SIMULATION OF MULTI-COMPONENT DISTILLATION FOR CONDENSATE STABILIZATION USING ASPEN HYSYS

Eze Kenneth .A, Nkwor Prince .E, Madubuike Esther .I, Nwaishienyi Freedom .C, Onwumere Alex .C.

ABSTRACT: → Developing a Standard Multi-component system requires sensitive specifications to be properly executed. The simulation of the raw material feed for condensate stabilization was conducted using the Aspen HYSYS Software, so as to examine the condition and specifications that will give the best end product. Analysis of three simulated condensate stabilization units (C.S.U) which have different process routes, maximum values of Reid vapor pressure (RVP) 80kPa, 89kPa and 88kPa was obtained at the product stream compared to a previous RVP value of 1041kPa in the feed stream. This is equivalent to a 90-95% reduction in the vapor pressure. This consequently shows that the condensate is stabilized. The most preferred process is the second alternative process because of the RVP value and the composition of the bottom product. The composition of the stabilized product was compared with data obtained from a plant and that of the Pro/II software. The result showed that the model is valid and can be used as a prediction tool for the plant under operation. At the first phase of C1-C5, the mole fraction of methane was the same for Pro/II and the data obtained from the existing plant. The mole fraction of propane has a difference of not less than 10% compared with that of plant data and Pro/II. The efficiency of the columns were rated at 90% which shows that the specifications used for the process simulation were standard and can run perfectly in a production plant. The performance of the distillation column was best achieved when the internal type was changed from Sieve tray to packed column internal type reducing the column environment specification or heat correlation error value from 7.6e-4 to 3.3e-4. It showed that packed column is better than the sieve tray for high performance of the column.

INDEX TERMS—*KEYWORDS:* Multi-component Distillation, Condensate Stabilization, Efficiency, Reid Vapor Pressure.

INTRODUCTION

The Lewis-Matheson and Smith-Brinkley algorithms are some of the models that have been used to improve distillation column efficiency. The major short-comings of these models are the length of time it takes for simulating the system. Another limitation to consider is the errors that may occur due to human factor, that's why software is a preferable tool in modeling of the system. (Adriana,2016).

However, the cost of the production process is optimized at the minimum rate without loss of raw materials; a production process can be predicted and analyzed from the feed point down to the final product. All these can be properly done through a virtual method called Simulation. Process simulation software is a powerful tool that allows refinery owners, operators, and engineers to virtually model a process in extreme detail without having to spend the time, manpower or money physically testing their design in real world environment. It's often performed during the design phase or before a plant becomes fully operational to see how changes in equipment specifications, scheduling, downtime and maintenance can affect a process throughout the duration of its life cycle. (Audubon, 2020).

Studies of multi-component distillation have been done using simulation tools such as Pro/II, Unisim, Matlab etc, but there is limited literature on the use of Hysys software for distillation column design thus the aim of this research.

Most condensate stabilization processes have a multi-component distillation unit. The data from Schlumberger Oilfield Glossary shows that the natural gas condensate is mainly composed of methane, propane, butane, pentane and heavier hydrocarbons, which are mostly the components that tend to evaporate at little increase in temperature. It is stabilized so as to ensure that the reid vapor pressure is at a lower rate and the condensate is safe for transport to any location (Ilias,2012). This project is executed by the utilization of a process simulation tool (Aspen-Hysys) to mitigate these problems so that the column operation will be effective and efficient. Specifically in this study, the software was used to model condensate stabilization Unit (CSU), and their distillation columns for optimal performance. (Rahmanian et al,2016)

METHODOLOGY

The Feed of the simulated condensate stabilization units as shown in figures 1, 2 and 3 are mixtures of filter separators, sludge catcher and regeneration gas separators of which the main compositions and specifications are listed in tables 1 and 2 (Navid et al 2012).

