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SIMULATION OF THE SEPARATION OF LIQUID FROM A NATURAL GAS STREAM IN AJE GAS FIELD USING THREE-PHASE HORIZONTAL SEPARATOR

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Abstract: Three-phase separators are very useful for the separation of hydrocarbons and water. Their applications have added value to the oil and gas industry as well as minimize the negative impacts of oil and gas operations on the environment. The major challenge faced by Aje gas and condensate field is the issue of production of natural gas that contains water vapor of which if not removed can form hydrates, which may block pipeline, choke and valve. These Water can also cause corrosion in pipeline as well as cause damage to high speed compressor blades. The aim of this thesis is to develop a model and simulate the liquid separation from gas stream in HYSYS. Then, evaluate the amount of water collected from the gas stream after separation and then recommend a way of removing such water that exist in solution in natural gas. The model was designed and simulated using ASPEN HYSYS V8.8 simulation package. The separator effectiveness was investigated by evaluating the amount of water collected from the gas stream after separation. From the simulation result taken from the product stream, the Vapour Stream produces little amount of both water vapour (of about 1% concentration) and dry gas with high concentration of methane and ethane (of about 33%)and entrained higher amount NGL with high concentration propane, butane and pentane (typically 66%),while the Light Liquid stream also produces higher amount of NGL with high concentration of propane, butane and pentane as well (typically 99%)with little amount of entrained dry gas of ethane concentration (of about 1%) and the Heavy Liquid stream produces only water (typically 100% of the entire concentration).Therefore, these result shows that the horizontal separator is effective in separating the streams into their respective three phases. However, the little amount of water vapour (typically 1%) that is associated with the natural gas in the vapour stream can be negligible as hydrate inhibitor based on chemical inhibitor such as homopolymers or copolymers of cyclic amide (lactam) is injected into the pipeline alongside with the natural gas containing the 1% water vapour to delay the nucleation and crystal growth of hydrates during transportation. This approach can lead to substantial cost savings because of the small amount of the inhibitor is required for injection into a pipeline containing 1% of the weight of water in natural gas stream than spending a lot of income to dehydrate such amount of water vapour in processing plant.

Key words: Simulation, Water, Natural Gas, Three phase separator, Aje field

LIST OF ABBREVIATION

1. NGL Natural Gas Liquid
2. API American Petroleum Institute
3. CBM Coal Bed Methane
4. MW Molecular Weight
5. GPSA Gas Processor Suppliers Association
6. KHI Kinetic Hydrate Inhibitor
7. HP High Pressure
8. LP Low Pressure
9. LPG Liquified Petroleum Gas
10. CCPS Center for Chemical Process Safety
11. CFD Computational Fluid Dynamics
12. GLS Gas-Liquid Separator
13. DEG Di-ethylene Glycol
14. NRU Nitrogen Rejection Unit
15. PSA Pressure Swing Adsorption

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16.	RVP	Reid Vapour Pressure
17.	SBM	Simulation Basis Manager

INTRODUCTION

Three-phase horizontal separator is widely used in gas field to separate liquid (which is oil and water) from gas stream, because liquid such as water and hydrocarbons can form hydrates, which may block pipeline, choke and valve. Water can also cause corrosion in pipeline as well as cause damage to high speed compressor blades (Svrcek, 2008).

The study field, Aje gas and condensate field lies in Oil Mining Lease 113 (OML 113) in the Benin Basin, approximately 24km offshore of western Nigeria (Folawiyo, 2017). The water depth in the region is 3,000ft (Folawiyo, 2017). The study field was discovered as the Aje-1 well in 1996. The study field is primarily a gas condensate field formed in a four-way dip closure trap. It contains gas and oil in the Turonian and Cenomanian reservoirs and an additional gas layer of the Albian formation. Gross contingent resources of the Aje gas and condensate field is estimated at 380 million BoE. This contains 28% of oil / condensate, 20% of Liquefied Petroleum Gas (LPG) and 52% is natural gas (Svrcek W.Y., 2012).

Furthermore, the field was developed as a subsea tie-back to a floating, production, storage and offloading (FPSO) vessel. The Aje-1, Aje-2 and Aje-4 wells were developed as producers (Folawiyo, 2017). The production wells are connected to subsea wellheads and associated flowlines and manifolds in water depths of 320ft. The flowlines are connected to the FPSO through risers. Produced hydrocarbons from the well are processed by the FPSO and exported through the West African Gas pipeline or through a direct pipeline to connect to the Lagos gas infrastructure (Folawiyo, 2017).

