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THE BEST TECHNIQUE FOR TREATMENT OF GAS IN DEHYDRATION UNIT AT BALHAF PLANT - YEMEN

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN OIL AND GAS ENGINEERING

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DECLARATION

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APPROVAL

This is to certify that the project titled **The Best Economical Treatment for Gas in Dehydration Unit.** has been read and approved for meeting part of the requirements and regulations governing the award of the Bachelor of Engineering (Oil and Gas) degree of Emirates International University, Sana'a, Yemen.

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ABSTRACT

The purpose of this study is to Dehydration natural gas from water vapor using the Dehydration unit and make a comparison between the methods of Dehydration processes and select the best economic way. It is realized that dehydration is necessary to ensure the smooth operation of gas, transmission lines. dehydration prevents the formation of gas hydrates that may cause a Deceleration in gas flow or cause a Piping plugging, reduces corrosion. dehydration is a very simple process, ideal for remote locations with limited facilities, environmental benefit, easy to install and operate and this work evaluates dehydration processes that are able to reach water contents ranging from 600 ppm down to < 10 ppm, with a focus on TEG (triethylene glycol) and molecular sieve systems. It considers a range of flow rates, constraints on the dehydration pressure and the range of other substances in the CO_2 gas.

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First of all, we owe our most sincere gratitude to Allah the almighty and the most powerful for offering us such a strength, endurance, willingness, and capability to accomplish this project.

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TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

CHAPTER ONE

1. INTRODUCTION

1.1. BACKGROUND

The formation of hydrates in gas lines and/or processing equipment is very dangerous in most cases as it can lead to the reduction of pressure across lines/equipment as well as possible line blockage and it is a serious concern in oil and gas production systems in both offshore and onshore field environments.

The formation and possible deposition of hydrates usually occur in suitable conditions, specifically as the gas-phases of reservoir fluid interact with water molecules. Usually, hydrates problems are found during normal multiphase flow of oil/water/gas, however, often the problem is more vulnerable in transient operations Many researchers have extensively studied this area, yet, the extent at which the properties of reservoir fluids interact is still on-going, especially at low temperature and high pressures. The basic technological features of hydrate formation and decomposition or dissociation processes have been poorly understood.

1.2. AIMS AND OBJECTIVES

1.2.1. AIMS

Treatment of the gas and select the best economical for removing impurities and dehydration process methods.

1.2.2. OBJECTIVES

1. Removal of acidic gases (H_2S and CO_2) by amine sweetening process.
2. Removal of water vapor by Dehydration unit.
3. Monitoring the temperature and pressure level.
4. Making a comparison between the dehydration processes ways in all aspects, especially the economic aspect.

1.3. PROBLEM STATEMENT

The formation treatment of hydrates in gas lines and/or processing equipment is very important in most cases as it can lead to the reduction of pressure across lines/equipment as well as possible line blockage and it is a serious concern in oil and gas production systems in both offshore and onshore field environments. Therefore, it is considered to be one of the main issues that must be analyzed and understood at the early stage of the oil and gas fields' development using all processes available for natural gas processing including Treatment of the gas and select the best economical for removing impurities and dehydration process methods. This problem will be the main focus of this graduation project study.

1.4. RESEARCH QUESTION

What are the Best Economical Treatment for Gas in Dehydration Unit that exist Yemen LNG company, Belhaf Yemen?

1.5. SIGNIFICANT OF THE RESEARCH

This research study will highlight the Best Economical Treatment for Gas in Dehydration unit at Yemen LNG company. The research will also validate the analysis of The Best Economical Treatment for Gas in Dehydration.

1.6. SCOPE OF THE RESEARCH

Yemen LNG is the scope of this research. only one problem was taken to be treatment.

1.7. YEMEN LNG COMPANY

Yemen LNG is the country's largest industrial project and by far its biggest foreign direct investment. between the government of Yemen and various stakeholders, the largest of which is Total. Launched in 2005 this is the biggest ever foreign investment in Yemen at around 4.5 Billion USD. Yemen LNG exports the Natural Gas resources of Yemen to the world. It is a key pillar to the economic development of Yemen.

Figure 1-1 Yemen LNG Company

LNG is exporting nations form a small and exclusive club. Yemen LNG therefore represents a major vote of confidence in the country. It provides a large, stable and long-running source of government revenues. Yemen LNG Plant has proved to be one of the most reliable and modern LNG plants in the world. At full capacity, it makes Yemen the third largest LNG exporter in the Middle East and amongst the top ten in the world. Yemen LNG’s strategic location allows it to serve markets in Asia, Europe and the Americas where it is important that customers have the confidence in a steady supply of energy.

Yemen LNG Company is the first LNG plant in Yemen, the Arab world’s poorest state, and is its largest industrial project Yemen LNG is the first LNG plant to utilize induction motors with voltage source inverted (VSI) drives as starter/helper motors for the refrigeration compressor strings. Previous plants had utilized either synchronous motors or steam turbines.

At Yemen LNG, the gas emitted from the LNG tanks is used to produce electricity for the plant on-site. This is now the only power source available in a region where there are no other remaining electricity production and distribution grids.

The Yemeni government has granted Yemen LNG exclusive rights to the gas reserves of the Marib area fields in block 18. The reserves currently dedicated to the project include 9.15 trillion cubic feet (TCF) of proven reserves and 0.7 TCF of probable reserves with 1 TCF allocated to the domestic market. The reserves were re-certified by the independent consultants DeGolyer and McNaughton in May 2005.

The reservoirs have been producing reliably since 1986 and proven gas reserves are sufficient to produce and export 6.7 million metric tons per annum of LNG for at least a period of 20 years.

Associated gas is currently produced with oil from some 450 active wells and a high percentage of the reserves will be produced from fields already in production.

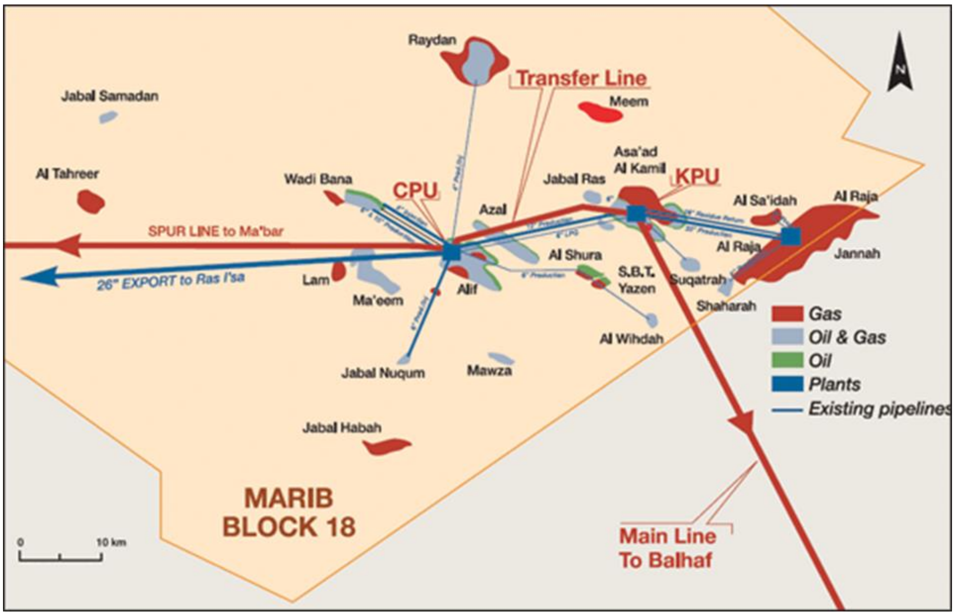


Figure 1-2 Marib fields, CPU: Central Processing Unit, KPU: Kamil Processing Unit.

The Yemen LNG project involves upgrading onshore gas production facilities at Marib oil and gas fields and constructing a buried pipeline and a world-class, highly automated LNG Plant facility in Balhaf harbor area on the coast of Shabwah governorate, approximately 130 kilometers west of Mukalla and 400 kilometers east of Aden. The main project components are:

- A 25 km, 20-inch transfer line linking the two gas processing units in the gas fields of block 18 in Marib.
- A transfer pipeline to connect the two gas processing centers at Safer
- A main pipeline of 320-kilometer length and 38-inch diameter to deliver gas from the processing center (KPU) to the planned liquefaction plant.
- A spur line to the city of Ma’bar to supply domestic consumption.
- A LNG plant located at Balhaf which will involve construction of the following marine facilities:
  - A jetty for LNG Carriers loading and shipping.
  - A Material Offloading Facility (MOF) for tug boat mooring.
  - A sea water intake pipe.
  - A water outfall pipe.
  - A shoreline protection.

1.7.1. THE MAIN PIPELINE

The Main Line is built with the capacity to supply feed gas from Marib at a rate of 1,140 million standard cubic feet per day to the LNG plant at Balhaf. This pipeline is 320 km in length with a 38-inch diameter and has been buried over its entire length. The pipeline route passes mainly through deserts and thinly populated regions ensuring minimal impact on the natural habitat and livelihoods of the local population.

