Analyzing Tri-Ethylene Glycol (TEG) Gas Dehydration System Performance of a Gas Processing Plant (GPP) with HYSYS Modeling

by

Mohd Aiman bin Mohd Noor

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

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CERTIFICATE OF APPROVAL

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Approved by,

____

(Dr Nooryusmiza bin Yusoff)

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November 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(Mohd Aiman bin Mohd Noor)

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Table of Contents

ABBREVIATIONS

GPP	*Gas Processing Plant*
TEG	*Tri-Ethylene Glycol*
H_2S	*Hydrogen Sulfide*
CO_2	*Carbon Dioxide*
H_2O	*Water*
RTO	*Real-Time Optimization*
RVP	*Reid Vapor Pressure*
lb /MMSCF	*Pound per Million Standard Cubic Feet*
MMSCFD	*Million Standard Cubic Feet per Day*

LIST OF TABLE

LIST OF FIGURES

ABSTRACT

Gas processing plant (GPP) converts gas reservoir's raw natural gases to produce sales gas, which is high price commodity in the market. Sales gas specification from buyer typically required processed gas with small amount of water to avoid pipelines corrosion, avoid hydrates formation in the gas and for their immediate industry consumption. GPP is equips with gas dehydration system facilities to absorb water from raw gas and most of the gas dehydration processes are using tri-ethylene glycol (TEG) process unit.

It is often unknown to operator the actual concentration of TEG used due to lack of equipment to analyze it. The operator's priority is to simply meet sales gas specification in term of water content in dry gas without acknowledging the integration of essential variables such as water content in wet gas, TEG circulation rate, TEG concentration and performance of regeneration system.

The project aims in developing performance analysis tool of TEG gas dehydration system to assist plant operations in understanding the current system operations and performance. The project aims in achieving two main objectives, which are developing accurate plant simulation model using Aspen HYSYS software and developing reasonable analysis of gas dehydration system. Accurate plant simulation is important as it is supplies necessary estimation values which are unavailable in plant to carry out the analysis calculation. The analysis should be reasonable to ensure it suits the plant operations and useful to operator.

Objectives successfully achieved where, the simulation model is accurate and the analysis is able to deduce four analyses which are essential in TEG gas dehydration system. This project successfully discovered potential optimization to improve GPP plant performance.

CHAPTER 1
INTRODUCTION

Introduction section introduces several topics covered on the project itself. Introduction section explains on the background basis study of this project especially on gas processing plant, gas dehydration and optimization practice in industry. The problem statement highlights current practice in gas dehydration operations and lack of ways to analyze the system performance. Objective and the scope of study in this project is constructing accurate plant simulation and reasonable gas dehydration system analysis.

1.1. BACKGROUND OF STUDY

1.1.1. Gas Processing Plant

Gas processing plant (GPP) is a plant that treats and processes raw gas from gas reservoir. Main buyers and consumer of GPP processed gas is gas power plant. Due to gas power plant importance in nationwide electricity supply, it requires dependable and consistent gas deliveries from GPP. The gas supply from GPP is based on contract and sales specification where buyer demands certain quality of processed gas it receives from GPP. Raw gas composition depends on its gas reservoir characteristic. Some gas reservoir contains high level of hydrogen sulfide (H_2S), carbon dioxide (CO_2) and water (H_2O). GPP receives the raw gas from gas reservoir and treated it with its gas separation, sweetening and dehydration facilities to achieve sales gas specification. GPP is in the middle of resource and demands end. The uncertain variation from raw gas deliveries of gas reservoir (resource) and processed gas demands made GPP operations to be more flexible and ready to process gas dependant on situation.

1.1.2. Gas Dehydration System

Raw gas contains high level of water dependant the gas reservoir characteristic. Sales gas specification from buyer typically required processed gas with small amount of water to avoid pipelines corrosion and for immediate consumption. GPP is equips with gas dehydration system facilities to absorb water from raw gas. Gas dehydration comes with several options such as cyclone and chemical absorption. Most of the GPP in worldwide are using chemical absorption as it is more handy and practical. Furthermore, chemical like tri-ethylene glycol (TEG) is regenerative type and works effective in removing water from raw gas effectively. TEG gas dehydration system is contacted with raw and wet gas in an absorption column. Water content difference between TEG and wet gas is the driving force to remove water from raw gas. Gas that streams out of absorption column became dry and moves to next treatment stages. Lean TEG became rich TEG that contains removed water from wet gas and requires regeneration before can be used back as an absorbent. TEG regeneration is the reverse of absorption with TEG entering reboiler to vaporize and remove water from TEG liquid.

1.1.3. Plant Optimization

Plant optimization is a continuous work develops by both managerial and technical side of plant operations. High level managerial strategize the optimization based on economical and business plan while technical team executes the optimization accordingly with safety, regulation and engineering line. Plant optimization aims in improving the economical benefits of the plant as well as improving the plant operations capability. Investment in plant optimization usually rewards plant in an increase of process capacity, product quality improvement, less waste and consumption and more others improvement.

1.2. PROBLEM STATEMENT

TEG dehydration system is a simple gas dehydration process. However, it has its own disadvantages. The use of optional fuel gas stripping in regenerative TEG process in ensuring high concentration of TEG is deemed a waste to many GPP operators. In regenerative process, TEG is boiled in reboiler to remove water from used absorbent TEG to achieve high concentration of TEG before used back as an absorbent. Failure in achieving high concentration of TEG lead to optional fuel gas stripping to ensure TEG acts as an absorbent that able to meet up sales gas specification.

It is often unknown to operator the actual concentration of TEG used due to lack of equipment to analyze it. The operator's priority is to simply meet sales gas specification in term of water content in dry gas without acknowledging the integration of essential variables such as water content in wet gas, TEG circulation rate, TEG concentration and performance of regeneration system. Analysis on TEG dehydration as a whole is welcome as more wide scope is considered and possibility of optimization if analysis able to identify relevant opportunity.

To develop on analysis, a lot of variable is required. However, TEG dehydration system lack of it and made it more difficult. To cater such lack of information, estimation is sufficient to generate and estimate the required info. Accurate estimation is required to ensure accurate information that leads to accurate analysis on gas dehydration system. Estimation can be done by constructing some modeling work to emulate and simulate the real plant operations.

1.3. OBJECTIVES AND SCOPES OF STUDY

This project is carried out based on two main objectives, which are as follow:

1. Develop Accurate Plant Simulation of GPP using HYSYS software
2. Develop Reasonable Analysis of TEG Dehydration Performance

1.3.1. Develop Accurate Plant Simulation of GPP using HYSYS software

Due to lack of available information from the GPP, it can be covered by accurate estimation of process integration software called HYSYS. HYSYS is a powerful tool and software to simulate plant operations in term of process integration. It is able to generate estimation variable of streams' temperature, pressure, flow rates and other important variable required. Accurate estimation certainly assists in producing accurate analysis in TEG dehydration system performance despite setback on lack of real operations variables.

1.3.2. Develop Reasonable Analysis of TEG Dehydration Performance

It is important to develop reasonable analysis that relevant to both plant operators and engineers. The analysis aims in assisting them to be alert and see wider scope of TEG dehydration performance. More added benefits of accurate and reasonable of TEG dehydration analysis is the possibility to identify opportunity in optimization to the system. Analysis could cover area of absorption process and regeneration of absorbent process itself.

CHAPTER 2

LITERATURE REVIEW

The literature review section highlighted the author review on several related literature particularly on gas processing plant operations, TEG gas dehydration system and optimization practice in industry. Literature review provide platform to the authors not only on understanding the literature but to make several critical analysis and improvement as pre-project work of developing TEG gas dehydration performance analysis.

2.1. GAS PROCESSING PLANT

Gas processing plant (GPP) is a plant that treats and processes raw gas from gas reservoir. Main buyers and consumer of GPP processed gas is gas power plant. Due to gas power plant importance in nationwide electricity supply, it requires dependable and consistent gas deliveries from GPP.

2.1.1. Plant Operations

GPP receives raw gas from gas reservoir and processes it to produces two main products. The two main products are sales gas and condensate (liquid form). Figure 2.1 show a simple example of GPP operations.

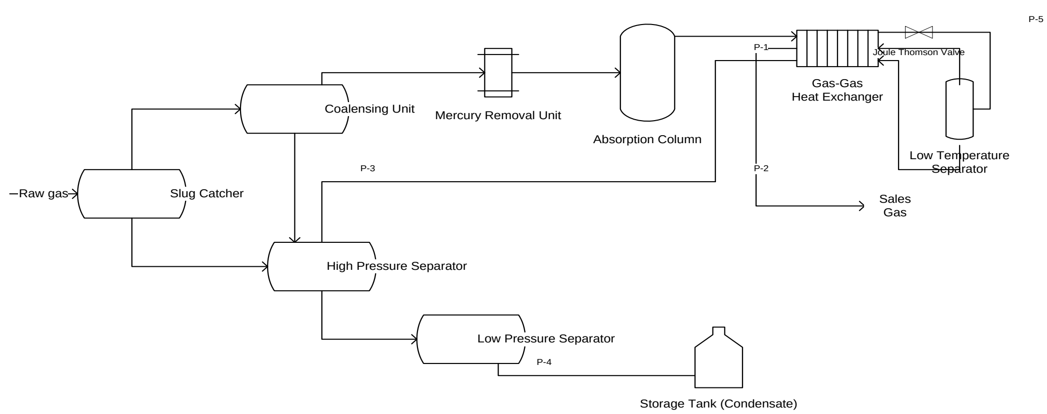


Figure 2.1: GPP Plant Operations

GPP has several main systems and it is dependable on raw gas characteristics it treated. Some of GPP processed clean type of gas which is low in carbon dioxide, CO_2 and hydrogen sulfide, H_2S in it and resulted in absence of amine treatment system such as Figure 2.1. Main treatment systems in GPP are including sequences of separation systems, mercury removal unit to remove mercury content in gas, absorption column to reduce water content in gas and refrigeration system (e.g. Joule-Thompson valve, low temperature separator) to recover more condensate present in sales gas.