However, the major challenge faced by Aje gas and condensate field is the issue of production of natural gas that contains water vapor. As such, when the gas travels up the well bore to the surface, it cools due to pressure reduction and heat conduction to cooler formations. So, the natural gas is nearly always saturated with the water vapor when it reaches the surface. This implies that the ability of gas to hold water vapor decreases as the gas temperature decreases. In addition, free water in a natural gas stream can result in line plugging due to solid hydrate formation. This can also increase the risk of pipeline damage because of the corrosive effects of water. Moreover, water droplet can also cause damage to high speed compressor blade.

There is therefore, a need to investigate the effects of the three-phase horizontal separator on the separator efficiency. The study thus presents the results of a gas-liquid separation simulation that provides insight into the treatment of natural gas that contains water vapour.

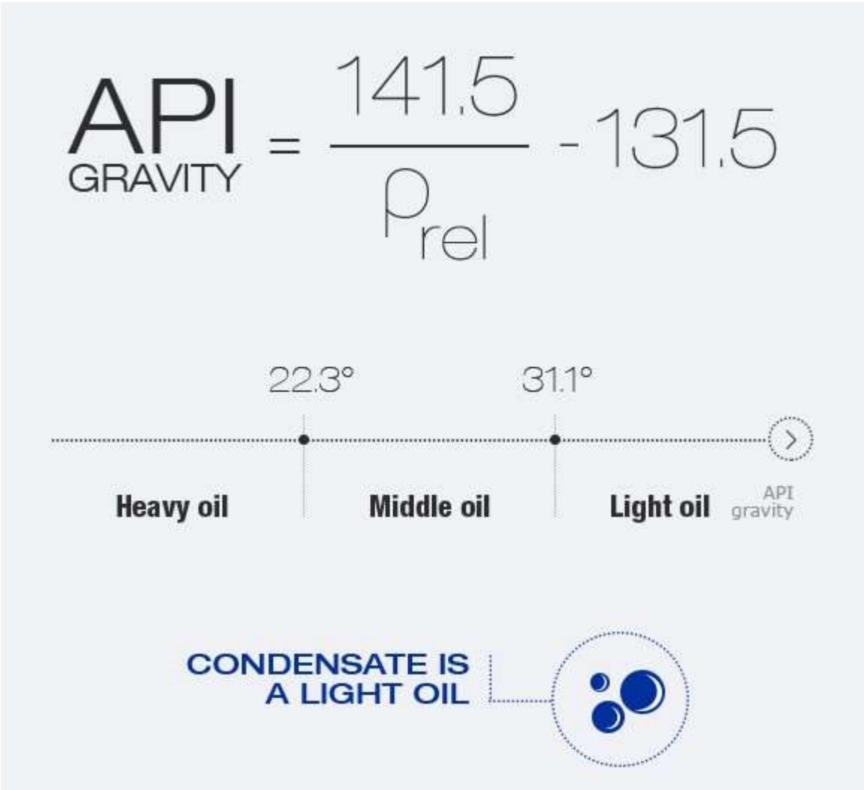

Figure 2-2: Classification of oil based on their API gravity (Wintershall, 2017).

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Condensate is obtained from gas condensate reservoirs and is separated from natural gas using various processes. The treatment process is explained here using Wintershall's Achimov condensate as an example. The reservoir containing a mixture of natural gas and condensate lies at a depth of 3,000 - 4,000m. This mixture - the gas condensate - is under high pressure and therefore flows upwards unaidedly. Pumping is not necessary. The gas condensate collected is transported to a processing facility. Here, the temperature of the gas condensate is reduced until it separates into condensate, water and gas. The collected gas condensate is then transported via pipelines to refineries for further processing (Wintershall, 2017).

MATERIALS

Aspen Hysys Simulation program

The Aspen Hysys simulator is a powerful engineering simulation tool used to model and predict the performance of the process.

Fluid Compositional data

The table shows the feed gas component and its compositions in mole fractions (%) of Aje Gas and Condensate field. This data will be inputted into the Aspen Hysys Simulator model.

COMPONENT	COMPOSITION (MOL%)
Methane	0.1000
Ethane	0.0300
Propane	0.0400
i-Butane	0.0800
n-Butane	0.1000
i-Pentane	0.1200
n-Pentane	0.1300
H_2O	0.400
TOTAL	100.00

Table: 1: Fluid Compositional Data

Fluid Properties data

The fluid properties data in table 3-2 shows the feed gas conditions. These properties will be inputted into the HYSYS Simulator model

FEED CONDITION	
Temperature [°C]	20.00
Pressure [kpa]	200.0
Flow rate [kgmole/h]	100.0

