SIMULATION ANALYSIS AND DEVELOPMENT DESIGN OF NATURAL GAS PURIFICATION PLANT

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ABSTRACT

Natural gas (NG) is a naturally occurring gas mixture that is collected straight from a gas well. When natural gas is burned, it produces very little pollution and is widely buried over the world. Because of these characteristics, NG is gaining popularity as a low-carbon, environmentally friendly alternative fuel. It is our country's primary energy source for both home and industrial operations. Natural gas processing plants convert raw natural gas from gas reservoirs into saleable gas, which is a highly sought-after commodity on the market. To avoid pipeline corrosion, hydrate development in the gas, and quick industry consumption, sales gas specifications often required processed gas with a modest amount of water. The facility is equipped with gas dehydration system facilities to absorb water from raw gas, with tri-ethylene glycol (TEG) process units being used in the majority of the gas dehydration processes. Using a typical gas process plant in Nigeria as an example, this article proposes a generalized framework for natural gas process plant modeling and optimization. In this investigation, Aspen HYSYS was used to do a steady-state simulation of the process plant. The project's major goals are to complete a plant simulation model using Aspen HYSYS software and to optimize the gas dehydration system in a suitable way.

Keywords: *Natural gas plant, Simulation, Hysys, Process optimization, Separation.*

1. INTRODUCTION

The contribution of gas to the world's overall primary energy consumption has increased dramatically during the last 35 years [1]. Natural gas (NG) is mostly used as a fuel, but it can also be used as a source of hydrocarbons for petrochemical feedstocks [2]. Its clean burning and ability to meet stringent environmental requirements have raised the demand for natural gas [3]. Much of the world's gas reserves are in offshore fields [4]. Natural gas is gas extracted from subsurface natural reserves as either free gas or gas mixed with crude oil. It typically contains high levels of methane (CH_4) and lower levels of other hydrocarbons. The presence of impurities such as H_2S, N_2, and CO_2 in the gas is common. It's usually saturated with water vapor as well. Transmission lines, which deliver natural gas to various consuming areas such as industrial, commercial, and residential, are the primary market for natural gas. Field processing activities are so required to treat natural gas in order to meet the gas transmission companies' criteria and specifications. The fundamental goal is to simply acquire impurity-free natural gas as a primary product [6]. Chemical solvents, Physical solvents, Adsorption Processes, Hybrid solvents, and Physical separation are only a few of the treatment options for removing acid gases from natural gas [5]. Furthermore, the higher liquid product (NGL) recovery obtained by field processing units over that obtained by conventional separation is economically justified. Dehydration plants employ a variety of processes. One of the most common and widely used procedures is absorption (Glycol dehydration). A hygroscopic liquid is utilized to touch the wet gas and extract water vapor from it in this operation. The most commonly used solvent is triethylene glycol (TEG) [6]. In the oil and gas business, process simulation has become an indispensable tool for operators and engineering organizations.

When used to their maximum extent, simulators can help with process design, debottlenecking, and optimization. Aspen HYSYS is the industry's most popular process modeling and simulation software, with a track record of delivering significant cost savings throughout the process engineering lifecycle. It introduces a unique blend of modeling technology and convenience of use to the engineering desktop, bringing the potential of process simulation and optimization to the engineering desktop [7].

In order to lower a plant's operating expenses, optimization studies are used to determine the process's best design condition. Chemical, mineral processing, oil and gas, petroleum, pharmaceuticals, and allied industries all use optimization. It is unsurprising that it has piqued the interest and attention of numerous chemical engineers over the years. The field of process systems engineering (PSE), which is essential in chemical engineering and has a wide range of applications, characterizes the optimization of chemical and related processes by combining process modeling, optimization, and control. Using the process simulation tool HYSYS in steady state, the utilization of Triethylene glycol (TEG) was studied for a range of situations in this simulation experiment.

2. EFFECT OF IMPURITIES FOUND IN NATURAL GAS

The following are examples of natural gas field processing processes, which are classified as a part of gas engineering:

1. Removal of water vapor, dehydration

2. Removal of acidic gases (H_2S and CO_2)

3. Separation of heavy hydrocarbons

The effect each of these impurities has on the gas industry, as end user, is briefly outlined.

