OPTIMIZING ETHYLENE GLYCOL REFRIGERATION PROCESS TO MAXIMIZE NGL RECOVERY

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Bill Chu, P.Tech. (Eng.)
Quadra Chemical Ltd.
700 – 4th Ave S.W
Calgary, Alberta T2P 3J3
CANADA
+1 403-450-0230
Bill_Chu@quadra.ca

Kim Mercier, P.Eng.
Encana Corporation
500 Centre Street SE
Calgary, Alberta T2G 1A6
CANADA
+1 403-645-2757
Kim.Mercier@encana.com

Andrew Lechelt, P.Eng.
Quadra Chemical Ltd.
700 – 4th Ave S.W
Calgary, Alberta T2P 3J3
CANADA
+1 403-450-0236
Andrew_Lechelt@quadra.ca

Juan Ruiz, P.Eng.
Encana Corporation
500 Centre Street SE
Calgary, Alberta T2G 1A6
CANADA
+1 403-645-2562
Juan.Ruiz@encana.com

ABSTRACT

The use of ethylene glycol for hydrate inhibition in natural gas refrigeration plants to recover LPG's is common practice. However, it is important that the ethylene glycol regeneration loop is properly designed to accommodate the operating conditions of the refrigeration process. If this is not the case, there may be issues in the process that can have a significant effect on the plant's performance. This paper provides a case study on a plant outlining simple changes that can be made in an ethylene glycol regeneration loop to increase liquid production and decrease operating costs.

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Juan Ruiz, P.Eng., Encana Corporation, Calgary, AB
Kim Mercier, P.Eng., Encana Corporation, Calgary, AB
Andrew Lechelt, P.Eng., Quadra, Calgary, AB
Bill Chu, P.Tech. (Eng.), Quadra, Calgary, AB

Introduction

Refrigeration plants are quite common throughout the province of Alberta for Natural Gas Liquid (NGL) recovery. The refrigeration process involves cooling a gas stream to condense hydrocarbon liquids. Because of the low temperatures involved, water is also condensed during this process and there is a risk of hydrate formation and freezing. There are two options to ensure hydrate formation is prevented: dehydrating the inlet gas stream to remove the water prior to refrigeration, or injecting a chemical hydrate inhibitor into the process stream during refrigeration. The decision on which option to choose depends on the inlet gas composition and plant process conditions.

In the summer of 2013, a study was completed on the refrigeration process at Encana's Clearwater plant in Central Alberta. The Clearwater plant refrigeration process includes ethylene glycol (EG) injection during refrigeration to prevent hydrate formation. During the study, several components of the plant were investigated, but the primary changes were made to the EG loop which will be the focus of this paper.

This paper discusses the refrigeration process, the Clearwater study results, the changes implemented at the plant and the resulting process improvements.

Refrigeration Overview

The purpose of refrigeration at the Clearwater plant is to remove NGL components from the process gas stream at a plant. Once gas leaves the inlet separator at the plant, it is then introduced to the first part of the refrigeration process: the gas-gas exchanger. The gas-gas exchanger cools the inlet gas by cross-exchanging it with cooled gas exiting the refrigeration process (going to sales). Because the gas stream is being cooled, water and NGLs will begin condense out of the stream. To prevent water from freezing, EG is sprayed through injection nozzles at the inlet of the gas-gas exchanger tube sheet, contacting the inlet gas stream. The EG is carried through the exchanger with the stream. The next component of this process is the chiller where the process gas is further cooled to the required process temperature to allow for the desired hydrocarbon liquids to condense. The chiller is an exchanger involving a propane cooling loop. The process gas enters the tube side, and propane is on the shell side. Additional EG injection occurs in the chiller as well. From here, the process gas, NGLs, and EG-water mixture enter a two two-phase or single three-phase low temperature separator (LTS) where the gas, NGL and glycol/water can be split out. The gas stream exits through the top of the LTS where it goes to sales, NGLs exit the LTS and are sent on for additional processing (as required) fractionation and the EG-water mixture (rich EG) exits the LTS and is sent to the glycol regeneration loop. The effectiveness of the refrigeration process is strongly dependant on the set points and conditions of the EG loop including EG injection, retention time and regeneration. A typical refrigeration loop can be seen in the following diagram:

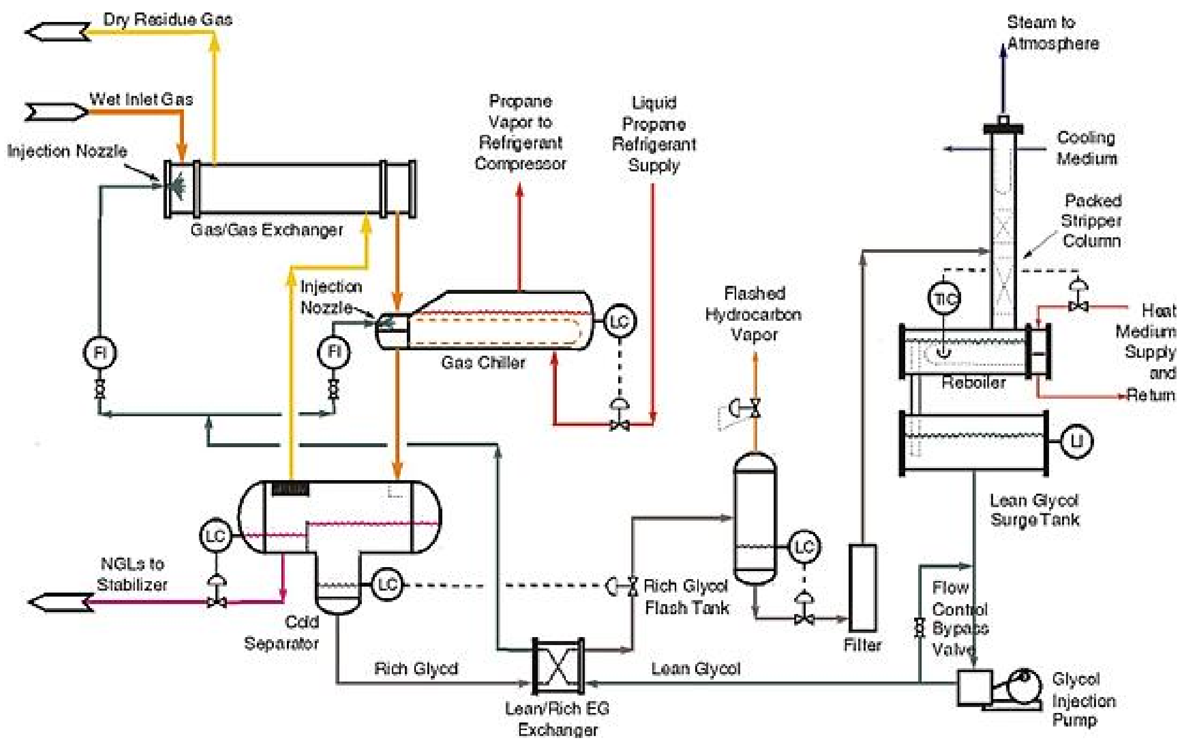

Figure 1- Typical EG Refrige Process Flow Diagram

Once the rich EG mixture exits the LTS, it enters the reflux coil in the still column (tube side), for pre-heating. From there the stream goes to the flash tank where the pressure is dropped down to approximately 10% of the process pressure. This allows for degassing of the entrained hydrocarbons from the stream. The rich EG stream then enters a series of filters (particulate followed by carbon) to remove any contaminants. From there the stream enters the tube side of a lean-rich exchanger (located in the bottom of the EG accumulator) before entering the still column where it is distributed evenly over the packing. As the water is liberated from the stream, the newly- lean EG enters the reboiler where it eventually cascades over the weir, flowing into the accumulator. At this point, the optimal EG:water weight ratio is 80:20 (for optimal fluid physical properties). The EG is then pumped back into the process where it is distributed in both the gas-gas exchanger and the chiller, and the glycol loop starts from the beginning again. Prior to actually entering the process, the heated, lean glycol goes through an exchanger in the bottom of the glycol surge tank and an exchanger in the boot of the LTS. The additional heat added to the process helps with separation.