Figure 1-3 Yemen LNG Pipeline

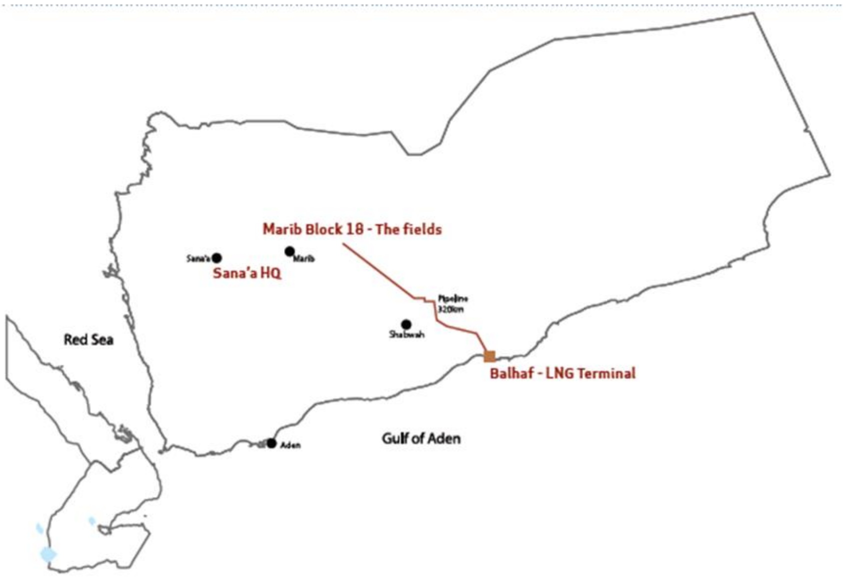


Figure 1-4 Yemen LNG Transfer Line

1.7.2. PLANT AND PORT FACILITIES

Yemen LNG has constructed the liquefaction plant and port facilities in Balhaf on the coast of Shabwah. The plant and the loading port area are located on a 20 km2 site at Balhaf, situated on the coast of Shabwah, approximately 200 km west of Mukalla and 400 km east of Aden.

Figure 1-5 Yemen LNG Liquefaction Plant and Port Facilities in Balhaf on the coast of Shabwah.

1.7.3. SITE SELECTION: WHY BALHAF?

The initial screening of the various site alternatives to identify the best LNG plant location took place in 1995. The rationale was to select a combination of LNG plant locations and pipeline routes to transport the gas which would optimize the economics of the project while minimizing its environmental and social impacts. The Marib gas field location being fixed, various alternatives were reviewed, and these considered the available options for an access to the sea and a pipeline route through difficult geographical features such as mountains and narrow valleys in areas with a rapid population growth.

In June 1995, a survey of six pre-selected sites was carried out, followed by preliminary comparative studies. Based on these additional surveys and studies, detailed studies were conducted for three sites, Ghubb Diknah, Ras Imran and Balhaf.

This thorough survey and the comparison of the three selected port sites identified Balhaf as the most suitable location for a number of reasons. Minimizing the likely impact on the environment and local communities played an important factor in the selection of the final location. Moreover, Balhaf has the lowest geotechnical risk, natural protection and shelter from the waves and winds of the winter monsoon, eliminating the need for a breakwater and a deep harbor, which reduces jetty length, and dredging requirements and which can accommodate large-capacity LNG carriers.

1.7.4. PLANT TECHNOLOGY:

Built and operated by Yemen LNG, the plant is based on the proven C3/MR industry standard APCI process and consists of two parallel processing trains with a total guaranteed production capacity of 6.7 million metric tons per year. In addition, two 140,000 m3 storage tanks are being operated as well as ancillary facilities, such as, power generation, desalination, waste water treatment and steam generation, to enable the project to operate on a self-supporting basis in an efficient, reliable and environmentally compliant manner in accordance with applicable international standards.

The proven production capacity of the plant has been reserved to supply sales commitments in the Asian, European and American markets.

Figure 1-6 Yemen LNG Liquefaction Storage Tanks

1.8. HISTORY OF YEMEN LNG COMPANY

Yemen LNG Company was incorporated in 1995 to develop the LNG plant. In 1997, the development was halted because of the Asian economic crisis. The project was launched only in August 2005 after signing three LNG supply contracts. On 29 October 2007, Yemen LNG and Yemen state-owned oil and gas company Safer Exploration and Production agreed a 20-year contract, according to which Safer grants the LNG plant with supply up to 12.5 billion cubic meter (BCM) of gas per year from the Block 18 of the Marib-Jawf field. The production started on 15 October 2009.

The Construction of the plant commenced in September 2005 and production is expected to begin early 2009. It is the Yemen LNG Company goal to achieve internationally recognized environmental performance in biodiversity conservation during all phases of design, construction, operation and decommissioning of the plant.

In 1995, the partners in the Block 18 fields in the Marib area had an ambition. They were producing oil, but they knew the fields also held large quantities of gas. How, in a remote and under-developed area, could they bring this gas to consumers, and so bring earnings to Yemen while assisting the local economy?

Liquefied natural gas – LNG – became during the 1990s a much more large-scale and mainstream way of moving gas over long distances. By cooling the gas to a liquid, its volume decreases by 600 times, so it can be carried by tanker. With reductions in cost, and the growth of the LNG market, the solution for the Marib gas became clear.

Table 1-1 History of Yemen LNG Company

Jan 1995	Yemen LNG established
March 1997	Yemeni Parliament ratifies the Gas Development Agreement.
Aug 2005	Yemen LNG signs sales & purchase agreements with KOGAS, GDF-Suez and Total Gas & Power Ltd.
Sep 2005	Construction of the plant and pipeline begins.
May 2008	Yemen LNG signs $2.8 billion of project financing.
May 2008	Yemen LNG completes 320-km gas pipeline construction from Marib fields to Balhaf.
Nov 2008	First gas arrives at Balhaf through the pipeline.
Nov 2009	Yemen LNG exports its first cargo of liquefied natural gas.
June 2010	Yemen LNG fully inaugurated, with both trains operating.
Nov 2012	Yemen LNG successfully achieves Lenders' Completion from its project financing consortium.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. INTRODUCTION

The Literature review is one of the main phases in performing any research, as it usually highlights the main gaps in the previous studies, which may need to be filled. It helps also to understand the necessary direction to follow to develop the study.

2.2. NATURAL GAS PROCESSING.

Natural-gas processing is a range of industrial processes designed to purify raw natural gas by removing impurities, contaminants and higher molecular mass hydrocarbons to produce what is known as pipeline quality dry natural gas natural-gas processing plants purify raw natural gas by removing contaminants such as solids, water, carbon dioxide (CO_2), hydrogen sulfide (H_2S), mercury and higher molecular mass hydrocarbons. Some of the substances which contaminate natural gas have economic value and are further processed or sold. An operational natural gas plant delivers pipeline-quality dry natural gas that can be used as fuel by residential, commercial and industrial consumers

2.3. LIQUEFACTION TECHNOLOGY

the refrigeration and liquefaction section is the key element of the LNG plant. there are a lot of licensed processes available with varying degrees of application and experience. the principle for cooling and liquefying the gas using refrigerants involve matching as closely as possible the cooling/heating curves of the process gas and the refrigerants. this result in a more efficient thermodynamic process requiring less power per unit of LNG produced. This applies to all liquefaction processes.

However, the way this is achieved and the equipment used play a major part in the overall efficiency, operability, reliability and cost of the plant. The liquefaction section typically accounts for 30-40 % of the capital cost of the overall plant.

Key equipment items include the compressors used to circulate the refrigerants the compressor drives and the heat exchangers used to cool and liquefy the gas and exchange heat between refrigerants. For recent base load LNG plants this equipment is among the biggest of its type and at the leading edge of technology.

2.4. THE LNG PROCESS

An example of an LNG plant overall flow scheme, and the main process unit and supporting utilities, is shown in **Fig. 2-1**. The process and utility requirement depend, amongst other things, on site conditions, feed gas quality and product specification.

In a typical scheme the feed gas is delivered at high pressure from upstream gas fields via trunk lines and any associated condensate will be removed. The gas is metered and its pressure controlled to the design operating pressure of the plant.

The gas is first preheated to remove any impurities that interfere with processing or are undesirable in the final products. these include acid gases and Sulphur compounds (for example, CO_2, H2S and mercaptans), water and mercury.

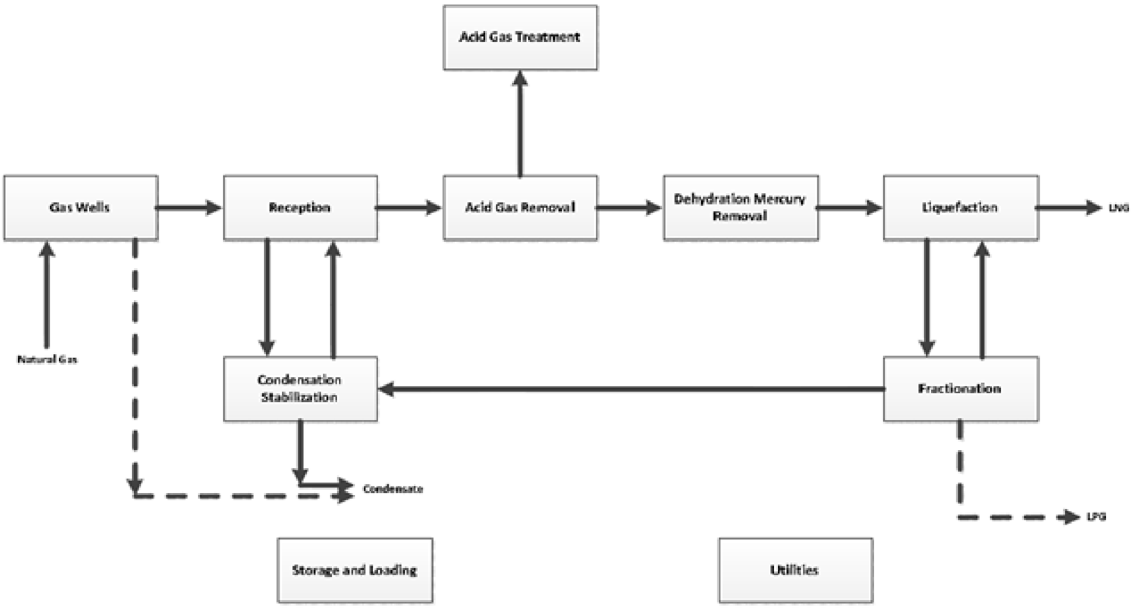


Figure 2-1 LNG Block Flow Scheme

2.5. THE AMINE PROCESS

Amine treating is a type of gas sweetening that refers to a group of processes that utilize solvents to remove acid gasses, H2S (Hydrogen Sulfide) and CO2 (Carbon Dioxide), from process streams. It is commonly used in refineries and gas plants to improve safety, prevent corrosion and meet environmental regulations. There are several types of Amines that are commonly used in industry today:

- Primary Amines: MEA, DGA.
- Secondary Amines: DEA, DIPA.