Table 1. Effect of natural gas impurities [6]

Water vapor	H_2S and CO_2	Liquid Hydrocarbons
It is a common impurity. It is not objectionable as such ➢ Liquid water accelerates corrosion. ➢ Solid hydrates, made up of water and hydrocarbons, plug valves, fittings in pipelines, and so forth	Both gases are harmful specially H_2S which is toxic if burned. It gives SO_2 and SO_3 which are nuisance to consumers ➢ Both gases are corrosive in the presence of water. ➢ CO_2 contributes a lower heating value to gas	Their presence is undesirable in the gas used as fuel ➢ The liquid form is objectionable to burners designed for gas fuel ➢ For pipelines it is a serious problem to handle two-phase flow; liquid and gas

3. TEG PROCESS

To achieve pipeline quality standards, most natural gas producers utilize Triethylene glycol (TEG) to remove water from the natural gas stream. This procedure is essential to avoid the production of hydrates at low temperatures or corrosion issues caused by carbon dioxide or hydrogen sulfide (regularly found in natural gas). Dehydration, or the elimination of water vapor, is achieved by lowering the inlet water dew point (the temperature at which vapor begins to condense into a liquid) to the outlet dew point temperature, which must contain a certain amount of water. The most typical way is to absorb water vapor in the TEG. In an absorber, the wet gas is brought into contact with dry glycol. The glycol absorbs water vapor, and as a result, its dew point drops. The entrained gas is separated and fractionated in a column and reboiler while the wet rich glycol flows from the absorber to the regeneration system. The water dry lean glycol is cooled (by heat exchange) and pumped back to the absorber after the absorbed water vapor is boiled off [8].

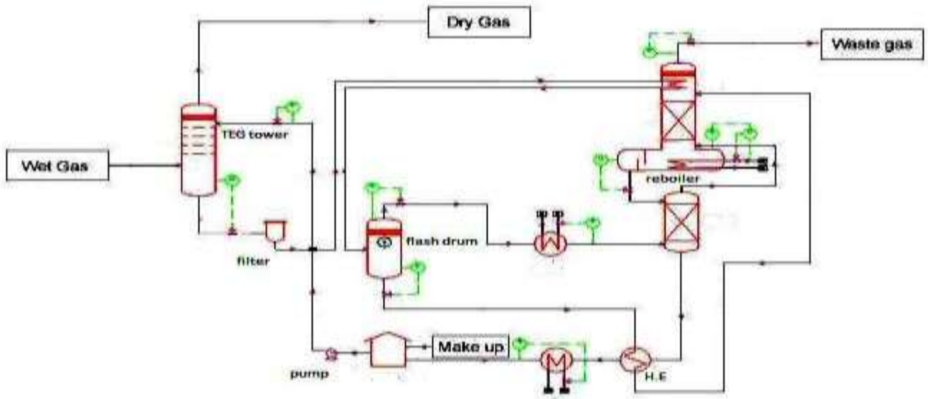

Fig. 1. Schematic diagram of a TEG dehydration type NG plant.

4. SIMULATION OF GAS PROCESSING PLANT

The simulation model is developed on Aspentech HYSYS 3.2.The type of fluid package selected is peng- robinson Package. TEG used as an aqueous absorbent to absorb water from gas streams. Before entering the contactor, the gas is passed through an inlet separator where entrained droplets of liquid are removed from the gas stream. Specification of feed gas is shown in figure 2.

Stream Name	well
Vapour / Phase Fraction	0.9949
Temperature [C]	86.67
Pressure [kPa]	2.925e+004
Molar Flow [kgmole/h]	1096
Mass Flow [kg/h]	1.873e+004
Std Ideal Liq Vol Flow [m3/h]	59.74
Molar Enthalpy [kJ/kgmole]	-7.925e+004
Molar Entropy [kJ/kgmole-C]	139.4
Heat Flow [kJ/h]	-8.683e+007
Liq Vol Flow @Std Cond [m3/h]	<empty>
Fluid Package	Basis-1

	Mole Fractions
Nitrogen	0.003674
CO2	0.004865
H2S	0.000000
Methane	0.947609
Ethane	0.025319
Propane	0.004269
i-Butane	0.001191
n-Butane	0.000596
i-Pentane	0.000298
n-Pentane	0.000199
n-Hexane	0.000796
n-Heptane	0.000497
n-Octane	0.000298
n-Nonane	0.000298
n-Decane	0.000895
TEGlycol	0.000000
H2O	0.009193

Fig. 2. Conditions and compositions of raw gas coming from well.