While Figure1 (First alternative Process), figure2 (Second alternative process) and figure3 (Third alternative process) show the process flow diagrams for condensate stabilization units simulated using Aspen HYSYS (v 8.8) software.

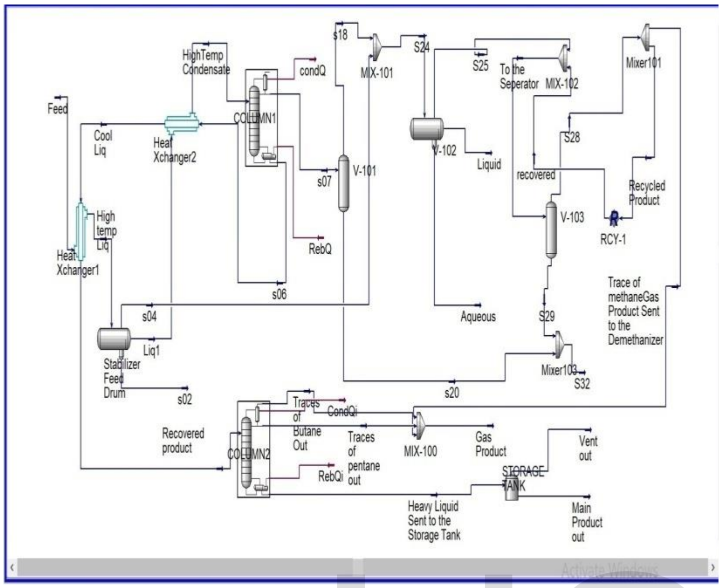

Figure1: Process Simulated condensate stabilization of Gas refinery

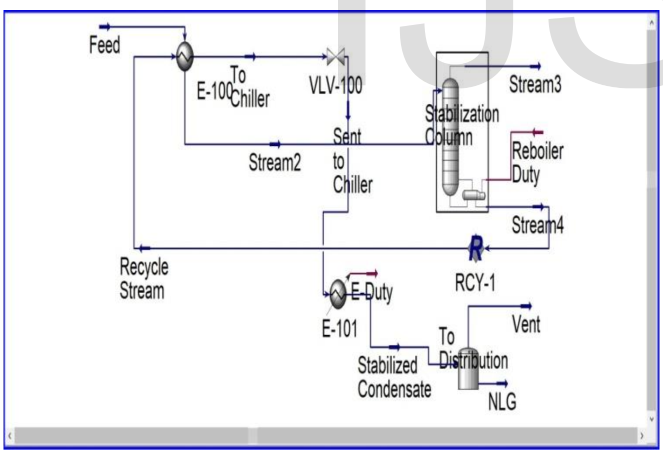

Figure2: Process simulated Condensate stabilization non-reflux stabilizer

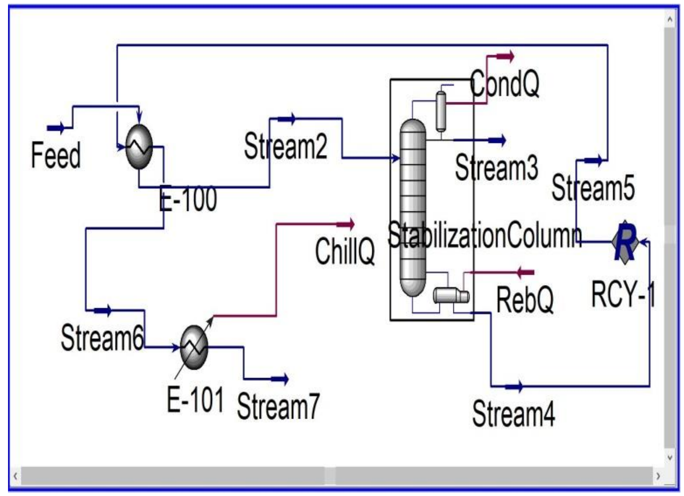

Figure3: Process simulated Condensate stabilization of Refluxed stabilizer.

