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Optimization of Methane and Natural Gas Liquid Recovery in a Reboiled Absorption Column

Usiabulu G. Idanegbe*, Azubuike H. Amadi**, Emeka J. Okafor***and Jumbo-Egwurugwu Precious***
*(World bank African Center of Excellence in Oilfield Chemical Research, University of Portharcourt, Nigeria
Email: godsdayusiabulu@gmail.com)
** (Petroleum Engineering Department, Universiti Teknologi PETRONAS, Malaysia
Email: azubuikehopeamadi@gmail.com)
*** (Gas Engineering Department, University of Portharcourt, Nigeria
Email: emeka.okafor@uniport.edu.ng)
**** (World bank African Center of Excellence in Oilfield Chemical Research, University of Portharcourt, Nigeria
Email: precious91egwurugwu@gmail.com)

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Abstract:

Since finding cost-effective solutions for optimal Methane and NGL recovery has become a priority. The goal of this project was to improve the existing plant framework of a tray absorption column. Aspen HYSYS simulator Version 8.6 was utilized for this study, and the feed gas composition was picked from Technip's Western Libya Gas Project. A simulation was conducted for 10 trays, 20 trays, and 30 trays to determine the optimum points for methane and NGL recovery. The number of trays used to determine the optimum NGL fraction was discovered to decrease as the number of trays increase while that of methane increased as the number of trays increased. It was further identified that the recovery affected the compressor duty as it increases as NGL recovery increases but reduces on recovery of methane. The results were exported to Microsoft Excel, and correlations were generated for predicting optimum Methane and NGL recovery.

Keywords **—Methane recovery, Natural Gas Liquid recovery, Absorption column, Tray optimization, Aspen HYSYS.**

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I. INTRODUCTION

Studies revealed that the Chinese are the first commercial users of natural gas[1]. The gas was produced from surface wells, conveyed with bamboo pipes, to heat up brine to produce salt. Gas derived from coal was utilized for streetlights and domestic lighting in Europe and the United States in the late 17th and early 18th century[2], [3]. In 1821, William Hart constructed a 9-meter deep well in Fredonia, New York, which was the first commercial use of natural gas[4]. According to the Natural Gas Suppliers Association, wooden pipes were used to transport gas to residents' homes and stores [4]. The demand for primary energy is growing all the time. As the globe searches for new sources of energy, fossil fuels will continue to play a prominent role in the foreseeable future[5].

Natural gas is seen by some environmentalists as a bridge fuel between today's fossil fuels and tomorrow's renewable energy [6]. Natural gas is the fastest-growing hydrocarbon in the hydrocarbon fuel family, with most estimates putting its average growth rate at 2.0% [7]. Natural gas is currently in high demand due to its clean burning qualities and capacity to meet environmental criteria [8]. The industry's current top priority is to increase the processing and production of all hydrocarbons in an environmentally friendly and cost-effective manner[8].

Natural gas is generally separated into two groups, viz: derived from conventional deposits and derived from non-conventional deposits[9]. The difference is typically due to a difference in the structure of the deposits, geologically and in their production methods [8]. It is projected that by 2030, natural gas will substitute coal as the second most frequently used energy source in the world[10]. Natural Gas from conventional deposits originates mainly from rocks of great permeability. It is mined by means of "traditional" vertical drilling know-how. The larger part of gas presently produced in the world is derived from conventional deposits, and its method of production is quite economical and simple. Although Natural Gas from non-conventional deposits can originate in rocks with very low permeability, it may not be mined through the same method as gas from conventional deposits [11].

Ethane, butanes, propane, and natural gasoline are among the heavier hydrocarbon liquids known as natural gas liquids (NGLs) (condensate). Recovery of NGL constituents in gas is not only a requirement for hydrocarbon dew point control in a natural gas stream (to avoid the formation of a dangerous liquid phase during transportation), but it also provides a revenue stream, as NGLs have a much higher value as separate marketable products than as part of the natural gas stream. Propane, ethane, and butanes are lighter NGL fractions that can be sold as fuel or feedstock to petrochemical facilities and refineries, while the heavier fraction can be utilized as a gasoline-blending stock [12].

Hydrocarbons and non-hydrocarbon gases existing either in a solution with crude or gaseous phase oil make up the natural gas [13]. This gas is frequently a combination of methane and other flammable hydrocarbons. Methane (CH_4), propane (C_3H_8), ethane (C_2H_6), butanes (C_4H_{10}), hexane (C_6H_{14}), pentanes (C_5H_{12}), heptane (C_7H_{16}), and trace amounts of octane (C_8H_{18}), and higher molecular weight hydrocarbons are all examples of hydrocarbon gas [13]. Aromatics such as toluene (C_6H_5 CH_3), benzene (C_6H_6), and xylenes (C_8H_{10}) may also be present, raising safety issues due to their toxicity[14], [15].