Natural gas, condensate, and water are extracted from a single well to simulate the processing plant. This field's gas composition is used. For the simulation, industrial data is acquired. The gas pressure is then decreased, and the gas is heated in a water bath heater H-101 to prevent hydrate formation. The heaters' output streams are then routed through the VLV-101 pressure reduction manifold to the intake two-phase separators (V-101) and finally to the TEG tower inlet scrubber. The separator's pressure is controlled by the pressure control valve (VLV-101) (V-101). The T-101 scrubber receives the vapor phase (stream 8) from the separator, which is then sent through the bottom of the dehydration unit (TEG contactor) to dehydrate the gas. TEGlycol enters the contactor from the top (stream 33). Glycol absorbs the water from the gas, and the water-free gas is then permitted to pass through the gas/glycol heat exchanger (E-202) to get heat from the hotter glycol. The gas is then sent to a fuel gas scrubber (V-104) for final gas-liquid separation before being sent to the sales line. The energy exchange pump (stream 17) receives the rich glycol from the T-101 contactor, and pressure drops dramatically. The pump is designated as a pressure reduction device with the designation VLV-100. The rich glycol is then sent through a reflux condenser (E-206), followed by a glycol flash separator (V-204), which separates the condensate from the gas. The rich glycol (stream 24) is preheated by passing via a Plate and Frame exchanger and then through a packed bed still column to the TEG reboiler. At nearly atmospheric pressure, the glycol heated up to roughly 400 degrees Fahrenheit. Water vaporizes from glycol and travels to V-206 via the cooling system from the top of the reboiler (stream 24). The lean glycol is pumped from the reboiler to E-201 (stream 28) for cooling, and then to the TEG contactor through E-202 and E-205, where it is chilled to the desired temperature. The liquid from the bottom of V-101, which consists of condensate plus water, is pumped to the three-phase separator V-102, where it is divided into three streams: water (stream API), condensate (stream 38), and gas (stream 39). (stream 36). The mixer of different streams of hydrocarbon liquid MIX-103 is the V-102's inlet. TEE-101 (stream 15), V-102 (stream 36), and V-204 are used to gather fuel gas (stream 21). The data is then gathered at MIX-105 and buffered at V-103 before being distributed further.

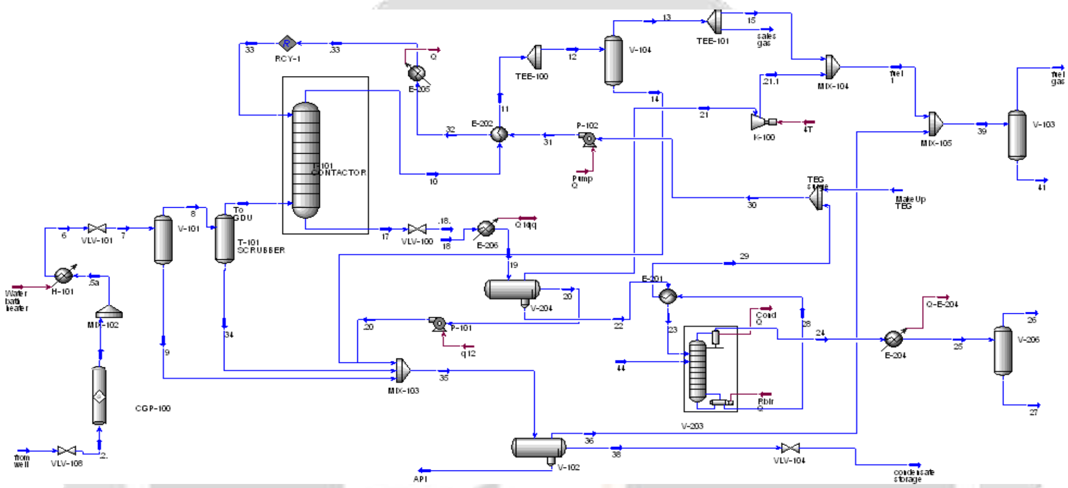

Fig. 3. Simulation model of natural gas processing plant.

