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SIMULATION OF NATURAL GAS INFRASTRUCTURE FOR CNG AND LPG RECOVERY - A CASE STUDY

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ABSTRACT

This research is a case study focused at presenting a framework upon which design methods can be followed to achieve an effective natural gas gathering, processing and fractionation process. It also reveals the incentive for flare reduction while encouraging domestic consumption of Liquefied Petroleum Gas (LPG) and the use of Compressed Natural Gas (CNG) for electricity generation. The simulation of the plant was done using ASPEN HYSYS version 11.0 with the Peng Robinson equation of state as the thermodynamic fluid package. The gas was gathered from two flow stations 0.8km and 6.4km respectively from the proposed processing field. Since the gases from the region under study is a sweet with negligible sulphur content there was no need for a sweetening process. The Tri-Ethylene Glycol (TEG) was used for the gas dehydration, then fractionators were simulated to produce LPG and CNG of high purity. Results from the HYSYS report shows good energy and mass balance as well as efficient gas flow throughout the processing cycle. The resulting volume of CNG and LPG is substantial to power several households and supply them with cooking gas respectively.

Keywords: Natural Gas Simulation, Liquefied Petroleum Gas, Compressed Natural Gas, Computer aided Design.

I. INTRODUCTION

Nigeria is described as a gas province with pockets of oil given the estimated proven gas reserve of 206.53TCF (Department of Petroleum Resources, 2021)[1], with the Department of Petroleum Resources (DPR) setting targets of 2010 TCF by 2025 and 220TCF by 2030 by employing advanced technology.

Despite the availability of this resource in commercial quantity, yet the region has not been able to fully take advantage of this gift of nature. This is evidenced by the volume of flaring occurring on a daily basis. Pricewaterhouse Coopers, PWC (2019), an international financial auditing firm, estimated that the Nigerian economy lost US$761.6 million in 2018 that is 3.8% of the global total costs in 2018, revealing that the nation has a major utilization problem (10).

Natural gas utilization has been a problem in Nigeria for decades now given that handling and infrastructural deficit has been an issue as flaring remains a popular practice (1). This poses unprecedented environmental and social issues as well as gross loss of revenue. Until 2008 when the interest in Natural Gas got its first official recognition by the establishment of the Nigeria Gas Master Plan (2), most of the gases are either flared or channeled for liquefaction by the Nigeria Liquefied Natural Gas company. Distribution to industrial areas have also been the norm. With the fast growing interest in the accomplishment of the Nigeria gas master plan, there have been a heightened call of the voracious use of natural gas especially for domestic purposes. Natural gas has found its use in transportation, space heating, cooking, feed for the petrochemical and chemical industry, feed for the pharmaceutical industry among others (3).

Compressed natural gas (CNG) is simply natural gas which is subjected to a given pressure, depending on the intended use. It is mainly composed of methane (8). In some climes, it is bottled and transported to where it is needed while in some cases, it is channeled via pipelines and used directly to turn turbines or other mechanical equipment. It is also used as a heating fuel and other petrochemical purposes (11). On the other hand, liquefied petroleum gas (LPG) also known in Nigeria as cooking gas, is composed mainly of Propane and Butane, because of its unique properties and ability to sustain clean burning (12). It is gradually gaining popularity in Nigeria but is faced with concerns of delivery, availability and safety. Albela Pundkar et al (2012) (13) presented the fuel properties of LPG and CNG in Table 6 on the Appendix 2.

The infrastructural outlook and preliminary design of a natural gas gathering and processing plan can be easily done using ASPEN HYSYS with the required knowledge and skill, thus the need to carry out a case study which is aimed at revealing the possibility and incentive for utilizing natural gas for electricity generation and cooking (4). The case study is for a new city called Greater Port located it is situated towards the south-east of the city stretching south from Oyigbo to and include Onne port while the second much larger one expands north of the city to include Port Harcourt International Airport and amongst others Araba, Umuechem, Igbo-Etche, Igwruta, Omagwa, Ozaha and Ipo settlement. The area’s eastern boundary is defined by Otamiri-Etche River, its couthern boundary by the old city, its western boundary is between Omagwa and Isiokpo settlements and its northern boundary is less defined allowing space for commercial development around the international airport (5).

II. MATERIALS AND METHODS

A. Overview

This research is a systematic attempt at developing a conceptual design to utilize flare gas from a flow station to more useful product – Liquefied Petroleum Gas (cooking gas) and compressed natural gas for electricity generation. Here, the gas is from a nearby flow station. Therefore, it is imperative to gather the gas to a common header, process it to meet specification then separate it into the useful fraction called the fractionators or separators. The gas gathering station largely comprises of segments of pipeline through which the gases from each flow station channeled (6). The pipes are chosen in line with the known massive pressure requirements, this process terminates at a junction where the resulting gas from a single stream is channeled to a processing plant. At the plant, the impurities are removes via series of physical reactions before it finally gets to fractionators where the final product is gotten.

B. Procedural Algorithm

A stepwise approach was adopted in this study and it is as shown below:

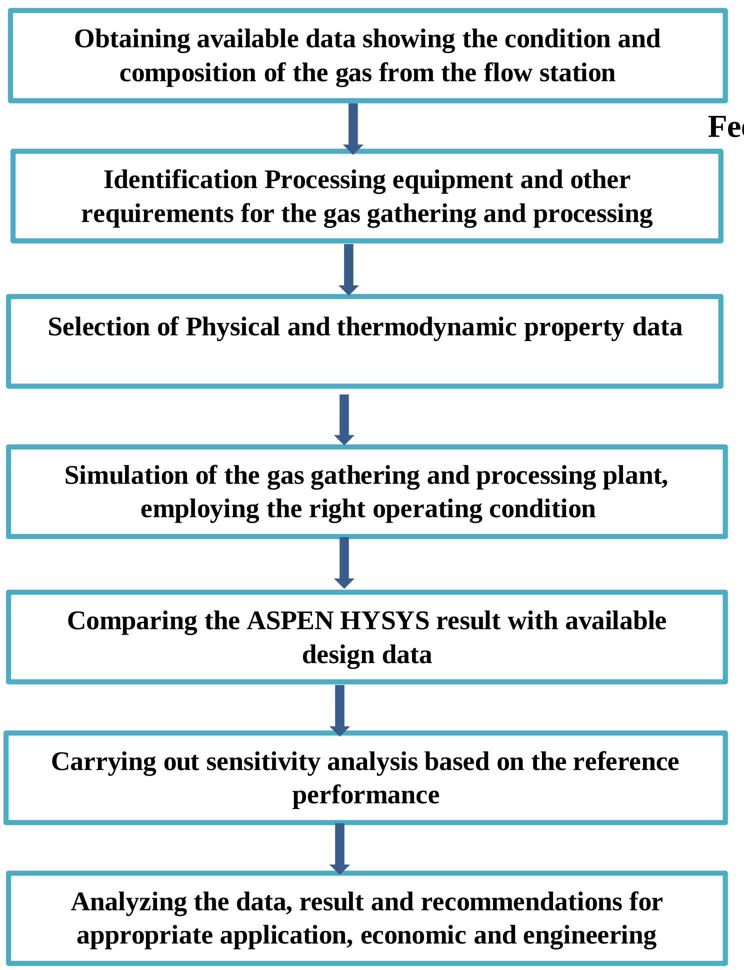

Figure 1: Procedural Algroithm for the research

Feed stream Parameters

Table 1: Data from Field-1

Property	**Value**
Temperature (^oC)	50.31
Pressure (kPa)	7101
Flowrate (MMSCFD)	15000000
Composition	**Mole fraction**
Nitrogen	0.0001
Carbon dioxide	0.0005
Methane	0.6230
Ethane	0.1800
Propane	0.1400
Iso Butane	0.0500
Normal Butane	0.0043
Iso Pentane	0.0000
Normal Pentane	0.0000
Normal Hexane	0.0001
Normal Heptane	0.0000
Normal Octane	0.0000
TEGlycol	0.0000
H2O	0.0020

Table 2: Data from Field-2

Property	**Value**
Temperature (°C)	30
Pressure (kPa)	6601
Flowrate (MMSCFD)	20000000
Composition	**Mole fraction**
Nitrogen	0.0001
Carbon dioxide	0.0002
Methane	0.5000
Ethane	0.1600
Propane	0.1400
Iso Butane	0.1100
Normal Butane	0.0500
Iso Pentane	0.0229
Normal Pentane	0.0150
Normal Hexane	0.0000
Normal Heptane	0.0000
Normal Octane	0.0000
TEGlycol	0.0000
H2O	0.0017

Simulation Tool

There are a number of simulation packages available, however, ASPEN HYSYS provides one of the best process modelling environments for conceptual design and operations improvement of oil and gas process. This modeling tool has been used by researchers and engineers for decades to achieve improved engineering design and energy efficiency as well as reduce capital cost thus the choice of ASPEN HYSYS 11.0. Peng-Robinson thermodynamic model was chosen fluid property package (14) (15).