The contents of crude oil are separated into a hydrocarbon liquid stream (condensate), a water stream (brine water), and a gas stream once it is delivered to the surface. The gas stream is referred to as rich gas because it contains a lot of NGLs. Rich gas has a high dew point as well as a high heating value [16], [17]. NGLs are a group of hydrocarbons that are liquid at room temperature and are made from methane (also known as "dry" natural gas) or as a by-product of crude oil processing [18]. While NGLs may not receive the same level of attention as crude oil, gasoline, or natural gas, they are an important part of the industrial sector. Natural gas liquids are separated from dry gas at gas processing facilities. NGLs are used extensively in the petrochemical industry, refining, and home and industrial heating, as indicated in Figure 1. Many industrial operations use liquids like ethane, such as the manufacturing of ethylene [19], which is a crucial component in the creation of plastics and other commodities.

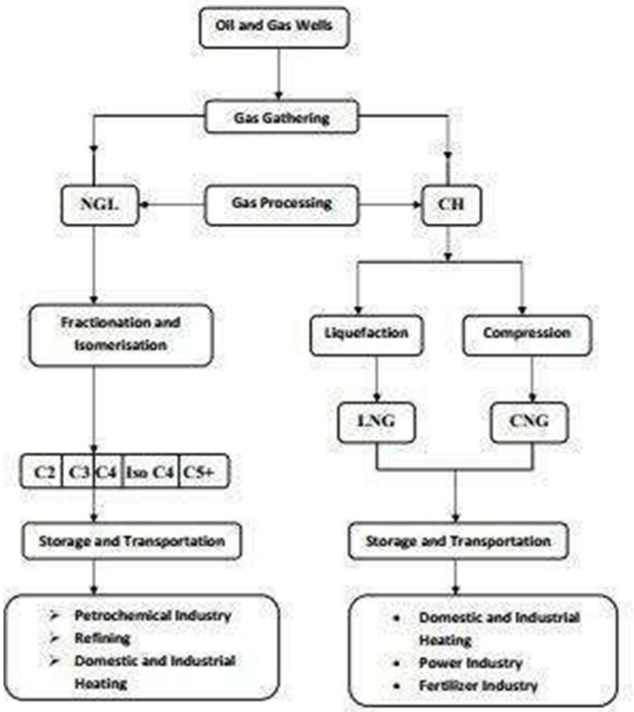


Fig. 1: Natural Gas Value Chain

Nigeria has traditionally focused on oil production, and gas was flared as a by-product of those activities for a long time, despite the fact that Nigeria is largely a gas province with pockets of oil [20]. In recent years, this pattern has shifted because, like with oil, the government is interested in producing economic value from the production of gas. Other factors include efforts to improve the domestic gas market, which are linked to the elimination of gas flaring. Nigeria loses about $2.5 billion while flaring gas [21]. Nigeria's recent power sector changes have sparked interest in the gas sector, with gas-to-electricity projects at the forefront of the country's gas agenda[22]. Domestic gas supply has been regarded as a vital success factor in the power reform, leading to the introduction of many incentives such as the initial Tax Holiday for gas-to-electricity projects[23].

Natural gas is a critical component of the world's energy supply [24]. It is arguably one of the safest, cleanest, and most practical energy sources available. In recent years, the world has been moving toward a lower-carbon economy, and as a result, gas has become the preferred fuel, mostly for power generation, in many places [24]. Natural gas is an appealing option for emerging economies aiming to meet rapid demand growth in rapidly growing cities as urbanization increases. According to the International Energy Agency in 2012, there are roughly 404Tm3 (14,285 trillion cubic feet) of residual recoverable conventional gas resources globally, with a value of around 130 years based on 2011 production rates[25]. Iran, Qatar, and Russia together account for about half of the world's proven gas reserves [26]. Natural gas has a life index of 64 years for proven reserves worldwide [27]. Unconventional gas is expected to grow from 13% to 22% of total global gas output between 2009 and 2035 [28]. These forecasts are susceptible to a large lot of uncertainty in locations where unconventional gas production is yet to begin or is just beginning. Environmental rules and laws, particularly in Europe, are likely to limit unconventional natural gas production [29]. The response of government and industry to environmental setbacks, general public acceptance, fiscal and regulatory frameworks, and access to expertise, technology, and water will all play a role in the future of unconventional natural gas production and development in the next decades[29], [30]. Since unconventional resources are more widely distributed than conventional resources, trade patterns and future gas production may alter[29].

A. NATURAL GAS LIQUIDS RECOVERY METHODS

Many NGL and methane recovery systems are available and in use on the market; they work in tandem, and you can recover NGL while extracting methane. Each of these recovery procedures has advantages and downsides that are distinct from one another. NGL recovery methods like turboexpanders, lean oil absorption, and cryogenic refrigeration require a lot of equipment and support facilities, as well as large amounts of chemicals, whereas Joule-Thomson and other supersonic devices, as well as ammonia refrigeration techniques combined with CHP, require a lot less [31].

THE REFRIGERATION RECOVERY METHODS

In the early 1930s, the initial method of processing gas was refrigeration, and ever since it has greatly advanced [32]. The use of a flowing refrigerating liquid/vapor to take heat from a cold location and transmit it to a warm area where it is sent to a thermal sink is the basis of refrigeration. A typical modern system uses propane, lithium, ammonium, Freon, or bromides as the flowing operational liquid [33]. While decreasing the quantity of energy and implements necessary to restore the NGLs, the aim of refrigeration units presently is to expand the restoration levels of NGL. The usage of cold remaining reflux & recycle split steam process is an optimization method, basically using cold liquids in many stages again, giving the necessary advantage to processors of gas to use for refrigeration. Joule-Thompson cryogenics & cooling are the most general methods of refrigeration [31], [34].

