Natural Gas Dehydration Process by Mono &Tri-Ethylene-Glycol

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Abstract:

The produced natural gas from a well normally contains: free and/or vapor water, hydrogen sulfide, carbon dioxide and other solid materials. These are considered as impurities that should be removed as much as possible in order to meet the requirement of marketable gas.

The process of natural gas dehydration is very important in: gas-pipelines, -storage, and –marketing. The dehydration by liquid media is more famous and economic than solid media.

Tri-Ethylene-Glycol (TEG), and Mono-Ethylene-Glycol (MEG), units are used for gas dehydration by two types: TEG absorption units, and MEG injection into the gas stream. In this paper, Raguba and Zelten fields are demonstrated as the two types of TEG-, and MEG-units. TEG is found

as the best suited for dehydration of natural gas. Glycol dehydrators are the most common equipment to remove water from gas.

Key words: *Natural gas - dehydration - Hydrates - dew point – absorption - adsorption*

1.Introduction:

Natural gas is one of the cleanest, safest, and most useful forms of energy in our day lives. It is made up of methane (CH_4) mainly, include ethane, propane, and butane. Natural gas can be found by itself or in association with oil. Water, oil, sulphur, carbon dioxide, nitrogen, and other impurities may be mixed with the gas when it comes out of the ground. These impurities are removed before the natural gas is delivered to our homes and businesses, [1-2].

The fact that natural gas is combustible and burns more cleanly than some other energy sources helps reinforce its position as one of the most highly used energy sources. Table 1 gives comparison of the main fossil sources [3].

Table 1: The usage and energy for the main fossil sources

year	consumed amount of:			energy produced in G.J./ tonne of:			
	coal %	oil %	N. gas %	coal		oil	N. gas
1980	25	46	19	brown	black	crude oil	methane
2007	27	36	23	9.5	24	49.5	55
2030	29	33	25				

The transportation of natural gas from a gas well to our homes and businesses requires an extensive network of interconnected pipelines that face some troubles discussed below.

1.1 Hydrates:

Crystalline substances formed by associated molecules of hydrogen and water and having a crystalline structure. Natural gas hydrates look like wet pressed snow turning into ice. Having accumulated in the gas pipeline, they can choke or completely block the pipe and cause damage to the system's operating conditions [4].

If the temperature of pipeline walls or storage tanks decreases below the dew point of the water vapors present in the gas, the water starts to condense on those cold surfaces, and the following problems can appear [5]:

- Natural gas in combination with liquid water can form methane hydrate that may plug the valves, the fittings or even pipelines
- Natural gas dissolved in condensed water is corrosive, especially when it contains CO_2 or H_2S
- Condensed water in the pipeline causes slug flow and erosion
- Water vapor increases the volume and decreases the heating value of the gas
- Natural gas with the presence of water vapor cannot be operated on cryogenic plants

1.2 Dehydration:

When large gas volumes are transported, dehydration is the most efficient and economical means of preventing the hydrate formation in the trunk pipeline. The existing methods for gas dehydration in the field fall into two main groups :

- Absorption (dehydration by liquid media) and
- Adsorption (dehydration by solid media), [6].

The dehydration is aimed at the depression of the water dew point below the minimal temperature that can be expected in the gas pipeline.

Gas dehydration by liquid media is most widely used in the gas industry.

The liquid sorbents used for the dehydration of natural and petroleum gases should have [4]:

- high solubility in water,
- low cost,
- high corrosion resistance.
- chemically neutral towards the gas components, and
- easily regenerated.

Diethylene glycol (DEG), triethylene glycol (TEG) and, to a lower extent, monoethylene glycol (MEG) satisfy most of these requirements.

Advantages of dehydration by means of liquid sorbents [4]:

- ✓ relatively small capital expenditure and operating costs,
- ✓ small pressure differentials in the dehydration system,
- ✓ ability to dehydrate gases containing substances poisoning solid sorbents, and
- ✓ continuous processes.