The following are procedures of the process simulation for first alternative process:

- From the property table in Aspen HYSYS simulation Case,

The composition of the gas condensate in table 1 was selected together with the property package of PENG ROBINSON.

- At the simulation environment
  - i) The material stream was added. Feed conditions from Table 2 were used to configure the material stream of the yet to be stabilized condensate. Temperature of 23.33°C
  - ii) and Pressure of 960kPa were plugged in to modify the feed conditions, which indicated that the feed is in mixed phase of vapor and liquid.
  - iii) It is directly sent into a 3-phase separator after an increase in temperature by the heat exchanger and the liquid phase of the feed was reheated up to 40°C through a boiler and another 3-phase separator was added to remove an incurred vapor that could arise due to the heating.
  - iv) It is therefore cooled using a heat exchanger before the liquid is sent into a Distillation Column for proper stabilization.

However, the column's input window was opened, which consists of five pages and the following operations were performed:

a. At the first page: Selection of the appropriate condenser-type (Total condenser) to be used. Selection of the feed entry point by clicking the "inlet stage", Selection of the number of tower stages and specifying of the column pressure from the condenser to the reboiler.
b. At the second page: The "once through regular reboiler" was selected.
c. At the third page: The pressure for condenser and reboiler is inputted.
d. At the fourth page: Temperature values were added.
e. At the final page: The desired top stream flow-rate and condenser's reflux ratio is added.

After which a qualitative analysis was done on the properties and composition of the bottom product to ensure a proper stabilization of the feed.

Note: Similar work was done to simulate the second and third alternatives of the process condensation stabilization.

The feed composition and feed stream conditions assumed the following data, which was obtained from khangiran gas processing plant stabilization unit (Navid et al 2012).

Table 1: Feed Composition of the feed.

	Mole Fractions
H2O	0.0000
Nitrogen	0.0002
CO2	0.0747
H2S	0.1120
COS	0.0000
Methane	0.1143
Ethane	0.0097
Propane	0.0059
i-Butane	0.0091
n-Butane	0.0127
i-Pentane	0.0112
n-Pentane	0.0112
n-Hexane	0.0183
n-Heptane	0.1041
n-Octane	0.0690
n-Nonane	0.0690
n-Decane	0.3786

Table 2: Feed Stream Conditions

Molarflow rate(m3/hr)	**1853**
Temperature(°C)	**23.33**
Pressure(kPa)	**960**
Reid vapor Pressure(kPa)	**1041**

RESULTS AND DISCUSSION OF THE SIMULATION

The analysis of the output data from the bench mark industry revealed that the process simulation program of HYSYS is well suited to modeling the behavior of the refining columns much more than other commercial simulators.

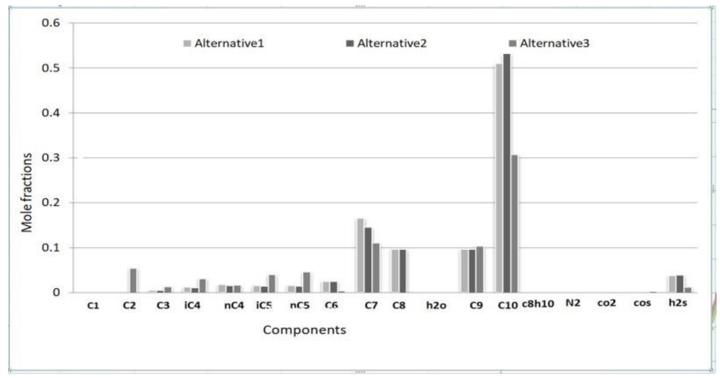

Figure4: Analysis of the three alternative processes of the condensate stabilization

At the end of the first simulation analysis, it can be concluded that the second alternative process flow diagram for condensate stabilization gave a better product with less unit operations than the first and third alternatives for the Process condensate stabilization.