Clearwater Plant Overview

The following diagram shows the design conditions at the Clearwater plant:

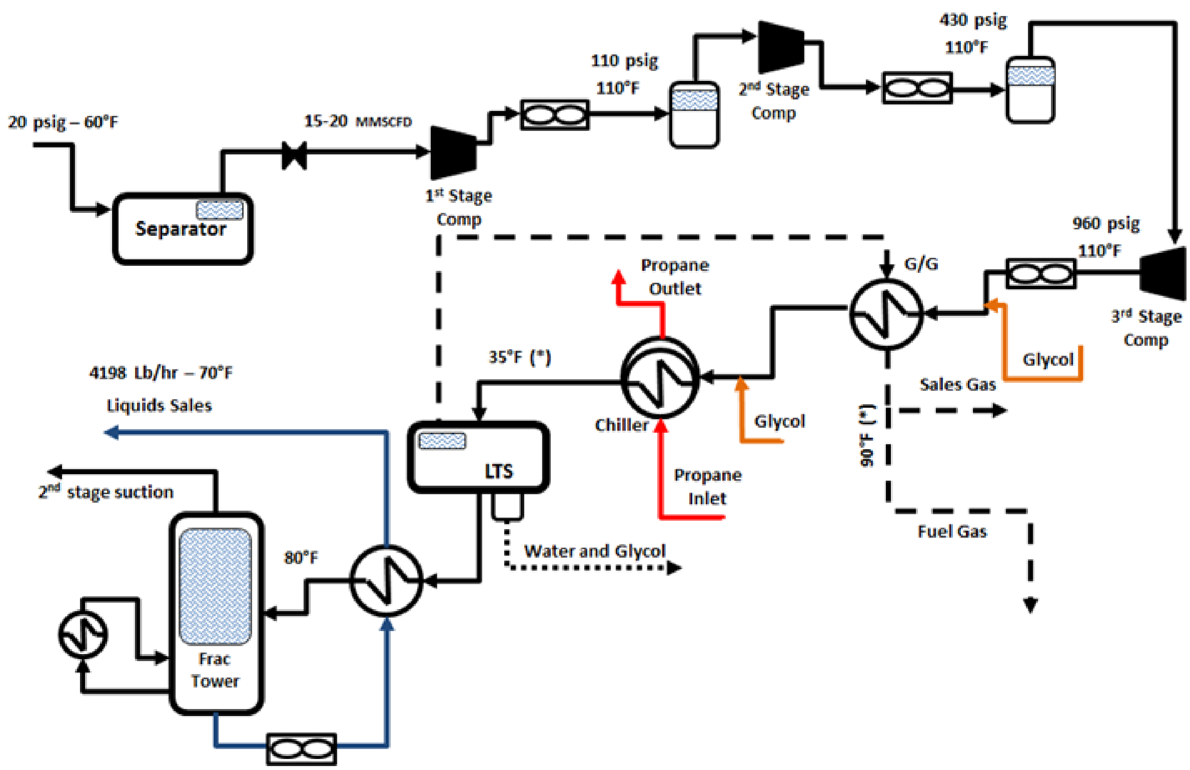

Figure 2- Design Conditions at the Clearwater Plant

The refrigeration process at the Clearwater Gas Plant occurs after three stages of compression, and is followed by a de-ethanizer. NGLs are stored in pressurized bullets and trucked from site, and the gas enters a sales line.

At the time of this study (June 2013), the Clearwater Gas Plant had a throughput of approximately 7.5 MMSCFD (well below design capacity), and the gas was compressed to 798 psi prior to entering the LTS. The NGL production averaged 143 bbls/day. One of the biggest problems at the plant at the time was the issue of freeze-ups in the LTS. Freeze-ups were occurring as water was solidifying in the LTS. This should not be happening if the EG system is running properly. During the 18 months prior to the study, the plant operators had dealt with 12 freeze-ups. The initial indicator was an increase of pressure in the LTS. To help prevent a total freeze-up of the separator, the operators would stop the propane refrigeration loop to allow the plant to warm up. It would then take approximately 24 hours to get the plant back up and running properly, and during that time, the majority of the NGL production was lost (exited with sales gas). In addition to this, the operators would inject methanol into the system on a regular basis to try to prevent freeze-ups throughout the year. However, if an EG system is running effectively, methanol should never be required. Methanol is another form of hydrate inhibition that can be used, but there is no need to use both EG and methanol at the same time if the system is working.