Disadvantages of dehydration by means of liquid sorbents [5]:

- ☒ smaller depression of the dew point (compared to solid sorbents), and
- ☒ foaming of glycols when the gas contains lighter hydrocarbons.

Glycol dehydration units are of two types [4]:

- absorption units, and
- glycol injection into the gas stream, [7].

Advantage of the absorption scheme (glycol concentration is 96-99%) is minimal glycol losses, but it is difficult to reach the water dew point of the dehydrated gas.

The glycol injection scheme (glycol concentration is 70-80%), the dew point is depressed as the gas cools down, and not only the gas is dehydrated, but also the condensate which has dropped out of the cooled gas.Disadvantage of the glycol injection is glycol losses due to its solubility in the hydrocarbon condensate.

1.3 Dehydration Processes in the Gas Plant:

There are two different dehydration processes in the gas plant.

- Mono- Ethylene Glycol (MEG) is used to remove water from the wet gas,
- Tri-Ethylene Glycol (TEG), which is used in all production fields.

The specifications of both Glycols are summarized in table 2.

Table 2: Comparison of Mono- and Tri- Ethylene Glycol properties

Property	**MEG**	**TEG**
Formula	$HO(C_2H_4O)H$	$HO(C_2H_4O)3H$
Flash point (^{o} F)	240	330
boiling point (^{o} F)	387	549

1.4 Problem statements:

gas treating facilities will be investigated in both fields At present there is a big discrepancy between equipment design parameters and the actual production parameters, Consequently the targeted pipeline specifications cannot be achieved and In this project the options for gas dehydration are reviewed and the glycol dehydration method is discussed in detail in both fields.

1.5 Objectives:

The overall aim of this project is to find solution to the problems of the discrepancy between the gas flow rates and the equipment capacity and consumption of glycol in the both fields , in order to accomplish this, the project will be divided into a number of individual objectives.

1. Conducting a comprehensive survey of the Raguba & zelten gas treating unit
2. To check the flow rate for the stream gas from the gas oil separation plant to the liquid recovery plant.
3. To check the two different dehydration processes in the gas plant.

2. DATA FIELD GAS:

In this work, Raguba and Zelten fields, are demonstrated as the two types of TEG-, and MEG-units. The two field gases are dehydrated by liquid media of TEG, and MEG as follows:

2.1 The First Process in Zelten Field:

The wet gas enters the absorber tower bottom and flows upwards, Fig.1, [8] through contacting devices (usually bubble-caps), Fig. 2, [4]. The glycol (called lean glycol) enters the tower top and flows down across the bubble-cap trays which give intimate contact between the gas and glycol.