Table: 2: Fluid Properties Data

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METHODS

PROCESS DESCRIPTION FLOW CHART

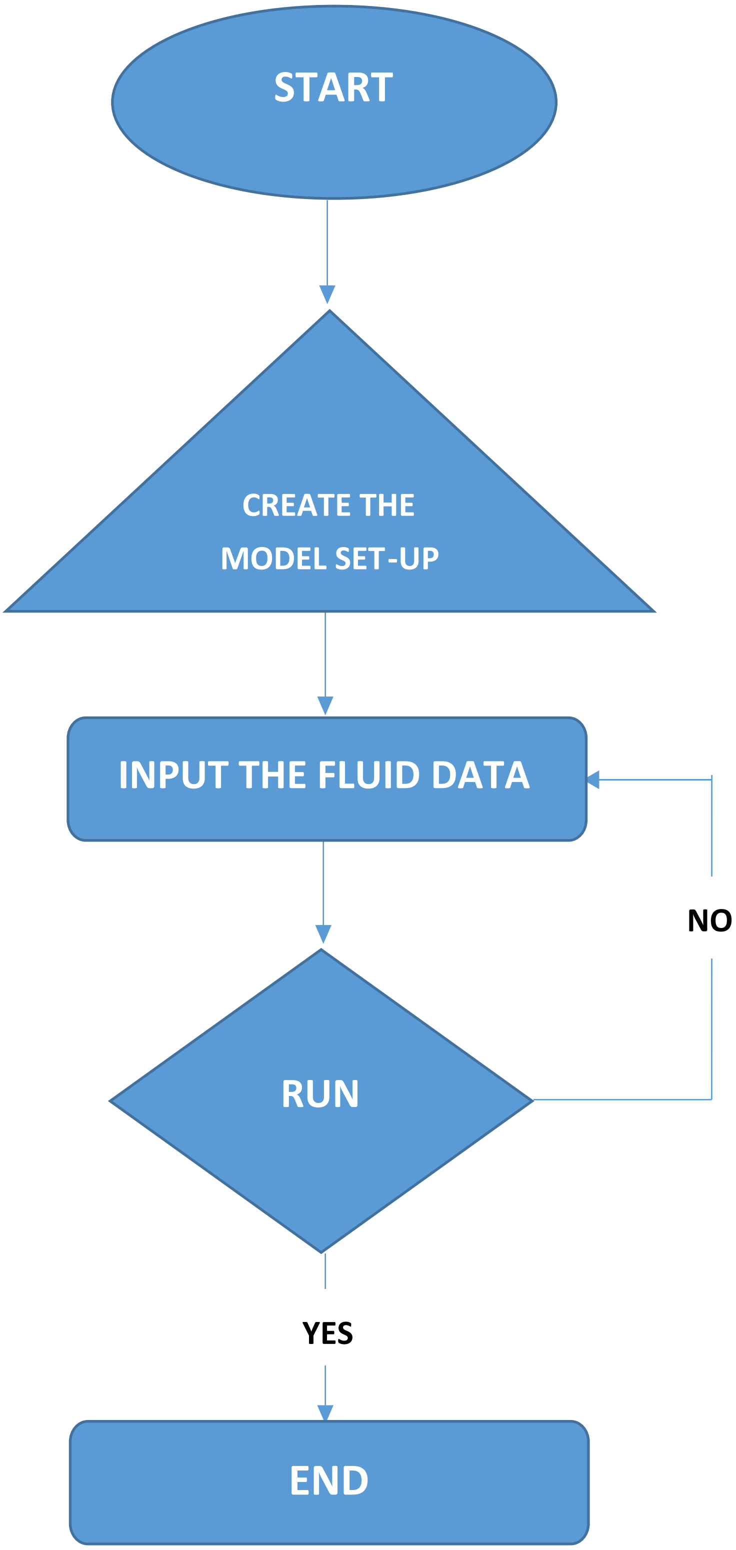

Figure 1: HYSYS simulation process description flow chart.

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MODEL SET-UP AND PROCESS DESCRIPTION

The fluid data for the inlet stream as shown in table 1 and 2 were inputted into the simulator model.
The fluid compositional data (from Aje gas and condensate field) shows the different composition of the mixed stream of gas, light oil and water. The components of the mixed stream were selected from the 'Component List View' of Peng Robinson specifications on the HYSYS simulator model as shown in figure 1

