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# Optimal Recovery of Methane Gas from Natural Gas Steam using Aspens Hysis Simulator

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*Abstract-* In this study, the recovery of natural gas has been carried out using the Aspens Hysis Simulator Version 8.6 for the plant simulation and Technip's feed gas composition was chosen for the process, while testing the effect of products recycles and optimal feed tray position. This work sought to optimize the existing plant framework. The results obtained were analyzed by observing the maximum methane recovery in the column overhead. It was discovered that methane gas recovery was maximum when product recycle was zero, and that increasing no of trays, led to increasing methane recovery in the overhead. A mathematical model was developed for predicting the optimal feed tray position and is given as y=-0.01x2 +x – 3, while the mathematical model for calculating the required number of trays for a desired fraction of methane in the overhead is given as y=2E-06x2 - 3E-05x+0.8931, and the mathematical model for calculating the required number of trays for a desired fraction of NGLs in the overhead was given as y=5E-07x2 - 5E-05x+0.0352.

*Keywords: methane, recovery, optimization, recycle, gas plant.*

*GJRE-C Classification: LCC: TP751*

OPTIMALRECOVERYOFMETHANEGASFROMNATURALGASSTEAMUSINGASPENSHYSISSIMULATOR

*Strictly as per the compliance and regulations of:*

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## I. Introduction

Several environmentalists vision natural gas as a bridge fuel between the prevailing fossil fuel of today and the renewable fuels of tomorrow (Mokhatab, 2006). The fastest growing hydrocarbon is natural gas in the hydrocarbon fuel family and most estimates put the average rate of its growth at 1.5–2.0%. Currently, the demand for Natural Gas is increasing due to its clean burning characteristics and its ability to meet environmental requirements. Increasing the processing and production of all hydrocarbons in an environmentally friendly and cost-effective practice is the current foremost ambition of the industry (Abdel-Aal & Mohamed, 2003). Natural gas is generally separated into two groups, viz: derived from conventional deposits and derived from non-conventional deposits (Peyerl & Figueirôa, 2016). The difference is typically due to a difference in the structure of the deposits, geologically and in their production methods (Ghalambor, 2005). It is projected that by 2030, natural gas will substitute coal as the second most frequently used energy source in the world (Alireza, 2014). Natural Gas from conventional deposits originates mainly from rocks of great permeability. It is mined by means of "traditional" vertical drilling know-how (Salah et al., 2021). 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. (Eggour & Fahim 2003).

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. (GPSA, 2004). The weightier hydrocarbon liquids normally referred to as natural gas liquids (NGLs), include ethane, propane, butanes and natural gasoline (condensate). Recovery of NGL constituents in gas not only may be a prerequisite for hydrocarbon dew point control in a natural gas stream (to avoid the unsafe formation of a liquid phase when transporting), but also produces a source of revenue, as NGLs normally have significantly greater value as distinct marketable products than as part of the natural gas stream (Kidnay and Parrish, 2006). Lighter NGL fractions, such as ethane, propane, and butanes, can be sold as fuel or feedstock to petrochemical plants and refineries, whereas the heavier portion can be used as gasoline-blending stock (GPSA, 2004). Natural gas coming directly from a well contains many natural gas liquids that are usually removed (Larson and Carl-Fredrik, 2021). In most instances, natural gas liquids have a higher value as separate products when they are not separated. Thus, it makes economic sense to remove them from the gas stream (EIA, 2012). NGL components products; Ethane, propane, butane, pentane and other heavier products are major markets for the petrochemical and plastic industries as well as the pharmaceuticals industry.

## II. Methodology

### a) *Modelling Environment*

The NGL recovery plant with recycling was modelled using the ASPEN HYSYS V8.6 simulation environment. The fluid package PENG-ROBINSON was chosen for the modelled process as recommended by the ASPEN tutorial manual. (Gayubo, 2000)

### b) *Unit Operations Needed*

The Unit-operations needed for the complete modelling of the process are given below:

Expander, Valve, reboiled absorber, Tee, Cooler, Compressor, Heater, Recycle, Heat Exchanger (Zaixing, 2018).

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*c) Inlet Feed Conditions*

The inlet conditions of the natural gas were modelled according to the following conditions listed in Table 1.

*Table 1:* Inlet feed conditions

| | |
|---|---|
| Temperature [C] | -34 |
| Pressure [kPa] | 6000 |
| Molar Flow [kgmole/h] | 40000 |

The component fractions are listed below:

*d) Specifications in the Fractionating Column*

The specifications for the fractionating column are listed in Figure 1 and Figure 2 they contain the no. of trays in the column, the inlet stages, the outlet stages and top and bottom operating pressures.