GPP operations can be categorized into two distinguished categories which are gas and condensate side. On gas side, the treatment targets on meeting sales gas specification and contract, a specification sets in sales gas agreement between GPP operators and buyers. The raw gas processed through separation, mercury removal, amine treatment, absorption and refrigeration system. On the condensate side, condensate is going through series of separation system as to ensure all liquid is separates and recovered from the gas side. It is also important for the separation system to works well as condensate is also required to meet its sales specification which is low Reid vapor pressure (RVP). Low RVP means condensate is stable and will neither vaporizing during transportation nor storage.

2.1.2. Economics

GPP is very important as the supply to electrical power plant that consume gas as the energy sources. Often the cases are GPP belong to oil and gas companies that operate gas wells, both onshore and offshore. GPP is the middle party between gas resources (supply) and sales gas demands. It is important for GPP to maintain this tradeoff between supply and demand. Usually, GPP agrees on contractual gas deliveries to its buyers as it is expensive to store gas and easier to deliver it right away. However, several GPP that locates away from its buyer is an exception and develop liquid pressured gas (LPG) storage for deliveries. Being the middle party between supply and demand requires GPP to manage reservoirs deliveries and gas processing in balance.

2.2. TEG DEHYDRATION SYSTEM

Natural gas and associates condensate are often produced from the gas reservoir in equilibrium with water. In gas processing, the wet gas required to be treated to reduce water content in the gas for several reasons. Some of it is meant to prevent corrosion, avoid hydrate formation during storage and meeting the required gas specification required by the buyers. Gas dehydration process has several variations and options which are membrane and chemical dehydration. Often used type of gas dehydration in many GPP is chemical absorption, especially tri-ethylene glycol (TEG) absorbent.

2.2.1. Process

TEG dehydration system in GPP divided two main areas, which are the gas absorption by TEG and TEG regeneration. Figure 2.2 shows the overview of TEG-gas dehydration process flow.

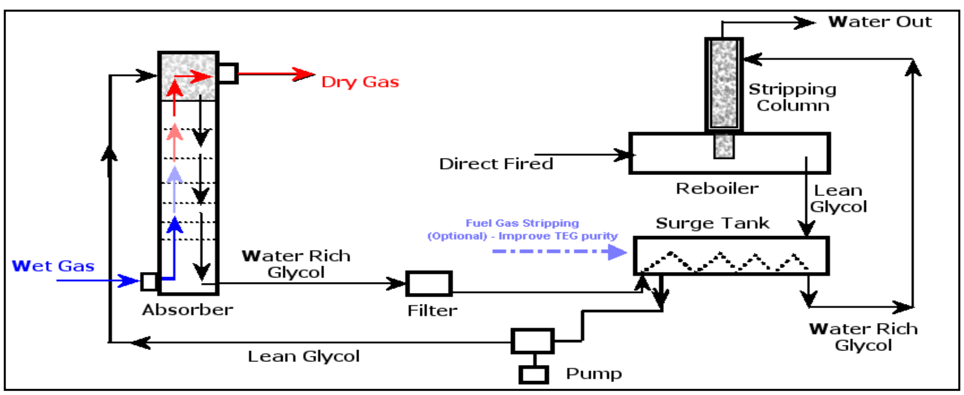


Figure 2.2: TEG-Gas Dehydration System [10]

Gas absorption normally occurs in absorption column, where wet gases entered in from bottom of the column while TEG as the liquid absorbent is entered from the topside. It is designed such way to ensure TEG and wet gases get contacted for extended period in the column tray. Lean TEG concentration liquid, usually extremely high concentration up to 99.97 weight percent of TEG in it (wt%), absorb water in the wet gases to give product of dry gas that meets contract specification (low water content, preferably minimum of 7 lb/MMSCF). Rich TEG, the used up lean TEG that now contains high water concentration, is sent to regeneration system to remove the water and regenerate TEG liquid to lean TEG before used back as the absorbent. TEG regeneration process is mainly using reboiler that vaporized water from TEG liquid. To achieve higher TEG concentration for cases where reboiler performance is limited and unable to achieve, optional fuel gas stripping is available. However, fuel gas stripping quite costly if it is just meant for the sake of regenerate TEG and should always be avoided whenever is possible.

2.2.2. Equilibrium

During TEG-wet gases absorption process occurred, the driving force for the process is the water content difference between the two streams. TEG, very low in water content, is absorbing water from high water content of wet gases. The process continues to achieve equilibrium behavior of water in TEG-water system.

Equilibrium water content, W_0 is the hypothetical equilibrium water content value exists in absorption column. W_0 is assumed to be achieved with infinite trays and pure concentration of TEG which is not possible in the real plant operations.

$W_0 = W_{N+1}(\gamma)(x_0)$,

γ is the activity coefficient factor (dependant on TEG concentration)

x_0 is mol fraction of water in lean TEG

W_{N+1} is water content in wet gas

However, W_0 is a great benchmark in determining absorption efficiency factor, E_a and absorption factor. E_a is able to be determined by using Kremser-Brown approach as below.

$$E_a = \frac{W_{N+1} - W}{W_{N+1} - W_0},$$ W is water content in dry gas

W_0 is achievable if only absorption efficiency factor is 1 and the maximum E_a is one ($E_a \leq 1$). W_0 is easily said as the lowest dry gases' water content can achieved. Hence, water content in the dry gases will always be higher than theoretical W_0.

2.2.3. Factor Affecting Gas Dehydration System

Gas absorption by using TEG is affected by several factors especially the system design and operating conditions. Figure 2.3 shows variables majorly involved in gas dehydration process.

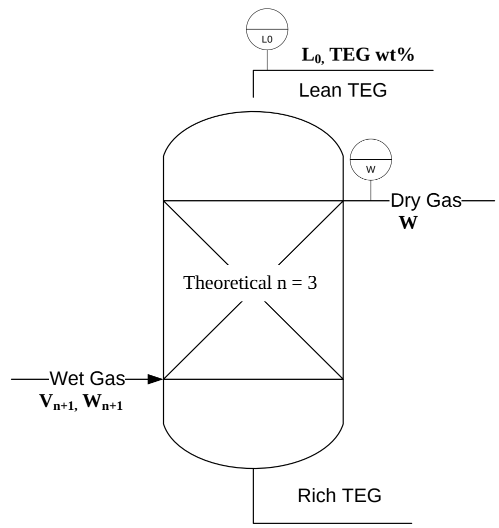


Figure 2.3: Major variables involved in gas dehydration process

The amount of TEG circulation rates (L_0) used and the TEG concentration (TEG wt %) value affects the W_0 and E_a value. The higher L_0 and TEG wt % value resulted in much lower W_0 due to the higher absorption driving force. It is resulted in better absorption efficiency in Ea value. Higher E_a will greatly reduced water content in dry gas to almost near to W_0. Low W is very dry gas and achieved the absorption purpose of reducing water content in the gas.

On design side, more trays in the contactor or column meant of more contact area and time between TEG and gases to happen. Increase in contact area and time for the absorption process will definitely increase absorption factor (A), a value indicates absorption capability. Several studies and experiment has been made to verify this theory. Figure 2.4 shows the effects of theoretical tray in absorption column to absorption efficiency value. Increasing theoretical trays meant more efficiency in absorption process.

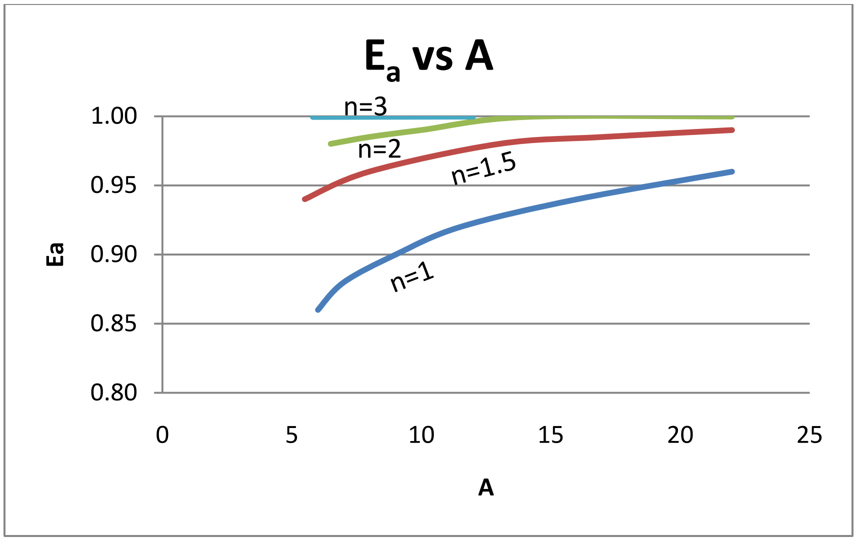


Figure 2.4: Effect of theoretical stages towards absorption process (Campbell, 2004)

2.3. OPTIMIZATION

Optimization by definition meant of to make out of; to plan or carry out an economic activity with maximum efficiency; to find the best compromise among several often conflicting requirements, as in engineering design[9]. However, due to hierarchy and different work scope in plant operation made optimization more difficult. For example, there are difference in perspective view of high level management, operators and engineers in running the plant. High level management is in business segment while operator and engineer more concern on plant operations and other technical area.