1.1) THE JOULE-THOMPSON COOLING RECOVERY METHOD

The process entails a high-pressure gas expanding over a small aperture to increase velocity while lowering pressure. JT cooling is the term for the temperature drop that occurs as a result of this process. Most gases are cool as they expand. Operators avoid the use of JT cooling as an initial base of recovery for NGLs due to rising fuel gas prices and the inefficiency of pressure recovery [31]. JT cooling is notoriously difficult to process and transport. The lost pressure is recovered by chilling with a booster compressor or by being close to the final user because there is no pressure recovery mechanism. However, this does not address the issue of effectively and efficiently transferring moist gas. In transport pipelines, there are few techniques for recovering lost energy as pressure drops, and is mostly seen as an issue [34]. When gas passes through distribution stations, an increase occurs, and in other to prevent a two-phase flow that adversely affects the accuracy of the meters and generates potential destructive liquid slugs, this increase needs to be countered. It is a simple recovery method but inefficient, also, there is an increase in the cost of fuel due to pressure drop, the damaging side effect accompanying transporting and processing stages is an issue, there is a need to install near end-user and the need to heat the gas to prevent drastic cooling.

1.2) THE CRYOGENICS RECOVERY METHOD

Cryogenics is a recovery process that uses both propane and ethane as working fluids in a cascading refrigeration plant to achieve extremely low temperatures and high ethane recovery levels [35]. The cryogenic system is capital costly and hence an essential capital investment due to the controls' complexity and unique materials handling procedures for the extreme cold [36]. To employ this approach, practically all the impurities in the gas must be eliminated before the NGLs can be recovered. To keep ice and prevent hydrate development, all water must be eliminated. It has the advantage of providing an ultra-low temperature and a high level of ethane recovery [31]. However, Cryogenic plants require significant capital expenditure, the systems require special and care material handling procedures due to the extremely cold operating conditions, it requires complex control systems [36]. Also, all water must be removed from gas before processing to avoid the formation of ice and hydrates that could damage equipment and its systems are slightly inefficient for NGL recovery above C2 [37], [38].

THE PHYSICAL METHODS

1.3) THE MEMBRANE TECHNOLOGY METHOD

In this method, large molecules of organic compounds are eradicated through membranes from the air. Smaller and even smaller organic molecules can be taken out of gas as technological advancement took place in the areas of materials manufacturing, resulting in the production of ever more exotic membranes. Membranes are one of the easiest, most cost-effective of conventional processes [39]. In recent times, membrane technology can eradicate NGLs, carbon dioxide, water, nitrogen, and hydrogen sulfide out of the gas streams. However, Membrane fouling frequently occurs at high driving force and there is an occurrence of concentration polarization [40].

1.4) THE TURBO EXPANDER METHOD

A high-energy gas is injected into a turbine, and as it expands through the turbine, it exerts a force on the blades and rotates the shaft while lowering the temperature and pressure. The shaft power generated by the natural gas extension is used to power a comparable turbine, rather than compressing gas later in the process. Although turbo expanders have massive equipment to further cool the gas and segregate the NGLs for shipping, they have a substantial cooling impact similar to the JT expansion method, where the gas is cooled as it expands. It was created in the 1960s and is one of the most innovative NGL recovery technologies [41], [42]. However, they require a huge capital investment, a large number of auxiliary equipment to function, and turbines embedded in turboexpanders require extensive and regular preventive maintenance [31].

1.5) THE SUPERSONIC NOZZLE METHOD

The supersonic nozzle method works by deflecting a high-energy gas over a fixed curved blade, resulting in the formation of a vortex. A supersonic vortex can be created inside static equipment using a nozzle. The vortex tube was developed to improve the separation of natural gas and NGLs while lowering the cost and complexity of the operation [31]. The vortex tube can accomplish this while still retaining the majority of the gas's pressure. The pressure drop of this model separation device is only 25-35% of the gas's inlet pressure [43]. The TwisterTM is an example of a vortex tube, and it was developed by Shell and uses supersonic flow that has veins at the inlet to create a swirling motion in the gas. The supersonic nozzle method does not require extensive maintenance, gas pressure is sharply maintained hence no need for booster compressor, operations can be unmanned, equipment is competitive in terms of cost, and it is capable of processing both small and medium scale volumes of gas [31], [44].

1.6) COMBINED HEAT AND POWER SYSTEMS

This is based on the use of a single fuel source to generate two types of power, lowering the system's production losses [45]. Cogenerations are a type of combined heat and power system [46]. The waste heat from a compressor engine is used to power a refrigeration unit that cools low-pressure gas. The 'Btus' produced as a by-product of combustion can be utilized instead of being released into the atmosphere by collecting the waste heat from a compressor engine. The attributed heat causes a refrigerant mixture to evaporate, which is subsequently distilled and employed in an evaporator to remove heat from the cold room. The combined heat and power systems use waste heat to provide power to the refrigeration system; they require a small amount of auxiliary equipment and support facilities, have low maintenance costs, can generate distributed power, are a well-established and advanced technology, and can be used in small and medium-scale gas utilization schemes [45], [47].