There, the reboiled distillation column was used in the stabilization and the reid vapor pressure was reduced to 89kPa. Therefore, it can be said that the second alternative for process condensate stabilization results in the lightest condensate product because of the column used, which differs from the first and third alternative.

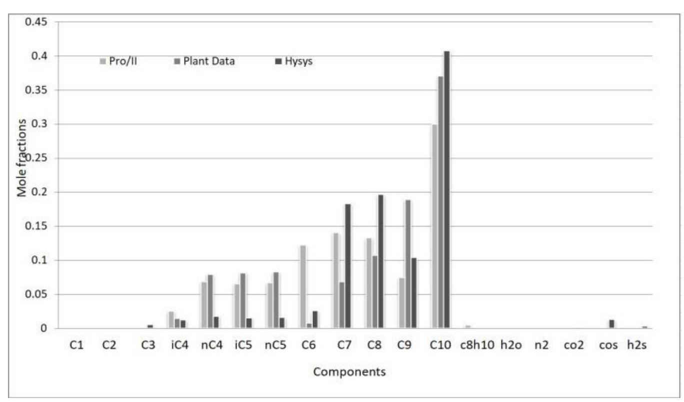

Figure5: Analysis of the results of the condensate stabilization from pro/II, Refinery plant Data and Hysys

A different analysis of comparing the product compositions gotten from the Simulation cases done with Pro/II, Hysys and the data obtained from an existing plant, which started from the gaseous Hydrocarbon (LNG) of C1-C5, their mole fractions were previously high at the feed composition (table 1) but the gases were separated completely as shown in figure 5; with no trace of methane nor propane. The remaining gas mixtures where drastically minimized because of their low boiling points.

From the above analysis, it can be concluded that the Pro/II simulation condensate contains the lightest components followed by the real plant data, and then HYSYS simulation results in the condensate with the heaviest components. Therefore, it can be said that the Pro/II simulation results in the lightest condensate product, the HYSYS simulation result in the condensate product and the real plant results in a rather balanced condensate as compared to the other two.

However, the trend of the mole fraction of the components is similar for all three sets of data. There are no major differences and thus, it is proven that the simulation done using the HYSYS software is valid and can be run in real life plants.

Reid Vapor Pressure

The initial Reid vapor pressure of the condensate was valued at 1041kPa. The condensate undergoes a lot of process to ensure that the product stream's vapor pressure is drastically reduced, which is one of the factors that determine the stability of the condensate. From table 4, we have a new Reid vapor pressure of the three alternative processes.

Table 3: Reid Vapor Pressure of the three alternative CSU processes

RVP result of First alternative CSU Process(kPa)	80
RVP result of Second alternative CSU Process(kPa)	89.16
RVP result of Third alternative CSU Process(kPa)	88

Effects of Reboiler's pressure on the Reid vapor pressure of the product.

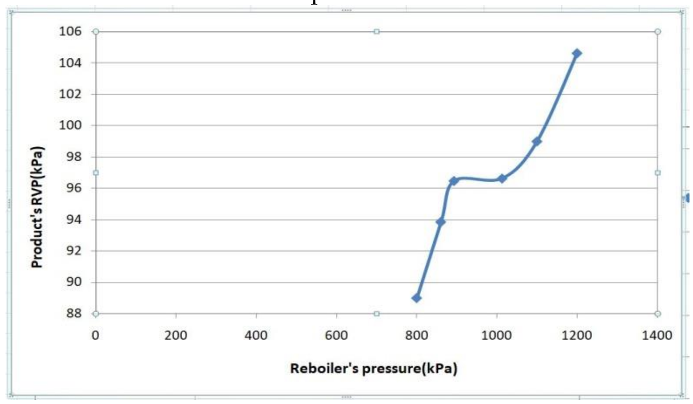

Figure6: Effect of Column's Pressure on Reid Vapor Pressure

The column's operating pressure at 800kPa up to 1200kPa where analysed to find the RVP. Investigating the effects of the RVP, it is directly proportional to reboiler's temperature. Rate of pressure applied has great influence in vaporization of the lighter components like butane which is the major component that determines the reid vapor pressure rate. The increase in pressure decreases the top product (light products) splits by 20% which increases the RVP of the stabilized product .The optimum column's pressure is at 800kPa which is the selected column's pressure.