Optimization nowadays have moved step forward by integrating new real time optimization (RTO) concept. Figure 2.5 show the cycle of RTO cycle. It is dealing with five aspects of reference which are measure, analyze, evaluate, decide and action. The start of the cycle begins with taking measurement, subsequent analysis of the measurement, evaluation of that analysis, decision making processes and execute optimization plan.

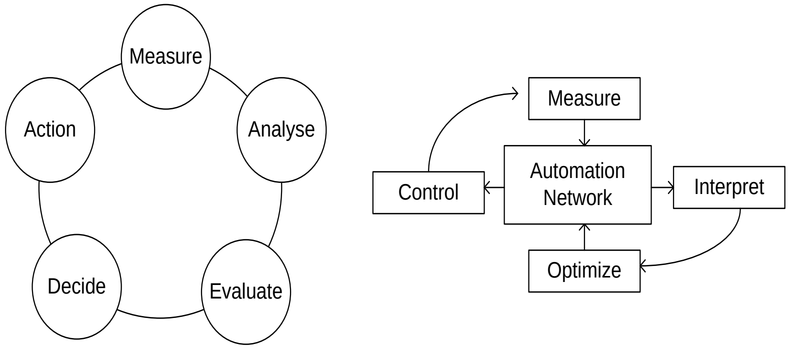


Figure 2.5: Real time optimization cycle (Saputelli, 2003)

The cycle is able to move the optimization opportunity faster to execute after consideration from all parties view. It also reduced time constant for various processes. In simpler word, RTO is a process of measurement-calculate-control cycle at a frequency, which maintains the system's optimal operating conditions with time-constant constraints of the system.

CHAPTER 3
PROJECT WORK & METHODOLOGY

This project is develop in two main phase which are construction of plant simulation and development of gas dehydration performance analysis. This section covers on the detail of the two main phases, especially on the project structure to give more clear description and understanding about the project itself. Methodology is also covered later in this chapter after project work writing.

3.1. PROJECT WORK

3.1.1. Overview

In analyzing TEG dehydration system performance, plant simulation is modeled first by using HYSYS simulation. It is essential to have a model that reliable in representing TEG dehydration system as some of the data is unavailable from the plant and only available from the estimation from HYSYS model. To achieve this objective, the plant simulation is using the actual operating value, gained from control transmitter available in plant. Plant simulation that is using plant actual operating value will able to represent the real simulation of current plant operations. To increase the reliability and confidence in the plant simulation, the estimated variables gained from the simulation is compared with available measured variable. It is called model tuning that tune the model to operating plant variables as to better represent the real plant and gives better simulation value.

Most of the GPP in the world are using TEG dehydration to reduce the water content in the processed gas to specified water content in sales gas agreement. It is essential to meet the sales gas specification as it has less water content to avoid pipeline corrosion and favorable to buyer. TEG dehydration is a gas-liquid absorption process. TEG in liquid is passed through wet gas in a contactor and water is removed from wet gas to TEG due to different water content driving force. The gas became dry to sales gas specification and moved to next processing stages. This dehydration performance is analyzed in several essential areas such as wet gas volume, outlet dry gas water content and lean TEG concentration. By performing such analysis, operator is able to know more and can strategize based on current operating TEG dehydration system

This project is conducted based on three separate components. First is the construction of GPP simulation model in HYSYS. It is constructed based on available design cases that cater most extreme condition such as maximum gas flow rate. Secondly, the integration of simulation model with current operating variable. Last component are the TEG dehydration analysis based from the available variable and estimation from simulation model. Capability to calculate engineering calculations such as absorption system performance rose from the availability of estimated value from reliable simulation model and current operating value. First two stages are important for TEG dehydration system performance analysis.

3.1.2. Plant Modeling

The model is constructed based on reference GPP plant operation. In the GPP, it consists of two main streams of operations which are the condensate and gas side. Crude gas from the wellhead pipelines are transferred to slug catcher that separates most of the gas from its condensate side. The gas side is later processed with TEG dehydration and refrigeration to extract the gas to sales gas specification. The condensate is treated to with further separation to remove and recover some gas to achieve low Reid Vapor Pressure (RVP) that ensure condensate is not vaporized during storage and transportation. Plant simulation model is constructed for the whole GPP plant. However, for initial model construction is based on design basis.

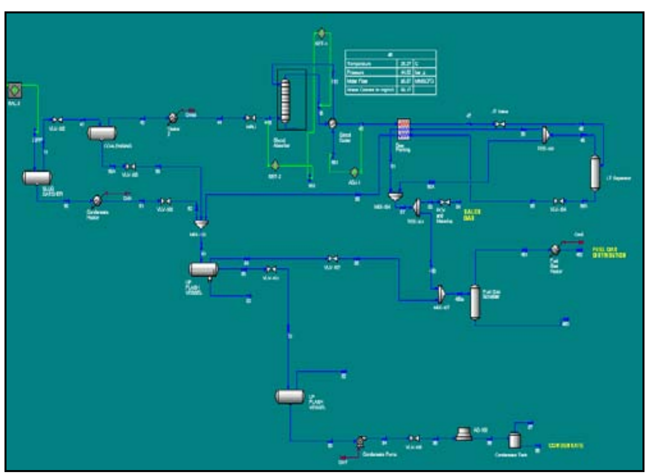


Figure 3.1: HYSYS Simulation Model

3.1.3. Integrate Model With Operating Variable

The earlier constructed model is based on design basis which cater design cases such as maximum and minimum gas flow. In operating plant, rarely plant operations are up to maximum condition. Instead of using design variable, the simulation is integrated with operating variable obtained from available transmitter. Using operating variable, the simulation simulates current plant operations. Moreover, not all available operating variables are needed to run the simulation. Hence, this type of variable is beneficial as check and balance to the model. Estimation from simulation model can be compared with the operating variable to show the reliability of simulation model.

In integrating simulation with operating value, available operating variables are needed to be identified. With the operating variable input, estimated variables are generated. With lots of variables involved, organized variables mapping is a practical use. As in Figure 3.2, operating variable is listed and extracted from historian. The operating variable value stored in operating data sheet. With operating variables as input to the model, simulation model will generates estimated variables and stored in the estimated data sheet. It is organized and easily to distinguish between two different database.

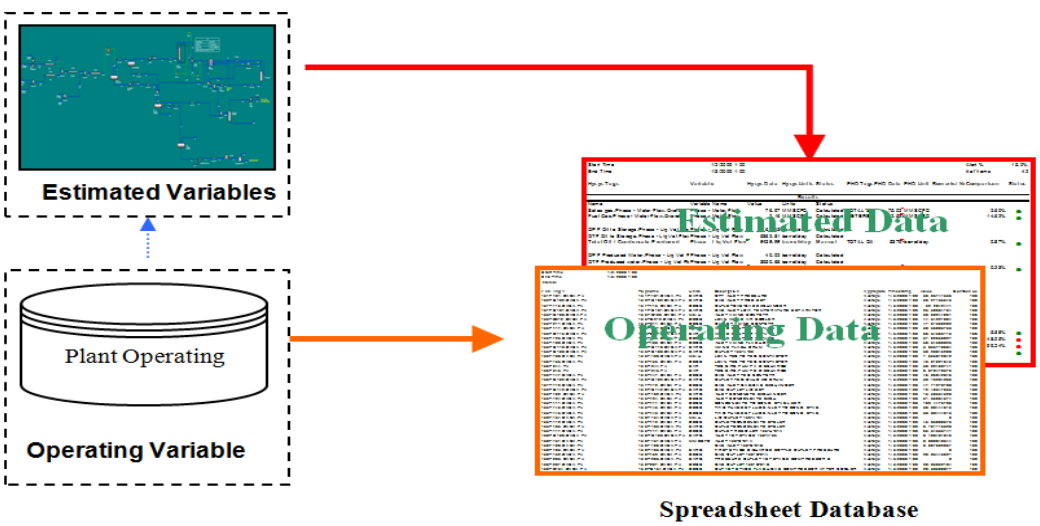


Figure 3.2: Operating and Estimated Variable Mapping

Further improvement can be made to the simulation model. It is known that not all available operating variables are needed for simulation input. As for unused operating variables, it acts as medium to verify similar variable from simulation model estimation is the same or almost same as it. It is called model tuning where simulation model are tuned to satisfy the condition. Usually 5% difference is tolerable in comparing real and simulation condition. Figure 3.3 shows a spreadsheet develop to assist model tuning and indicate variables or area that requires adjustment and modification. Red box represents for more than 5% difference in operating and simulation variable while green is the ideal condition, where the difference is less than 5%. More green boxes show that simulation model able to represent reliable simulation and estimation for current plant operations.