- Tertiary Amines: MDEA, TEA.
- Mixed Amines.
- Formulated Amines: UCARSOL, FLEXSORB.

There are more 30 processes for natural gas sweetening, below are some point for selection of sweetening processes:

- Type of impurities to be removed
- Inlet and outlet acid gas concentration
- Gas flow rate, Temperature and pressure.
- Environmental consideration
- Relative economics

The most widely used for sweetening of natural gas are aqueous solutions alkanolamine. It used for bulk removal of CO_2 and H2S with low operation cost.

The acid gas is fed into a scrubber to remove entrained water and liquid hydrocarbons. The gas then enters the bottom of Absorption tower which is either a tray (for high flow rate) or packed (for lower rate). The sweet gas exits at the top of tower. The regenerated amine (lean amine) enter at the top of this tower and the tow streams are contacted counter currently. The chemistry involved in the amine treating of such gases varies somewhat with the particular amine being used. For one of the more common amines, monoethanolamine (MEA) denoted as RNH2, the chemistry may be expressed as:

RNH2 + H2S = RNH+3 + SH−

The amine concentration in the absorbent aqueous solution is an important parameter in the design and operation of an amine gas treating process.

Depending on which one of the following four amines the unit was designed to use and what gases it was designed to remove, these are some typical amine concentrations, expressed as weight percent of pure amine in the aqueous solution.

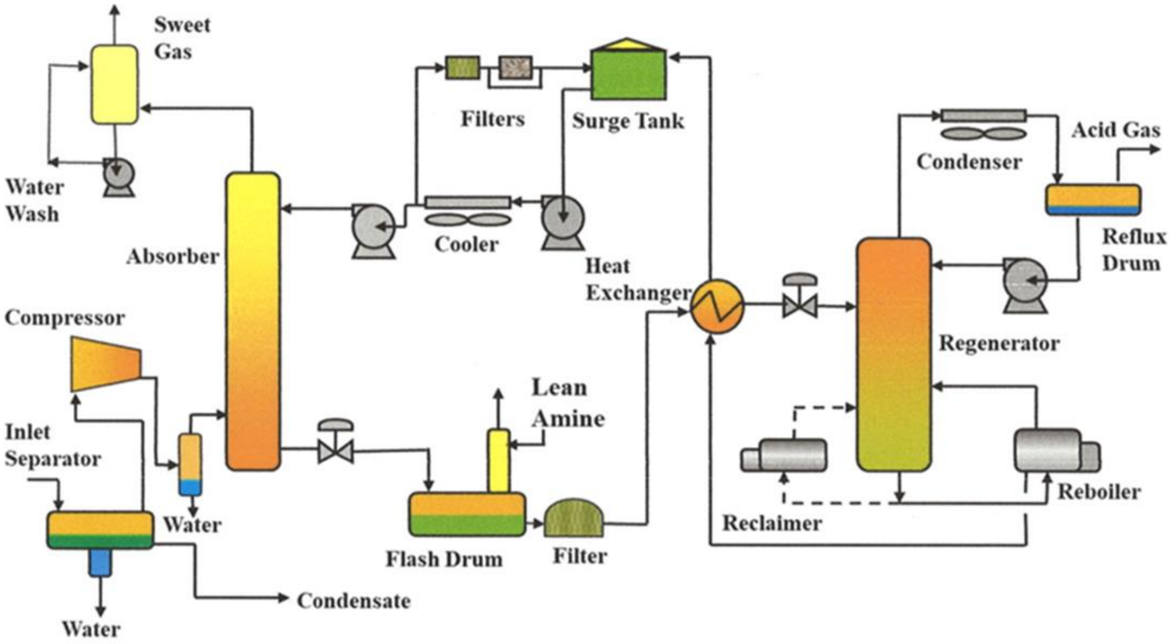


Figure 2-2 Amine Sweetening Process Block Diagram

2.6. CLAUS TECHNOLOGY

The Claus Process was invented in 1883 by the English scientist, Carl Friedrich Claus. The basic Claus Process mixed hydrogen sulfide with oxygen and passed the mixture across a pre-heated catalyst bed. The end products were sulfur, water and thermal energy. Because the process performed best at 400°F to 600°F, and the reaction heat could be removed only by direct radiation, only a small amount of H2S could be processed at one time without overheating the reactor. The process was improved in 1938 by I.G. Farbenindustrie A.G., a German company, by the addition of free-flame oxidation ahead of the catalyst bed and revising the catalytic step. This “Modified Claus Process” greatly increased the sulfur yield and is the basis of most Sulfur Recovery Units (SRU) in use today.

2.6.1. CLAUS PROCESS

Feed gas for a Claus Sulfur Recovery Unit usually originates in an acid gas sweetening plant. The stream, containing varying amounts of H2S and CO_2, is saturated with water and frequently has small amounts of hydrocarbons and other impurities in addition to the principal components.

In a typical unit, H2S-bearing gas enters at about 8 psig and 120°F. Combustion air is compressed to an equivalent pressure by centrifugal blowers.

The free-flame Modified Claus reaction can convert approximately 50% to 70% of the sulfur gases to sulfur vapor. The hot gases, up to 2,500°F, are then cooled by generating steam in a waste heat boiler. the gases are further cooled by producing low-pressure steam in a separate heat exchanger.

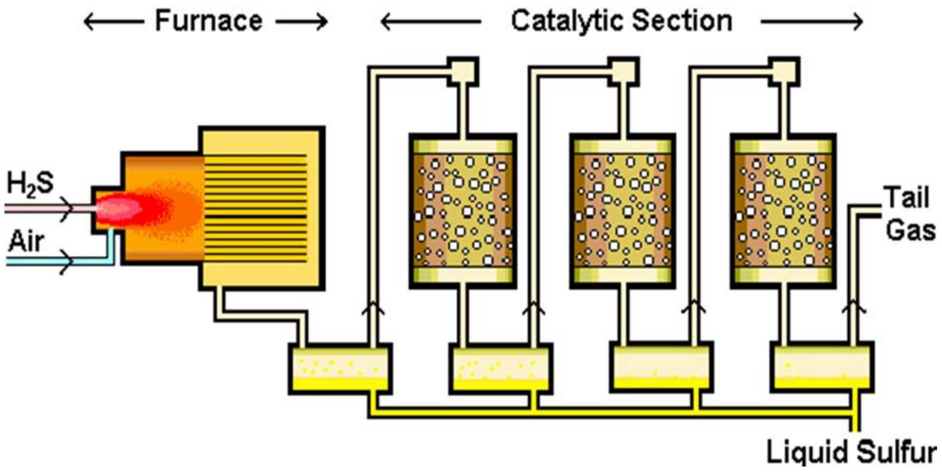


Figure 2-3 Claus Process Block Diagram

2.7. NGL FRACTIONATION UNIT

NGL fractionation comprises a series of distillation columns. such as deethanization, depropanization, debutanization, and butane splitting (or deisobutanization). The control schemes for each are analogous. The major control points for these fractionators are reboiling heat, reflux, and pressure. Again, As the stripping and rectification are interactive and affect both top and bottom product purities, the control of the columns is not straightforward. A dynamic model will provide the capability to select the best control strategy given the particular column operation and specifications and given the expected disturbances in the feeds.

2.8. DEHYDRATION UNIT

Natural gas dehydration is the process of removing water vapor from the gas stream to lower the dew point of that gas. Water is the most common contaminant of hydrocarbons. It is always present in the gas–oil mixtures produced from wells. The dew point is defined as the temperature at which water vapor condenses from the gas stream. The sale contracts of natural gas specify either its dew point or the maximum amount of water vapor present.

2.8.1. THE PURPOSE OF DEHYDRATION IS TO:

- Eliminate the water vapor from the gas
- Prevent corrosion of equipment, especially if the separation gas contains CO_2, as $CO_2 + H_2O$ = carbonic acid (which is present only in ionic form)
- Eliminate the risk of droplets arriving in centrifugal compressor rotors
- Decrease pressure loss in pipelines and accumulation of free water in the low
- Make possible downstream processing such as gasoline stripping and LPG recovery
- Decrease the work load of molecular sieve dryers upstream of the turbo expanders
- Prevent corrosion problems in the lift gas or injection gas systems.