Equipment and Materials

In the design model equipment necessary for its optimal process are; Different diameters of pipes, Mixers, Separators (main separators and two phase separator), Distillation Columns/ Fractionators, Valves, Absorbers, Recycle system, Tri-Ethylene glycol (TEG), Heat Exchangers, Booster pumps, Condensers, Air coolers, Knockout drums, Storage tank and compressors (7) (16).

Product Specification

The main interest of this design is to ensure that the resulting Liquefied Petroleum Gas (LPG) and compressed natural gas (CNG) is within acceptable specification to be used in cylinders and turbines respectively. According to the Standards Organisation of Nigeria (2014), the LPG Acceptable range is as stated below:

Table 3: LPG Acceptable Range (SON, 2014)

Properties	**Values**
Temperature (oC)	Unspecified
Pressure (kPa)	>900
Flowrate (Kg/hr)	>20000
Composition	**Mole Fraction**
Nitrogen	0.000
Carbon dioxide	0.0000
Methane	0.0000
Ethane	> 0.0301
Propane	>0.149
Iso Butane	<0.01
Normal Butane	>0.8500
Iso Pentane	>0.0001
Normal Pentane	>0.01
Normal Hexane	0.0000

DESCRIPTION OF THE SIMULATION ENVIRONMENT

There are some technicalities involved in simulating the gas gathering and processing segments especially converging the separators and fractionators. Another threat to accuracy is determining the unspecified conditions and parameters and ensuring that the results are accurate representation of reality.

Some parameters to be considered in order to achieve a good process simulation results with minimal error are;

- Pipeline thickness
- Column specifications
- Type of dehydrating agent
- Product specification
- Compressor adiabatic efficiency
- Feed gas composition and properties
- Pressure drop at valves
- Pressure drop at cooler

The Gas Gathering Model

Here, the gas from the flow stations are labelled Well A and Well B transported through a pipeline at the pressure as contained in Table 1 and Table 2 for Well A and Well B respectively. The distance of the flow stations from the free trade zone is obtained via the use of Google Maps and found to be 11km and 15km for flow station A and flow station B respectively. The pipe is without out insulation therefore the fluid takes the temperature of the ambient temperature (25^{o}C) over the length of the pipe. The gas from both flow stations meets at a junction and then channeled to the gas plant for processing.

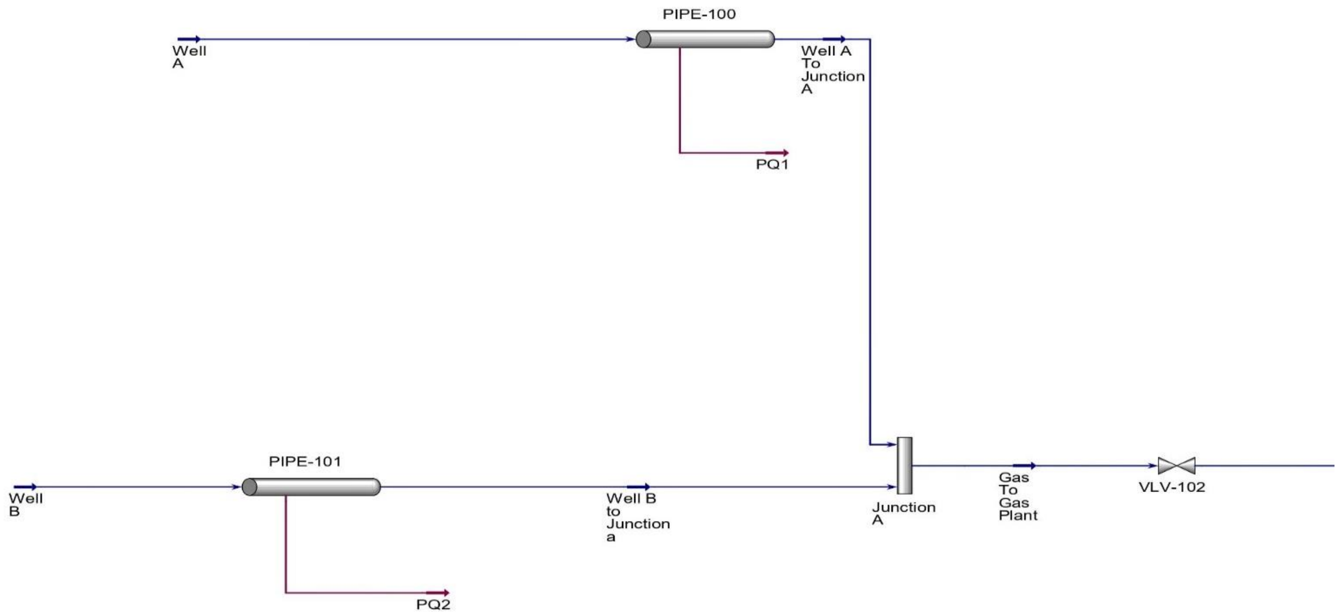

Figure 2: Simulated Flow sheet of the Gas gathering Station

Other specifications are as stated below:

- Pipe material: Mild Steel
- Ground type: Dry peat
- Depth of Burial: 1m
- Pipeflow correlation: Beggs and Brill (1979)
- Emulsion viscosity method: HYSYS

Natural Gas Processing Model

The gas processing method employs the use of a number namely; Mixers, Separators (main separators and two phase separator), Distillation Columns/ Fractionators, Valves, Absorbers, Recycle system, Tri-Ethylene glycol (TEG), Heat Exchangers, Booster pumps, Condensers, Air coolers, Knockout drums, Storage tank and Compressors.