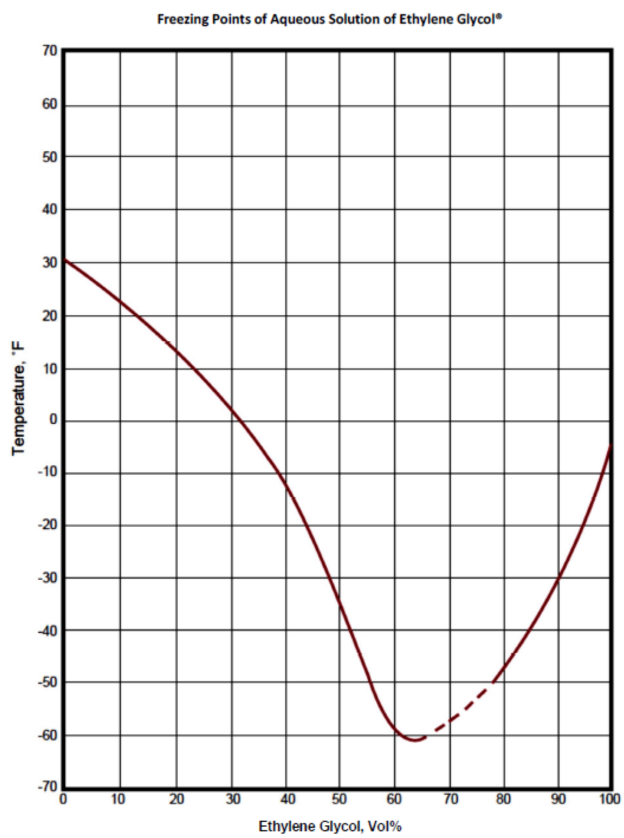

Figure 3- Freezing Point of Aqueous Ethylene Glycol Solution

Analysis and Recommendations

The first step of the study was to take a sample of the lean and rich glycol streams in the process. The samples were tested for water content, glycol degradation, pH, solid contamination, etc. The first thing noted was the lean EG sample water content was lower than the target range. Typically, the lean EG water content should be between 18-25 wt% to effectively suppress the freezing point of the water in the system. The Clearwater lean EG sample had a water content 15.8 wt%. Lean EG water content is a function of reboiler temperature, so it was suggested that this be addressed. Typically reboilers for an EG system are set between 237°F to 248°F. The Clearwater EG reboiler was running at 248°F, so it was recommended to slightly reduce this temperature to allow for higher water content in the lean EG stream. This was a quick change that could be done with the plant online. Having the reboiler run too hot is a waste of energy, and it also may cause degradation of the EG.

Table 1 - EG Analysis Results Prior with Historical Data (2012 – 2013)

Company Name:	Encana	Encana	Encana		
Date Sampled:	9/18/2013	18-Jul-13	9/12/2012		
Location:	Clearwater Plant	Clearwater Plant	Clearwater Plant		
Unit:	Refrige	Refrige	Refrige		
Product Type	Lean EG	Lean EG	Lean EG		
		Analysis Results		Units	**Target Range**
Lean Water Content	0.159	0.158	0.187	Wt. Frac.	0.18-0.25
Rich Water Content	0.228	0.204	0.234	Wt. Frac.	0.35-0.45
Pickup	**0.069**	**0.046**	**0.047**	Wt. Frac.	
PG	0.011	0.101	N/A	Wt. Frac.	<0.001
EG	0.830	0.741	0.813	Wt. Frac.	0.75-0.82
DEG	<0.001	<0.001	<0.001	Wt. Frac.	<0.001
TEG	<0.001	<0.001	<0.001	Wt. Frac.	<0.001
TTEG	<0.001	<0.001	<0.001	Wt. Frac.	<0.001
Methanol	<0.001	<0.001	<0.001	Wt. Frac.	<0.001
Hydrocarbon Content	0.004	<0.001	<0.001	Vol. Frac	<0.001
Amines as Contaminants	<0.001	<0.001	<0.001	Wt. Frac.	<0.001
Foaming Tendency	Nil	Nil	Nil		Nil
Chlorides	<30	<30	<30	mg/L	<1000
pH	9.63	9.09	9.63		7.5 - 9.5
Reserve Alkalinity*	0.48	0.34	2.12		
Suspended Solids	96	34	842	mg/L	<80
Color	Light brown	Light brown	Brown		

The second issue noted in the lean EG sample was the presence of Propylene Glycol (PG). Approximately 10 wt% of the sample was PG, which in theory should not be present at all. PG in the sample indicates that the glycol purchased was contaminated before it even entered the system. PG is counterproductive to the entire refrigeration process; it has a high affinity for hydrocarbons and will carry them into the glycol regeneration loop where they will be boiled off with the water. This can result in unnecessary hydrocarbon liquid losses. This could have also been contributing to additional glycol losses through the still column as well. Because there is no way to rid the system of PG besides emptying it, it was recommended that the entire EG system was flushed and replaced with a fresh batch of 80:20 EG. A complete flush of this system was estimated to be $5,000. A turnaround was planned for September 2013, so the timing was great for this replacement to occur.