There are three basic reasons for the dehydration of natural gas streams:

1. To prevent hydrate formation. Hydrates are solids formed by the physical combination of water and other small molecules of hydrocarbons. They are icy hydrocarbon compounds of about 10% hydrocarbons and 90% water. Hydrates grow as crystals and can build up in orifice plates, valves, and other areas not subjected to full flow. Thus, hydrates can plug lines and retard the flow of gaseous hydrocarbon streams. The primary conditions promoting hydration formation are the following:
    A. Gas must be at or below its water (dew) point with ‘‘free’’ water present.
    B. Low temperature.
    C. High pressure.
2. To avoid corrosion problems. Corrosion often occurs when liquid water is present along with acidic gases, which tend to dissolve and disassociate in the water phase, forming acidic solutions. The acidic solutions can be extremely corrosive, especially for carbon steel, which is typically used in the construction of most hydrocarbon processing facilities.
3. Downstream processing requirements. In most commercial hydrocarbon processes, the presence of water may cause side reactions, foaming, or catalyst deactivation.

Consequently, purchasers typically require that gas and liquid petroleum gas (LPG) feedstock meet certain specifications for maximum water content. This ensures that water-based problems will not hamper downstream operations.

2.8.2. GAS DEHYDRATION PROCESSES

This section discusses the conventional methods for drying natural gas, and then briefly describes some less-conventional methods. Two processes, absorption and adsorption, are the most common and are discussed in more detail.

1. Absorption Processes

Overview of Absorption Process:

Water levels in natural gas can be reduced to the 10 pmmv range in a physical absorption process in which the gas is contacted with a liquid that preferentially absorbs the water vapor. The solvent used for the absorption should have the following properties:

- A high affinity for water and a low affinity for hydrocarbons.
- A low volatility at the absorption temperature to reduce vaporization losses.
- A low viscosity for ease of pumping and good contact between the gas and liquid phases.
- A good thermal stability to prevent decomposition during regeneration.
- A low potential for corrosion.

In practice, the glycols, ethylene glycol (EG), diethylene glycol (DEG), triethylene glycol (TEG), tetraethylene glycol (TREG) and propylene glycol are the most commonly used absorbents; triethylene glycol is the glycol of choice in most instances. For operations in which frequent brine carryover into the contactor occurs, operators use EG because it can hold more salt than the other glycols. The solubility of sodium chloride in EG water mixtures is around 20 wt% (Masaoudi, 2004; Parrish, 2000; Trimble, 1931), whereas it is only around 5 wt% in TEG (Kruka, 2005).

Table 2-1 Glycols Used in Dehydration

Name	Formula	Maximum Recommended Regeneration Temperature, °F (°C)a
Ethylene glycol (EG)	HO—(CH2)2—OH C2H6O2	
Diethylene glycol (DEG)	HO—((CH2)2—O)—(CH2)2—OH C4H10O3	325 (160)
Triethylene glycol (TEG)	HO—((CH2)2—O)2—(CH2)2— OH C6H14O4	360 (180)
Tetraethylene glycol (TREG)	HO—((CH2)2—O)3—(CH2)2— OH C8H18O	400 (200)
Propylene glycol	HO—(CH2)3—OH C3H8O2	

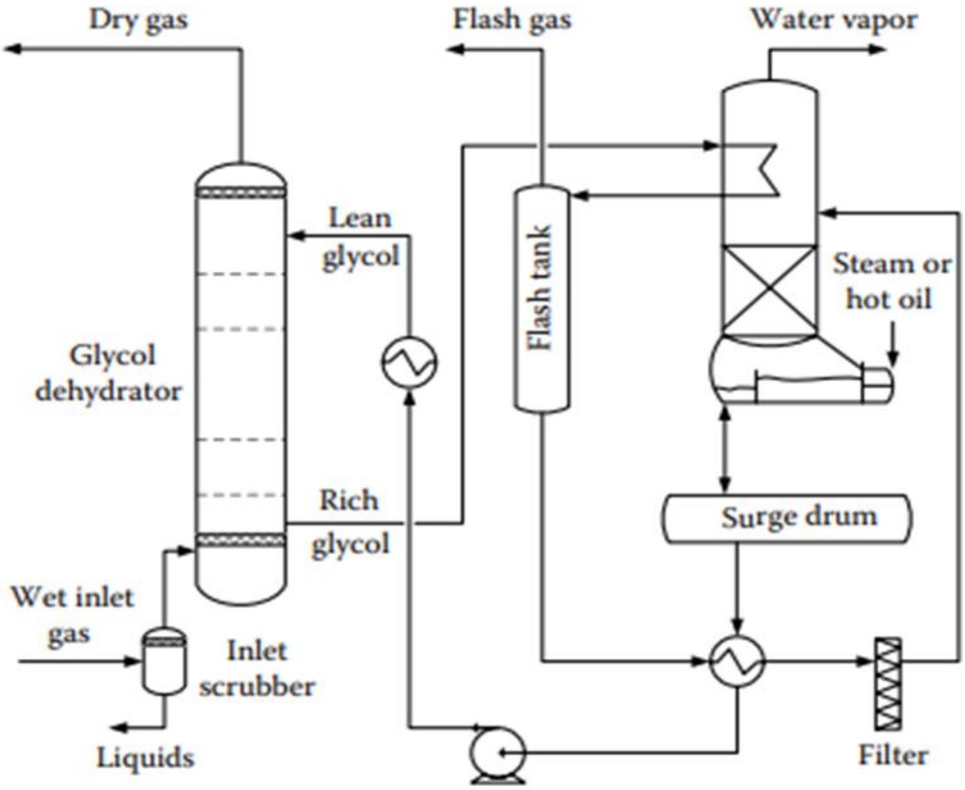


Figure 2-4 Schematic of typical glycol dehydrator unit. (Adapted from Engineering Data Book, 2004b)

The wet gas passes through an inlet scrubber to remove solids and free liquids, and then enters the bottom of the glycol contactor. Gas flows upward in the contactor, while lean glycol solution (glycol with little or no water) flows down over the trays. Rich glycol absorbs water and leaves at the bottom of the column while dry gas exits at the top. The rich glycol flows through a heat exchanger at the top of the still where it is heated and provides the coolant for the still condenser. Then the warm solution goes to a flash tank, where dissolved gas is removed. The rich glycol from the flash tank is further heated by heat exchange with the still bottoms, and then becomes the feed to the still. The still produces water at the top and a lean glycol at the bottom, which goes to a surge tank before being returned to the contactor.

2. Adsorption Processes

The second type of adsorption are physical adsorption and chemisorption. In physical adsorption, the bonding between the adsorbed species and the solid phase is called van der Waals forces, the attractive and repulsive forces that hold liquids and solids together and give them their structure. In chemisorption, a much stronger chemical bonding occurs between the surface and the adsorbed molecules. This chapter considers only physical adsorption, and all references to adsorption mean physical adsorption.

For a given vapor-phase concentration (partial pressure) and temperature, an equilibrium concentration exists on the adsorbent surface that is the maximum concentration of the condensed component (adsorbate) on the surface.

Gas plants, polar molecules, like water, will be more strongly adsorbed than weakly polar or nonpolar compounds. Thus, methane is displaced by the weakly polar acid gases that are displaced by the strongly polar water. How size affects adsorption depends upon the pore size of the adsorbent. An adsorbate too large to fit into the pores adsorbs only on the outer surface of adsorbent, which is a trivial amount of surface area compared with the pore area.

If the pores are sufficiently large to hold different adsorbates, the less volatile, which usually correlates with size, adsorbates will displace the more volatile ones. Therefore, ethane is displaced by propane. In commercial practice, adsorption is carried out in a vertical, fixed bed of adsorbent, with the feed gas flowing down through the bed. As noted above, the process is not instantaneous, which leads to the formation of a mass transfer zone (MTZ) in the bed. the three zones in an adsorbent bed:

1) The equilibrium zone, where the adsorbate on the adsorbent is in equilibrium with the adsorbate in the inlet gas phase and no additional adsorption occurs

2) The mass transfer zone (MTZ), the volume where mass transfer and adsorption take place
3) The active zone, where no adsorption has yet taken place

When used as a purification process, adsorption has two major disadvantages:

- It is a fixed-bed process that requires two or more adsorption beds for continuous operation.
- It has limited capacity and is usually impractical for removing large amounts of impurity. However, adsorption is very effective in the dehydration of natural gas

because water is much more strongly adsorbed than any of the alkanes, carbon dioxide, or hydrogen sulfide. Generally, a higher degree of dehydration can be achieved with adsorbents than with absorption processes.

2.8.3. PROPERTIES OF INDUSTRIAL ADSORBENTS FOR DEHYDRATION

Three types of commercial adsorbents are in common use in gas processing plants:

- Silica gel, which is made of pure SiO_2.
- Activated alumina, which is made of Al_2O_3.
- Molecular sieves, which are made of alkali aluminosilicates and can be altered to affect adsorption characteristics.

Table 2-2 lists the more important properties of three adsorbents compiled primarily from commercial literature. The properties are representative and vary between manufacturers.