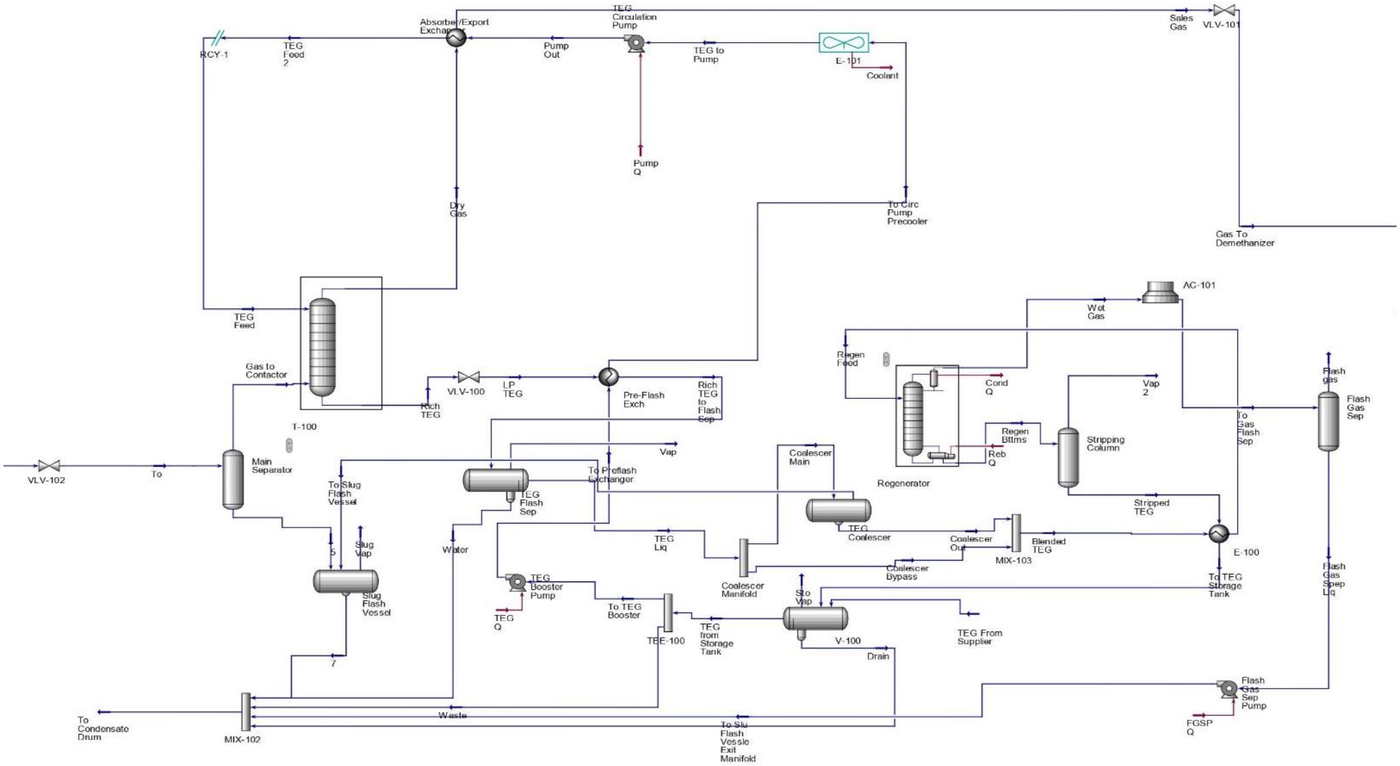

Figure 3: Simulated Flow sheet of the gas processing plant using Aspen Hysys 11.0

WORKING MECHANISM

Dehydration

It is comprised of two main processes namely; dehydration proper and regeneration as illustrated in the simulated plant in Figure 2 above:

Dehydration Proper – The equipment here include; 1 valve, 1 horizontal separator, 1 absorber (contactor), 1 vertical separator, 1 heat exchanger and 1 mixer. This process starts from the valve which reduces the pressure of the gas coming from the gathering station to meet the operating pressure of the vertical separator (Main Separator). At the main separator, the heavier/liquid ends are channeled to a Horizontal separator (Slug Flash Vessel) where vapour entrained in the liquid/heavier ends are given off at the top of the vessel while the liquids go below to a common mixer where it will be collected to the condensate drum. The top/gaseous ends of the Main Separator is channeled to the Gas Contactor where the dehydration takes place. Here, Tri Ethylene Glycol (TEG) is used as the desiccant. The dehydration takes place when the gas moves in opposite direction of the TEG (that is as the TEG which is in liquid form moves down the vessel, the gas moves up) in a process known as contacting. The TEG absorbs the liquids/vapour entrained in the gas as it moves down the vessel. The products from this process is the dry gas which passes through a heat exchanger and then to the sales gas point.

Regeneration

This is the process whereby the Spent or Rich TEG is stripped of the liquid it has absorbed so the Lean TEG will be rechanneled for reuse in a continuous process. The equipment here includes: 1 valve, 3 pumps, 3 heat exchangers, 2 Tees, 2 mixers, 2 3phase horizontal separators, 1 horizontal separator, 2 vertical separators, 1 air cooler and 1 valve cooler. The regeneration of the Spent TEG also starts by first passing it via a valve to drop its pressure before it is preheated via a heat exchanger before being channeled to a 3-Phase Separator where water and possibly solids (slug) is given off at the bottom (where it goes to the mixer and then to the condensate drum) and water vapour and entrained gas is given off at the top with the side stream being the TEG liquid. The TEG liquid is passed through a Tee (Coalescer manifold). The Tee divides the TEG liquid into two in the ratio of 3:1; the bigger part goes to the TEG Coalescer (separator) where emulsion formation is taken care of, while the smaller part is simply channeled to a mixer where it blends with the product from the TEG Coalescer. The blended TEG is sent to a heat exchanger where it is pre-heated to meet the regenerator operating requirement. At the regenerator, the top product of the column which is gaseous goes to the air cooler where the liquid entrained is condensed before being channeled to a vertical separator for the final flash off of the gas to the atmosphere while the liquid is pumped to the mixer which will be channeled to the condensate drum. The bottom product of the regenerator goes to a vertical separator (stripping column) where vapor of entrained water is given off at the top and the bottom is sent to a heat exchanger to a knock out drum (3 phase horizontal separator) to remove liquids as vapour and solids or heavier liquids (which will is channeled to a the condensate drum. The pure TEG coming out as a side stream from the 3 phase horizontal separator is pumped back to the contactor for reuse haven been passed through series of heat exchanger as shown in Figure 2. The details of the internals are as contained in Appendix A

Fractionation

At the fractionation plant, the dry natural gas is separated out into its fractions with methane and ethane channeled to be used to turn turbines for electricity generation and the propane and butane (LPG) for use as source of energy for domestic cooking. The process equipment include; 2 distillation columns, 1 mixer, 1 compressor, 1 pump, 1 valve and 1 storage tank.

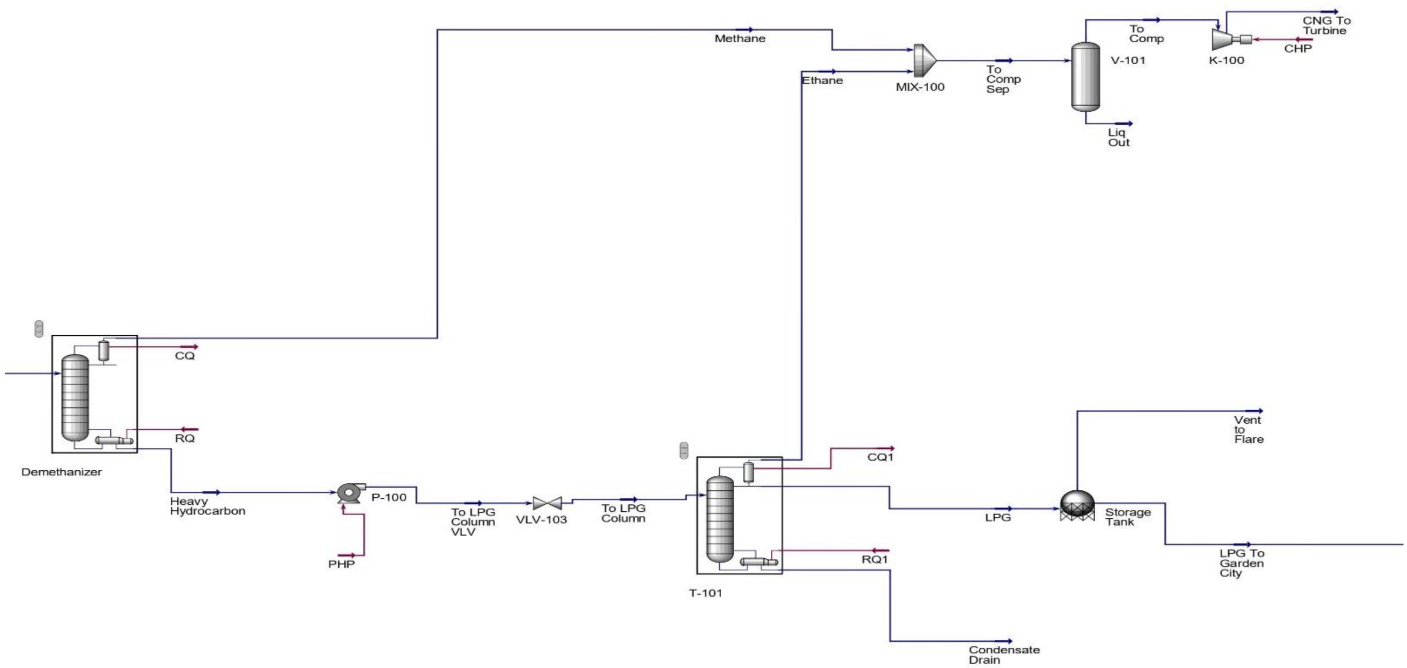

Figure 4: Simulated Flow sheet of the fractionation section using Aspen HYSYS 11.0

The feed to the first fractionating column (de-methaniser) is the dry gas produced from the dehydration process. As the name implies, methane is collected at the top of the de-methaniser. This is made possible by setting the operating conditions to increase methane yield. The bottom of the de-methaniser are other NGLs which are pumped into the LPG column. This column will be optimized in such a manner that ethane is given off at the reflux while LPG is (Propane and Butane) collected and sent off to the storage tank before being distributed to consumers. Methane and Ethane is collected via a mixer and passes through a separator to further ensure product purity for the turbine as seen in the simulation in Figure 4.