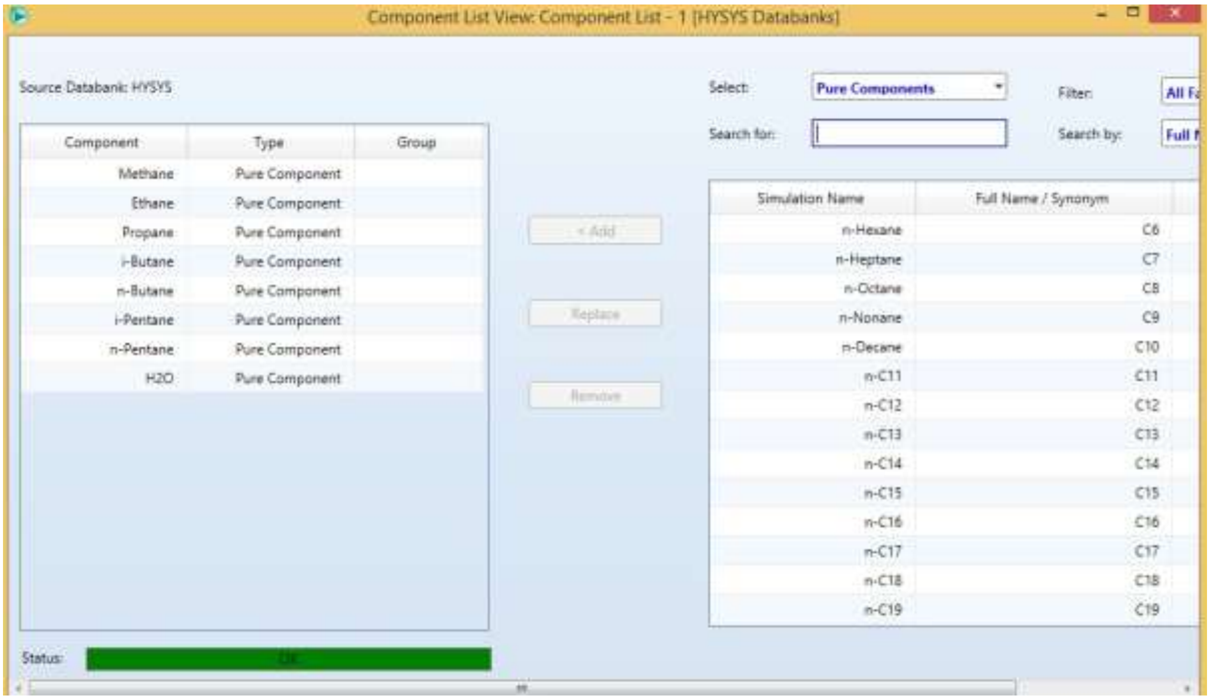

Figure 2: Component list

This mixed stream is allowed to enter into the three-phase separator through the inlet stream 1 as shown in figure 3 of the general flowsheet in the simulator model.

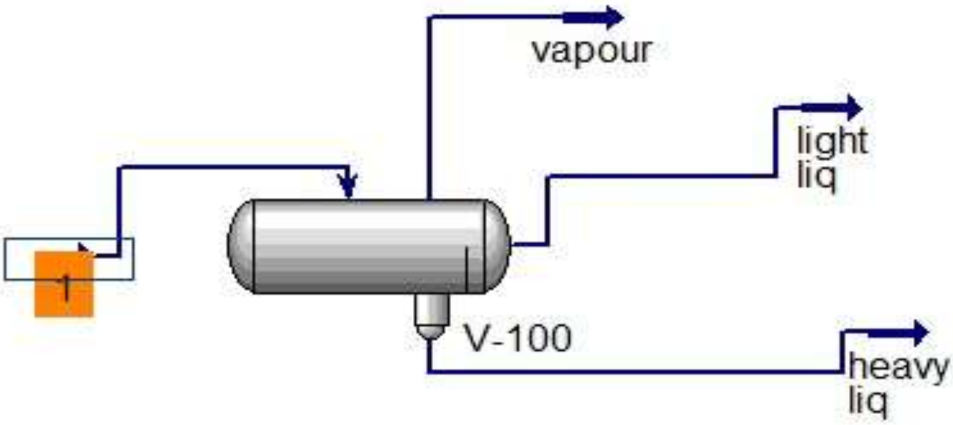

Figure 3: General Flowsheet

The feed conditions of the inlet stream in table 2 were inputted on the 'Material Stream' specifications as shown in Figure 2: on the simulation model.