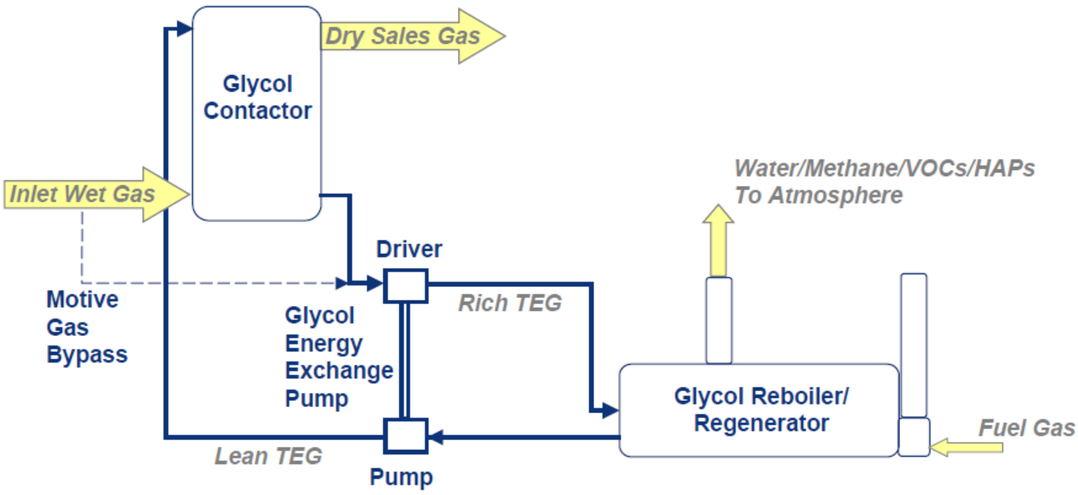

Figure 1: Process diagram of basic glycol dehydrator system

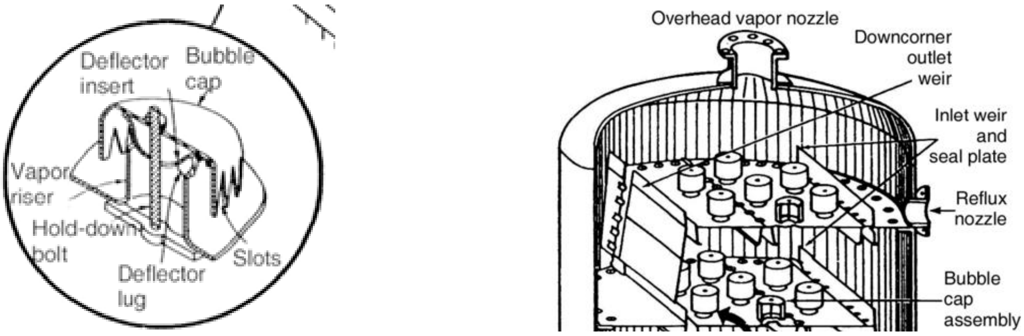

Figure 2: Bubble cap and bubble cap tray in contractor

Dry gas leaves the top of the tower and goes for further processing, while the glycol (now called Rich glycol) leaves the tower bottom and passes to the glycol (Regenerator or Reconcentrator), whereby Distillation the water is vaporized out and passed to the atmosphere as steam. The Rich glycol, is then re-circulated around the dehydration unit.

2.2 The Second Process in Raguba Field:

The lean glycol (MEG) is injected into the wet gas through four points in plant system (there is no contactor –absorption tower), Fig 3. The injection of glycol will prevent the freezing of the water in the gas when a refrigerant (usually propane) is used to cool the gas to below 0 °F for glycol recovery. The rich glycol is collected, separated from gas condensate in a two section separator and then sent to a glycol regeneration system similar to the systems used in other field plants .

It is important to keep the Reflux Coil in the Still column at a temperature of 212 ^{o}F to condense the MEG and allow only water vapor to pass to the vent stack to atmosphere. The lean glycol (after regeneration) is returned from the reboiler to the four injection points, [9].