		Estimated Value			Operating Value			Comparison & Notes		
Hysys Tags	Variable Name	Hysys Da	Hysys Uni	Status	PI Tags	PI Dat	PI Unit	Compariso	Statu	Calibration Notes
PIG RECEIVER (001)										
GPP.Phase - Temperature.Overall	Phase - Temperature	26.45776	C	Calculated						
GPP.Phase - Pressure.Overall	Phase - Pressure	56.7508	bar_g	Calculated						
GPP.Phase - Molar Flow.Overall	Phase - Molar Flow	40.2558	MMSCFD	Calculated						
GPP**.Phase - Molar Flow.Overall	Phase - Molar Flow	40.2558	MMSCFD	Calculated						
GPP**.Phase - Temperature.Overall	Phase - Temperature	28.69	C	Specified	00TI101.DACA.PV	28.69	DegC	0.01%		
GPP**.Phase - Pressure.Overall	Phase - Pressure	68.75	bar_g	Specified	00PIA101.DACA.PV	68.75	Barg	0.01%		
SLUG CATCHER (002)										
41.Phase - Temperature.Overall	Phase - Temperature	28.57743	C	Calculated	00TI104.DACA.PV	28.79	DegC	0.73%		
41.Phase - Pressure.Overall	Phase - Pressure	68.45	bar_g	Specified	00PICA102.DACA.PV	68.45	Barg	0.01%		
41.Calculator.Std. Gas Flow	Calculator	40.03366	MMSCFD	Calculated	00FIA101.DACA.PV	38.08	MMscfd	5.13%		
42.Phase - Temperature.Overall	Phase - Temperature	18.98169	C	Calculated						
42.Phase - Pressure.Overall	Phase - Pressure	45.44	bar_g	Specified	00PIA104.DACA.PV	45.44	Barg	0.00%		
60.Phase - Temperature.Overall	Phase - Temperature	28.57743	C	Calculated						
60.Phase - Pressure.Overall	Phase - Pressure	68.45	bar_g	Calculated						
60.Calculator.Act. Volume Flow	Calculator	1.223554	m3/h	Calculated	02FICA101.DACA.PV	0.006	m3/hr	20832.41%		
INLET COALENSING (003)										
43.Phase - Temperature.Overall	Phase - Temperature	18.93248	C	Calculated						
43.Phase - Pressure.Overall	Phase - Pressure	45.3309	bar_g	Calculated						
Heater 2.Pressure Drop	Pressure Drop	10	kPa	Specified						
44.Phase - Temperature.Overall	Phase - Temperature	25	C	Specified	00TICA102A.DACA.PV	25.04	DegC	0.15%		
44.Phase - Pressure.Overall	Phase - Pressure	45.2309	bar_g	Calculated						
MRU (004)										
44.Phase - Pressure.Overall	Phase - Pressure	45.2309	bar_g	Calculated						
MRU.Pressure Drop	Pressure Drop	12.24	kPa	Specified	00PDIA102.DACA.PV	0.057	Bar	21542.07%		Different Unit

Figure 3.3: Model Tuning

3.1.4. TEG Dehydration Performance Analysis

Based on literature review and Figure 2.2, after being used in absorption contractor, TEG concentration became low and needs to be treated before being used back. It can be regenerated by boiling and gas stripping method to remove water from it and reached lean TEG concentration needed. In the plant, the available operating variables are only the circulation rate of TEG and water content in dry gas. The dry gas water content is always monitored to ensure it is not more than 0.2 lb water per MMSCF of gas as per sales gas specification. TEG circulation rate is important to know the amount of pumped TEG and loss in TEG during the process.

To analyze TEG dehydration performance, more details and variables are needed. Simulation model able to provide very essential variable such as wet gas volume entered (MMSCFD) and wet gas water content (lb water/MMSCFD gas). With the available and estimated variables, absorption system performance is able to calculate. It is often cases, plant operators unable to determine the concentration of lean TEG used. Operators main task are ensure dry gas from the TEG contactor meeting the specification and amount of TEG used that relates in avoiding pump cavitation and determine losses of TEG. Regeneration system is acting based on unknown lean TEG concentration and merely used up direct fired reboiler and fuel gas to reduce water content.

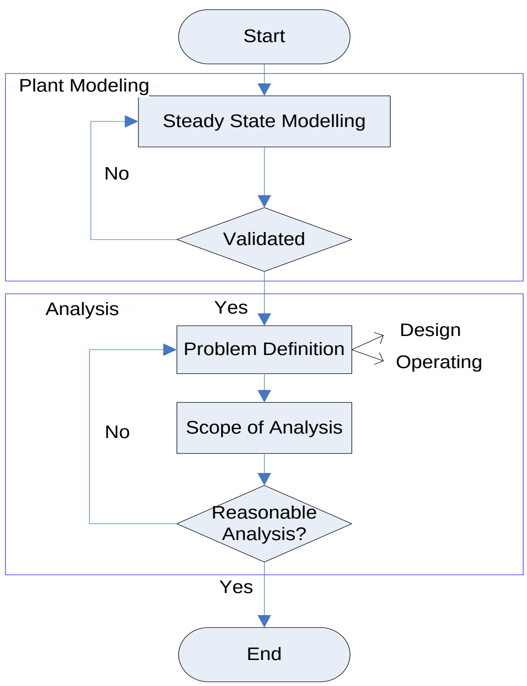
In literature review, even to the highest lean TEG concentration and highest TEG volume will only to achieve TEG-wet gas equilibrium water content. The equilibrium water content is possibly 0.06 lb/MMSCFD while the required water content is only 0.2 lb/MMSCFD. It will be such a waste that the absorption system used the highest TEG concentration and volume to reach equilibrium state not required condition. More waste is when optional fuel gas stripping is used when other alternative can be considered. It could be the fault in reboiler that arise the need of fuel gas stripping. Fuel gas stripping quite costly as it waste the fuel gas just to dry up TEG.

In TEG dehydration performance analysis, estimation of required lean TEG concentration and effort in avoiding fuel gas stripping is prioritized. Analysis should cover on areas such as TEG circulation rate needed and the performance of reboiler in TEG regeneration.

3.2. METHODOLOGY

3.2.1. Project Methodology

Project activities categorizes into two main phases which are the plant modeling and TEG dehydration system performance analysis. Plant simulation required validation process to ensure its robustness, practicability with current plant operations and accurate simulation. Validation process is conducted by model tuning work. On analysis phase, scope of analysis is identified based on familiarization of TEG dehydration system in design cases and current operations practice. Analysis should be reasonable to both operators and engineers as the analysis purpose is on identifying opportunities and optimization in absorption process.



3.2.2. Project Activities

Plant Modeling

Plant modeling consist of two modeling works which are GPP modeling based on design cases and model tuning with operating variable input. Robust and accurate simulation required to estimate process variables needed in system analysis.

Analysis

In performing any system performance analysis, familiarization is required to understand key area and calculation in the system. By understanding the system, it easier to identify analysis area scope and noted reasonable variables that require attention and calculation. The analysis should be easily understandable and reasonable to all parties such as operator and engineer in order to identify any problems and opportunities lies within current operations practice.

3.2.3. Project Tools

The project is a simulation project. Several related softwares are used on the process to develop the project. The mentioned software are;

1) Aspen HYSYS

   Aspen HYSYS is a process simulation software that enables plant operations simulation in mostly on process area. The software a powerful simulation tools especially in material and heat balance, flow estimation and unit operations.

2) Aspen Simulation Workbook

   Aspen Simulation Workbook (ASW) is an integrated software that links up Aspen HYSYS with Microsoft Office Excel. ASW enables process variables calculated in HYSYS to be transferred into Excel interface spreadsheet. It also automates any changes in variable changes to simultaneously record into spreadsheet. With Excel work function, the author able to extract data easily from plant operations servers with PivotTable function. Author also manages to automate all calculation in Excel file.

CHAPTER 4
RESULT AND DISCUSSION

This project's results is presented and discussed in two categories. The first one is the analysis on the accuracy of the plant simulation model. Second category falls on the TEG gas dehydration performance analysis and the expected analysis that beneficial for the parties that involved and interested

4.1. MODEL TUNING

Table 4.1 shows the summary of model tuning with 5 percent different between estimated and real operating value.

Total Operating Variable	**32**
Total Estimated Variable	19
Total Specified Variable (Input)	13
Meet Specification (Green)	12 (out of 19)
Not Meeting Specification	7 (out of 19)

Table 4.1: Summary of Model Tuning

Continuous improvement is required to ensure less number of fault estimations, which are categorized in 5 percent difference from real operating value. However, several causes results in high difference is unavoidable such as ideal separation in simulation compared to real separation process (4 variables), very small unit which larges the percentages effect (2 variables) and existence of recirculation route in operations but neglect in simulation (1 variable).

4.2. TEG DEHYDRATION PERFORMANCE ANALYSIS

Figure 4.1 is the developed analysis of TEG dehydration system. The analysis graph consists of three constraint lines, two operating lines and one operating point. The three constraints lines are minimum, maximum pump capacity and maximum water content in dry gas. The constraint lines are the limitations and any operating point should lies within these lines. The operating lines represent the characteristic of different TEG concentrations (99.97 and 99.9 wt% concentration) with water content of dry gas and TEG circulation rate variation. The operating point is the actual operating value that runs by the plant.