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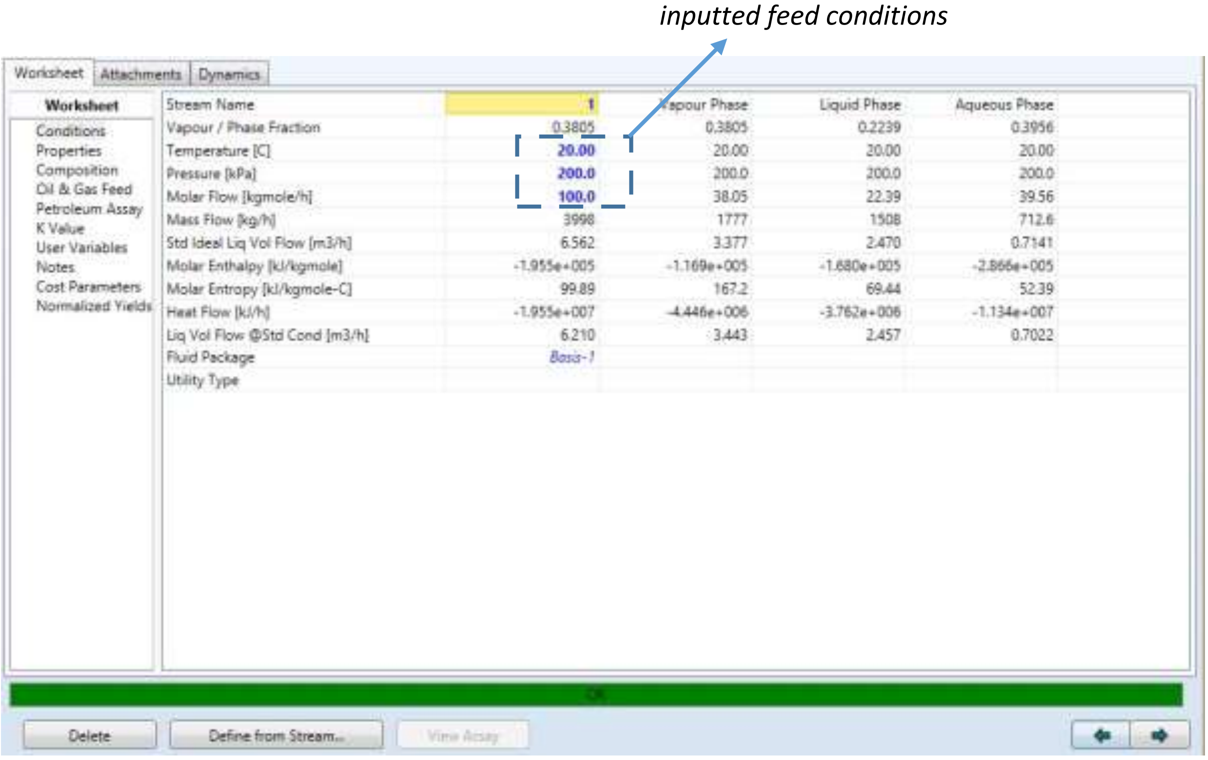

Figure 4: Material Stream Inlet specification of the dispersions droplets.

The rest of the conditions for the inlet stream such as Vapour/Phase Fraction, Molar Flow, Mass Flow, Std Ideal Liq Vol Flow etc. is automatically generated by the HYSYS Simulator.

The horizontal separator is adopted as the basis for the design. On the 'Design Connections' specifications the name of the different streams was specified into Vapour, Light liq and Heavy liq as shown in figure 5.