5. RESULTS AND DISCUSSIONS

In a typical gas processing plant in Bangladesh, the effect of process parameters was investigated. Sweet natural gas was fed to a contactor with a capacity of 20 MMSCFD and a working pressure of 1010 Psig. Different inlet gas temperatures and reboiler operating conditions were used to test glycol circulation rates.

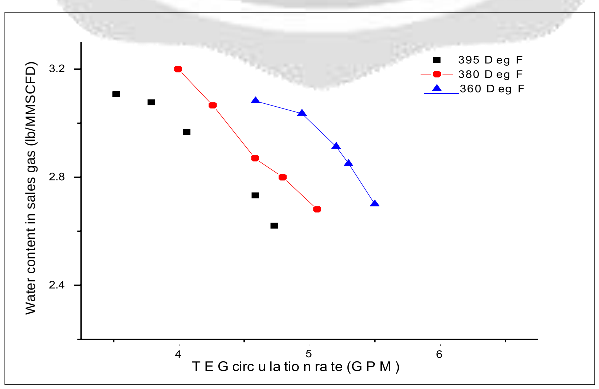

Fig. 4. Water content VS circulation rates and reboiler Temperature (Contactor Inlet Gas Temperature fixed at 90 ^{o}F)

The data clearly illustrates the TEG reboiler's optimal working temperature. The TEG reboiler is set to 395 degrees Fahrenheit, which results in lower dew points. The result also shows the optimal circulation rates under the operational conditions. It's safe to assume that, under the design conditions, the lowest dew point corresponds to a circulation rate of 4.5 to 5.5 GPM.

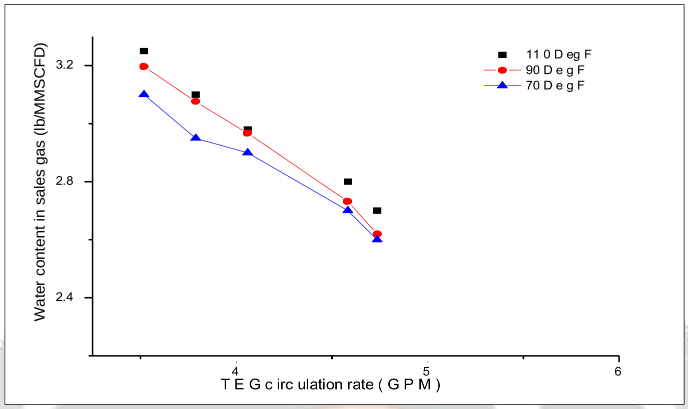

Fig. 5. Water content VS circulation rates for different inlet gas temperature. (Re-boiler Operating Temperature 395 ^{o}F)

Another graph was created depending on the contactor's incoming gas temperatures. The results clearly illustrate that a lower contactor inlet gas temperature necessitates less TEG circulation. However, it would be clearer if there was another graph depicting the experimental findings below 70 oF, however the results are limited to the value of 70 oF due to the raw gas temperature, composition, and hydrate formation. The water content in the wet gas from the high-pressure two-phase separator determines the flow direction and settling time (V-101). The graph below shows the findings for two different equilibrium circumstances. The high-pressure separation was initially designed to handle 20 MMSCFD of sweet natural gas at a pressure of 1010 psig. Later, a contactor (T-101) inlet scrubber was introduced to improve the inlet fluid's settling time (V-101 plus inlet scrubber time) and flow direction. The results show that the water content of the HP separator output gas stream dropped after the inlet scrubber was installed, as well as the water content of the sales gas (lb/MMSCF). Lower dew points have been seen in the same TEG circulation rates as the inlet water content lowers due to the equilibrium condition.

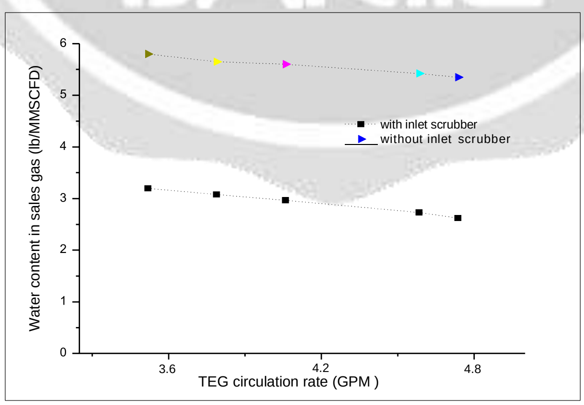

Fig. 6. Water content VS circulation rates in different settling time.