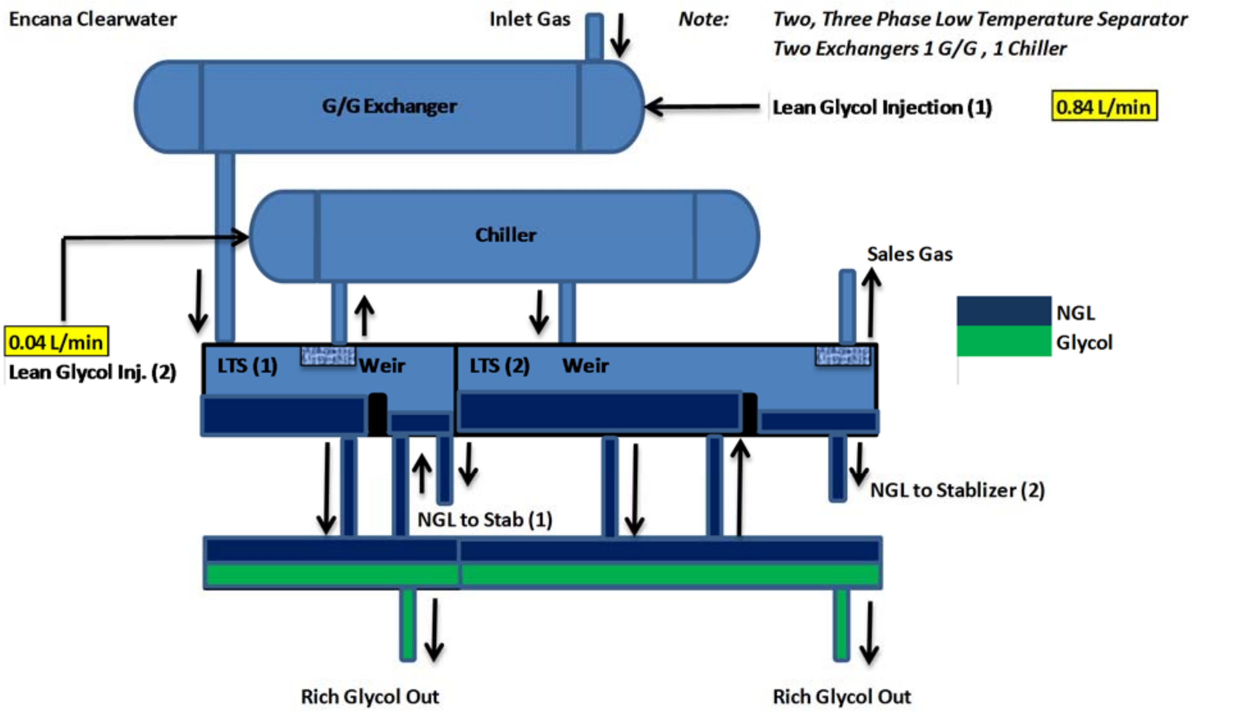

Figure 4 - Plant Layout with Recommended Injection Rates

It was also noted that the rich glycol water content was 24 wt%, and the recommended practice is to be between 35-45 wt%. This shows the extent of the water pick-up after the glycol enters the chiller, gas-gas exchanger and settles in the LTS. Higher water pick-up is better, and is a function of glycol circulation rate. A lower glycol circulation rate allows for longer retention time in the LTS which results in a higher water pick-up by the EG. At the time of sampling, the glycol circulation rate at the plant was 1 gpm; however, the calculated required glycol circulation rate based on plant conditions at the time of the study was only 0.26 gpm. The lower glycol rates increased the glycol-NGL separation time in the LTS, allowing the liquids to separate more efficiently with less NGL carryover. As a result, the production went from, 143 bbl/day to 163 bbl/day, an increase of 14% in NGL production. It is interesting to note that higher glycol circulation did not reduce or eliminate the freeze-ups in the LTS, the EG pump installed at site was functioning at its lowest possible rate. The recommendation was to re-sheave the pump and install a variable frequency drive (VFD) to allow for lower EG circulation rates. This would also reduce fuel gas usage by the pump. The glycol nozzles in the gas-gas exchanger and the chiller would also need to be replaced to ensure the EG still had an effective spray pattern onto the process gas with the lower circulation rate. The cost for a VFD install on a pump of this size as well as nozzle replacements in the gas-gas exchanger and the chiller was estimated to be approximately $6,000.

Lastly, it was recommended to discontinue methanol injection into the refrigeration process. Because the above recommendations would optimize the glycol loop, the methanol would no longer be required as a safety net. The savings from this would be $3,000 per year in methanol costs.

Benefits from Optimization

Based on the recommendations above, the following changes were implemented at the Clearwater plant during the plant turnaround in September, 2013:

1) Discontinued methanol use.
2) Replaced entire EG system with new 80:20 EG.
3) Installed a VFD on the EG Pump.
4) Changed out EG nozzles in the gas-gas exchanger and the chiller

After implementing these changes, several benefits were realized. First of all, the Clearwater plant has not experienced a freeze-up situation in the LTS since the modifications were made. An average of 8 freeze-ups were occurring per year prior to these changes, which caused a loss of approximately 1120 bbls/year of NGL (based on 143 bbls/day NGLs on average). This proves that a properly-functioning EG system does make a difference. Methanol usage has been discontinued and has not been required since.