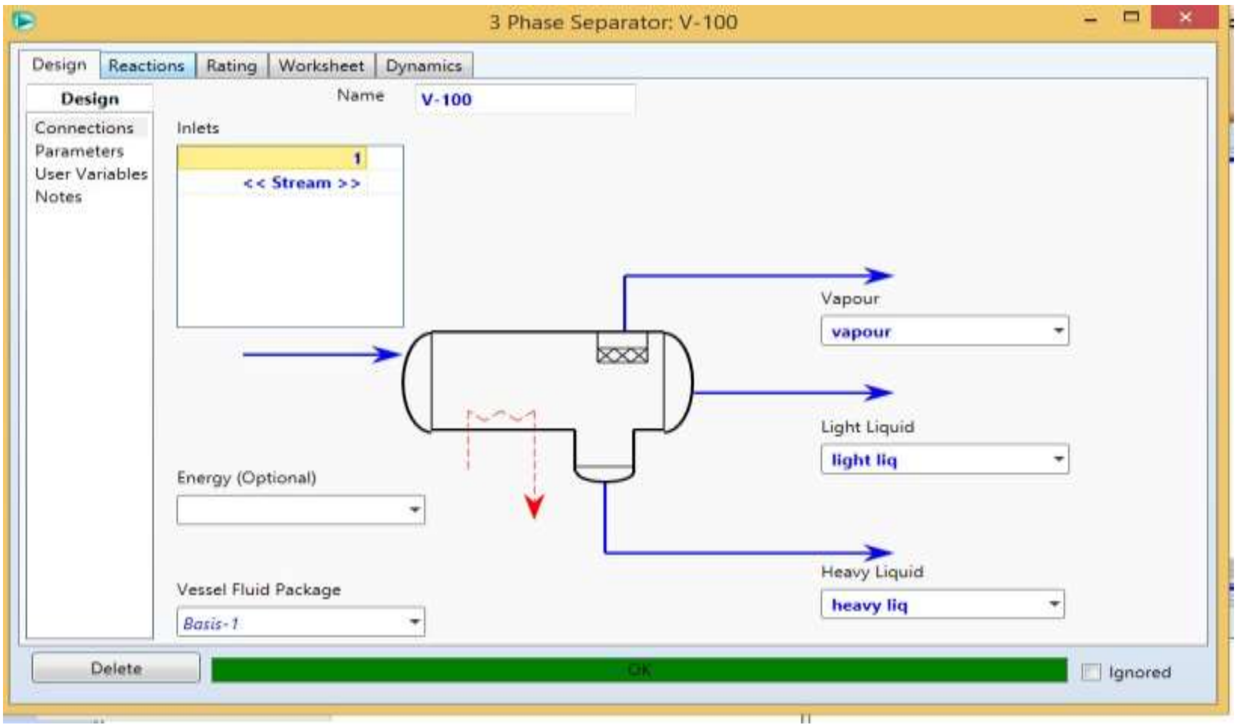

Figure 5: The Separator Stream Specifications

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On the 'Design Parameters' specifications10 KPa for the separator pressure is inputted and also the volume of the stream streams were also specifiedinto 34m^3 for the Vapour stream and 17 m^3 for the Liquid streams as shown in figure 4.

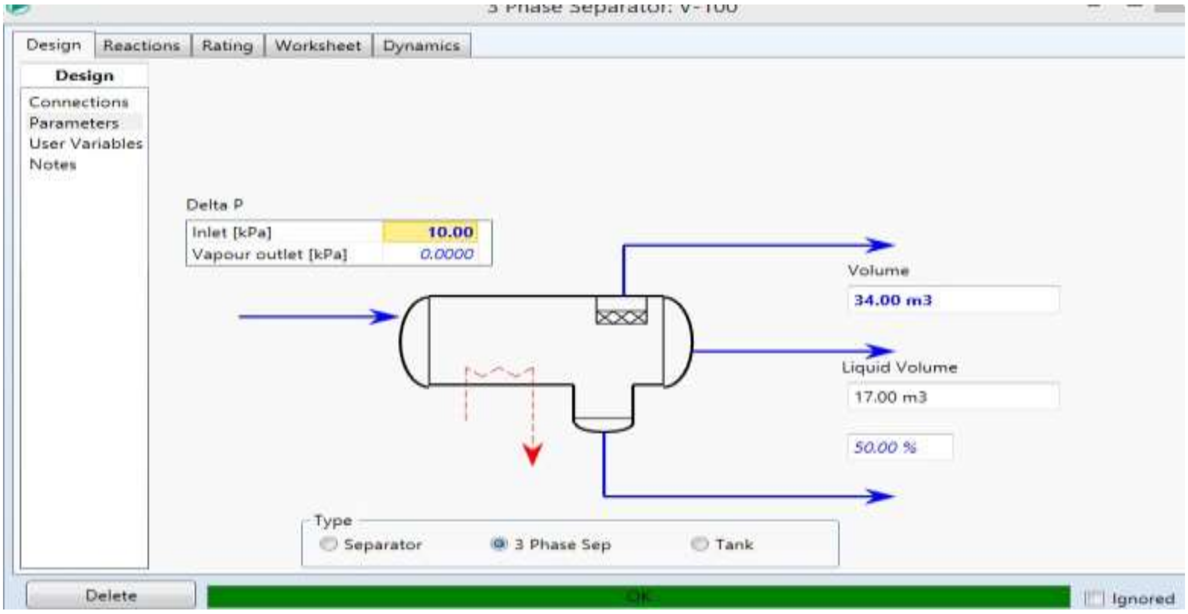

Figure 6: Design Parameter of the Horizontal Three-Phase separator

On the 'Rating' specifications for the model the size for the separator were indicated as shown in figure 3: 'Flat Cylinder' is selected in terms of the Geometry of the separator and the horizontal separator volume size of 34 m^3 is inputted.