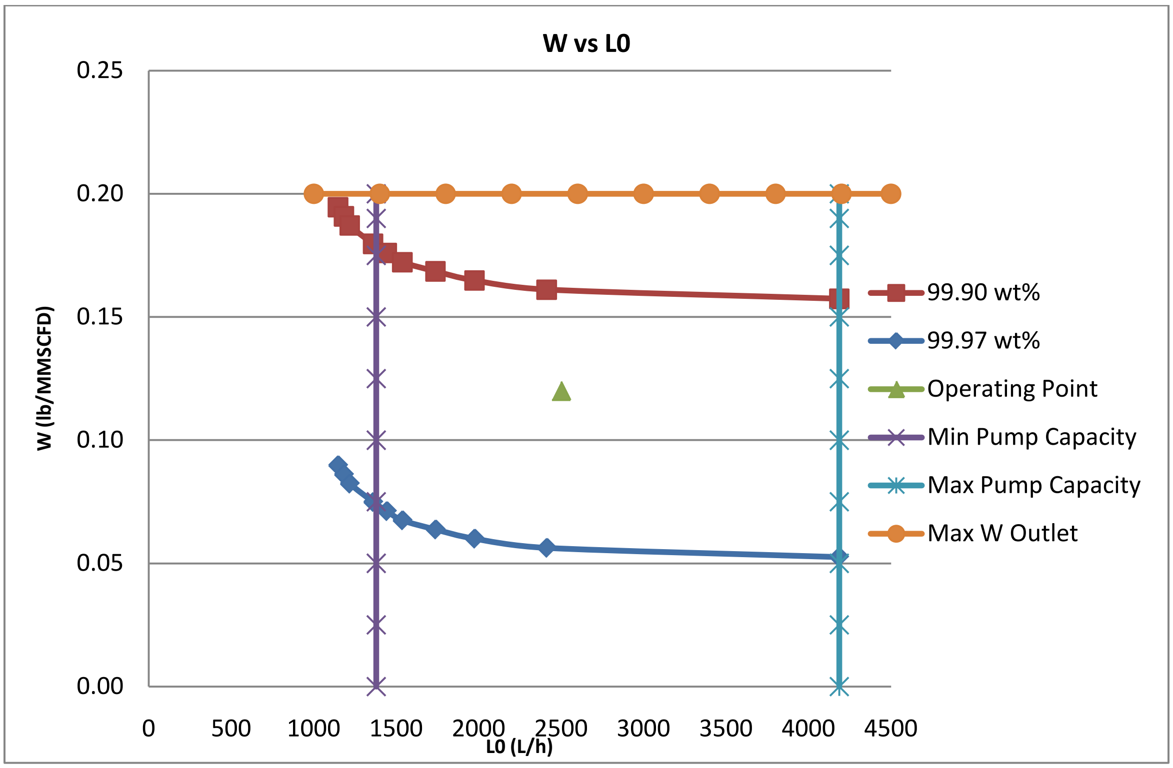


Figure 4.1: TEG Dehydration Performance Analysis

The first analysis is the operating point coordinate. Operating point should lies within the three constraint region. It is easily identified when the operations goes beyond the limits and avoid major problem such as not meeting sales gas specification and pump cavitation.

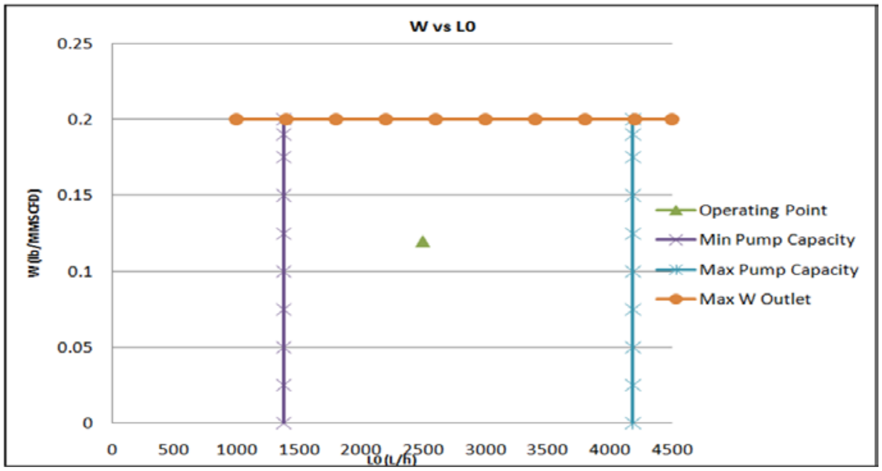


Figure 4.2: Constraint Analysis

Second analysis can be deduced from the graph is the minimum TEG concentration required to perform gas dehydration process. With setting of lowest TEG flow rate required (minimum pump flow rate) and maximum of water content in dry gas, W (minimum sales gas specification), the lowest TEG concentration required is 99.9 wt% to achieve sufficient gas dehydration with current operations conditions such as wet gas flow rates of 40.1 MMSCFD and wet gases' water content of 37.38 lb/MMSCF. By identifying TEG concentration, it will enable to know whether the TEG regeneration system able to regenerate used up TEG up to the concentration. It is also known whether fuel gas stripping necessary for current operations. Deduction also can be made if fuel gas stripping is still needed during a time period while the analysis clearly identified only low concentration needed without the optional stripping, there might be some problem with reboiler system that not efficiently working.

Third analysis is estimation of current produced TEG concentration. With more operating line included in the graph, operating TEG concentration able to identified. Even with two operating lines, the concentration is known to be lies between 99.90 and 99.97 wt%. It is quite high concentration and current regeneration system was performing well to achieve that concentration.

Fourth analysis can be made is potential optimization process. If the plant operations are assumed to continue same operations margin in a month period, optimization strategy can be planned out. For example, reduction in TEG flow rates from 2500 L/h to 1500 L/h with 99.90 wt% of TEG, gas dehydration is still meeting the required processing specification. Reduced consumption in TEG flow rates also reduced the amount of TEG losses during operations. Reduced TEG flow rates also can result in changes of TEG pump to pump with smaller capacity. Pump with smaller capacity flow rates use less power and leads in some reduction in operating expenditure (OPEX).

CHAPTER 5

CONCLUSION

This project is carried out based on two main objectives, which are developing accurate plant simulation of GPP using HYSYS software and develop reasonable analysis of TEG dehydration performance.

As in Table 4.1 in result and discussions section, accurate plant simulation is successfully developed and only 7 out of 32 are outside the acceptable region. There are several acceptable reasons about the out of margin error. Basically, the objective of developing accurate plant simulation of GPP using HYSYS software is achieved and justifies the correct estimation for analysis phase.

On developing reasonable analysis of TEG dehydration performance, the analysis is as Figure 4.2 in result and discussions section. It is identified that with the analysis, there are four types of analysis that can be deduced from it. The constraints analysis, minimum required lean TEG concentration for gas dehydration, estimation of current TEG concentration and identified potential optimization opportunities. The second project's objective, which is developing reasonable analysis of TEG dehydration performance, was also achieved and resulted in four reasonable analyses for engineers, operators and any parties related.

CHAPTER 6

RECOMMENDATION

The projects objectives were successfully achieved and continuation on the project lays the possibility of extending the project actual potential. With accurate simulation model, the author can't help the feel that analysis can be applied to other system such as separation and machineries system available in the plant operations. Using the same idea that gives birth to TEG gas dehydration analysis, expansion to other system performance analysis can be achieved with some opportunity and effort given to it.

There are several advantages in using HYSYS software. The author came across several recommendations in adding integration of another software in HYSYS itself. For example is the PIPESIM software developed by Schlumberger, a pipeline simulation software which is powerful tools in predicting pipeline flow trending and properties estimation and even reported to be more accurate than similarly pipelines calculations available in HYSYS. PIPESIM, specialized and accurate pipeline simulation integrated with HYSYS, a powerful simulation tool in process integration will definitely only results more accurate model for the plant operations (refer Appendix V). It is also will create wider scope of the simulation to cater pipeline which can start from wellhead to GPP and then to sales gas buyers.

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APPENDIX I
CALCULATION INVOLVED

Design Capacity

Maximum TEG concentration, (TEG wt%) = 99.97

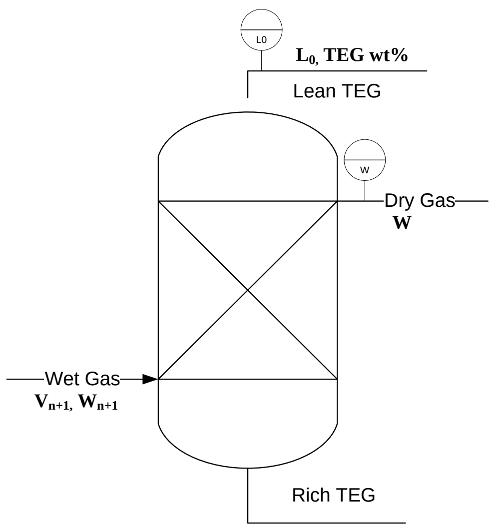
Maximum Water Content in Dry Gas, (W) = 0.2 lb/MMSCF

Maximum Wet Gas Flow rate, (V_{n+1}) = 135.7 MMSCFD

Minimum Pump Capacity = 1378.8 L/h

Maximum Pump Capacity = 4186.6 L/h

Design Cases Calculation



Available operating variable from plant operations:

W = 0.12 lb/MMSCF

TEG circulation rate, (L_0) = 2500.2 L/h

Extracted variables from HYSYS simulation:

V_{n+1} = 40.1 MMSCFD

W_{n+1} = 37.38 lb/MMSCF

Conversion between units, (kg/m_3 to lb/MMSCF);

1 std ft^3 (@60^0F, 14.7 psia) = 0.0286 std m^3 (@15^0C, 100kPa)

$$W = \frac{0.0005928kg}{m_3} \times 40.1x10^6\, SCFD \times \frac{0.0286m_3}{1\,ft_3} \times \frac{2.205lb}{kg} \times \frac{1}{40.1MMSCFD}$$

= 37.38 lb/MMSCF

With given TEG concentration, several related variables are calculated.