THE CHEMICAL METHODS

1.7) THE LEAN OIL ABSORPTION METHOD

It was regarded as a chemical approach when the process was designed in the early 1910s, and it has been in use since then [31]. Its principal role is to allow/permit a moist natural gas stream above it for the oil to absorb the NGLs. After the NGLs are absorbed, lean oil becomes rich oil, which is then delivered to a distillation tower to separate the constituents. To maintain consistency, the NGLs are separated and transferred from the system, while the ethane, methane, and lean oil are recovered and delivered back through the process.

This procedure requires large equipment and big physical space/clearing to function. There are other recovery methods that are effective and efficient, of lower costs and smaller physical sizes. However, the lean oil absorption method can be used to remove both light and heavy NGL, also, other non-hydrocarbon gases like nitrogen can be isolated using the lean oil adsorption method [48], [49].

The reboiled absorber column is also a unique facility for absorption that contains a number of plates (or trays) that tend to determine the extent of absorption of a particular feed [50]. Knowing the usefulness of Methane and NGL in the present day and the uniqueness of the absorption method in the removal of both light and heavy NGL, this study capitalizes on the use of plates in the absorption column to optimize the recovery of Methane and NGL in a gas processing plant. The later sections explain the methods and findings unraveled by this study using ASPEN HYSYS process simulator

II. METHODOLOGY

A gas processing plant was built on the ASPEN HYSYS V8.6 simulator using feed gas composition from Technip's Western Libya Gas Project. The reboiled absorber column was identified as the major component for this study and simulations were conducted for 10, 20, and 30 plates respectively.

The following are assumptions made in this study:

- Spacing between trays is constant
- Absence of water in inlet fluid

- The system is a closed system

AModelling Environment

The ASPEN HYSYS V8.6 simulation environment was utilized to model the methane and NGL recovery plant, and the PENG-ROBINSON fluid package was employed because the study was on gaseous fluids, where methane and NGL are the primary fluids targeted. The governing equation used for simulation was the Peng-Robinson equation of state that expresses the attraction and repulsion activities between gas molecules, and it was expressed in equation 1 [51].

$$P = \frac{RT}{\tilde{v}-b} - \frac{\alpha a}{\tilde{v}^2+2b\tilde{v}-b^2} \quad (1)$$

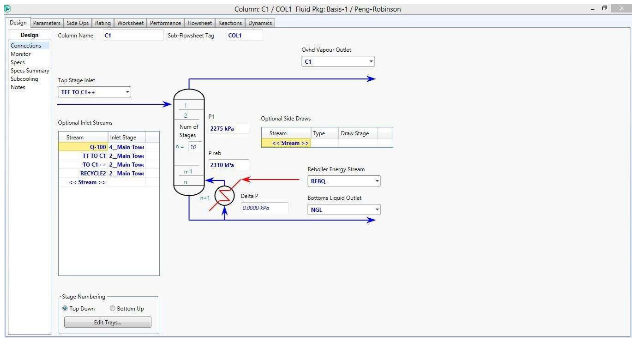
Where a & b are:

$$a = 0.45724\frac{R^2T_c^2}{P_c} \quad (2)$$

$$b = 0.07780\frac{RT_c}{P_c} \quad (3)$$

$$\alpha = [1 + (0.37464 + 1.54226\omega - 0.26992\omega^2)(1 - \sqrt{T_r})]^2 \quad (4)$$

$P, \tilde{v}$, T_r, R, ω, T, T_c and P_c are Pressure (Pa), molecular volume (m^3mol^{-1}), Reduced Temperature, Gas constant (8.314 $Jmol^{-1}K^{-1}$), acentricity factor, Absolute Temperature (K), Critical Temperature (K), and Critical Pressure (Pa). Also, $a, b \& \alpha$, are constants that were defined in equations 2, 3, and 4.



Column: C1 / COL1 Fluid Pkg: Basis-1 / Peng-Robinson

Column Name: C1

Sub-Flowsheet Tag: COL1

Ovhd Vapour Outlet: C1

Top Stage Inlet: TEE TO C1++

Optional Inlet Streams

Stream	Inlet Stage
Q-100	4__Main Towe
T1 TO C1	2__Main Towe
TO C1++	2__Main Towe
RECYCLE2	2__Main Towe
<< Stream >>	

Num of Stages: n = 10

P1: 2275 kPa

P reb: 2310 kPa

Optional Side Draws

Stream	Type	Draw Stage
<< Stream >>		

Reboiler Energy Stream: REBQ

Delta P: 0.0000 kPa

Bottoms Liquid Outlet: NGL

Stage Numbering: ● Top Down ○ Bottom Up

B Components List

The components for this process were chosen from the ASPEN HYSYS library for pure components and are namely Methane, Ethane, Propane, I-Butane, n-Butane, I-Pentane, n-Pentane, n-Hexane, n-Heptane, n-Octane, Nitrogen, and CO_2.

C Unit Operations Needed

The Unit-operations needed for the complete modeling of the methane and NGL recovery process are the Expander, Valve, Reboiled-Absorber, Tee, Cooler, Compressor, Heater, Recycle, Heat Exchanger.

D Inlet Feed Conditions

The inlet conditions of the natural gas (feed gas) were modeled according to the conditions shown in Tables 1 and 2.