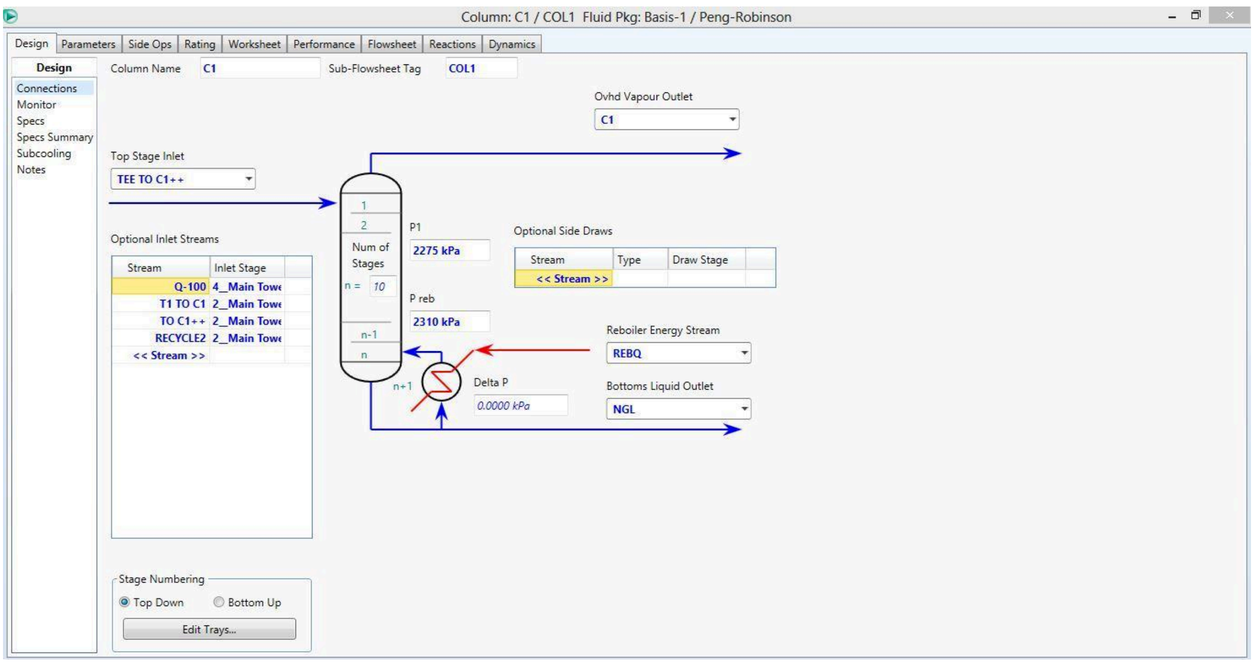


*Figure 1:* Column specifications 1

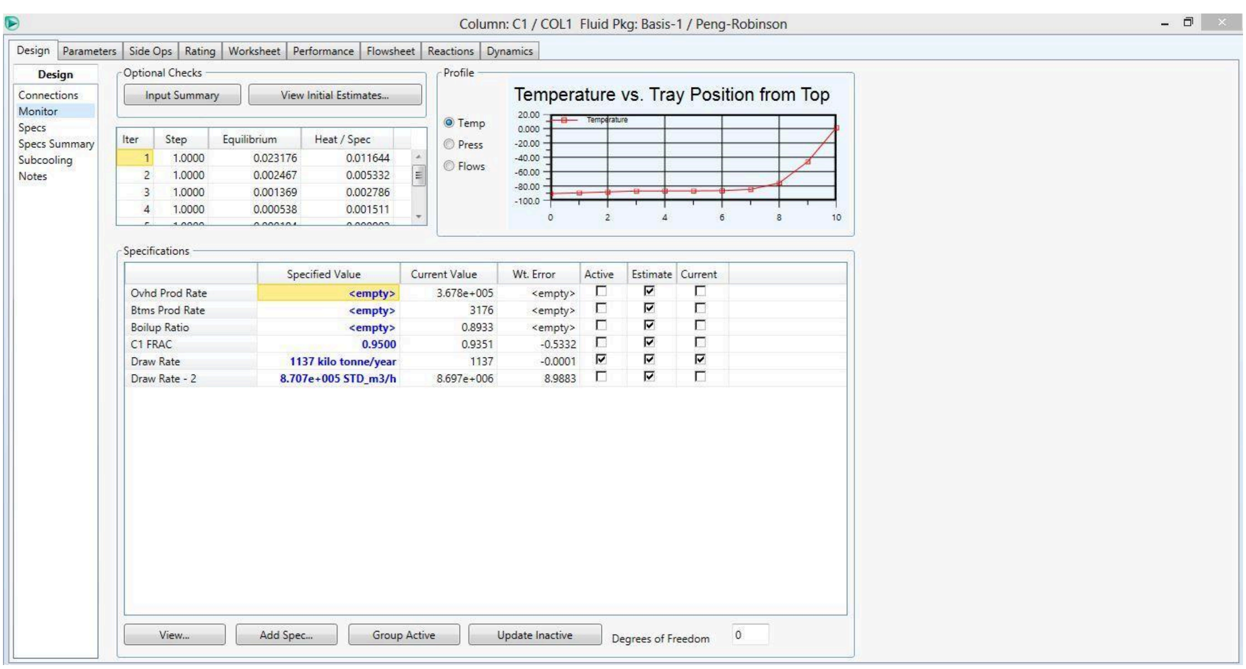


*Figure 2:* Column specifications 2

*e) 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 (EIA, 2012.). The specifications of the sales gas are 6000kPa and 34$^o$C.

*f) Products Recycle*

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

*g) Feed Inlet Trays*

The inlet tray of the incoming natural gas was varied for a column with 10 trays, 20 trays and 30 trays. 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 (Xinghe et al., 2018). 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 (Ghalambor, 2005).