- Water mol fraction in lean TEG, x_0

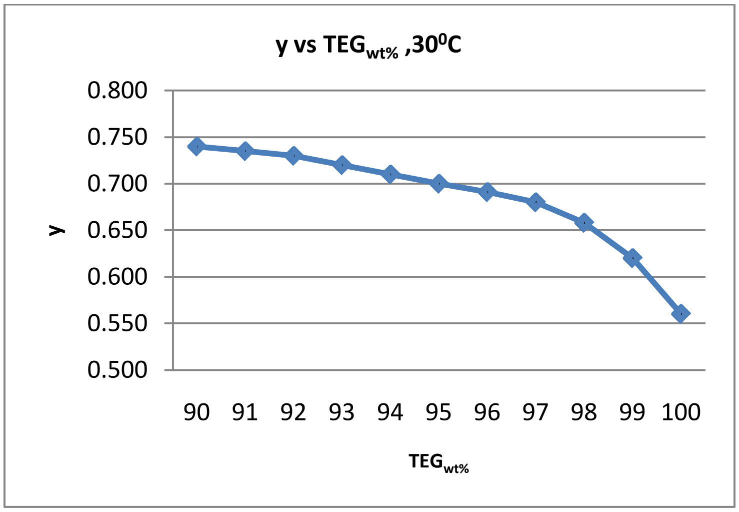
$$x_0 = \frac{(100 - X_{gl})/18}{[(100 - X_{gl})/18] + (X_{gl}/150)}$$

X_{gl} is TEG concentration in weight percent ($TEG_{wt\%}$), 99.97 wt%

$$x_0 = \frac{(100 - 99.97)/18}{[(100 - 99.97)/18] + (99.97/150)}$$

= 0.00249

- Activity coefficient, γ can only be find from below graph;



With TEG concentration of 99.97wt%, matching γ is 0.563.

- Equilibrium water content, W_0

  $W_0 = W(\gamma)(x_0)$

  = 37.38(0.563)(0.249)

  = 0.525 lb/MMSCF

- General Absorption equation;

$$L_0 = AKV_{n+1}$$

L_0, V_{n+1} in kmol, A is absorption factor and K is water equilibrium constant in TEG-water system.

V_{n+1} is current wet gas flow rate which is 40.1 MMSCFD. Conversion to kmol/hour unit is as follow;

Conversion between units,

1 std ft^3 (@60^0F, 14.7 psia) = 0.0286 std m^3 (@15^0C, 100kPa)

1739 kmol/h = 1 x 10^6 std m^3/d

$$V_{n+1} = 40.1x10^6\,SCFD \times \frac{0.0286 m_3}{1 ft_3} \times \frac{1739 kmol/h}{10^6 m_3/d}$$

= 1994.39 kmol/h

K, water equilibrium constant calculated from following formulae,

$K = B(W)(\gamma)$, B is 2.11 x 10^{-5} when W in lbm/MMSCF

K = 2.11 x 10^{-5} x 37.38 x 0.563

= 0.00044

Undetermined variables from general absorption equation are A and L_0,

To construct design operating curves, let varies W based on absorption efficiency and generates the required TEG circulation rate amount.

Effective absorption factor, Ea is derived from following Kremser-Brown approach,

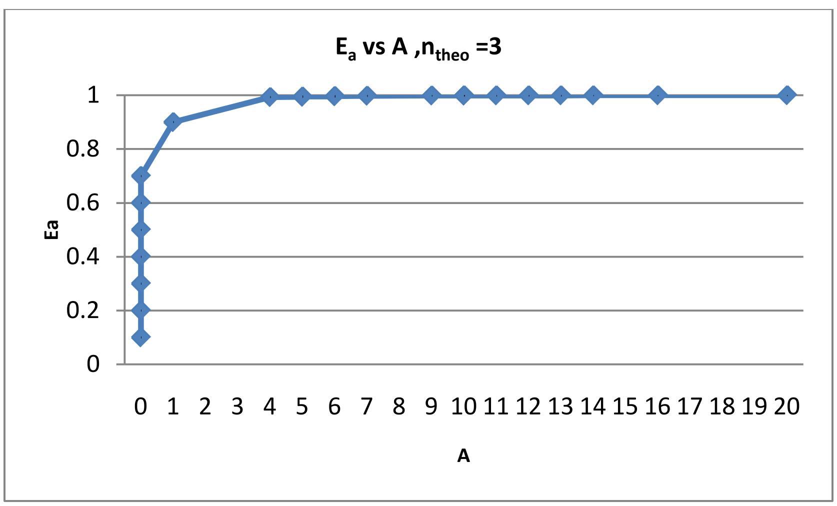
$$E_a = \frac{W_{N+1} - W}{W_{N+1} - W_0}$$

Take Ea value of 0.999,

$$0.999 = \frac{37.38 - W}{37.38 - 0.525}$$

W = 0.0898 lb/MMSCF

To obtain A value, value are extracted from below diagram with theoretical tray equal to 3.



A = 9.7 when Ea of 0.999.

$L_0 = AKV_{n+1}$, A=9.7, K=0.00044, V_{n+1} = 1994.39 kmol/h

L_0 = 8.59 kmol/h

Conversion to L/h unit is as below;

ρ_{TEG} = 1120 kg/m3,

Molar weight of TEG = 18 x_0 + (1- x_0)(150) , x_0 = 0.00249

= 18(0.00249) + (1-0.00249)(150)

= 149.67 kg/kmol

$$L_0 = \frac{8.59kmol}{h} \times \frac{149.67kg}{kmol} \times \frac{m_3}{1120kg} \times \frac{1000L}{m_3}$$

L_0 = 1147.97 L/h

Efficiency	A	W (lb/MMSCF)	L_0 (L/h)
0.9990	9.7	0.0898	1147.97
0.9991	10	0.0861	1183.47
0.9992	10.3	0.0824	1218.98
0.9994	11.5	0.0749	1361
0.9995	12.2	0.0712	1443.84
0.9996	13	0.0674	1538.52
0.9997	14.7	0.0637	1739.71
0.9998	16.7	0.0600	1976.4
0.9999	20.4	0.0562	2414.29

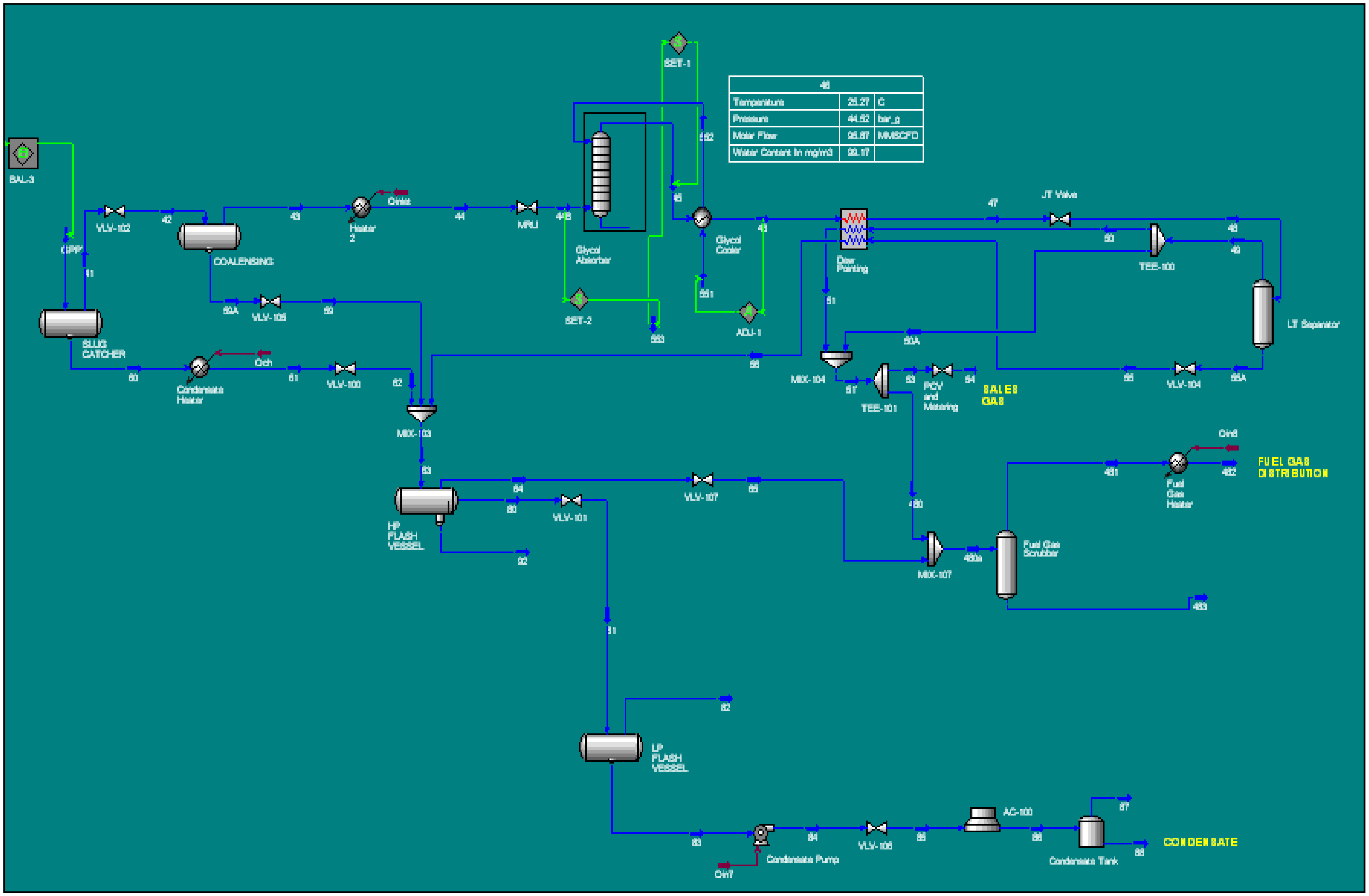
Minimum TEG Concentration based On Current Operations