Table 1: Thermodynamic Condition of Feed Gas

Temperature [ºC]	-34
Pressure [kPa]	6000
Molar Flow [kgmole/hr]	40000

Table 2: Mole Ratio of Feed Gas

Component	Mole Ratio
Nitrogen	0.0400
CO_2	0.0000
Methane	0.8680
Ethane	0.0550
Propane	0.0210
i-Butane	0.0030
n-Butane	0.0050
i-Pentane	0.0020
n-Pentane	0.0020
n-Hexane	0.0020
n-Heptane	0.0010
n-Octane	0.0010

E. Specifications in the absorber Column

The specifications for the absorber column are shown in figure 2 and 3. They contain the no of trays in the column, the inlet stages, the outlet stages, and the top & bottom operating pressures.

Fig. 2: Absorber column specifications for connections

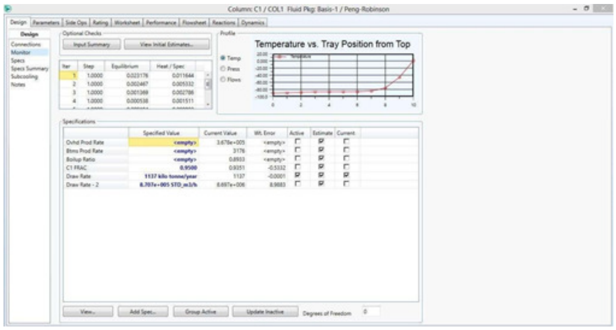


Fig. 3: Absorber column parameters for monitoring

F. Sales Gas Compressor

The sales gas compressor was modeled as a one-stage compressor for simplicity, under the conditions of different Adiabatic efficiencies ranging from 20%-75%, with the aim of observing the energy demand on the compressor with different recycling options.

The specifications of the sales gas are 6000kPa and 34ºC

G. Products Recycle

The overhead product of the column was sent to a Tee where it was split into two parts of the same composition; with splits starting at 5% - 95% recycled back into the column.

H. Feed Inlet Trays

The inlet tray of the incoming natural gas was varied for a column with 10 trays, 20 trays and 30 trays in determining the best possible inlet tray for maximum NGL recovery. It would be determined by observing the inlet tray that gives us the maximum methane in the column overhead, minimum NGL in the column overhead, and Lower sales gas compressor power rating. The results from this analysis would be used in developing a model for easy prediction of the best feed tray position for this specific natural composition.

I. Operation flow

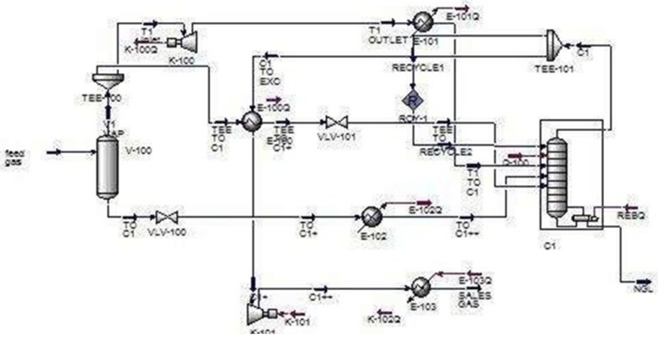


Fig. 4: Gas processing plant design using ASPEN HYSYS

Figure 4 shows the flow process for recovering methane and NGL starting from the feed gas. First, the incoming feed gas goes to a flash drum v-100, and the overhead vapor from the drum is then sent to a Tee feed splitter which split in equal proportions. One streamline from the feed splitter was sent to an expander to drop the pressure rapidly to achieve a corresponding drop in temperature and then sent to a cooler for further refrigeration and then sent to a column, and the other stream from the feed splitter is sent to a heat exchanger where the overhead product from the column is used for subcooling it, and then sent to the separation column. The process design of the column is showing the feed, the reboiler and output are shown in figure 5.

The Bottom products of the flash drum are sent to a cooler and valve for further refrigeration and pressure drop after which it is sent directly to the separation column. A stream containing mainly methane comes out of the column overhead, while the remaining NGL products come out of the column bottoms. The column overhead product is then sent to a Tee feed splitter where it is split based on the recycle proportion. Some of the products are then recycled back to the column for separation.

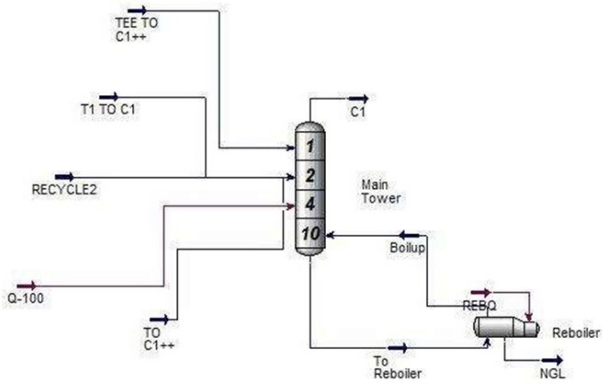


Fig. 5: Reboiled Absorber Column design using ASPEN HYSYS

III. RESULTS AND DISCUSSION

The outcomes of the simulations for methane and NGL recovery on an absorber column using ASPEN HYSYS simulator are as shown below.