Stripping gas flow rate is actually a parameter in the stripping column of TEG regeneration system, which is a function with the reboiler efficiency.

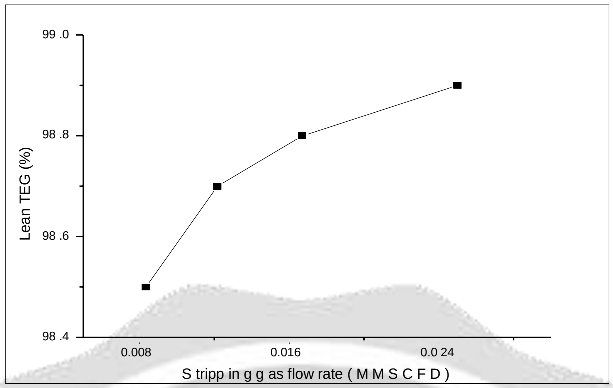

Fig. 7. Water Removal Efficiency VS Stripping Gas Flow Rate.

Different reboiler stripping rate conditions were investigated, and the water removal efficiency from the rich glycol was determined at various circulation rates. The purity of Lean glycol can be enhanced to a considerable extent by increasing the stripping gas flowrate in the TEG reboiler. Because the quality of the lean TEG delivered to the contactor determines countercurrent absorption, a higher water removal efficiency (> 99%) is one of the key areas of concern in optimizing this process.

	Mole Fractions
Nitrogen	0.003707
CO2	0.004900
H2S	0.000000
Methane	0.956841
Ethane	0.025543
Propane	0.004301
i-Butane	0.001199
n-Butane	0.000599
i-Pentane	0.000299
n-Pentane	0.000199
n-Hexane	0.000784
n-Heptane	0.000475
n-Octane	0.000266
n-Nonane	0.000234
n-Decane	0.000558
TEGlycol	0.000000
H2O	0.000097

Fig. 8. Composition of sales gas before fuel gas scrubber.

Some of the equipment in this processing facility can be removed without affecting the quality of the finished product. The process parameters must be kept in good shape. They've been fitted for further safety. Fuel Gas Scrubber (V-104) and Air/Glycol Exchanger were planned to be eliminated here (E-205). Even though there is no liquid phase in the conditions tab, Stream 11 at the exit of the TEG contactor to the sales gas line contains a very little amount of water. As a result, V-104, which was previously needed for additional gas/liquid separation, can be removed. Figure 8 shows the composition of stream 11.

Stream Name	32
Vapour / Phase Fraction	0.0000
Temperature [F]	120.0
Pressure [psig]	1045

Stream Name	33
Vapour / Phase Fraction	0.0000
Temperature [F]	115.0
Pressure [psig]	1040

Fig. 9. Inlet and outlet condition of air/glycol cooler.

The air/ glycol exchanger (E-205) reduces the temperature of TEG from 120 to 115 degrees Fahrenheit in order to keep the TEG contactor tower inlet temperature constant (Fig. 9). E-202 (gas/glycol heat exchanger) or E-201 (glycol/glycol PFE heat exchanger) can readily reduce this 5 oF temperature by a small amount of greater overdesign. Below are the process conditions for the E-205 intake (stream number 32) and E-205 output (stream nr 33).

6. CONCLUSION

The purification simulator HYSYS is used to create a simulation model of a natural gas purification plant in this paper. Different unit processes' properties and circumstances were optimized. Plant equipment optimization is also carried out in order to make it more cost effective. Process optimizes operating conditions to maximize total profit for the process by loss reduction, cost reduction, and change of existing plant equipment. The experimental results are based on specific operating settings, but they show the overall trend of the data, allowing any proactive action to be done in response to the experimental results. Experiments to evaluate the effect of one parameter were conducted while the other parameters were held constant based on the best operating circumstances.

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