Due to complexity of calculations when TEG concentration is unknown, try and error is the best solution available. Try and error solution must obey several constraints as in Appendix 1.1 (design capacity). Since maximum W is set at 0.2 lb/MMSCF, the maximum W is likely to achieve at the least TEG circulation rate. The least circulation rate must obey minimum pump capacity to avoid pump cavitation. With selected TEG concentration and minimum TEG circulation rate, W must be less than 0.2 lb/MMSCF. With 99.9 TEG wt%, at 1378.8 L/h TEG circulation rate (minimum pump capacity), W is 0.18 lb/MMSCF less than set constraint of 0.2 lb/MMSCF.

TEG (wt%)	V_{n+1}	K	Efficiency	A	W (lb/MMSCF)	L_0 (L/h)
99.90	40.1	0.00045	0.9990	9.7	0.195	1147.01
			0.9991	10	0.191	1182.49
			0.9992	10.3	0.187	1217.96
			0.9994	11.5	0.18	1359.86
			0.9995	12.2	0.176	1442.63
			0.9996	13	0.172	1537.23
			0.9997	14.7	0.169	1738.26
			0.9998	16.7	0.165	1974.75
			0.9999	20.4	0.161	2412.27

APPENDIX II

PROCESS FLOW DIAGRAM



APPENDIX III

MODEL TUNING

Start time	30/5/2010 0:00
End time	31/5/2010 0:00

Hysys Tags	Hysys Data	Hysys Units	Status	PI Tags	PI Data	PI Unit	Diff.	Status	Calibration Notes
PIG RECEIVER (001)									
GPP.Phase - Temperature.Overall	26.4577563	C	Calculated						
GPP.Phase - Pressure.Overall	56.7507986	bar_g	Calculated						
GPP.Phase - Molar Flow.Overall	40.255805	MMSCFD	Calculated						
GPP'''.Phase - Molar Flow.Overall	40.255805	MMSCFD	Calculated						
GPP'''.Phase - Temperature.Overall	28.69	C	Specified	00TI101.DACA.PV	28.688	DegC	0.01%		
GPP'''.Phase - Pressure.Overall	68.75	bar_g	Specified	00PIA101.DACA.PV	68.745	Barg	0.01%		
SLUG CATCHER (002)									
41.Phase - Temperature.Overall	28.5774296	C	Calculated	00TI104.DACA.PV	28.789	DegC	0.73%		
41.Phase - Pressure.Overall	68.45	bar_g	Specified	00PICA102.DACA.PV	68.446	Barg	0.01%		
41.Calculator.Std. Gas Flow	40.0336578	MMSCFD	Calculated	00FIA101.DACA.PV	38.079	MMscfd	5.13%		Ideal Separation
42.Phase - Temperature.Overall	18.9816869	C	Calculated						
42.Phase - Pressure.Overall	45.44	bar_g	Specified	00PIA104.DACA.PV	45.442	Barg	0.00%		
60.Phase - Temperature.Overall	28.5774296	C	Calculated						
60.Phase - Pressure.Overall	68.45	bar_g	Calculated						
60.Calculator.Act. Volume Flow	1.22355391	m3/h	Calculated	02FICA101.DACA.PV	0.0058	m3/hr	20832%		Ideal Separation

INLET COALENSING (003)									
43.Phase - Temperature.Overall	18.9324757	C	Calculated						
43.Phase - Pressure.Overall	45.3309	bar_g	Calculated						
Heater 2.Pressure Drop	10	kPa	Specified						
44.Phase - Temperature.Overall	25	C	Specified	00TICA102A.DACA.PV	25.039	DegC	0.15%		
44.Phase - Pressure.Overall	45.2309	bar_g	Calculated						

MRU (004)									
44.Phase - Pressure.Overall	45.2309	bar_g	Calculated						
MRU.Pressure Drop	12.24	kPa	Specified	00PDIA102.DACA.PV	0.0566	Bar	21542%		Different Unit

GLYCOL CONTACTOR (005)									
44B.Phase - Temperature.Overall	24.9454713	C	Calculated						
44B.Phase - Pressure.Overall	45.1085	bar_g	Calculated						
45.Phase - Pressure.Overall	45.1017	bar_g	Calculated						
45.Phase - Temperature.Overall	25.8758118	C	Calculated	13TI101.DACA.PV	26.407	DegC	2.01%		
46.Phase - Pressure.Overall	45.0017	bar_g	Calculated	13PICA101.DACA.PV	45.004	Barg	0.01%		
46.Phase - Temperature.Overall	28.4587018	C	Calculated	13TI104.DACA.PV	28.935	DegC	1.65%		
551.Phase - Mass Flow.Overall	2821.01424	kg/h	Calculated						
551.Phase - Pressure.Overall	45.5	bar_g	Specified						
551.Phase - Temperature.Overall	65.13	C	Specified	13TI103.DACA.PV	65.136	DegC	0.01%		
552.Phase - Pressure.Overall	45.1	bar_g	Specified						
552.Phase - Temperature.Overall	30	C	Specified	13TI102.DACA.PV	29.422	DegC	1.96%		
553.Phase - Pressure.Overall	45.1085	bar_g	Calculated						
553.Phase - Temperature.Overall	25.5444038	C	Calculated						

GAS/GAS EXCHANGER (008)									
46.Phase - Molar Flow.Overall	40.0653328	MMSCFD	Calculated						
46.Phase - Pressure.Overall	45.0017	bar_g	Calculated						
46.Phase - Temperature.Overall	28.4587018	C	Calculated						
47.Phase - Molar Flow.Overall	40.0653328	MMSCFD	Calculated						
47.Phase - Pressure.Overall	44.907	bar_g	Calculated	00PI110.DACA.PV	45.089	Barg	0.40%		
47.Phase - Temperature.Overall	-23.82	C	Specified	00TI110.DACA.PV	-23.823	DegC	0.01%		
50.Phase - Molar Flow.Overall	35.4573656	MMSCFD	Calculated						
50.Phase - Pressure.Overall	28.2164695	bar_g	Calculated						
50.Phase - Temperature.Overall	-35	C	Calculated						
51.Phase - Molar Flow.Overall	35.4573656	MMSCFD	Calculated						
51.Phase - Pressure.Overall	27.67	bar_g	Calculated						
51.Phase - Temperature.Overall	28.85	C	Specified	00TI109.DACA.PV	28.849	DegC	0.00%		
55.Phase - Molar Flow.Overall	0.04851613	MMSCFD	Calculated						
55.Phase - Pressure.Overall	9	bar_g	Calculated						
55.Phase - Temperature.Overall	-39.521167	C	Calculated						
56.Phase - Molar Flow.Overall	0.04851613	MMSCFD	Calculated						
56.Phase - Pressure.Overall	7	bar_g	Calculated						
56.Phase - Temperature.Overall	-39.521167	C	Calculated						

LT SEPARATOR (009)									
48.Phase - Pressure.Overall	28.2164695	bar_g	Calculated	00PICA111.DACA.PV	27.857	Barg	1.29%		
48.Phase - Temperature.Overall	-35	C	Specified						
49.Phase - Pressure.Overall	28.2164695	bar_g	Calculated						
49.Phase - Temperature.Overall	-35	C	Calculated	00TICA111.DACA.PV	-34.995	DegC	0.02%		
55A.Phase - Temperature.Overall	-35	C	Calculated						
55A.Phase - Pressure.Overall	28.2164695	bar_g	Calculated						