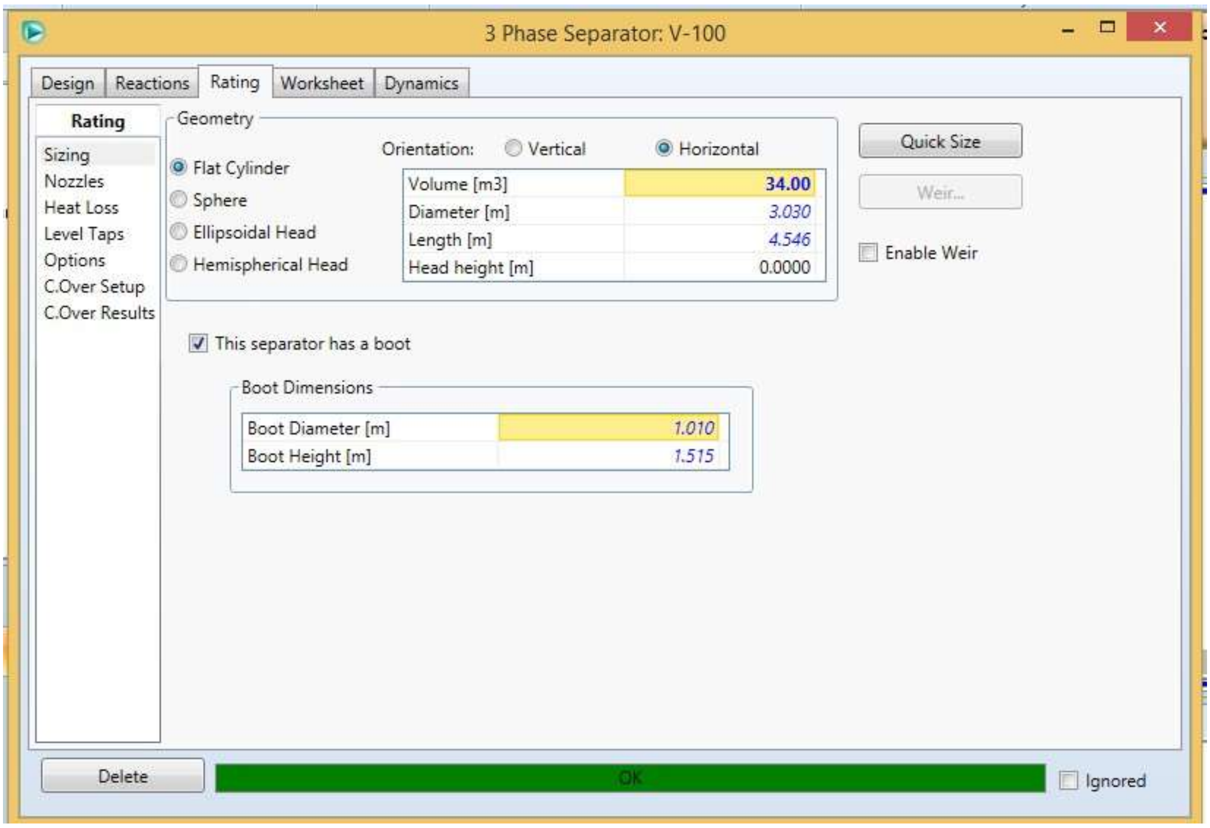

Figure 7: Basic Dimensions of the Horizontal Three-Phase Subsea Separators.

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The rest of the values for the 'sizing specifications' such as the Diameter, Length, Head height and Boot dimensions of the horizontal separator is automatic generated by the simulator.

RESULTS AND DISCUSSIONS

Result shown in the figure 8, out of 100% by mole fraction of each component at the streams the dominant component released from the vapour stream is a lighter gas with mole fraction approximately 26% methane by composition. Together with little amount of heavier gas by mole fraction approximate 8% ethane, 9% propane, 15% i-butane, 17% n-butane, 13% i-pentane and 12% n-pentane. And very little amount of water vapour of 1% by mole fraction.