Table 2-2 Representative Properties of Commercial Silica Gels, Activated Alumina, and Molecular Sieve 4A

	Silica Gel	Activated Alumina	Molecular Sieve 4A
Shape	Spherical	Spherical	Pellets (extruded cylinders) and beads
Bulk Density **Ib/ft^3 (Kg/M^3)**	49 (785)	48 (769)	40 – 45(640 – 720)
Particle Size	4 – 8 mesh 5 – 2 mm	7 – 14 mesh, 1/8-inch 3/16-inch, 1/4-inch diameter (3-mm, 5-mm, 6mm)	1/16-inch,1/8-inch,1/4-inch diameter cylinder (1.6-mm, 3.2-mm, 6-mm
Packed Bed % Voids	35	35	35
Specific Heat **Btu/Ib-^{O}f (KJ/Kg-K)**	0.25 (1.05)	0.24 (1.00)	0.24 (1.00)
Surface Area M^2/G	650 – 750	325 – 360	600 – 800
Pore Volume Cm^{3}g	0.36	0.5	0.28
Regeneration **Temperature, ^{O}f (^{O}c)**	375 (190)	320 to 430 (160 to 220)	400 to 600 (200 to 315)
Average Pore **Diameter (A)**	22	NA	3,4,5,10
Minimum Dew Point Temperature **Of Effluent, ^{O}f (^{o}c)**	-80 (-60)	-100 (-75)	-150 (-100)
Average Minimum Moisture Content Of Effluent Gas, PPMV	5 – 10	10 – 20	0.1

Silica gels: are used mostly where a high concentration of water (> 1 mole %) vapor is present in the feed, and low levels of water in the dehydrated gas are not needed. They are relatively noncatalytic compounds. Aluminas are very polar and strongly attract water and acid gases. They are used for moderate levels of water in the feed when low levels of water in the product are not required. They have the highest mechanical strength of the adsorbents considered here. However, for gas going into cryogenic processing, the only adsorbent that can obtain the required dehydration is a molecular sieve.

Molecular sieves (MSs): are crystalline sodium alumino silicates and have very large surface areas and a very narrow range of pore sizes. They possess highly localized polar charges on their surface that act as adsorption sites for polar materials at even very low concentrations. This is why the treated natural gas could have very low H2S concentrations (4ppm). In order for a molecule to be adsorbed, it first must be passed through a pore opening and then it is adsorbed on an active site inside the pore.

$$2/3\ K_2O.1/3\ Na_2O.Al_2O_3.2\ SiO_2.9/2\ H_2O$$

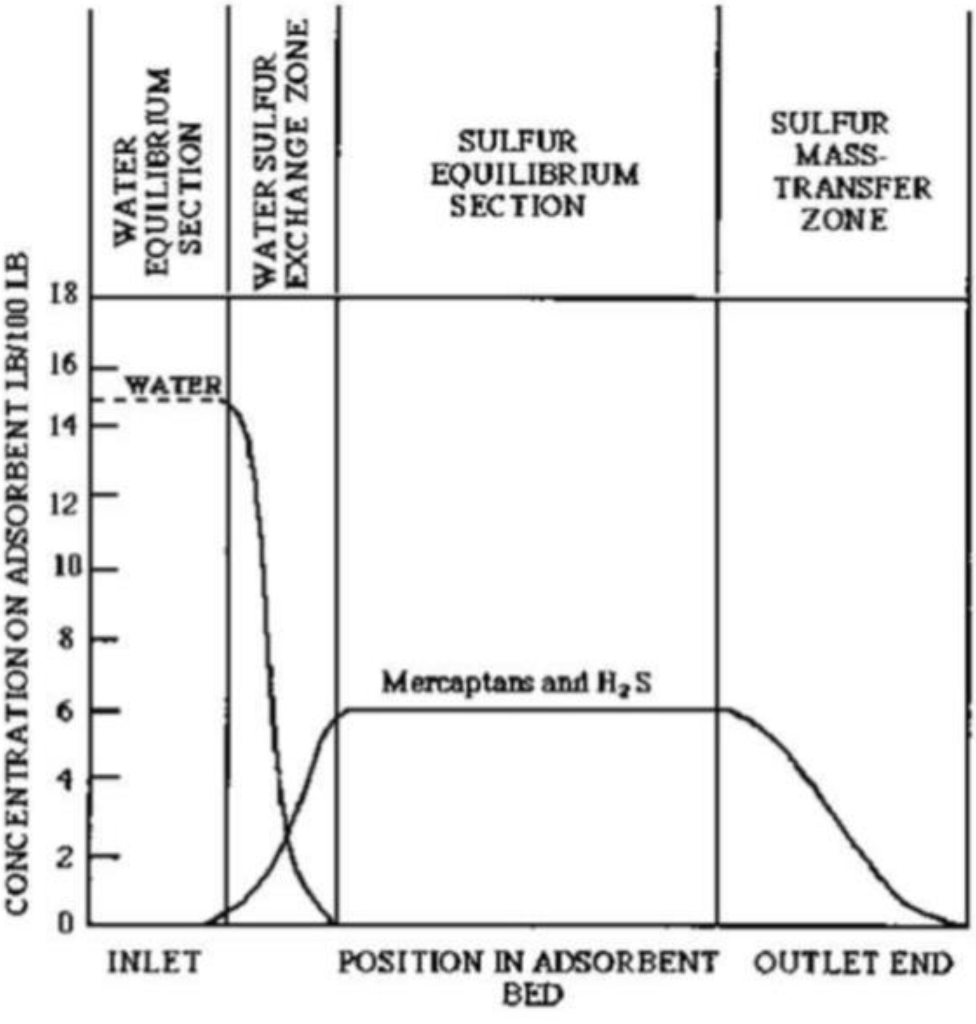


Figure 2-5 Adsorbents zone in a Molecular sieves

2.8.4. ADSORPTION PROCESS

Although this discussion uses molecular sieve as the example of an adsorbent to remove water, with the exception of regeneration temperatures, the basic process is the same for all gas adsorption processes. **Figure 2-6** shows a schematic of a two-bed adsorber system. One bed, adsorber #1 in **Figure 2-6**, dries gas while the other bed, adsorber #2, goes through a regeneration cycle. The wet feed goes through an inlet separator that will catch any entrained liquids before the gas enters the top of the active bed. Flow is top-down to avoid bed fluidization. The dried gas then goes through a dust filter that will catch fines.

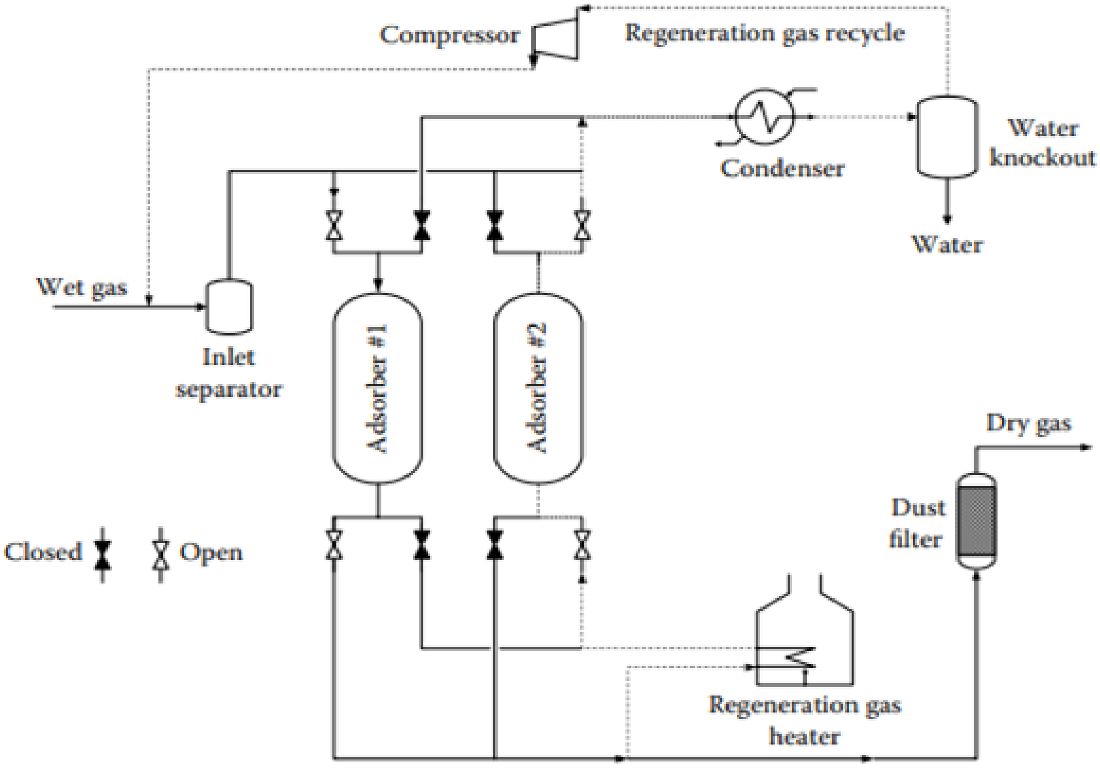


Figure 2-6 Schematic of A Two-Bed Adsorber System. One Bed, Adsorber #1, Dries Gas While the Other Bed, Adsorber #2

2.8.5. DESICCANT PROCESSES

In some situations, such as remote gas wells, use of a consumable salt desiccant, such as $CaCl_2$, may be economically feasible. The system can reduce the water content down to 20 pmmv. Typical salt capacities are 0.3 lb. CaCl2 per lb. H2O. The Engineering Data Book (2004b) provides more details.

2.8.6. MEMBRANE PROCESSES

Membranes offer an attractive option for cases in which drying is required to meet pipeline specifications. Their modular nature, light weight, large turndown ratio, and low maintenance make them competitive with glycol units in some situations.

Polymeric membranes separate gases by selective permeation of gas species in these membranes. The gas dissolves at the contact surface of the membrane and permeate across the membrane under the partial pressure gradient across the membrane wall. The rate of permeation of gas A(qA) can be expressed as $qA = (PM /t)\ AmPA$.

Where PM is the gas permeability in the membrane, Am and t are the surface area and thickness of the membrane, respectively, and PA is the partial pressure of gas A across the membrane. The basic idea of the process is to flow sour gas on one side of the membrane where only acid gases diffuse across the membrane to the permeate side and the rest of the gas exits as sweet gas.