SALES GAS METERING (010)									
51'''.Phase - Temperature.Overall	21.4900677	C	Calculated						
51'''.Phase - Pressure.Overall	27.67	bar_g	Calculated						
51'''.Phase - Molar Flow.Overall	40.0168167	MMSCFD	Calculated						
53.Phase - Temperature.Overall	21.4900677	C	Calculated						
53.Phase - Pressure.Overall	27.67	bar_g	Calculated						
53.Phase - Molar Flow.Overall	39.7867475	MMSCFD	Calculated						
54.Phase - Temperature.Overall	21.4900677	C	Calculated	00TICA114.DACA.PV	22.85	DegC	5.95%		Small Unit
54.Phase - Pressure.Overall	27.67	bar_g	Specified	00PICA114.DACA.PV	27.666	Barg	0.01%		
54.Phase - Molar Flow.Overall	39.7867475	MMSCFD	Calculated						

CONDENSATE HEATER (011)									
60.Phase - Molar Flow.Overall	0.14699214	MMSCFD	Calculated						
60.Phase - Pressure.Overall	68.45	bar_g	Calculated						
60.Phase - Temperature.Overall	28.5774296	C	Calculated						
Condensate Heater.Pressure Drop	100	kPa	Specified						
61.Phase - Pressure.Overall	67.45	bar_g	Calculated						
61.Phase - Temperature.Overall	57.49	C	Specified	02TICA102.DACA.PV	58.372	DegC	1.51%		

HP FLASH VESSEL (012)									
63.Phase - Temperature.Overall	38.7310527	C	Calculated						
63.Phase - Pressure.Overall	7	bar_g	Calculated						
63.Phase - Molar Flow.Overall	0.20746618	MMSCFD	Calculated						
64.Phase - Molar Flow.Overall	0.04993079	MMSCFD	Calculated	02FIA102.DACA.PV	0.1587	MMscfd	68.53%		Ideal Separation
64.Phase - Pressure.Overall	7	bar_g	Specified	02PICA105A.DACA.PV	7.001	Barg	0.01%		
64.Phase - Temperature.Overall	38.7310527	C	Calculated						
80.Calculator.Act. Volume Flow	1.23618956	m3/h	Calculated	02FI103.DACA.PV	1.1813	m3/hr	4.65%		
80.Phase - Pressure.Overall	7	bar_g	Calculated						
80.Phase - Temperature.Overall	38.7310527	C	Calculated	02TIA106.DACA.PV	39.514	DegC	1.98%		
92.Phase - Temperature.Overall	38.7310527	C	Calculated						

92.Phase - Pressure.Overall	7	bar_g	Calculated						
92.Phase - Molar Flow.Overall	0.00600793	MMSCFD	Calculated						

FUEL GAS SYSTEM (017)									
65.Phase - Temperature.Overall	38.2696064	C	Calculated						
65.Phase - Pressure.Overall	6.09	bar_g	Specified						
65.Phase - Molar Flow.Overall	0.04993079	MMSCFD	Calculated						
480.Phase - Temperature.Overall	21.4900677	C	Calculated						
480.Phase - Pressure.Overall	27.67	bar_g	Calculated						
480.Phase - Molar Flow.Overall	0.23006921	MMSCFD	Calculated						
481.Phase - Molar Flow.Overall	0.28	MMSCFD	Calculated						
481.Phase - Pressure.Overall	6.09	bar_g	Calculated	15PICA101A.DACA.PV	6	Barg	1.50%		
481.Phase - Temperature.Overall	15.6521184	C	Calculated						
482.Phase - Molar Flow.Overall	0.28	MMSCFD	Calculated	15FIA101.DACA.PV	0.2768	MMscfd	1.15%		
482.Phase - Molar Flow.Overall	0.28	MMSCFD	Calculated						
482.Phase - Pressure.Overall	5.09	bar_g	Calculated						

LP FLASH VESSEL (018)									
81.Phase - Molar Flow.Overall	0.15152747	MMSCFD	Calculated						
81.Phase - Pressure.Overall	0.25	bar_g	Specified						
81.Phase - Temperature.Overall	38.1485504	C	Calculated						
82.Phase - Molar Flow.Overall	0.00592014	MMSCFD	Calculated						
82.Phase - Pressure.Overall	0.25	bar_g	Calculated						
82.Phase - Temperature.Overall	38.1485504	C	Calculated						
83.Phase - Molar Flow.Overall	0.14560733	MMSCFD	Calculated						
83.Phase - Pressure.Overall	0.25	bar_g	Calculated						
83.Phase - Temperature.Overall	38.1485504	C	Calculated	02TIA107.DACA.PV	62.439	DegC	38.90%		Pump Circulation

CONDENSATE PUMPS AND COOLER (019)									
84.Calculator.Act. Volume Flow	1.47177289	m3/h	Calculated	02FICA105.DACA.PV	34.996	m3/hr	95.79%		Less Condensate
84.Phase - Pressure.Overall	6.07552026	bar_g	Calculated	02PIA113.DACA.PV	6.1313	Barg	0.91%		
84.Phase - Temperature.Overall	55.0327111	C	Calculated						
85.Phase - Pressure.Overall	4.07552026	bar_g	Calculated						
85.Phase - Temperature.Overall	55.1363219	C	Calculated						
86.Phase - Pressure.Overall	0.07552026	bar_g	Calculated						
86.Phase - Temperature.Overall	55.2679696	C	Calculated						

CONDENSATE STORAGE TANKS (013)									
88.Phase - Molar Flow.Overall	0.14524016	MMSCFD	Calculated						
88.Phase - Pressure.Overall	0.07552026	bar_g	Calculated	02PIA107B.DACA.PV	0.0155	Barg	388.61%		Small Unit
88.Phase - Temperature.Overall	55.2679696	C	Calculated						

APPENDIX IV

TEG GAS DEHYDRATION ANALYSIS

Required Information (From Design & Simulation)

Design	Max TEG wt%	99.97	wt%
	Wmax	0.2	lb/MMSCFD
	Max Gas Flowrate	135.7	MMSCFD
	Min Pump Cap	1378.8	L/h
	Max Pump Cap	4186.8	L/h
Required	Vn+1	40.1	MMSCFD
	Wn+1	37.38	lb/MMSCFD
	W	0.12	lb/MMSCFD
	W0	0.00	lb/MMSCFD
	Ea	0.997	
	A	6.5	
	K	0	
	wt% TEG	99.97	
	L0	2500.2	L/h
HYS	Vn+1	40.1	MMSCFD
	Wn+1	37.38	lb/MMSCFD
PI	W	0.12	lb/MMSCFD
	L0	2500.2	L/h

Design Cases Variable (99.97wt% TEG)

99.97 wt%	pTEG	1120	kg/m3
	mol frac H2O	0.002494512	
	MW	149.6707244	
	y	0.563	
	L0	3000	L/h
		22.44928	kmol/h
	Vn+1	1994.38954	kmol/h
	K	0.000444048	
	W0	0.052496857	
	eff	0.999	
		0.9991	
		0.9998	
		0.9999	

	W	0.08982436	lb/MMSCFD
		0.08609161	
		0.059962358	
		0.056229607	
	A	9.7	
		10	
		14.7	
		16.7	
	L0	1147.970445	L/h
		1183.474686	
		1976.402725	
		2414.288359	

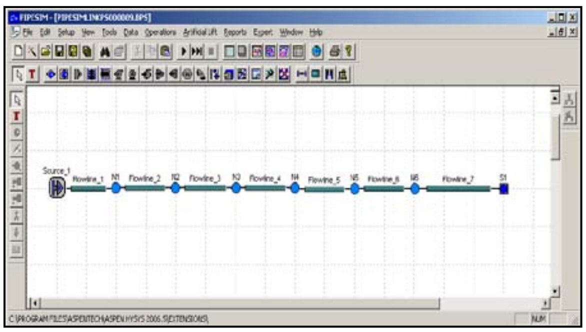
Operating Cases Variable (99.90wt% TEG)

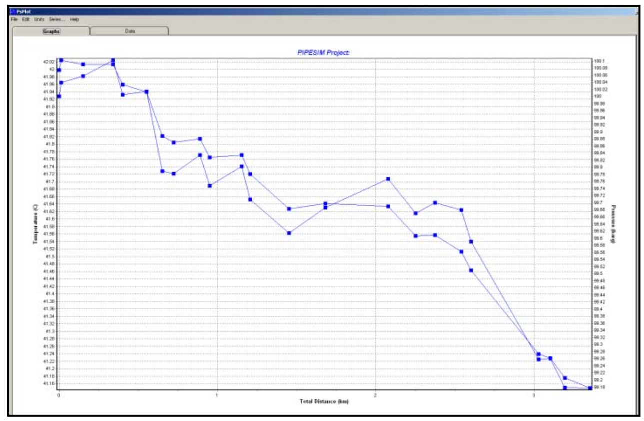
99.90 wt%	wt% TEG	99.90	kg/m3
	pTEG	1120	
	mol frac H2O	0.007450825	
	MW	149.0164912	
	y	0.565	L/h
	Vn+1	1994.38954	kmol/h
	K	0.000445626	
	W0	0.157359179	
	eff	0.999	
		0.9991	
		0.9998	
		0.9999	
	W	0.19458182	lb/MMSCFD
		0.190859556	
		0.164803708	
		0.161081443	
	A	9.7	
		10	
		14.7	
		16.7	
	L0	1147.012716	L/h
		1182.487336	
		1974.753851	
		2412.274165	

APPENDIX V

PIPESIM – HYSYS INTEGRATION

PIPESIM simulation on pipeline connecting well pad to GPP





Integration of PIPESIM into Aspen HYSYS