## III. Results and Discussion

*a) Results*

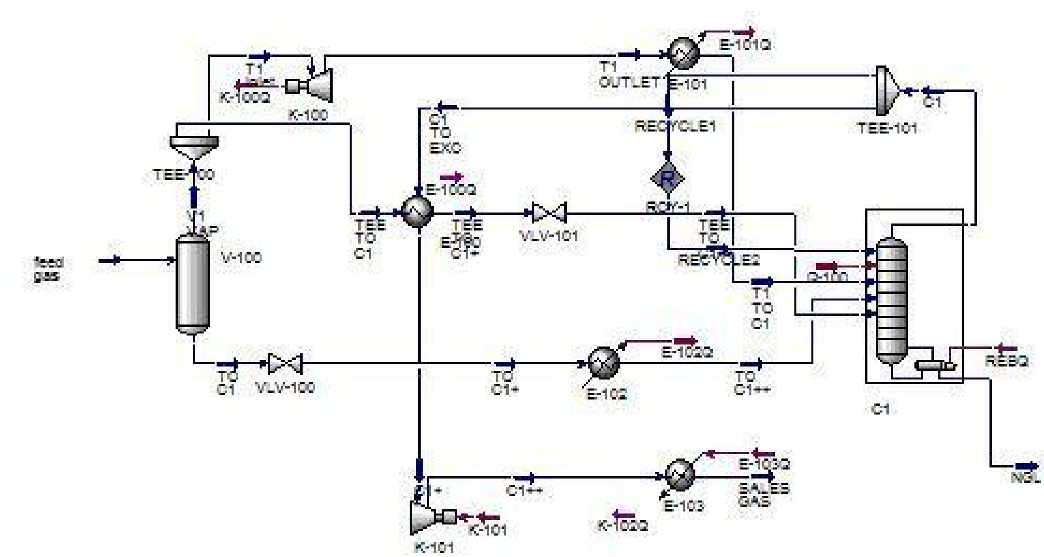


*Figure 3:* Complete NGL recovery plant

The incoming feed gas goes to a flash drum v-100, and the overhead vapour from the drum is then sent to a Tee feed splitter which split in equal proportions. one stream line 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 sub cooling it, and then sent to the separation column. The Bottom products of the flash drum is sent to a cooler and valve for further refrigeration and pressure drop and sent directly to the separation column. A stream containing mainly methane comes out of the column overhead.

*b) Effect of Product Recycle*

The product recycle versus methane in overhead is shown in table 2 below.

*Table 2:* Product recycle vs. Methane in overhead

| PRODUCTS RECYCLE | METHANE IN OVHEAD |
|---|---|
| 0.0000 | 0.8887 |
| 0.0500 | 0.8883 |
| 0.1000 | 0.8880 |
| 0.2000 | 0.8872 |
| 0.3000 | 0.8865 |
| 0.4000 | 0.8858 |
| 0.5000 | 0.8851 |
| 0.6000 | 0.8849 |
| 0.7000 | 0.8841 |
| 0.8000 | 0.8845 |
| 0.9000 | 0.8854 |
| 0.9500 | 0.8852 |

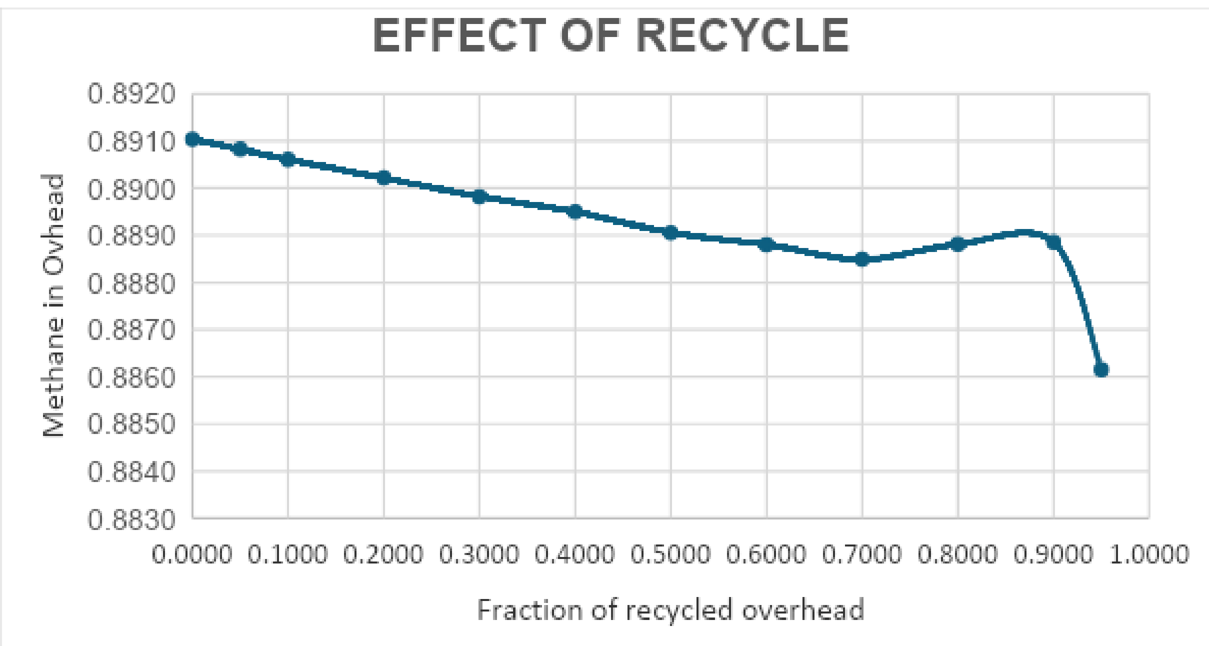


*Figure 4:* Graph showing the effect of recycling on methane fraction in a column overhead