The inlet gas must be free of solids and droplets larger than 3 microns Inlet gas temperature should be at least 20°F (10°C) above the dew point of water to avoid condensation in the membrane.

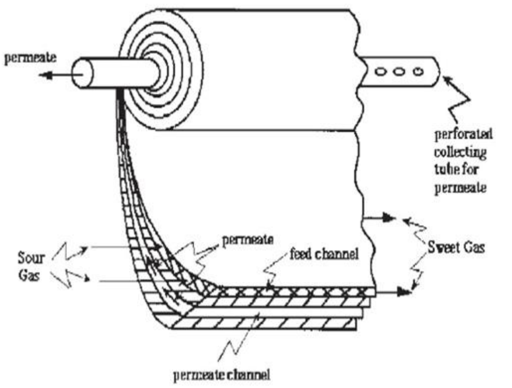


Figure 2-7 Spiral-wound Elements and Assembly

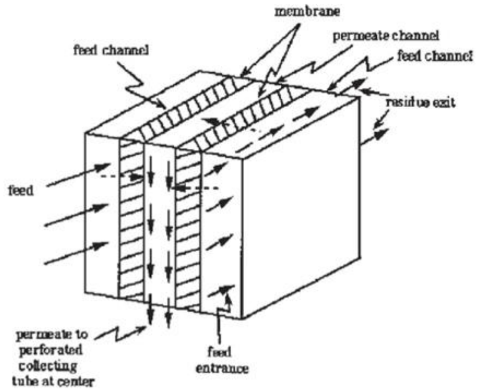


Figure 2-8 Gas Flow Paths for Spiral-wound Module

2.8.7. COMPARISON OF DEHYDRATION PROCESSES

A number of factors should be considered in the evaluation of a dehydration process or combination of processes. If the gas must be dried for cryogenic liquids recovery, molecular sieve is the only long-term, proven technology available. It has the added advantage that it can remove CO_2 at the same time. If CO_2 is being simultaneously removed, because water displaces CO2, the bed must be switched before the CO_2 breaks through, which is before any water breakthrough. Enhanced TEG regeneration systems may begin to compete with molecular sieve. Skiff et al. (2003) claim to have obtained less than 0.1 pmmv water by use of TEG with a modified regeneration system that uses about 70% of the energy required for molecular sieves.

High inlet water-vapor concentrations make molecular sieve dehydration expensive because of the energy consumption in regeneration. Two approaches are used to reduce the amount of water going to the molecular sieve bed First, another dehydration process, (e.g., glycol dehydration) is put in front of the molecular sieve bed. The second option is to have combined beds with silica gel or activated alumina in front of the molecular sieve. The bulk of the water is removed with the first adsorbent, and the molecular sieve removes the remaining water.

If dehydration is required only to avoid free-water formation or hydrate formation or to meet the pipeline specification of 4 to 7 lb./MMscf (60 to 110 mg/Sm$_3$), any of the

above-mentioned processes may be viable. Traditionally, glycol dehydration has been the process of choice. System constraints dictate which technology is the best to use. Smith (2004) provides an overview of natural gas dehydration technology, with an emphasis on glycol dehydration.

2.8.8. SAFETY AND ENVIRONMENTAL CONSIDERATIONS

Dehydration processes offer few safety considerations outside of having high temperature and high-pressure operations. Probably the most unique safety consideration is when adsorbent beds are being changed. The bed must be thoroughly purged, preferably with nitrogen, to remove adsorbed hydrocarbons before the adsorbent is dumped.

A potential exists for hydrocarbons on the adsorbent to ignite when exposed to air because the adsorbent heats as it adsorbs moisture from the air. Either a highly trained company expert or an adsorbent company representative should be present to help ensure safe dumping and filling operations The dumping process produces dust, and operators must wear protective clothing and dust masks.

A major environmental concern in dehydration with glycol solutions is BTEX emissions.

2.8.9. PREDICTION OF HYDRATE FORMATION

In this section, methods for determining the operating conditions leading to hydrate formation are presented. In particular, methods are presented to determine the following:

1. Hydrate formation temperature for a given pressure.
2. Hydrate formation pressure for a given temperature.
3. Amount of water vapor that saturates the gas at a given pressure and temperature (i.e., at the dew point).

At any specified pressure, the temperature at which the gas is saturated with water vapor is being defined as the ‘‘dew point’’. Cooling of the gas in a flow line due to heat loss can cause the gas temperature to drop below the hydrate formation temperature. Two methods are discussed next for predicting the conditions leading to hydrate formation: approximate methods and analytical methods.

2.8.10. MAJOR ZONES IN A SIEVE BED.

In the presence of water, which is a highly polar compound, H_2O is first adsorbed in the bed, displacing any sulfur compounds. Water equilibrium with the sieves is established in this zone.

The second zone (zone 2) is the water–sulfur compound exchange zone, where water is still displacing the sulfur compounds but some sulfur sites will be left adsorbed. An adsorption front for sulfur compounds is formed and a concentration profile is established. The concentration profile of sulfur compounds declines along the bed.

Zone 3 is the sulfur equilibrium section, showing the highest concentration of sulfur compounds in the bed depending on the MS capacity.

Zone 4 is the mass transfer section for sulfur compounds. As this profile reaches the end of the bed, this will mean some sulfur compounds (H2S) will appear in the gas stream.

2.8.11. THE DEW POINT:

The dew point is defined as The temperature at which vapor begins to condense into a liquid at a particular system pressure.

Depending on composition, these hydrates can form at relatively temperatures plugging equipment and piping. Glycol dehydration units depress the hydrate formation point of the gas through water removal. Without dehydration, a free water phase (liquid water) could also drop out of the natural gas as it is either cooled or the

pressure is lowered through equipment and piping. This free water phase will often contain some portions of acid gas (such as H2S and CO2) and can cause corrosion.

For the above two reasons the Gas Processors Association sets out a pipeline quality specification for gas that the water content should not exceed 7 pounds per million standard cubic feet.

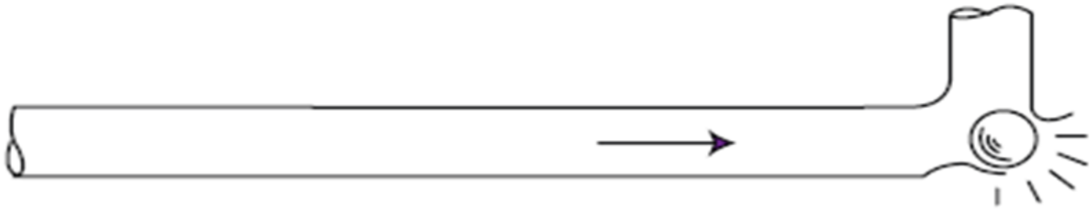
2.9. GAS HYDRATES

A gas hydrate is an ice-like crystalline solid called a clathrate, which occurs when water molecules form a cage-like structure around smaller guest molecules. The most common guest molecules are methane, ethane, propane, isobutene, normal butane, nitrogen, carbon dioxide, and hydrogen sulfide, of which methane occurs most abundantly in natural hydrates and it is the mixture of water and light hydrocarbons. it forms varies from a jelly-like much to a solid ice block. it can completely plug piping or valve so that no flow will occur. hydrates have been known to flow through piping like a shot out of a gun and rupture the piping when it made a bend, methane and ethane are the most common hydrocarbons that combine with water to form hydrate. in isolated cases, propane will also combine with water to from hydrate. butane and heavier hydrocarbons rarely form hydrates.

2.9.1. WHEN HYDRATE CAN OCCUR:

The unusual characteristic of hydrates is that it forms at temperatures well above the freezing point of water. As we mentioned, hydrate often takes the form of ice. it may be difficult to imagine ice forming at a temperature of 20c (68f) but under certain conditions of flow which are not unusual in the oilfield, hydrates will form at that temperature. in order for hydrates to form, free water must be present as a liquid, in a stream of hydrocarbons containing methane, ethane, or propane. the most common occurrence of hydrate is in natural gas, which is primarily composed of methane the temperature at which hydrate will form in a gas stream depends upon the pressure of the stream. as pressure increase, the hydrate formation temperature also increases. the curves shown on pages 2-3 indicate average conditions of temperature and pressure at which hydrates will start to from when free water is present.

A HYDRATE PLUG CAN FLOW IN A PIPELINE



WHERE THE PIPE BENDS THE PLUG CAN RUPTURE
THE LINE IF IT IS TRAVELLING FAST ENOUGH

2.9.2. HYDRATES FORMATION AND PREVENTION

Find the operating pressure on the vertical scale. Move horizontally until you reach the curved line. Move vertically downward until you reach the bottom scale. Read the temperature of 18.6C [66F]. This is the hydrate formation temperature.

When gas containing water vapor flows through piping that is exposed to low temperature, the gas will slowly begin to cool, and water vapor in the gas will begin to condense into drops. When the condensed water cools to the hydrate formation temperature, hydrate will form. It will be pushed along the wall of the piping until it reaches an obstruction, such as a weld Determine the temperature hydrate will form in a gas pipeline operating at a pressure of 10 000 KPA [1500 psi]. joint. It will begin to accumulate at the obstruction, and will eventually fill the line and block the flow of gas.

2.9.3. HYDRATES FORMATION CONDITIONS

Hydrate are prevented from forming in two ways:

1. By removing water vapor from the gas stream in a dehydration unit.

The most common way to drying gas is that of contacting the gas with a concentrated glycol liquid or molecular sieves which absorbs the water from the gas.