The operators can operate the distillation column at high pressure provided it's does not affect the rate of flow which can cause shortages. Else it is advised to maintain the best pressure all through the column stages for easier separation (Roger,2012).

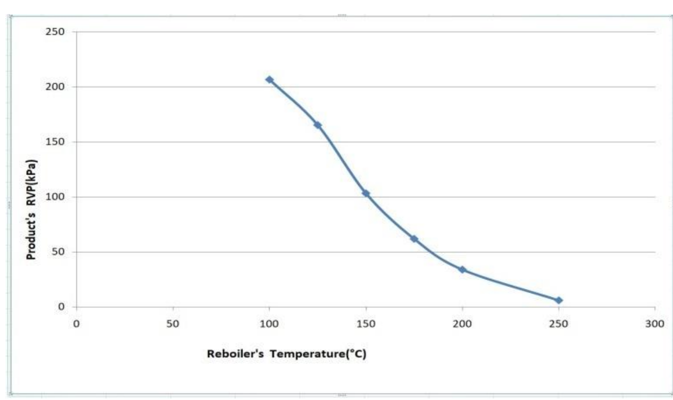

Figure7: Effect of Reboiler's Temperature on the product's Reid vapor pressure

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Figure 7 shows the reboiler's temperature and how its effects to product's reid vapor pressure are studied. It is changed from 100°C to 250°C ensure proper changes in the product's RVP at 25 and 50°C interval. The RVP decreases as reboiler's temperature increases. This decrease in the RVP is because as the temperature increases, more light components will flash off from the condensate thus leaving less amount of volatile component in the product.

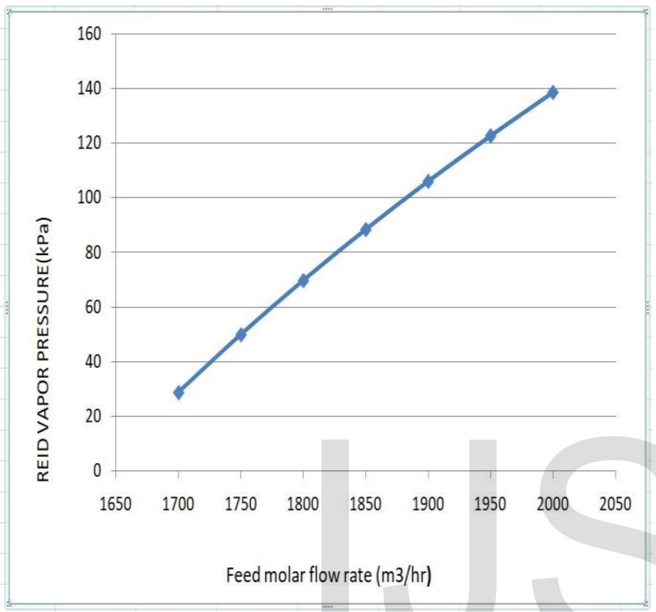

Figure8: Effect of feed flow rate on the product's reid vapor pressure

The normal feed flow rate used for the base case study is 1850 m3/hr which is the optimum feed flow rate. Figure 8 shows how the change in feed flow rate affects the RVP of the condensate. From the graph, it can be seen that as the flow rate increases, the RVP also increases. This increase in RVP is because when the flow rate increases, more heat is required to flash off the light components in the condensate. Since the column reboiler duty is kept constant, there is insufficient heat to maintain a constant RVP. Therefore, the RVP would gradually increase with the increase of feed flow rate.