*FEED INLET POSITION*

*Column with 10 Trays*

*Table 3:* Effect of tray position on methane fraction in column overhead and sales gas compressor power requirement for column with 10 tray

| TRAY | METHANE IN OVERHEAD | POWER REQUIREMENT OF SG COMP |
|---|---|---|
| 2.0000 | 0.8910 | 23261.2474 |
| 3 | 0.8921 | 23179.5078 |
| 4 | 0.8927 | 23152.3384 |
| 5 | 0.8930 | 23141.5127 |
| 6 | 0.8930 | 23139.9554 |
| 7 | 0.8927 | 23151.0407 |
| 8 | 0.8915 | 23193.7471 |
| 9 | 0.8887 | 23291.7624 |
| 10 | 0.8826 | 23489.5450 |

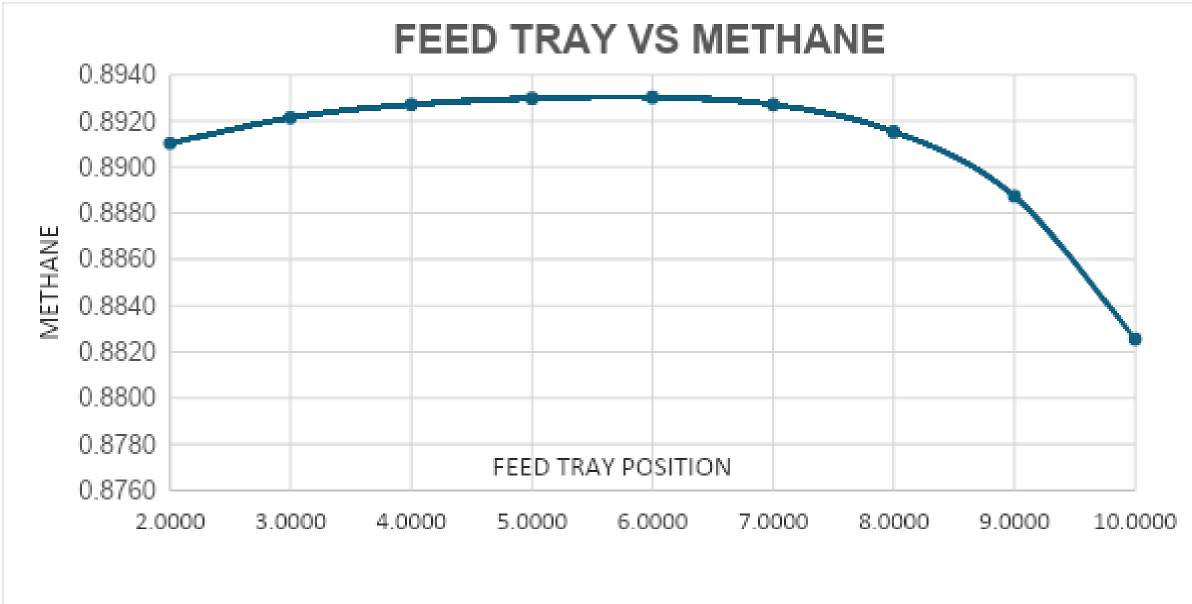


*Figure 5:* Feed tray vs. Methane in column overhead for column with 10 trays

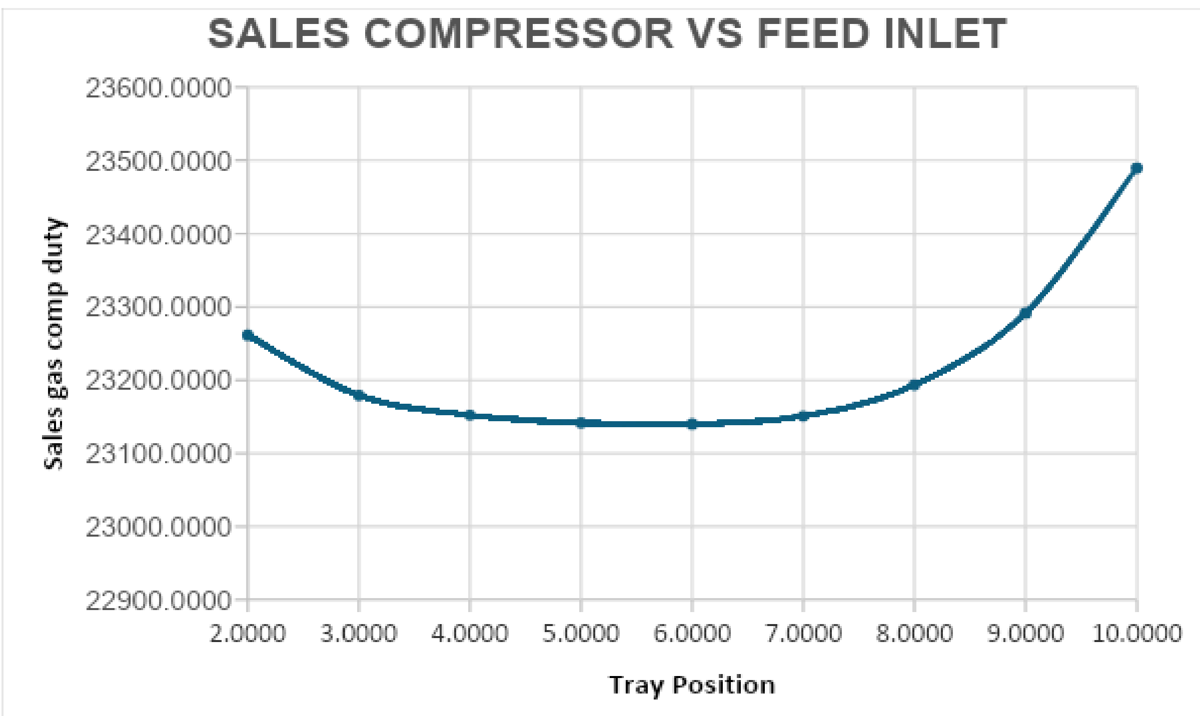


*Figure 6:* Feed tray vs. Sales gas compressor power requirement for column with 10 trays

*Column With 20 Trays*

*Table 4:* Effect of tray position on methane fraction in column overhead, and sale gas compressor power requirement for column with 20 trays

| TRAY POSTION | METHANE | POWER |
|---|---|---|
| 2.0000 | 0.8910 | 23383.9375 |
| 3.0000 | 0.8921 | 23179.3346 |
| 4.0000 | 0.8927 | 23151.9647 |
| 5.0000 | 0.8930 | 23140.5291 |
| 6.0000 | 0.8931 | 23135.4195 |
| 7.0000 | 0.8932 | 23133.1497 |
| 8.0000 | 0.8932 | 23132.1299 |
| 10.0000 | 0.8933 | 23129.3333 |
| 12.0000 | 0.8932 | 23132.3115 |
| 13.0000 | 0.8933 | 23128.8161 |
| 14.0000 | 0.8933 | 23129.9213 |
| 15.0000 | 0.8933 | 23130.3923 |
| 16.0000 | 0.8932 | 23133.7765 |
| 17.0000 | 0.8928 | 23148.2351 |
| 18.0000 | 0.8916 | 23191.8348 |
| 19.0000 | 0.8887 | 23291.2662 |
| 20.0000 | 0.8826 | 23489.6270 |