2. Inject glycol or methyl alcohol (methanol) or molecular sieves into the gas to dissolve in the water that condenses as the gas is cooled. Glycol or methanol lowers the water freezing point in the same way that adding glycol or methanol to a car radiator prevents

the water from freezing. The purpose of injecting glycol or methanol is not to absorb some water from the gas, but to mix with the water that condenses as the gas is cooled and lower its freezing temperature. Injecting methanol or glycol into gas to prevent hydrate formation is commonly referred to as hydrate inhibition in oilfield terminology.

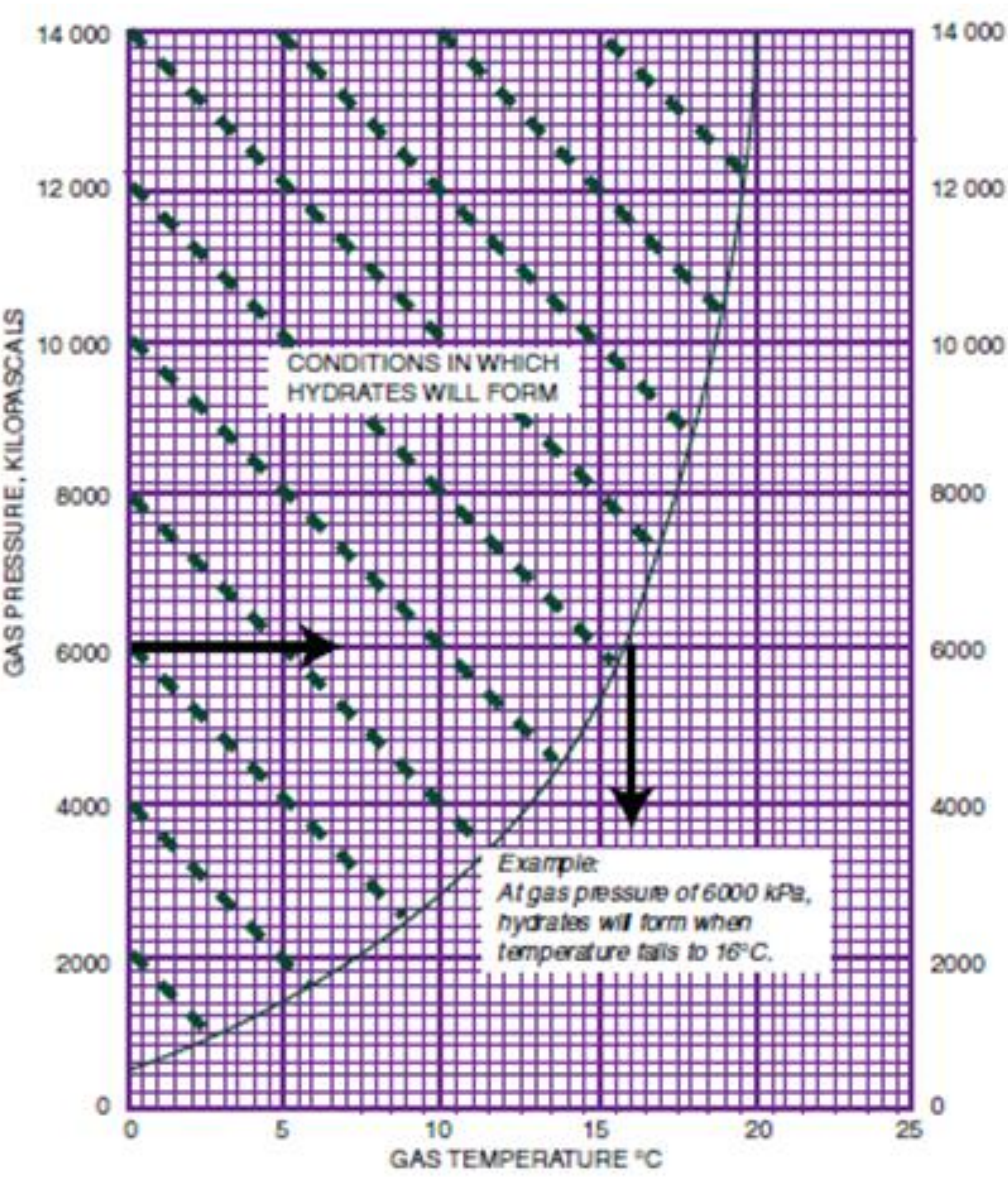


Figure 2-9 Hydrate Formation Conditions SI Units

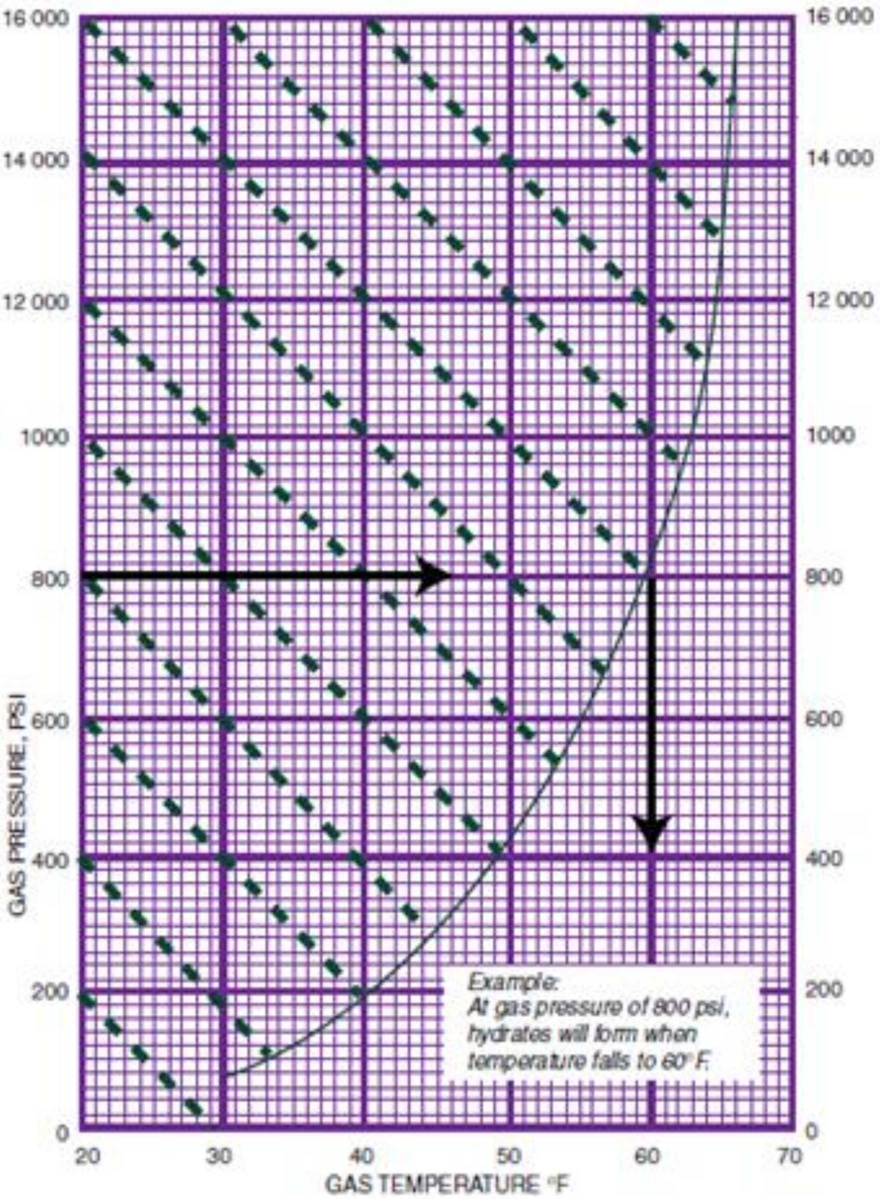


Figure 2-10 Hydrate Formation Conditions English Units

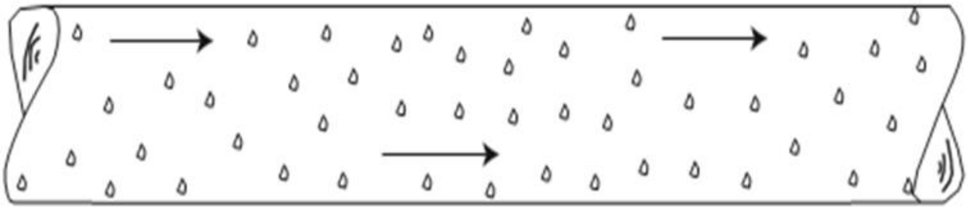
2.9.4. METHODS OF REMOVING HYDRATES

As hydrate begins to form in piping, it will restrict the flow of gas through the piping, and cause a pressure drop in the piping at the point of formation. It will eventually completely block the flow of gas through the piping. If the piping becomes completely plugged with hydrate, the quickest way to remove the hydrate block is to de pressure the piping and allow the hydrates to melt. When de pressuring, it is essential that each end of the line is vented the same amount. If one end is vented to a lower pressure than the other, the hydrate block may break loose and travel to the low pressure end and possibly damage piping or equipment. Another method is to heat the portion of piping in which the hydrate is located and thereby melt it. This is usually not practical because the exact location of the hydrate blockage may not be known.