EFFECT OF THE TRAY TYPE ON COLUMN'S EFFICIENCY

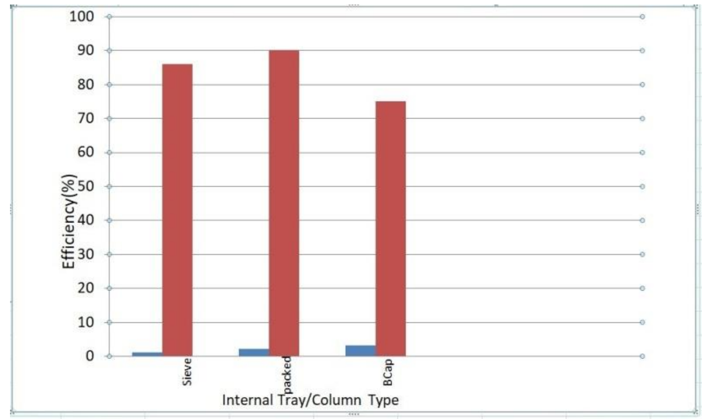

Figure9: Effect of Tray type on the Efficiency of operation.

The efficiency of the packed tower is 90% sieve 85% and BBcap is 76%. The reason could be as a result of more heat transfer co-efficient, less foaming formation and no weeping attributes.

Foaming can be mitigated by using a larger size packing that is further away from flood. This is formally done when designing the internal column of the distillation with a random packing. It will ensure a properly operating column with very high efficient operation. (Ross et al; 1975)

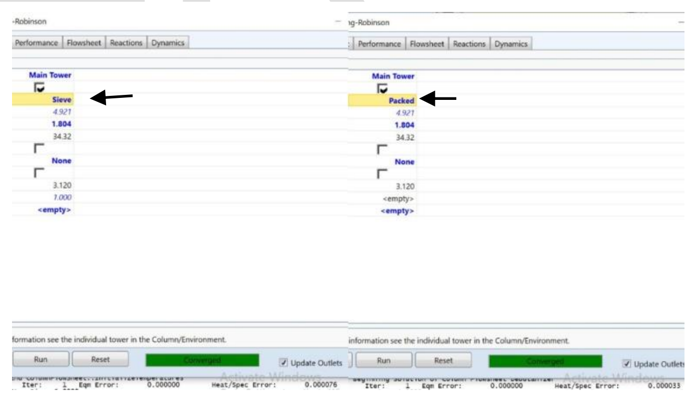

Figure10: Internal Configuration of the Sieve Tray type and packed type

Most mixtures have the tray type that is best soothed for them. They tend to give a product free from impurities. Foaming is one of the factors that affect distillation, and changing of plate type can help in reducing foam. The packed plate type tends to help in reducing the amount of foam formed and that's why it is highly recommended. Heat correlation error tends to decrease as the packed column was selected from 7.6e-4 to 3.3e-4. This shows that there's an increase in the column's effective performance as displayed by the arrows in figure 8

Conclusion

In conclusion, a maximum value of the Reid vapor pressure of 80, 89, 88kPa which shows a reduction in RVP compared to its previous value of 1041kPa was achieved. This is equivalent to about 90-95% which consequently shows that the condensate is stabilized.

The Data composition of the result for the stabilized product was compared with simulation result of the Pro/II software. The comparison of the result shows that the model was valid and can be used as a prediction tool for the plant under operation. At the first phase of C1-C5, the mole fraction of methane was the same for all three scenarios. Mole fraction of propane has a difference of not up to 10% compared to that of the plant data and Pro/II.

The efficiency of the columns were rated at 90% which show that the specification used for the process simulation is standard and can run perfectly in a production plant.

The performance of the distillation column was best gotten when the internal tray type was changed from Sieve tray to packed, reducing the column environment heat correlation error value from 7.6e-4 to 3.3e-4. Consequently this shows that, the best tray type which mitigates some factors affecting distillation column by choosing the packed tray type over the sieve tray type for this kind of feed.

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