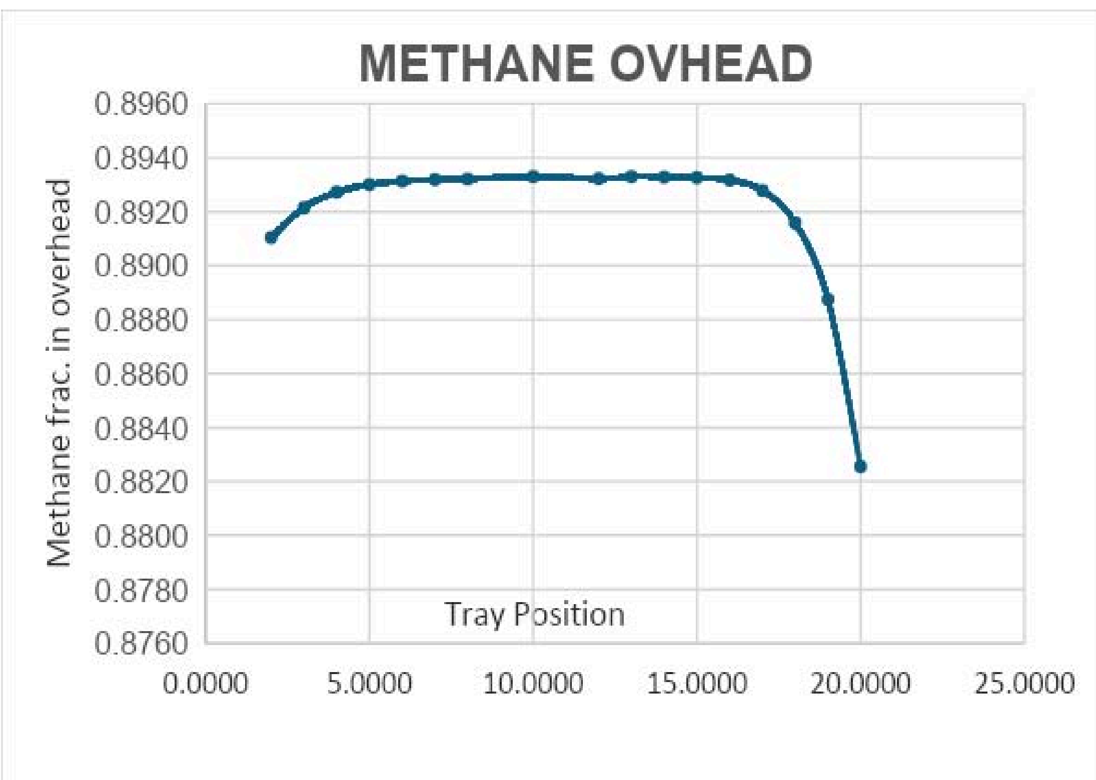


*Figure 7:* Feed tray vs. methane in column overhead for column with 20 trays

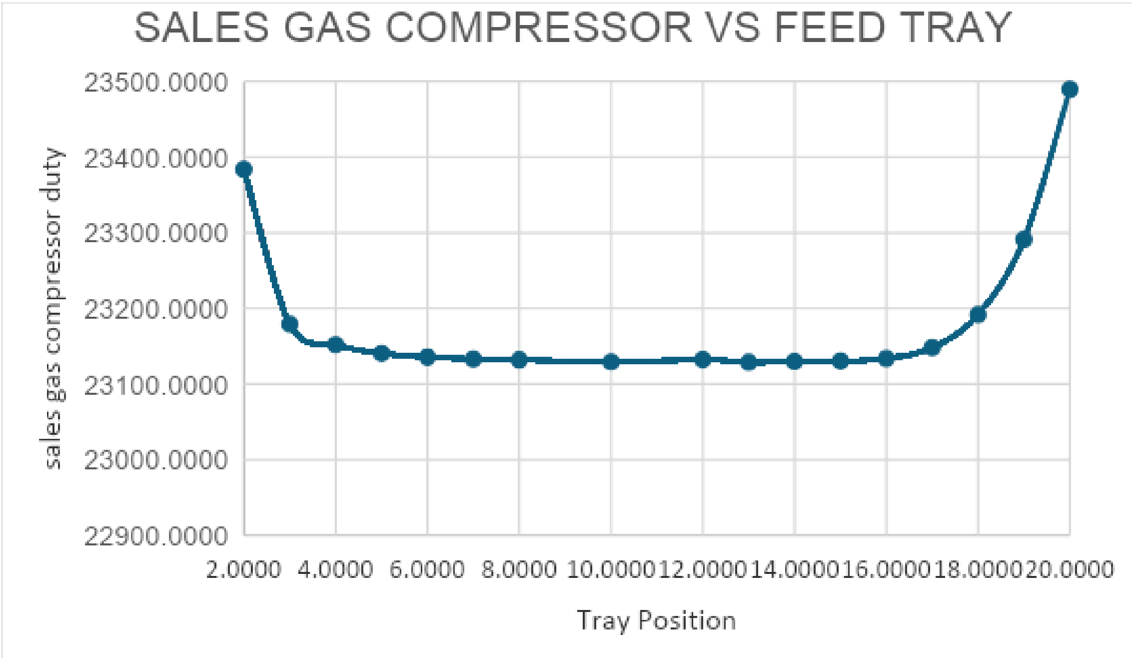


*Figure 8:* Feed trays vs. sale gas compressor power requirement for column with 20 trays

*Column with 30 Trays*

*Table 5:* Effect of tray position on methane fraction, NGL fraction in column overhead, and sales gas compressor power requirement for column with 30 trays