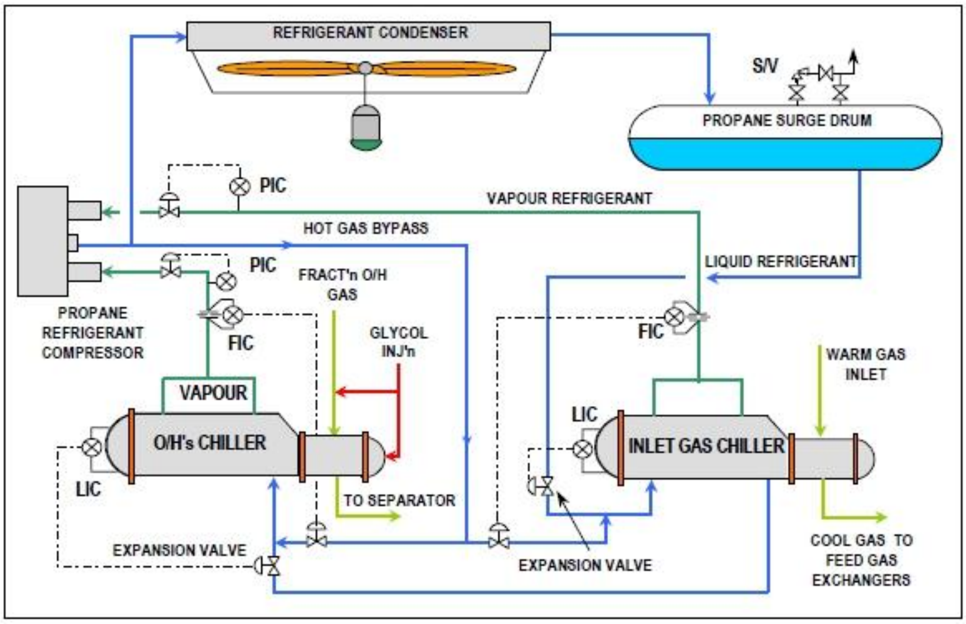

Figure 3: Glycol injection system and propane refrigeration unit

The gas operating pressure in Raguba field is 250 psi and the Dew point is between (-5 and 0 ^{o}F) this well gave (5 to 6 lb.) water / MMSCF of gas, which is within the gas specifications required

3. OPERATING MECHANISM OF THE GLYCOL:

The glycol dehydration process is affected by the following four major variables:

1. Temperature
2. Pressure
3. Glycol flow-rate
4. Glycol concentration

3.1. Temperature of the Wet Gas and Lean Glycol :

It is the key factor affecting the potential use of a glycol dehydrator. It is found that:

- The higher the wet gas temperature, the more water content in vapor form.
- If the temperature of the wet gas is ≥ 140°F, the gas is too difficult to give up the water vapor to the glycol. If the wet gas temperature is ≤ 40°F, the glycol becomes viscous and cannot pick-up the water vapor. So, dehydration will be at temperatures (50 – 130)°F, [9].
- The temperature of the lean glycol should be (10 -15) °F above the wet gas temperature. If it is more, the glycol will tend to foam.
- If the glycol temperature is much lower than the wet gas temperature, liquid hydrocarbons (condensate) will form, causing problems in the glycol regeneration.

3.2 Pressure of the Wet Gas:

At constant temperature, the lower the pressure, the higher the water content of the wet gas. Pressure has very little effect on the mechanics of glycol dehydration.

3.3 Lean Glycol Flow-Rate:

Many factors must be considered but, for simplicity, over a normal pressure range up to 1200 psi, (3 – 5) gallons of glycol must be circulated for every pound of water removed at a 55 °F dew point depression 2.

3.4 Lean and Rich Glycol Concentration:

The usual practice is to introduce the lean glycol concentration from (97 – 99) % at the top, and to remove from the base rich glycol concentration of (80- 90) %.

4. CALCULATIONS AND RESULTS:

The results of glycol dehydration process of the wet gas coming from both Raguba and Zelten field, can be summarized as follows:

4.1 Data and Results of Zelten Field Gas Plant :

Table 3 gives the data of zelten field gas plant of the TEG process for gas dehydration.

Table 3: The given data of Zelten field

Gas flow rate	120 MMSCFD
Gas inlet temp.	100 F
Contactor gas pressure	143 psig
Lean glycol concentration	0.996
Rich glycol concentration	0.97
water content allowed in dry gas	7 lbs / MMSCF
Glycol (TEG) density	9.35 lb /gallon

The amount of water removed by dehydration process is [10]:

(99.6 - 97.0) = 2.6 lb

Lb of water removed Lb Glycol required for removal

2.6 Lb 100

1.0 n

n = 38.46 Lb of glycol 38.46/ 9.35 = 4.113 gallons

The minimum circulation rate of glycol to remove 1 Lb of water is 4.113 gallons. The operational glycol rate should be more than minimum with 20%. So,

The operational glycol flow = 4.113 * 1.2

= 4.936 gal. glycol /Lb water removed

The amount of water required to be removed is defined from the initial water content of the natural gas, and allowed water content of gas in use.
The initial water content of the natural gas is determined; by using saturation curves for gas pressure of 143 psig & temp.100^{o}F, [11].
The initial water content = 305 mmscf (at 14.7 psia-60^{o}F)
The water required to be removed = 305 -7 = 298 lb/mmscf
The minimum glycol flow required/day = 120 * 298 * 4.113
=147080.9 gallon/day
Operational **g**lycol flow **p**er **m**inute = 147080.9 *1.2 /(24*60)
(Operational glycol circulation rate) =122.6 gpm
Operational glycol circulation rate is a function of gas flow rate, as shown in Table 4 [12]:

Table 4: Results of Zelten Field gas plant

Gas flow rate, mmscfd	glycol flow rate Required, gpm
120	122.6
115	117.5
110	112.4

4.2 Data and Results of Raguba Field gas plant :

Table 5 gives the data of Raguba field of the MEG process for gas dehydration.

Table 5: The given data of Raguba field

Gas flow rate	40 MMSCFD
Gas inlet temp.	(80 -120) F
Lean glycol concentration	0.82
Rich glycol concentration	0.67
gas water content required	5 lbs / MMSCF
gas water content	(120 - 400) lb / MMSCF
Glycol density	9.31 lb /gallon

The glycol flow rate can be calculated as follows:

Assume inlet glycol concentration, Ws = 82 %

Wf = 67%

Estimated water balance (EsWb) = 100 (Ws-Wf) / Wf

= 100(82 - 67) / 67

= 22.388 %

Actual water balance = 400 - 5

= 395 lb/ MMSCF

For 40 mmscfd, actual water balance = 40 * 395 / (24 * 60)

= 10.97 lb/min

= (100* Actual water balance / (Estimated water balance)*2

= (100*10.97 / 22.388)*2 = 97.9989

= 98 lb/min

inlet glycol density = 9.16 lb/gal

Water density = 8.328 lb/gal

Lean glycol flow rate = 98 / 9.16

= 10.7 gal/min

Max. water Removed = 10.97/8.328

= 1.3 gal/min

Min. water Removed = 10.97*120/(400*8.328) = 0.395

= 0.4 gal/min

Rich glycol flow rate: max. = 10.7 + 1.3

= 12.0 gpm

min. = 11.1 gpm

The operational parameters of dehydration of gas Raguba field are summarized as follows, Table 6:

Table 6: Results of Raguba Field gas plant

Lean glycol	Concentration (pump discharge)	82 %
	Flow rate	10.7 gpm
Rich glycol	Concentration (to generator)	67 %
	Flow rate: max.	12.0 gpm
	Min.	11.1 gpm

5. DISCUSSIONS AND CONLUSIONS:

From the results obtained in Tables (4, 6) from the data given in Tables (3, 5), it can be said that:

- For Zelten Field Gas Plant, it is found that the operational glycol flow is as follows:
  4.936 gal. glycol /Lb water removed
  Glycol flow rate required is:
  112.4 gpm, when Gas flow rate is 110 mmscfd
- For Raguba Field gas plant:
  For Lean glycol flow rate is 10.7 gal/min
  Max. water Removed is: 1.3 gal/min
  Min. water Removed 0.4 gal/min
  Rich glycol flow rate is 12.0 - 11.1 gal/min

- Glycol is an anti-freeze commonly used in heating loops that are subjected to freezing weather and some cooling loops that are shut down in winter and have piping exposed to the outside. There are two types of glycol. Ethylene glycol performs better but is toxic to humans and animals. Unfortunately it is also sweet smelling and tasting. Typically it is fluorescent pink in color. The second type is propylene glycol. It is less toxic but also less affective. This is the preferred glycol used in businesses concerned with safety such as schools, churches or food plants. Visually it is usually a fluorescent yellow or green.

- Glycol is added to water systems because it is effective in reducing the freezing point and mini-mizing the risk that pipes will freeze and be damaged. glycol does affect the efficiency of heating systems because it does not transfer heat as well as plain water. The use of uninhibited glycol requires the addition of a corrosion protection program. Even if your glycol has an inhibitor you will want to treat your water. Glycol breaks down over time and becomes corrosive to metals. The inhibitors themselves are also broken down through this process leaving the metal in your system unprotected. The presence of oxygen, elevated temperatures, iron and corrosion by-products all increase the rate of break down.