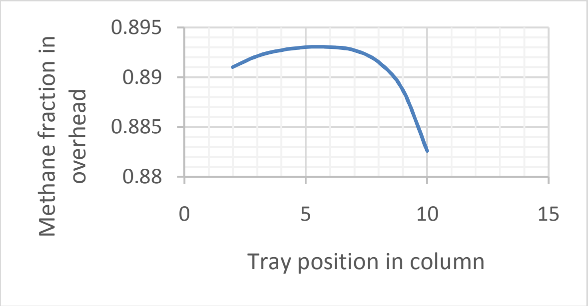


Fig. 6:Methane recovery fraction vs tray position for 10 trays

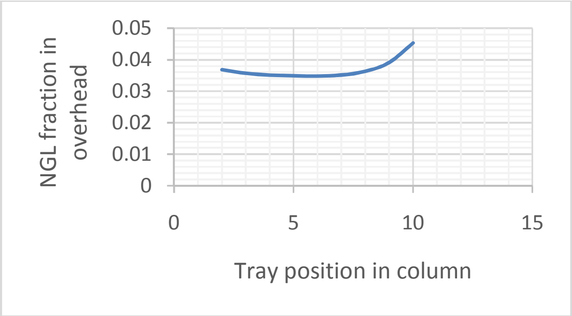


Fig. 7: NGL Recovery fraction vs tray position for 10 trays

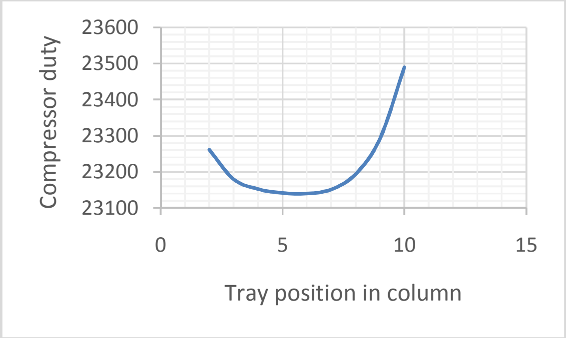


Fig.8: Compressor duty vs tray position for 10 trays

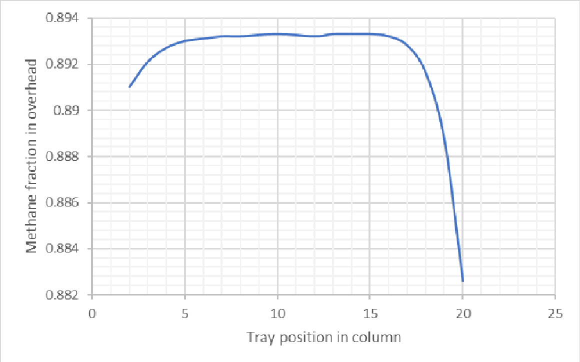


Fig.9:Methane recovery fraction vs tray position for 20 trays

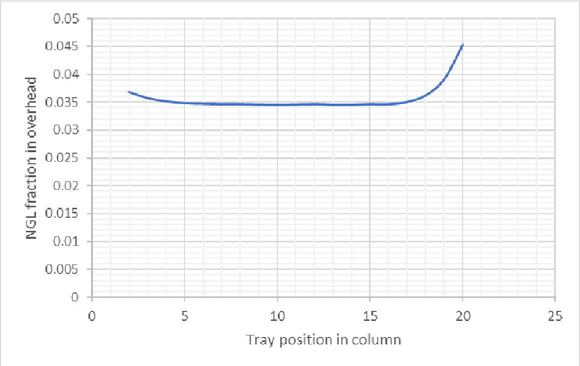


Fig.10: NGL recovery fraction vs tray position for 20 trays

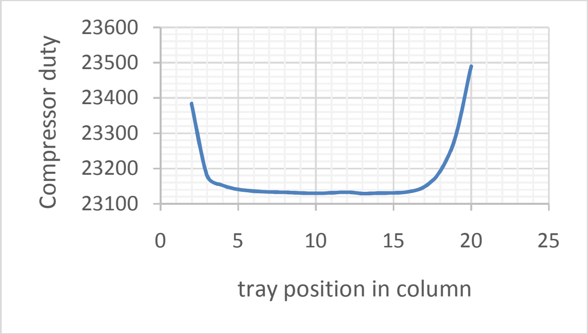


Fig.11: Compressor duty vs tray position for 20 trays

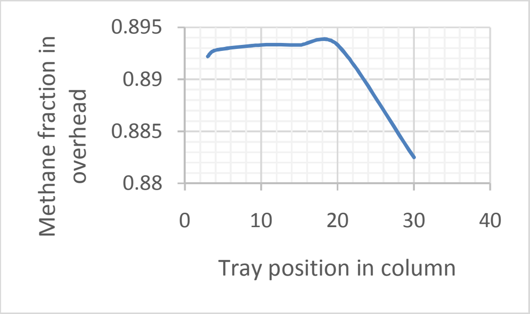


Fig.12:Methane recovery fraction vs tray position for 30 trays

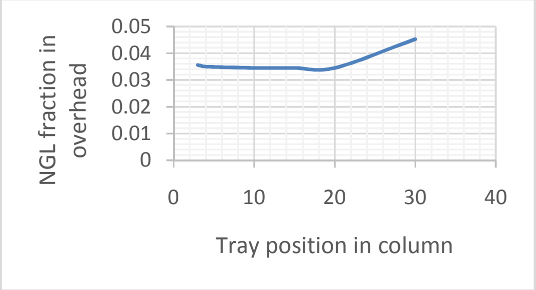


Fig.13: NGL recovery fraction vs tray position for 30 trays

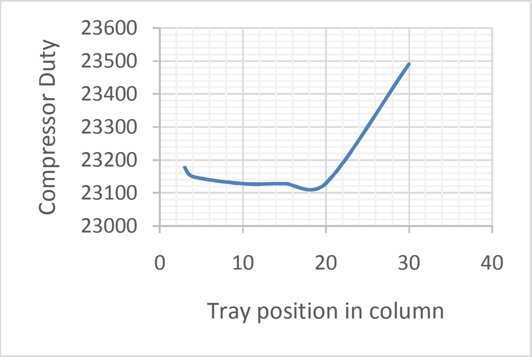


Fig.14: Compressor duty vs tray position for 30 trays

A. Column With 10 Trays

Figures 6, 7, and 8 show that the tray that would give the maximum recovery of Methane in the column, minimum NGL overflow in the column overhead, and the lowest sales compressor power requirement is the 6th tray.

It can be observed in figure 6 that the recovery of methane keeps rising until it reaches a peak at tray 6 and then keeps dropping it reaches the final tray. This goes to show that maximum recovery is not inversely proportional to recovery in the column overhead. The same trend goes for figure 7 and figure 8, as the values keep decreasing with increasing feed tray position and reaches its minimum value when it gets to tray 6, and after that begins to increase until it approaches tray 10.

B. Column With 20 Trays

From figures 9, 10, and 11 It can be seen that the tray that would give the maximum recovery of Methane in the column, minimum NGL overflow in the column overhead, and the lowest sales compressor power requirement is the l3th tray.

It can be observed in figure 9 that the recovery of methane keeps rising until it reaches a continuous peak at tray 5 and continues through to tray 16, but reaches its maximum value at tray 13, after tray 16 it keeps dropping until it reaches the final tray. This goes to show that maximum recovery is not inversely proportional to recovery in the column overhead. The same trend goes for figures 10 and 11, as the values keep decreasing with increasing feed tray position, reaches a continuous crest from tray 5 to tray 16, but reaches its minimum value at tray 13. Both values begin to increase again at tray 16 and keep increasing till it reaches the 20th tray.