| Tray | Methane | Power |
|---|---|---|
| 3 | 0.8922 | 23176.8016 |
| 4.0000 | 0.8928 | 23149.3691 |
| 10.0000 | 0.8933 | 23128.0054 |
| 15.0000 | 0.8933 | 23128.3660 |
| 20.0000 | 0.8933 | 23129.1485 |
| 30.0000 | 0.8825 | 23489.8744 |

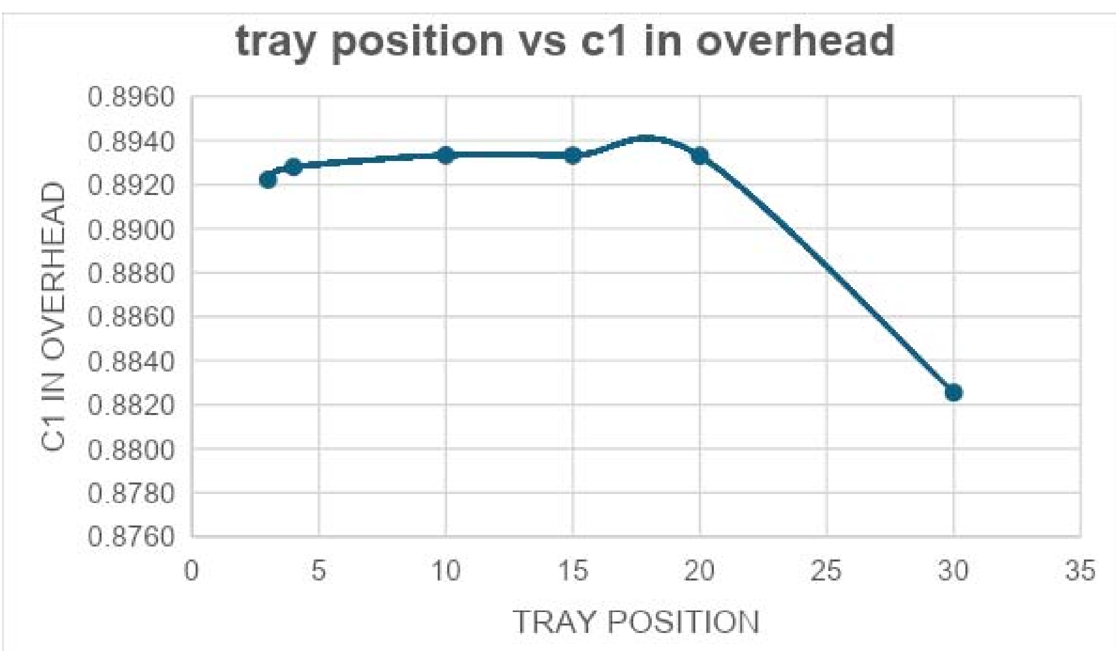


*Figure 9:* Feed trays vs. methane fraction in column overhead f or column with 30 trays