There are four glycols that are used in removing water vapor from natural gas or in depressing the hydrate formation temperature:

- Ethylene glycol (EG), or Mono Ethylene glycol (MEG) is not used in a conventional glycol dehydrator. The main use of it in the dehydration of natural gas is in depressing the hydrate temperature in refrigeration units.
- Of the other three glycols, triethylene glycol (TEG) is the most commonly used glycol for dehydration of natural gas because of its relative advantages relative to DEG:
  - TEG is more easily regenerated to a higher degree of purity
  - Vapor losses are lower
  - Operating costs are lower

- Tetraethylene (T_4EG) glycol would have to be regenerated at higher temperatures than TEG to reach the required purity for application in a glycol dehydration unit.

So, TEG is the best suited for dehydration of natural gas.

The economic efficiency of the absorption plants depends heavily on the sorbent losses.To reduce these it is necessary in the first place strictly to:

- maintain the designed temperature regime of the desorption,
- separate water vapor from the gas carefully, and
- use special additives in order to prevent foaming in the gas/absorbent contact area, if possible.

Glycol dehydrators are the most common equipment to remove water from gas. 36,000 dehydration units in natural gas production, gathering, and boosting. Most use triethyleneglycol (TEG)Glycol. dehydrators create:

- emissions Methane, Volatile Organic Compounds (VOCs),
- Hazardous Air Pollutants (HAPs) from reboiler vent Methane and pneumatic controllers source

The majority of the MEG injection unit problems can be divided into four categories:

- glycol concentration
- glycol circulation
- glycol solution condition
- glycol distribution

It is necessary to control the amount present of water vapor in the residual gas in order to prevent the formation of hydrates in pipeline. If hydrates are formed, it may lead to plugging of the pipe line and pressure control valves or cause corrosion of the pipe line.

Most operating and technical problems occur when the circulating glycol solution gets dirty. In order to get a

long, trouble-free life with the glycol system, it is necessary to recognize the following problems and know

how to prevent them:

- Glycol loss
- Foaming
- Thermal Decomposition of glycol
- Dew point control
- glycol PH control
- Salt contamination
- Glycol oxidation
- Sludge formation

6. RECOMMENDATIONS:

Methane that flashes from rich glycol in an energy-exchange pump can be captured using a Flash Tank Separator (FTS), Fig.4

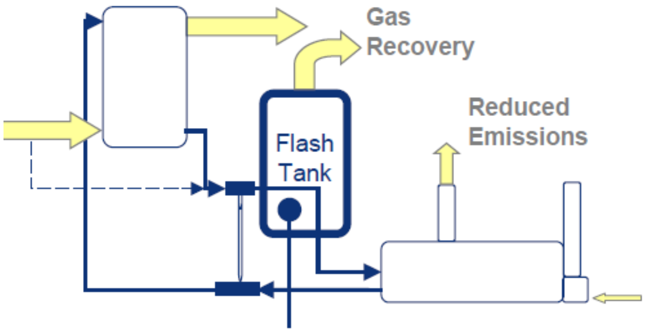

Figure 4: Glycol dehydrator system with Flash Tank Separator (FTS)

When the glycol reaches the flash tank, its temperature has been raised through the coil in the reboiler still, and the pressure in the flash tank is at a much lower level, generally between 15 to 50 psig, than the pressure in the contactor. In light of these changed conditions of pressure and temperature between the absorber and flash tank, most of the dissolved gases evolve from the glycol in the flash tank.

Flash Tank Separator (FTS), has the following merits:

- recovers about 90% of methane emissions
- reduces VOCs by 10 to 90%
- must have an outlet for low pressure gas:
  - Fuel Compressor
  - suction Vapor
  - recovery unit Flash
- Capital costs range from $3,500 to $7,000 per flash tank
- Installation costs range from $1,200 to $2,500 per flash tank [5]
- Negligible Operational & Maintenance costs

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