In course of the Aspen HYSYS simulation, it is ensured that the configuration converged and all process equipment solved. This is a proof that the simulation met the law of physics and process engineering.

RESULTS AND DISCUSSION

Liquefied Petroleum Gas Fraction

The properties and composition of the resulting Liquefied Petroleum Gas is as shown in the table below:

Table 4: Composition of the Gas from LPG stream

Properties	**Values**
Temperature (oC)	25
Pressure	883.1
Flowrate (kg/hr)	17880
Composition	**Mole fraction**
Nitroogen	0.000
Carbon dioxide	0.0000
Methane	0.0000
Ethane	0.0271
Propane	0.1211
Iso Butane	0.0106
Normal Butane	0.8750
Iso Pentane	0.1211
Normal Pentane	0.0142
Normal Hexane	0.0000
Normal Octane	0.0000
TEGlycol	0.0000
H_2O	0.00001

Acceptable range as presented by the Standards Organisation of Nigeria in 2014 is presented in Table 3 above:

Comparing Table 3 and Table 4, it is seen that the simulation is validated as it shows a case of compliance with the regulatory body vis-à-vis product specification and composition

Compressed Natural Gas Fraction

The properties and composition of the resulting compressed natural gas is as shown in the table below:

Table 5: Composition of the gas from CNG stream

Properties	**Values**
Temperature (^oC)	25
Pressure	883.1
Flowrate	17880
Composition	**Mole Fraction**
Nitrogen	0.0002
Carbon dioxide	0.0001
Methane	0.9765
Ethane	0.0218

Propane	0.0013
Iso Butane	0.0000
Normal Butane	0.0000
Iso Pentane	0.0000
Normal Pentane	0.0000
Normal Hexane	0.0000
Normal Octane	0.0000
TEGlycol	0.0000
H2O	0.0001

Table 6: Acceptable Range of CNG (SON Guideline for CNG, 2014)

Properties	**Values**
Temperature (^oC)	Unspecified
Pressure (kPa)	Unspecified
Flowrate (Kg/hr)	Unspecified
Composition	**Mole fraction**
Nitrogen	>0.001
Carbon dioxide	>0.001
Methane	<0.8500
Ethane	> 0.1
Propane Plus	>0.05
H2O	>0.001

Comparing Table 5 and Table 6, it is seen that the simulation is right as it shows a case of compliance with the regulatory body vis-à-vis product specification and composition.

Plot of Performance of Column Internals are presented below:

Absorber: This is the contactor where the TEG meets the wet natural gas. The data and the plot is presented in table 6 below:

	Stage	Pressure [bar_g]	Temp [C]	Net Liquid [MMSCFD]	Net Vapour [MMSCFD]
1_TS-1	0	60.93	47.01	2.110	27.78
2_TS-1	1	61.04	39.11	2.113	27.89
3_TS-1	2	61.04	35.68	2.114	27.89
4_TS-1	3	60.93	34.13	2.131	27.89

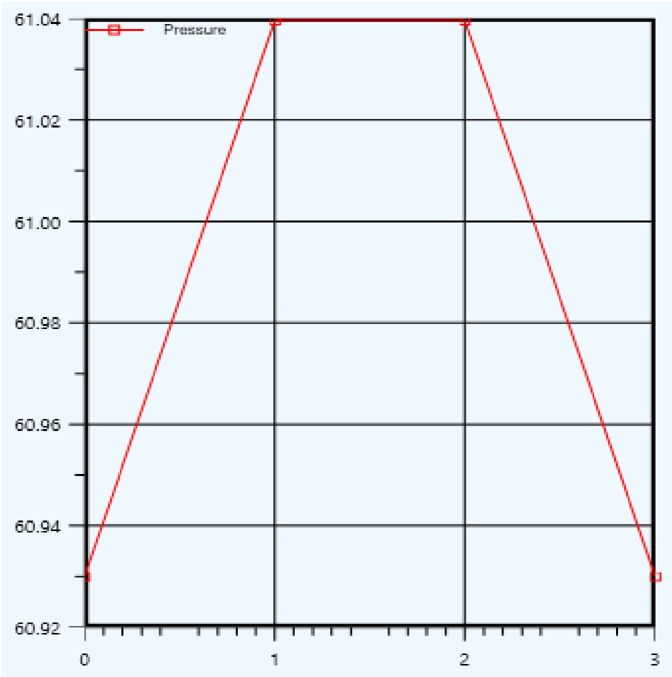

Figure 5: Graph of Pressure vs Tray Position from Top of the Absorber.

LPG Stream: The T-P Table and Plot is presented below

Table 7: Temperature – Pressure Table of LPG Stream

Pressure (bar_g)	**Temperature (C)**
1.013	22.70
2.328	38.82
4.495	56.98
9.702	84.86
17.42	111.3
26.47	133.1
34.04	147.5
36.24	151.2
36.79	152.1
36.96	152.3
36.96	152.3
36.96	152.3

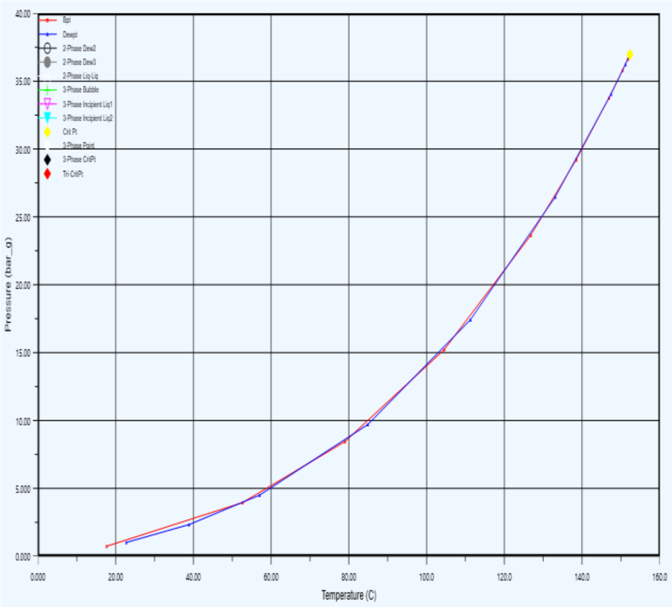

Figure 6: Pressure – Temperature Plot for LPG Stream

From this plot on Figure 6, the two phase critical temperature is 152.3C while the two phase critical pressure is 36.96 bar_g. The Cricondenterm and Cricondenbar is 152.3C and 36.96 bar_g respectively. This plot shows a near single phase condition revealing that the product therein with low possibility of hydrates forming in this process unless met by unfavourable underground condition during transmission.