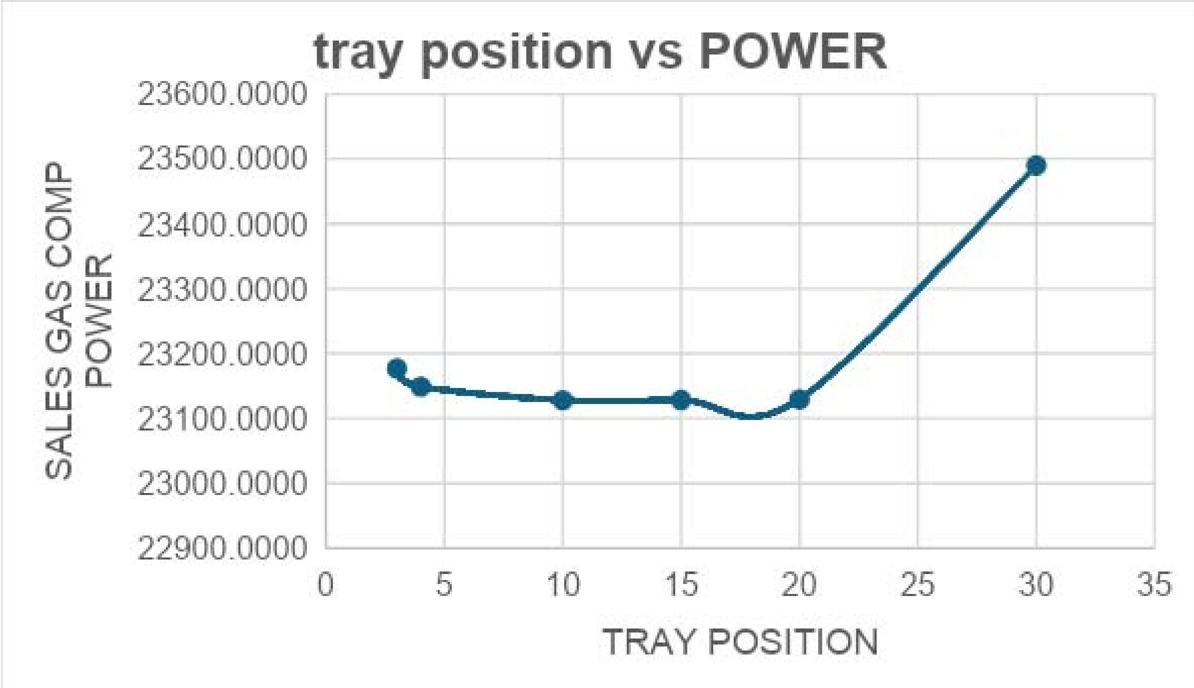


*Figure 10:* Feed trays vs. Sale gas compressor power requirement for column with 30 trays

c) *Optimum Feed Tray Position for Nth Number of Trays*

*Table 6:* Optimum feed tray position for different number of trays

| No. of Trays | Optimum Feed Tray Position | Methane Fraction in Column Overhead |
|---|---|---|
| 10 | 6 | 0.8930 |
| 20 | 13 | 0.8933 |
| 30 | 18 | 0.8940 |

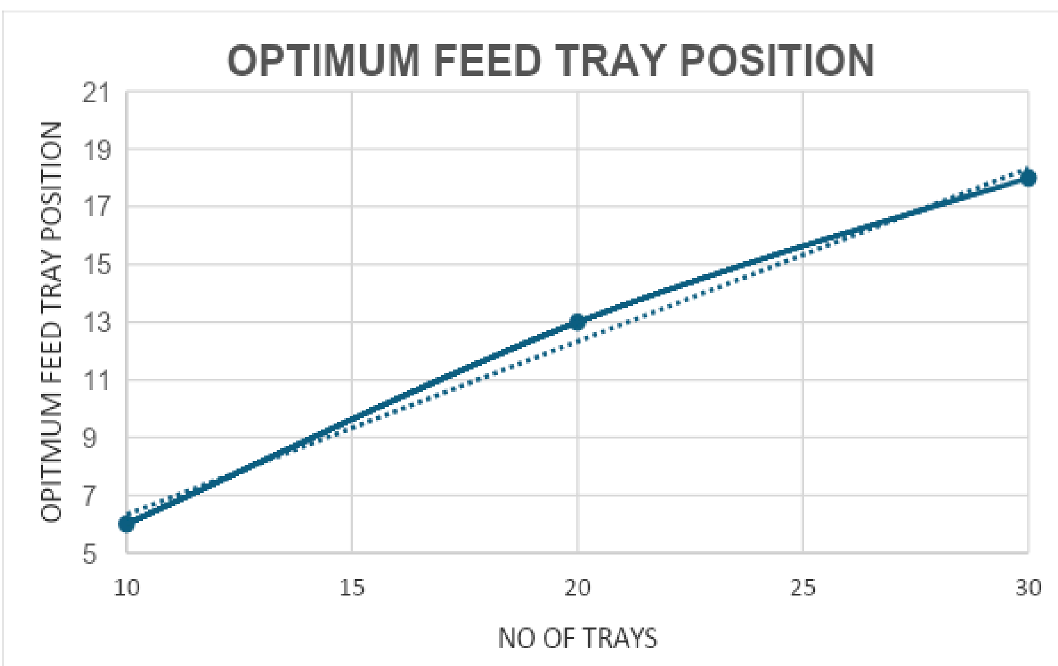


*Figure 11:* Graph showing optimum feed tray position for different number of trays