Table 2- Quantifiable Parameters, Before & After Optimization and % Change

Quantifiable Parameters	Before Optimization	After Optimization	% Change
Total EG Injection Rate (US gallons/min)	1	0.26	- 74 %
Reboiler Temperatures (°F)	248	237	- 5.0 %
Production (Liquids- bbl/d)	143	163	+ 14 %
EG Losses (US gallons/month)	500	300	- 40 %
Downtime (Days per year due to Freezing)	8	0	- 100 %
Methanol Usage (US gallons/month)	106	0	- 100%

All EG systems will require top-ups from time to time, as there will always be EG losses to an extent. Prior to these changes, it was estimated that 500 gallons of EG were required per month to top up the EG system. The high circulation rate and contamination, among other factors, all contributed to unnecessary EG losses. After these changes, it was estimated that only 300 gallons of EG were required per month to top up the system. This is a savings of approximately $1000/month.

The table below outlines the simple changes that were made to the EG regeneration system and the methanol system, as well as the associated costs and savings. This is a small plant, so the savings below make a significant impact on the annual budget.

Table 3- EG System Changes, Costs and Annual Savings

<table>
<tr><th>Recommended Change</th><th>Cost</th><th>Annual Savings</th></tr>
<tr><td>Stop Methanol Usage</td><td>$0</td><td>$3,000</td></tr>
<tr><td>Replace Ethylene Glycol</td><td>$5,000</td><td rowspan="2">$76,000 (freeze-up prevention and glycol savings)</td></tr>
<tr><td>Install a VFD on EG Pump and Replace Nozzles</td><td>$6,000</td></tr>
<tr><td>TOTAL</td><td>$11,000</td><td>$79,000</td></tr>
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Conclusion

The changes made to the EG system at the Clearwater plant have had a measureable effect on liquid production and operational costs. Replacing contaminated glycol, reducing the EG circulation rate by installing a VFD on the pump, and replacing the glycol nozzles have allowed the glycol system to run properly based on the refrigeration process conditions. These changes have prevented freeze-ups in the LTS which in turn have increased annual NGL production. Methanol is no longer required at site, so significant chemical savings have been realized. In addition liquids production has increased

The Clearwater plant is a small-scale plant, but it is an effective case study to show that process monitoring and regular EG sampling is important. In many cases, small changes can be made to the EG system to increase NGL production and significantly reduce operating costs at refrigeration plants.

References

1. **Gas Processors Suppliers Association (2012), “Engineering Data Book”, Thirteenth Edition, Dehydration Section 20.**

2. **John M. Campbell and Company, Web, MEG Dehydration Process Flow Diagram**