LPG Stream: The T-P Table and Plot is presented below

Table 8: Temperature – Pressure Table of CNG Stream

S/N	Pressure (bar_g)	Temperature (C)
1	0.9071	-134.8
2	1.300	-131.1
3	1.769	-127.2
4	2.329	-123.1
5	2.994	-188.8
6	3.783	-114.2
7	4.717	-109.4
8	5.820	-104.3
9	7.118	-98.84
10	8.642	-93.09
11	10.43	-86.97
12	12.51	-80.43

13	14.93	-73.44
14	17.75	-65.93
15	21.00	-57.83
16	24.74	-49.07
17	29.02	-39.56
18	33.89	-29.21
19	39.37	-17.93
20	45.43	-5.637
21	52.00	7.684
22	58.87	21.97
23	65.63	37.00
24	71.60	52.30
25	75.08	64.14
26	76.67	75.03
27	76.70	76.42
28	75.56	84.16
29	74.13	87.20

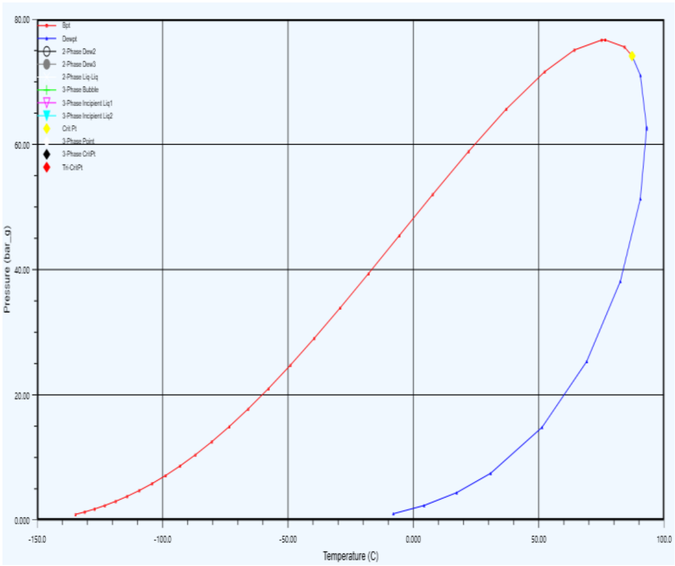

Figure 7: Pressure – Temperature Plot for CNG Stream

From this plot on Figure 7, the two phase critical temperature is 87.20C while the two phase critical pressure is 74.13 bar_g. the Cricondenterm and Cricondenbar 92.97 C and 76.70bar_g respectively.

CONCLUSION

This study has shown that ASPEN HYSYS Version 11.0 is a veritable tool for simulating a natural gas system with high level of accuracy and it presents a great interface for conceptual engineering design. Careful examination and ensuring that streams to converge. The safety analysis from the interface shows that the entire process is safe, material balance shows an accuracy of over 99.99%, there are no flow assurance issues as no hydrate was formed in the lines and no back flow was experienced.

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APPENDIX

Appendix 1: The internals of some key equipment are presented in the figure below:

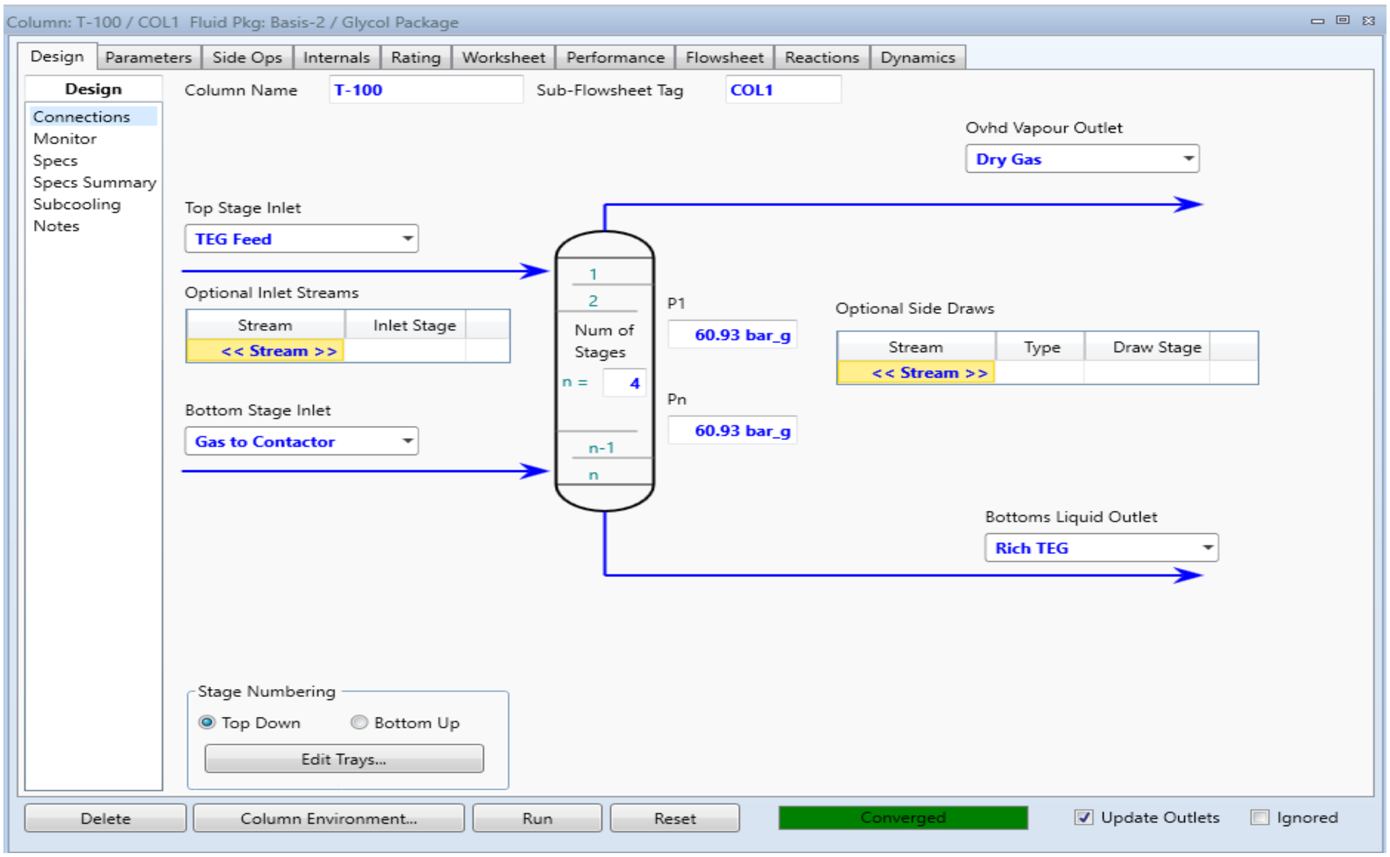

Figure a: Contactor

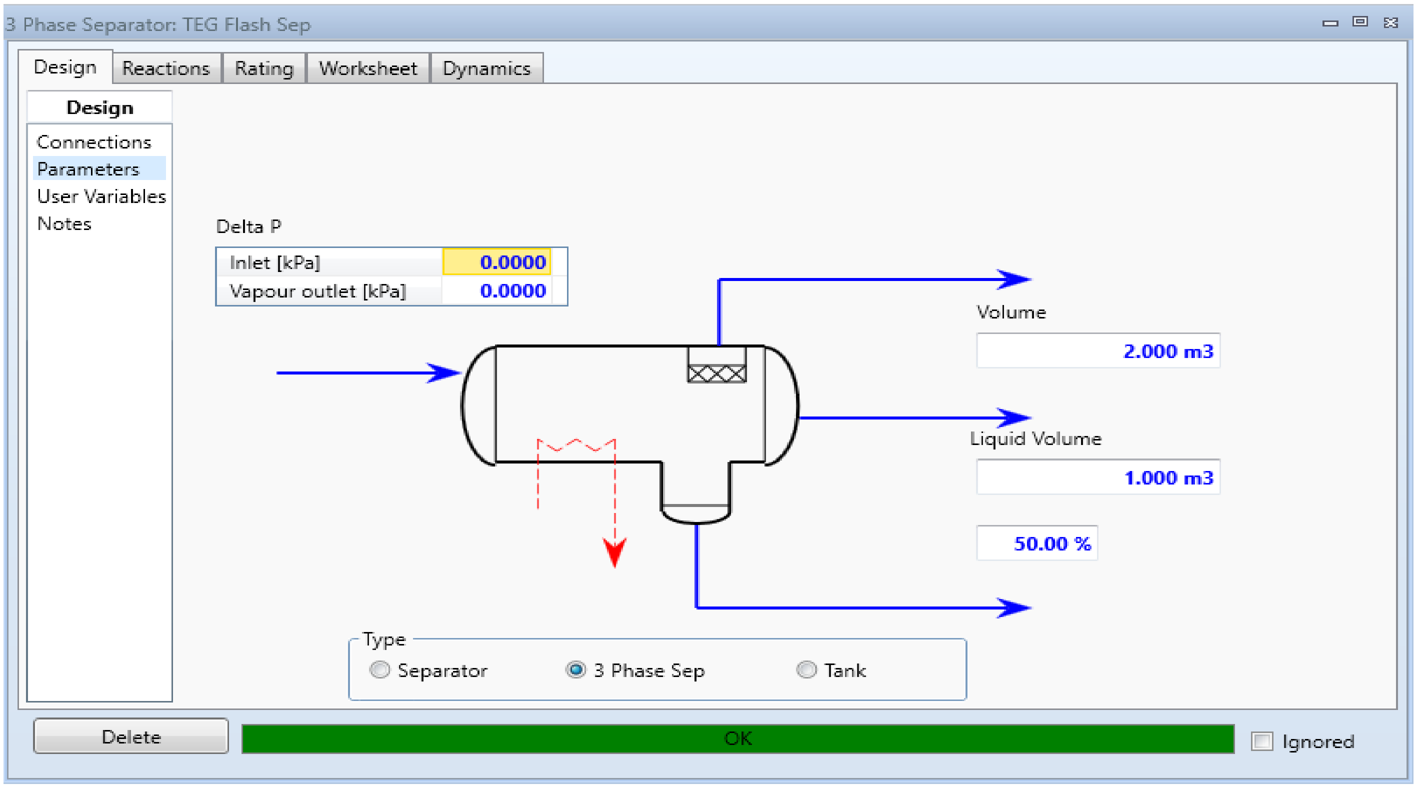

Figure b: 3 Phase Separator

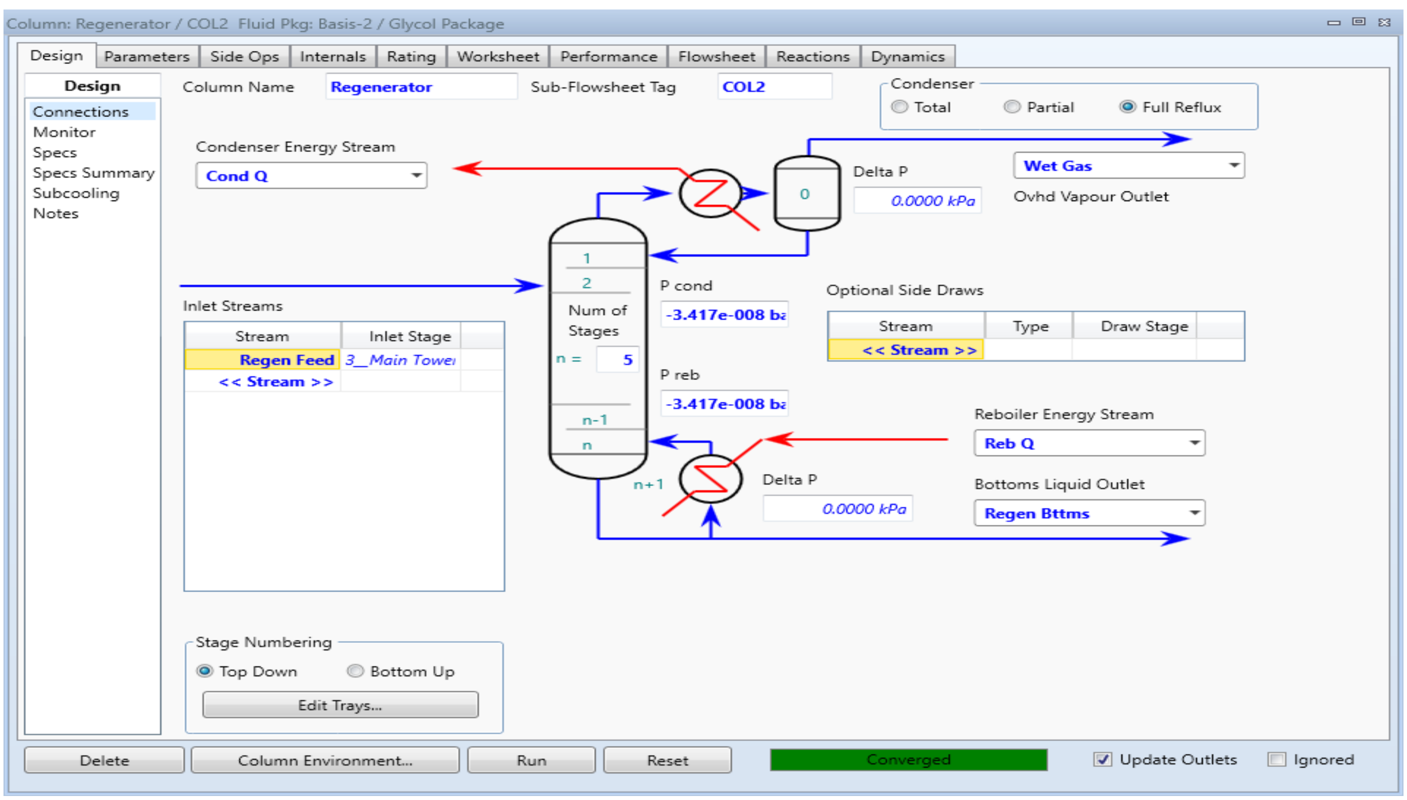

Figure c: Regenerator

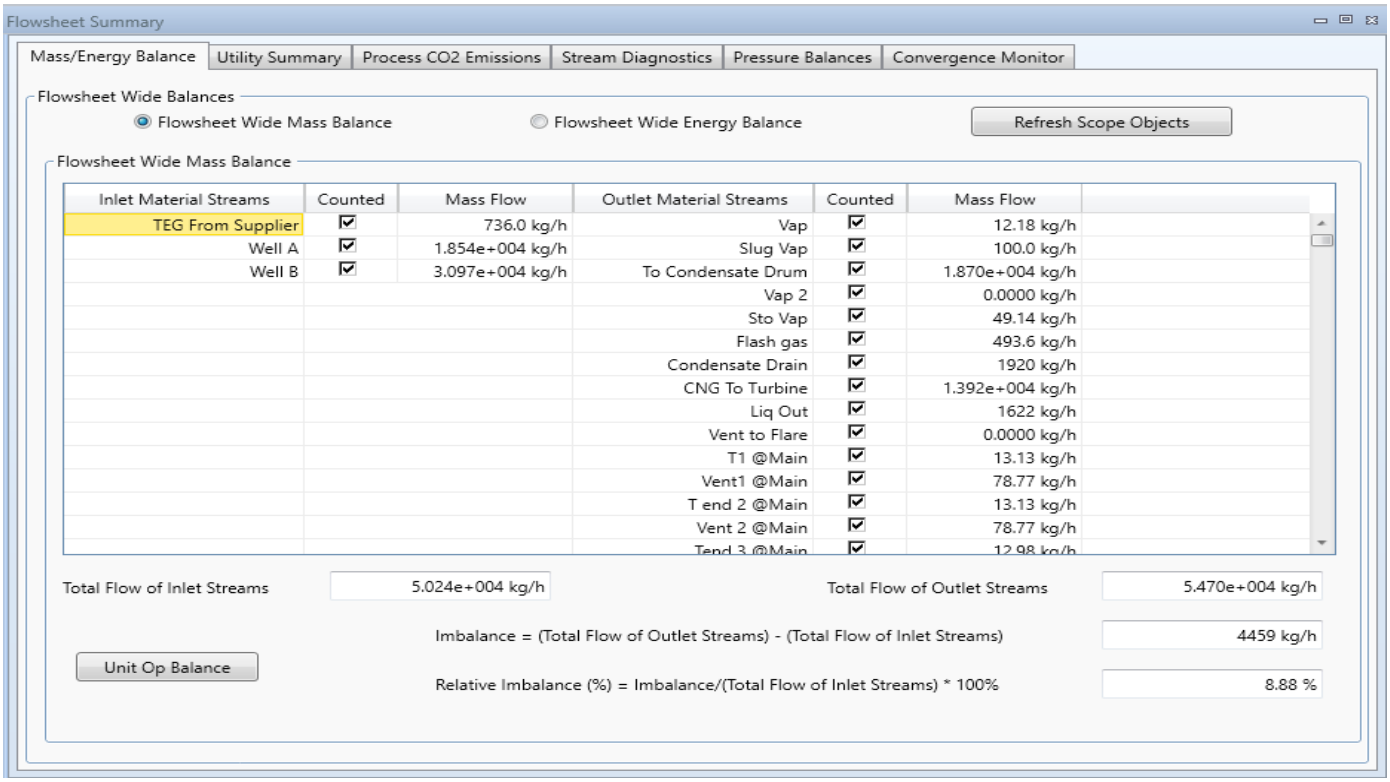

Figure d: Mass and Energy balance sheet

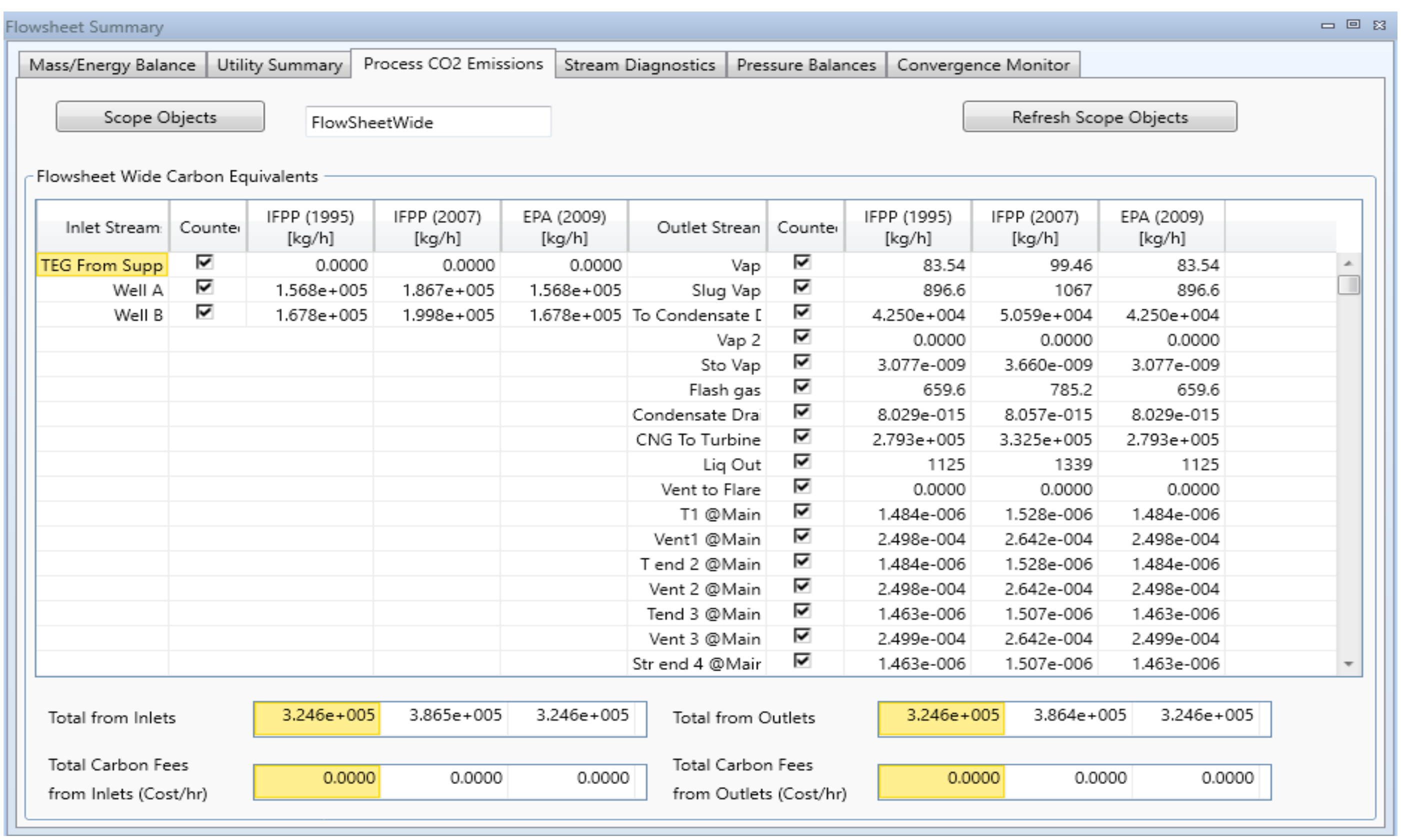

Figure e: Process CO2 Emission for the Entire Process

Appendix 2: Comparative Properties of LPG and CNG

Table 6: Properties of LPG and CNG

Properties /fuels	**Liquefied Petroleum Gas (LPG)**	**Compressed Natural Gas (CNG)**
Chemical structure	C_3H_8	CH_4
Energy density	84,000	35,000 @ 3000 psi
Octane number	105+	120+
Lower heating value (MJ/Kg)	46.60	47.14
High Heating Value	50.15	52.20
Stoichiometric air/fuel ratio	15.5	17.2
Density at 15^oC, kg/m^3	1.85/505	0.78
Auto ignition temperature ^oK	724	755-905
Specific gravity 60^oF/60^o	0.85	0.424

Source: Albela Pundkar et al (2012) (13)

Appendix 3: ASPEN HYSYS Report of the LPG Stream

Company Name Not Available Bedford, MA USA	Case Name: Gas distribution1.hsc Unit Set: NewUser4 Date/Time: Wed Aug 11 23:18:45 2021
Material Stream: Greater PH City Gas	Fluid Package: Basis-1 Property Package: Peng-Robinson

CONDITIONS

	Overall	Liquid Phase			
Vapour / Phase Fraction	0.0000	1.0000			
Temperature: (C)	25.00	25.00			
Pressure: (bar_g)	7.818	7.818			
Molar Flow (MMSCFD)	7.021	7.021			
Mass Flow (kg/h)	1.788e+004	1.788e+004			
Std Ideal Liq Vol Flow (m3/h)	33.37	33.37			
Molar Enthalpy (kJ/kgmole)	-1.367e+005	-1.367e+005			
Molar Entropy (kJ/kgmole-C)	94.63	94.63			