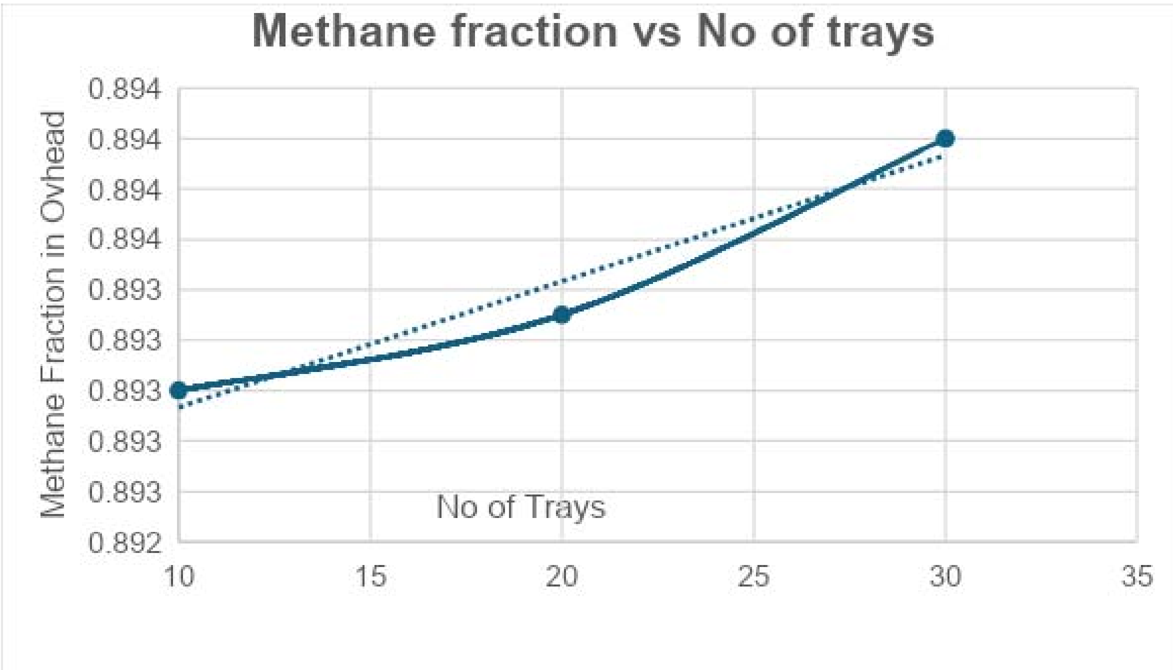


*Figure 12:* No of trays vs. methane fraction in the overhead

*d) Discussion*

i. *Effect of Recycle on Methane Recovery*

From figure 4 and table 2, it can be seen that the methane fraction in the overhead is maximum when there is no recycle, and keeps decreasing with increasing fraction of products recycle, and keeps decreasing till it gets to 80% recycle products where and increase is observed until another peak is reached in 90% recycle but not up to the maximum methane recovery as in when no products where recycled.

ii. *Optimum Feed Tray Position*

*Column With 10 Trays*

From figure 5, 6, 11 it can be seen that the tray that would give the maximum recovery of Methane in the column, overhead and the lowest sales compressor power requirement is the $6^{th}$ tray. It can be observed in figure 5 that the recovery of methane keep 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.

*Column with 20 Trays*

From figure 7, 8 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 $13^{th}$ tray. It can be observed in figure 7 that the recovery of methane keep rising until it reaches a continuous peak at tray 5 and continuous 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. An observation from this graph shows that this column gives us a wide range of tray number 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.

*Column with 30 Trays*

From figure, 9, 10 it can be seen that the tray that would give the maximum recovery of Methane in the column overhead and the lowest sales compressor power requirement is the 18th tray.

It can be observed in figure 9 that the recovery of methane keep rising until it reaches a peak at tray 18 and then keeps dropping until it reaches the final tray 30.

*e) Optimum Feed Tray Position for Nth Number of Trays*

From table 8 the fraction of methane in the overhead increases with increasing number of trays, showing that a higher of trays will give higher recovery of methane in the column bottoms.

From figure 11 a $2^{nd}$ order polynomial mathematical model was developed for determining the optimum feed tray location for a given number of trays.

The Mathematical model developed:

$$y = -0.01x^2 + x - 3 \ (R^2 = 1) \quad \text{Equation 1}$$

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

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:

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

Equation 2

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

From figure 12 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:

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

Equation 3

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

*f) Testing the Model*

Assuming our desired methane in the Overhead was 90% mass fraction, let's calculate the number of trays required for the desired separation and the Optimum feed tray position:

Using equation 2, we have 67 trays

Using equation 1 the Optimum Feed Tray Position is the 19th tray.

## IV. Conclusion

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

It was discovered that the methane fraction increased with increasing number of trays. Different models were developed for calculating the Optimum feed tray location for any number of trays, and the % of methane in the column overhead. The models were tested for a 90% recovery for methane, and it was calculated to be 67 trays to achieve the desired separation, with tray 19 being the optimum feed tray location.

## V. Recommendations

Simulation should be tested for other natural gas compositions to develop other models. Also, economic analysis varying the best feed tray position for a specified column should also be worked on.

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