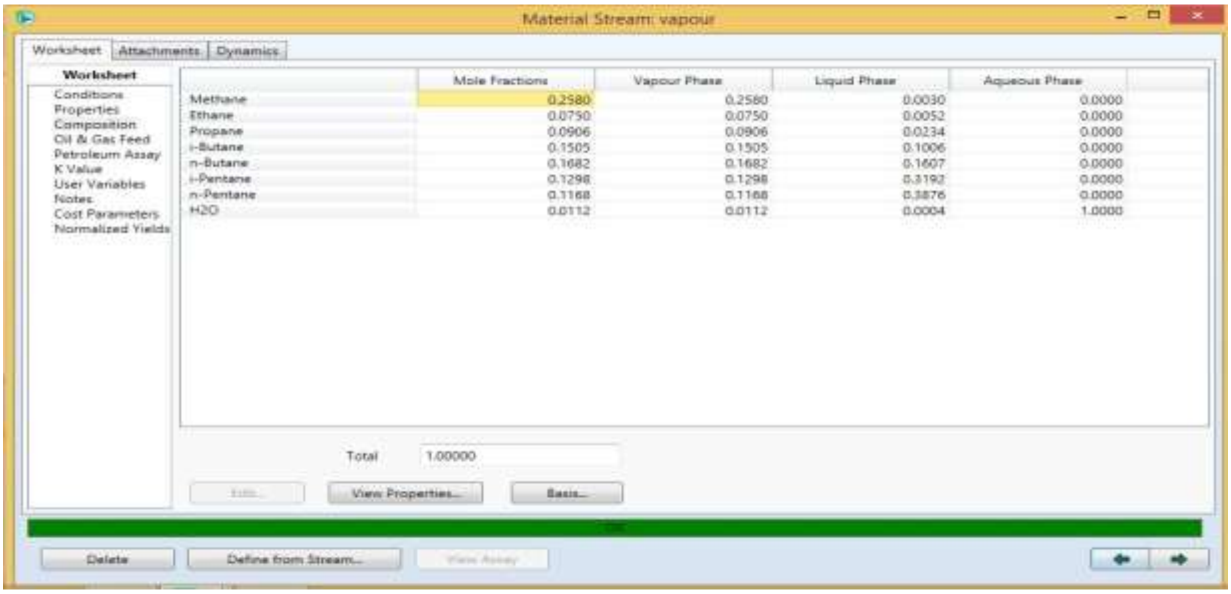

Figure 8: Result from the vapour Stream

The figure 8 shows the result from the vapour Stream after simulating the model.

Light Liquid Stream

From the simulation result shown in figure 8, out of the 100% composition by mole fraction of each component at the stream streams the dominant component observed at the light liquid stream is the lighter liquid with mole fraction approximately 1% ethane, 2% propane, 10% i-butane, 16% n-butane, 32% i-pentane and 39% n-butane. Also 0% of methane gas was observed at the light liquid stream which indicate that there is probably no methane gas released. And the heavier liquid by mole fraction is approximately 0% water as well which also indicate that there are probably no water molecules released from the stream.

Heavy Liquid Stream

From the simulation result shown in figure 8, out of 100% by mole fraction of each component at the stream streams the dominant component released from the heavy liquid stream is approximately 100% water by composition. This means that only water is released from this stream with probably no lighter gas and liquid condensate present in this stream.

DISCUSSION

Vapour Stream

The vapour stream produces little amount dry or lean natural gas with high concentration of methane and ethane (typically 33% percent) together with higher amount of NGL with high concentration of propane, butane and pentane (typically 66% percent). And very little amount of water vapour of about 1%.

In the separator column, the Lighter wet gas migrates to the top where it comes in contact with a coalescer made of a braided wire mesh mat which then extracts small amounts of liquid droplets from the wet gas by collision on the surface where they coalesce to liquid and then drops to the bottom of the vessel while the dry or lean natural gas is allowed to escape via vapour stream. And the higher amount of droplet (such as NGL and water vapour) that also escaped alongside with that dry gas in vapour stream is because the droplets are too small to be trapped by this separation device.

Light Liquid Stream

The light liquid stream produces very little amount dry or lean natural gas of ethane concentration (of about 1 percent) together with higher amount of NGL with high concentration of propane, butane and pentane (typically 99 percent).

As the pressure of the inlet streams reduces from 200kpa to 10 kpa in the separator column this as well causes the temperature of the streams to also reduce from 20ºC to 19.83ºC as a result the natural gas condenses into NGL with smaller amount of entrained dry gas which moves at a relatively low velocity and with little turbulence that enable both droplet to escape via the light liquid stream.

Heavy Liquid Stream

The Heavy liquid stream produces entirely water.

The coalesced water droplet extracted from natural gas stream in the separator column drops to the bottom of the vessel by force of gravity where it is being trained off via the heavy liquid stream.

CONCLUSION

The Vapour Stream produces little amount of both water vapour and dry gas and entrained higher amount NGL. While the Light Liquid stream also produces higher amount of NGL with little amount of entrained dry gas. And the Heavy Liquid stream produces entirely water. Therefore, these result shows that the horizontal separator is effective in separating the streams into their respective three phases.

The little amount of water vapour (typically 1%) that is associated with the natural gas in the vapour stream can be negligible as hydrate inhibitor based on chemical inhibitor such as homopolymers or copolymers of cyclic amide (lactam) can be injected into the pipeline alongside with the natural gas containing the 1% water vapour to delay the nucleation and crystal growth of hydrates during transportation. This approach can lead to substantial cost savings because of the small amount of the inhibitor is required for injection into a pipeline containing 1% of the weight of water in natural gas stream than spending a lot of income to dehydrate such amount of water vapour in the processing plant.

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