 m

	Condensed Propane	Refrigerant Propane
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000
Elevation (% of Height) (%)		

AC-100 (Air cooler): Design, Rating, Performance, HTFS - ACOL

Air cooler: AC-100
CONNECTIONS
Inlet Stream
STREAM NAME FROM UNIT OPERATION
Second Stage Compressed Propane K-102 Compressor
Outlet Stream

STREAM NAME TO UNIT OPERATION
Condensed Propane VLV-100 Valve
DESIGN PARAMETERS

Pressure Drop: 2.000 kPa UA: 6.453e+005 kJ/C-h
Inlet Air Temp: 25.00 C Outlet Air Temp: 51.20 C
Configuration: one tube row, one pass
User Variables

SIZING

Number of Fans 1

Fan	Fan 0
Speed (rpm)	60.00
Speed (rpm)	60.00
Max Acceleration (rpm)	---
Design Speed (rpm)	60.00
Design airflow (ACT_m3/h)	3.600e+005
Current airflow (ACT_m3/h)	3.600e+005

NOZZLE PARAMETERS

Base Elevation Relative to Ground Level 0.0000 m

	Second Stage Compressed Propane	Condensed Propane
Diameter (m)	5.000e-002	5.000e-002
Elevation (Base) (m)	0.0000	0.0000
Elevation (Ground) (m)	0.0000	0.0000

PERFORMANCE RESULTS

Working Fluid Duty: -1.080e+007 kJ/h Correction Factor: 0.6973
UA: 6.453e+005 kJ/C-h LMTD: 15.89 C
Feed Temp: 62.07 C Prod Temp: 47.24 C
Air Feed Temp: 25.00 C Air Prod Temp: 51.20 C
Volumetric Air Flow: 3.600e+005 ACT_m3/h Mass Air Flow: 4.067e+005 kg/h
PERFORMANCE TABLE
Overall Phase
Temperature Pressure Heat Flow Enthalpy

(C)	(kPa)	(kJ/h)	(kJ/kgmole)
62.07	1620.80	0.00	-102811.71
47.29	1620.60	-1079650.22	-104238.88
47.29	1620.40	-2159300.44	-105666.04
47.28	1620.20	-3238950.65	-107093.20
47.28	1620.00	-4318600.87	-108520.36
47.27	1619.80	-5398251.09	-109947.52
47.27	1619.60	-6477901.31	-111374.68
47.26	1619.40	-7557551.53	-112801.84
47.25	1619.20	-8637201.75	-114229.00
47.25	1619.00	-9716851.96	-115656.16
47.24	1618.80	-10796502.18	-117083.32

Vapour Fraction	Vap Phase Mass Frac	Heat of Vap (kJ/kgmole)
1.0000	1.0000	---
0.9990	0.9990	---
0.8879	0.8879	---
0.7769	0.7769	---
0.6659	0.6659	---
0.5549	0.5549	---
0.4439	0.4439	---
0.3329	0.3329	---
0.2219	0.2219	---
0.1110	0.1110	---
0.0000	0.0000	---

Vapour Phase

Mass Flow (kg/h)	Molecular Wt	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)
33359.47	44.10	33.00	2.16	0.01	0.02
33324.45	44.10	36.51	2.19	0.01	0.02
29620.50	44.10	36.50	2.19	0.01	0.02
25917.08	44.10	36.50	2.19	0.01	0.02
22213.19	44.10	36.49	2.19	0.01	0.02
18510.13	44.10	36.49	2.19	0.01	0.02
14807.02	44.10	36.48	2.19	0.01	0.02
11104.70	44.10	36.48	2.19	0.01	0.02
7403.09	44.10	36.47	2.19	0.01	0.02
3701.25	44.10	36.47	2.19	0.01	0.02

Std Gas Flow (STD_m3/h)	Z Factor	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
17887.06	0.78	4256.66	96.75	0.28	0.15
17868.29	0.73	4256.66	96.75	0.28	0.15
15882.26	0.73	4256.66	96.75	0.28	0.15
13896.52	0.73	4256.66	96.75	0.28	0.15
11910.52	0.73	4256.66	96.75	0.28	0.15
9924.98	0.73	4256.66	96.75	0.28	0.15
7939.40	0.73	4256.66	96.75	0.28	0.15
5954.24	0.73	4256.66	96.75	0.28	0.15
3969.47	0.73	4256.66	96.75	0.28	0.15
1984.58	0.73	4256.66	96.75	0.28	0.15

Light Liquid Phase

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
---	---	---	---	---	---
35.02	454.30	3.30	0.08	0.08	4.38
3738.97	454.31	3.30	0.08	0.08	4.38
7442.38	454.33	3.30	0.08	0.08	4.38
11146.28	454.33	3.30	0.08	0.08	4.38
14849.33	454.34	3.30	0.08	0.08	4.38
18552.45	454.35	3.30	0.08	0.08	4.38
22254.77	454.36	3.30	0.08	0.08	4.38
25956.38	454.38	3.30	0.08	0.08	4.38
29658.22	454.38	3.30	0.08	0.08	4.38
33359.47	454.40	3.30	0.08	0.08	4.38

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15

44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15

Heavy Liquid Phase

Mass Flow (kg/h)	Density (kg/m3)	Mass Sp Heat (kJ/kg-C)	Viscosity (cP)	Thermal Cond (W/m-K)	Surface Tens (dyne/cm)
---	---	---	---	---	---
35.02	454.30	3.30	0.08	0.08	4.38
3738.97	454.31	3.30	0.08	0.08	4.38
7442.38	454.33	3.30	0.08	0.08	4.38
11146.28	454.33	3.30	0.08	0.08	4.38
14849.33	454.34	3.30	0.08	0.08	4.38
18552.45	454.35	3.30	0.08	0.08	4.38
22254.77	454.36	3.30	0.08	0.08	4.38
25956.38	454.38	3.30	0.08	0.08	4.38
29658.22	454.38	3.30	0.08	0.08	4.38
33359.47	454.40	3.30	0.08	0.08	4.38

Molecular Wt	Sp Gravity	Pseudo Pc (kPa)	Pseudo Tc (C)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15
44.10	0.45	4256.66	96.75	0.28	0.15