Heat Flow (kJ/h)	-4.778e+007	-4.778e+007			
Liq Vol Flow @Std Cond (m3/h)	32.92 *	32.92			

PROPERTIES

	Overall	Liquid Phase			
Molecular Weight	51.14	51.14			
Molar Density (kgmole/m3)	10.36	10.36			
Mass Density (kg/m3)	529.9	529.9			
Act. Volume Flow (m3/h)	33.74	33.74			

29	Mass Enthalpy (kJ/kg)	-2672	-2672			
30	Mass Entropy (kJ/kg-C)	1.850	1.850			
31	Heat Capacity (kJ/kgmole-C)	131.4	131.4			
32	Mass Heat Capacity (kJ/kg-C)	2.570	2.570			
33	LHV Molar Basis (Std) (kJ/kgmole)	2.351e+006	2.351e+006			
34	HHV Molar Basis (Std) (kJ/kgmole)	2.535e+006	2.535e+006			
35	HHV Mass Basis (Std) (kJ/kg)	4.958e+004	4.958e+004			
36	CO2 Loading	---	---			
37	CO2 Apparent Mole Conc. (kgmole/m3)	9.496e-005	9.496e-005			
38	CO2 Apparent Wt. Conc. (kgmol/kg)	1.792e-007	1.792e-007			
39	LHV Mass Basis (Std) (kJ/kg)	4.597e+004	4.597e+004			
40	Phase Fraction [Vol. Basis]	0.0000	1.000			
41	Phase Fraction [Mass Basis]	0.0000	1.000			
42	Phase Fraction [Act. Vol. Basis]	0.0000	1.000			
43	Mass Exergy (kJ/kg)	77.74	---			
44	Partial Pressure of CO2 (bar_g)	-1.013	---			
45	Cost Based on Flow (Cost/s)	0.0000	0.0000			
46	Act. Gas Flow (ACT_m3/h)	---	---			
47	Avg. Liq. Density (kgmole/m3)	10.48	10.48			
48	Specific Heat (kJ/kgmole-C)	131.4	131.4			
49	Std. Gas Flow (STD_m3/h)	8268	8268			
50	Std. Ideal Liq. Mass Density (kg/m3)	535.8	535.8			
51	Act. Liq. Flow (m3/s)	9.373e-003	9.373e-003			
52	Z Factor	3.438e-002	3.438e-002			
53	Watson K	14.23	14.23			
54	User Property	---	---			
55	Partial Pressure of H2S (bar_g)	-1.013	---			
56	Cp/(Cp - R)	1.068	1.068			
57	Cp/Cv	1.516	1.516			