An observation from this graph shows that this column gives us a wide range of tray numbers to choose from as they all give us nearly similar values; therefore, an optimum feed tray position can be chosen based on other economic factors apart from recovery alone.

C. Column With 30 Trays

From figures 12, 13, and 14, it can be seen that the tray that would give the maximum recovery of Methane in the column, minimum NGL overflow in the column overhead, and the lowest sales compressor power requirement is the 18th tray.

It can be observed in figure 12 that the recovery of methane keeps rising until it reaches a peak at tray 18 and then keeps dropping until it reaches the final tray 30. The same trend goes for figure 13 and figure 14, as the values keep decreasing with increasing feed tray position and reaches its minimum value when it gets to tray 18, and after that begins to increase until it approaches tray 30.

The power required to drive these processes also increases as the NGL recovery increases while it reduces as the methane recovery increases (figures 8, 11 and 14 shows the changes that occurs when tied to NGL and methane recovery)

D. Optimum Feed Tray Position for Nth Number of Trays

Figure 15, 16 and 17 suggests that there is a clear relationship between the number of trays in an absorber column and the recovery of Methane and NGL. However, while the optimum fraction of methane in the overhead increases with increasing number of trays (see figure 16), the optimum fraction of NGL in the column overhead decreases with increasing number of tray (see figure 17). Furthermore, the optimum feed tray position increases as the number of trays increase (see figure 15). This study creates a quick look framework for field decision making during methane and NGL processing since an operator would be open to series of choices when simulating optimal values

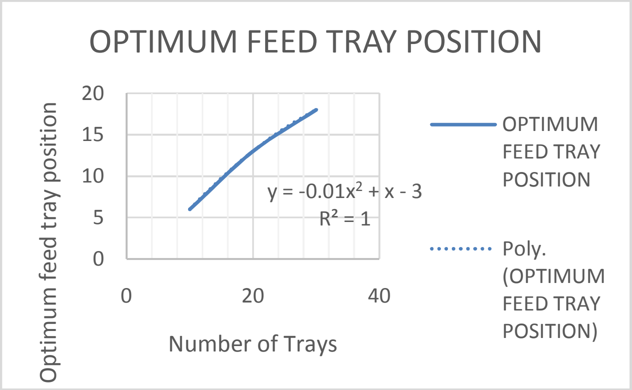


Fig. 15: plot of optimum feed at optimum tray positions

From figure 15 a 2nd order polynomial mathematical model was developed for determining the optimum feed tray location for a given number of trays.