58	Ideal Gas Cp/Cv	1.107	1.107			
59	Ideal Gas Cp (kJ/kgmole-C)	86.27	86.27			
60	Mass Ideal Gas Cp (kJ/kg-C)	1.687	1.687			
61	Heat of Vap. (kJ/kgmole)	1.838e+004	---			
62	Kinematic Viscosity (cSt)	0.2491	0.2491			
63	Aspen Technology Inc.	Aspen HYSYS Version 11 Page 1 of 3				

ZX

Company Name Not Available Bedford, MA USA	Case Name: Gas distribution1.hsc
	Unit Set: NewUser4
	Date/Time: Wed Aug 11 23:18:45 2021

Material Stream: Greater PH City Gas (continu

Fluid Package: Basis-1

Property Package: Peng-Robinson

PROPERTIES

	Overall	Liquid Phase			
Liq. Mass Density (Std. Cond) (kg/m3)	543.2	543.2			
Liq. Vol. Flow (Std. Cond) (m3/h)	32.92	32.92			
Liquid Fraction	1.000	1.000			
Molar Volume (m3/kgmole)	9.650e-002	9.650e-002			
Mass Heat of Vap. (kJ/kg)	359.5	---			
Phase Fraction [Molar Basis]	0.0000	1.0000			
Surface Tension (dyne/cm)	8.550	8.550			
Thermal Conductivity (W/m-K)	8.989e-002	8.989e-002			
Bubble Point Pressure (bar_g)	6.372	---			
Viscosity (cP)	0.1320	0.1320			
Cv (Semi-Ideal) (kJ/kgmole-C)	123.1	123.1			
Mass Cv (Semi-Ideal) (kJ/kg-C)	2.408	2.408			
Cv (kJ/kgmole-C)	86.68	86.68			
Mass Cv (kJ/kg-C)	1.695	1.695			
Cv (Ent. Method) (kJ/kgmole-C)	80.28	80.28			
Mass Cv (Ent. Method) (kJ/kg-C)	1.570	1.570			
Cp/Cv (Ent. Method)	1.637	1.637			
Reid VP at 37.8 C (bar_g)	8.060	8.060			
True VP at 37.8 C (bar_g)	8.901	8.901			
Liq. Vol. Flow - Sum(Std. Cond) (m3/h)	32.92	32.92			
Viscosity Index	-33.18	---			

COMPOSITION

36	aspentech			**Overall Phase**		Vapour Fraction 0.0000	
37 38	COMPONENTS	MOLAR FLOW (kgmole/h)	MOLE FRACTION	MASS FLOW (kg/h)	MASS FRACTION	LIQUID VOLUME FLOW (m3/h)	LIQUID VOLUME FRACTION
39	Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40	CO2	0.0032	0.0000	0.1410	0.0000	0.0002	0.0000
41	Methane	0.0004	0.0000	0.0065	0.0000	0.0000	0.0000
42	Ethane	21.1704	0.0605	636.5907	0.0356	1.7898	0.0536
43	Propane	144.6110	0.4136	6376.9134	0.3566	12.5857	0.3771
44	i-Butane	124.6550	0.3565	7245.4489	0.4052	12.8930	0.3863
45	n-Butane	46.3495	0.1325	2694.0178	0.1507	4.6192	0.1384
46	i-Pentane	8.7763	0.0251	633.2188	0.0354	1.0157	0.0304
47	n-Pentane	4.0956	0.0117	295.5012	0.0165	0.4693	0.0141
48	n-Hexane	0.0011	0.0000	0.0948	0.0000	0.0001	0.0000
49	n-Heptane	0.0001	0.0000	0.0127	0.0000	0.0000	0.0000
50	n-Octane	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000
51	TEGlycol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
52	H2O	0.0136	0.0000	0.2448	0.0000	0.0002	0.0000
53	Total	349.6762	1.0000	17882.1911	1.0000	33.3733	1.0000
54 55				**Liquid Phase**		Phase Fraction 1.000	
56 57	COMPONENTS	MOLAR FLOW (kgmole/h)	MOLE FRACTION	MASS FLOW (kg/h)	MASS FRACTION	LIQUID VOLUME FLOW (m3/h)	LIQUID VOLUME FRACTION
58	Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
59	CO2	0.0032	0.0000	0.1410	0.0000	0.0002	0.0000
60	Methane	0.0004	0.0000	0.0065	0.0000	0.0000	0.0000
61	Ethane	21.1704	0.0605	636.5907	0.0356	1.7898	0.0536
62	Propane	144.6110	0.4136	6376.9134	0.3566	12.5857	0.3771
63	Aspen Technology Inc.			Aspen HYSYS Version 11			Page 2 of 3

Company Name Not Available Bedford, MA USA	Case Name: Gas distribution1.hsc
	Unit Set: NewUser4
	Date/Time: Wed Aug 11 23:18:45 2021

Material Stream: Greater PH City Gas (continu

Fluid Package: Basis-1

Property Package: Peng-Robinson

COMPOSITION

Liquid Phase (continued)

Phase Fraction 1.000

COMPONENTS	MOLAR FLOW (kgmole/h)	MOLE FRACTION	MASS FLOW (kg/h)	MASS FRACTION	LIQUID VOLUME FLOW (m3/h)	LIQUID VOLUME FRACTION
i-Butane	124.6550	0.3565	7245.4489	0.4052	12.8930	0.3863
n-Butane	46.3495	0.1325	2694.0178	0.1507	4.6192	0.1384
i-Pentane	8.7763	0.0251	633.2188	0.0354	1.0157	0.0304
n-Pentane	4.0956	0.0117	295.5012	0.0165	0.4693	0.0141
n-Hexane	0.0011	0.0000	0.0948	0.0000	0.0001	0.0000
n-Heptane	0.0001	0.0000	0.0127	0.0000	0.0000	0.0000
n-Octane	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000
TEGlycol	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0136	0.0000	0.2448	0.0000	0.0002	0.0000
Total	349.6762	1.0000	17882.1911	1.0000	33.3733	1.0000

K VALUE

COMPONENTS	MIXED	LIGHT	HEAVY
Nitrogen	0.0000	0.0000	---
CO2	0.0000	0.0000	---
Methane	0.0000	0.0000	---
Ethane	0.0000	0.0000	---
Propane	0.0000	0.0000	---
i-Butane	0.0000	0.0000	---
n-Butane	0.0000	0.0000	---
i-Pentane	0.0000	0.0000	---
n-Pentane	0.0000	0.0000	---
n-Hexane	0.0000	0.0000	---
n-Heptane	0.0000	0.0000	---
n-Octane	0.0000	0.0000	---

40	TEGlycol	0.0000	0.0000	---
41	H2O	0.0000	0.0000	---
42	**UNIT OPERATIONS**			
43				
44	FEED TO	PRODUCT FROM	LOGICAL CONNECTION	
45	Separator: DEPRESSURIZER	Standard Sub-Flowsheet:Gas plant		
46	**UTILITIES**			
47				
48	(No utilities reference this stream)			
49	**PROCESS UTILITY**			
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