The Mathematical model developed is shown in equation 5 below.

$$y = -0.01x^2 + x — 3 \qquad (R^2 = 1) \qquad (5)$$

Where x = number of trays, y = the optimum feed tray position

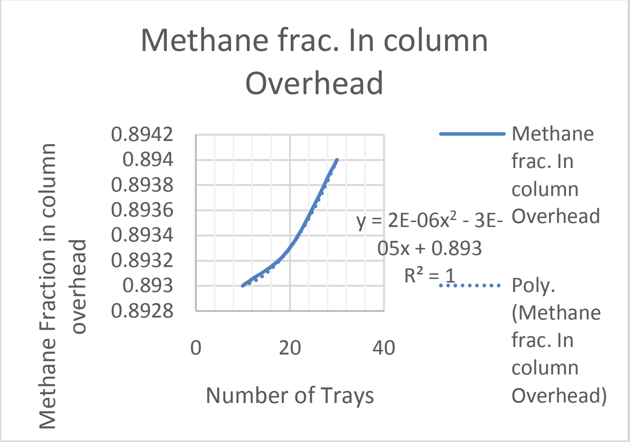


Fig. 16: Plot of optimum methane recovery

From figure 16 a 2nd order polynomial mathematical model was developed for determining the maximum methane recovery in the column overhead for a given no of trays.

The Mathematical Model developed is shown in equation 6 below.

$$y = 2E\text{-}06x^2 - 3E\text{-}05x + 0.8931(R^2 = 1) \qquad (6)$$

Where X = Number of trays, Y = Fraction of methane overhead

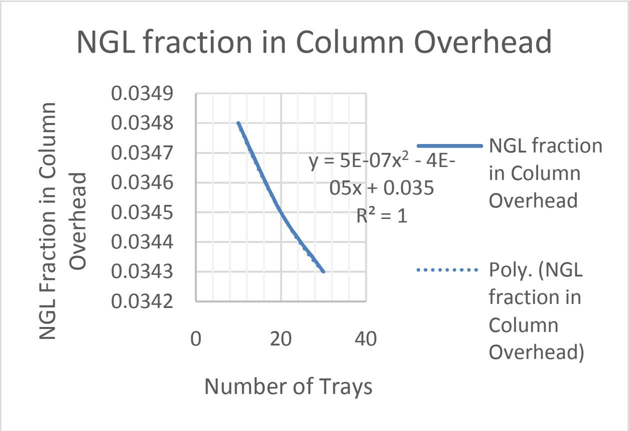


Fig. 17: Plot of optimum NGL recovery

From figure 17 a 2nd order polynomial mathematical model was developed for determining the minimum NGL fraction in the column overhead for a given no of trays.

The Mathematical Model developed is shown in equation 7 below.

$$y = 5E\text{-}07x^2 - SE\text{-}05x + 0.0352(R^2 = 1) \qquad (7)$$

Where X = Number of trays, Y= Fraction of NGL overhead.

E. Testing the Model

Assuming a 90% mass fraction of methane in the Overhead, calculate the number of trays necessary for the desired separation and the optimal feed tray position:

Using equation 6, we have 67 trays

Using equation 5 the Optimum Feed Tray Position is the 19th tray.

Let's use equations 7 and 5 to compute the NGL fraction in the Column Overhead and the Optimum feed tray positions, assuming the number of trays in the absorber column for the separation was 108.

Using equation 7 we have 2.9% of NGLs in the Overhead

Using equation 5, the Optimum Feed Tray Position is the 12th tray.

IV. CONCLUSIONS

The results from this study presented a framework for predicting the optimum number of trays for the desired separation of methane and NGL, and the optimum feed tray position for the calculated number of trays, for the specified natural gas composition.

It was discovered that NGL recovery reduced as the percentage of methane recovery increased, showing that the NGL fraction recovery is inversely proportional to the methane recovery.

The Optimum feed tray location was tested for different columns with 10, 20, and 30 trays, and results show that the 6th, 13th, and 18th trays respectively were the Optimum feed tray position for the investigated absorber column. It was discovered that the methane fraction increased with the increasing no of trays, while the NGL fraction decreased with the increasing no of trays.

Three models were developed for calculating the Optimum feed tray location for any no of trays, the percentage of methane in the column overhead, and the percentage of NGL in the column overhead. The mathematical models were tested and found to be reliable for the optimization of production. Hence, it is prevalent to further research on other natural gas compositions to develop other models that could be unique in solving optimization challenges using the framework provided by this study. Also, economic analysis varying the best feed tray position for a specified column can be added as a variable for validating its optimization.

DATA AVAILABILITY STATEMENT

The authors affirm that the data behind the study's conclusions are included in the article.

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CONFLICT OF INTEREST

There is no conflict of interest.

NOMENCLATURE

NGL – Natural Gas Liquid
CHP – Combined Heat and Power Systems
°C – Degree Celsius
kPa – Kilo Pascal
kgmole/hr – Kilogram mole per hour
R^2 – R-square factor
CO_2 – Carbon dioxide
m^3mol^{-1} – meters cube per mole
P – Pressure
$\tilde{v}$ - molecular volume
T_r - Reduced Temperature
ω - acentricity factor
R - Gas constant
T – Absolute Temperature
T_c – Critical Temperature
P_c – Critical Pressure
$Jmol^{-1}K^{-1}$ – Joules per mole per kelvin
a - Constant
b - Constant
α – Constant

C_2 – Methane
JT – Joule Thomson

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