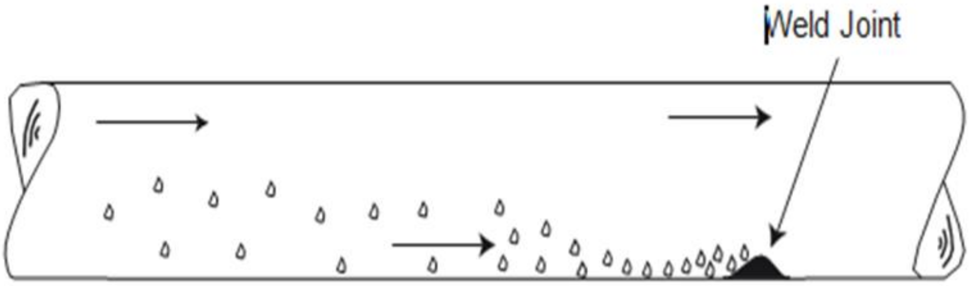
2.9.5. HYDRATE FORMATION CONDITION

If the hydrate formation has not completely blocked the flow of gas through the piping, methanol can be injected into the gas and it will dissolve the hydrate over a period of time. Methanol injection will be helpful only if gas is flowing in the line. In the case of a complete line blockage with hydrate, the line must be completely filled with methanol in order to melt the hydrate in a reasonable time.

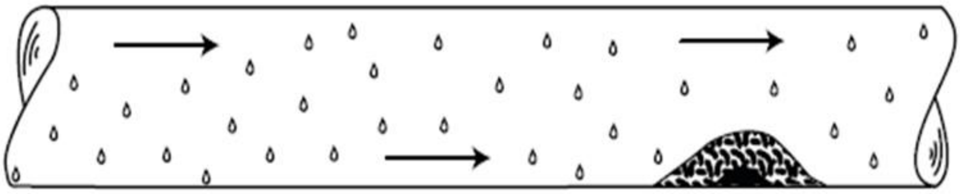
Glycol can also be used to melt hydrate, but is not effective as methanol.



AS GAS FLOWS DOWN PIPE, IT IS COOLED AND WATER DROPLETS FORM.



AS TEMPERATURE FALLS BELOW HYDRATE FORMATION POINT, WATER AND GAS COMBINE TO FORM HYDRATE. HYDRATE MOVES ALONG THE WALL OF THE PIPE UNTIL IT REACHES AND IRREGULARITY IN THE PIPE AT A WELD JOINT.



HYDRATES ACCUMULATE AT THE IRREGULARITY AND START RESTRICTING THE FLOW OF GAS.

ENOUGH HYDRATE WILL EVENTUALLY ACCUMULATE TO BLOCK THE FLOW OF GAS.

HYDRATE FORMATION IN PIPELINE

2.9.6. HYDRATES INHIBITION GAS PIPING

As we mentioned, hydrate will form in a gas stream when free water is present and the temperature and pressure of the gas is within the hydrate forming zone as shown in Figures 1A and B. We inhibit or prevent the formation of hydrate by injecting glycol or methanol into the gas.

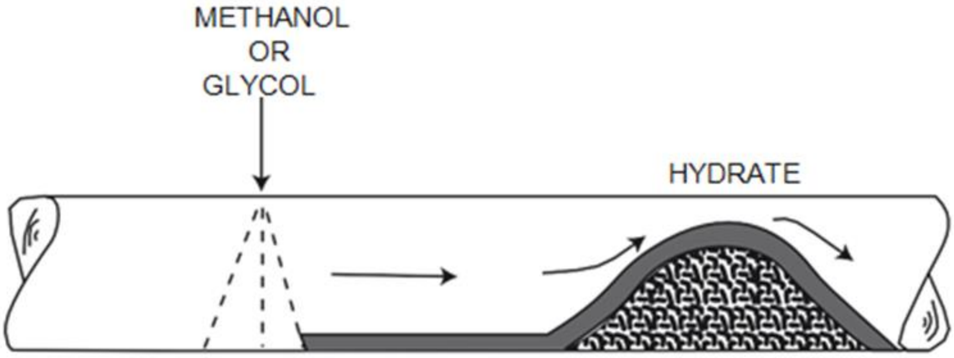
The quantity of inhibitor to inject is determined in a manner similar to that of adding antifreeze to an automobile radiator. If the lowest expected temperature is -40, enough antifreeze is added to lower the freezing temperature of the radiator liquid to 40. The amount of antifreeze de- pends upon the quantity of water in the radiator, and the degrees of freezing temperature reduction that is necessary.

The amount of inhibitor (methanol or glycol) which must be added to gas de- pends upon two factors:

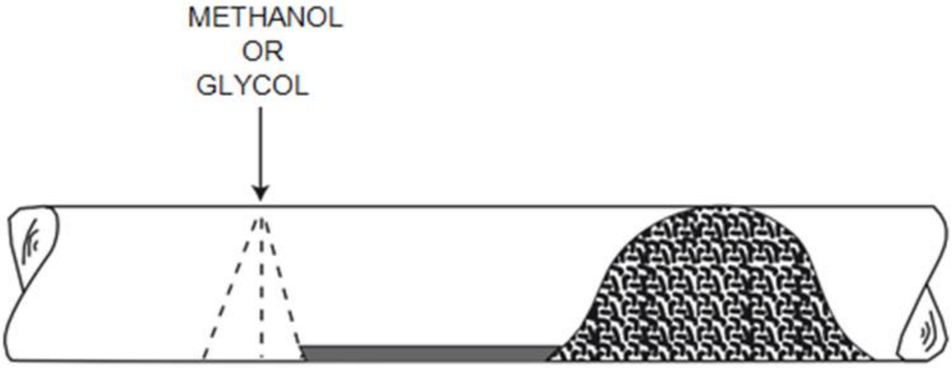
1) The amount of water which can con- dense from the gas as it cools.

2) The hydrate temperature reduction, which is the difference in temperature at which hydrates will start to form and the lowest temperature the gas can reach.

Each will be discussed separately.

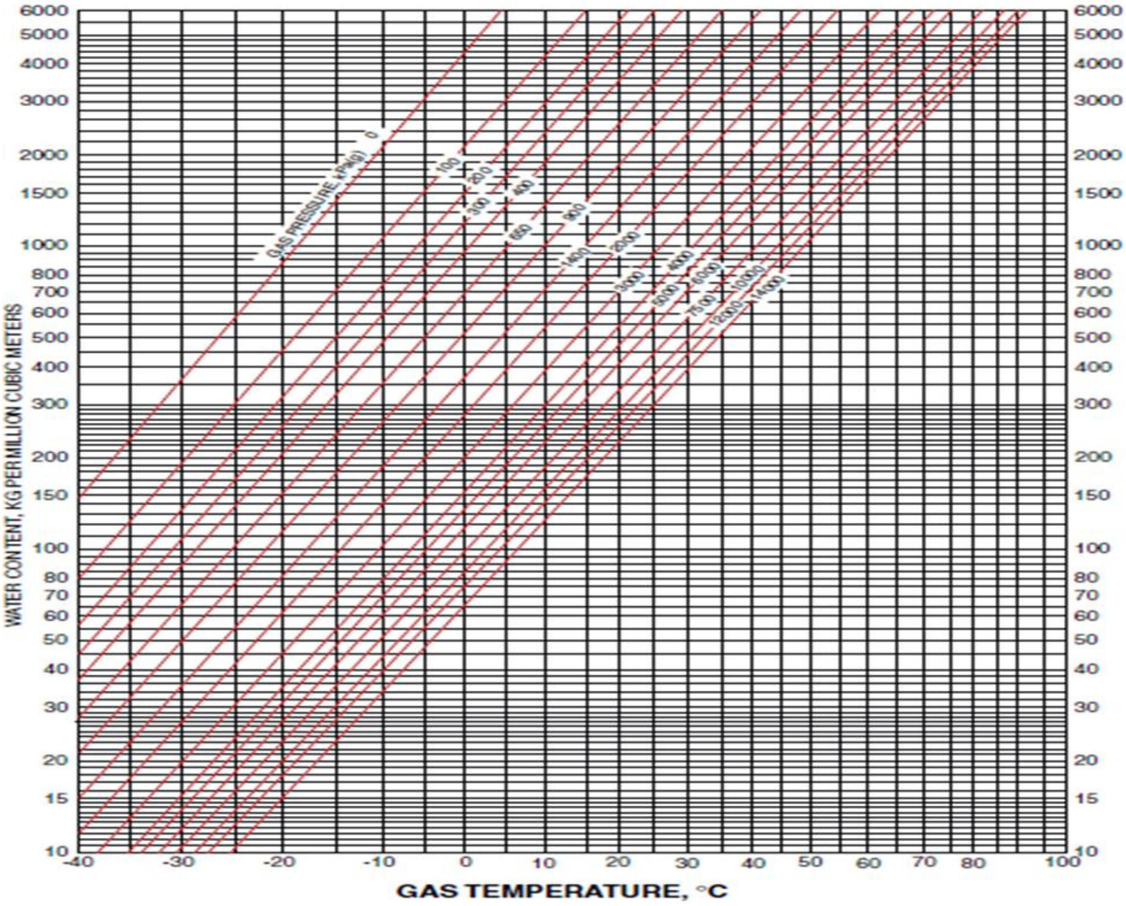


METHANOL OR GLYCOL ADDED TO THE GAS WILL MELT HYDRATE SO LONG AS GAS FLOW CARRIES INHIBITOR TO THE HYDRATE.



WHEN HYDRATE COMPLETELY BLOCKS THE FLOW OF GAS, THE PIPE MUST ME FILLED WITH INHIBITOR IN ORDER TO MELT THE HYDRATE.

2.9.7. WATER VAPOR CONTENT OF NATURAL GAS SI UNITS

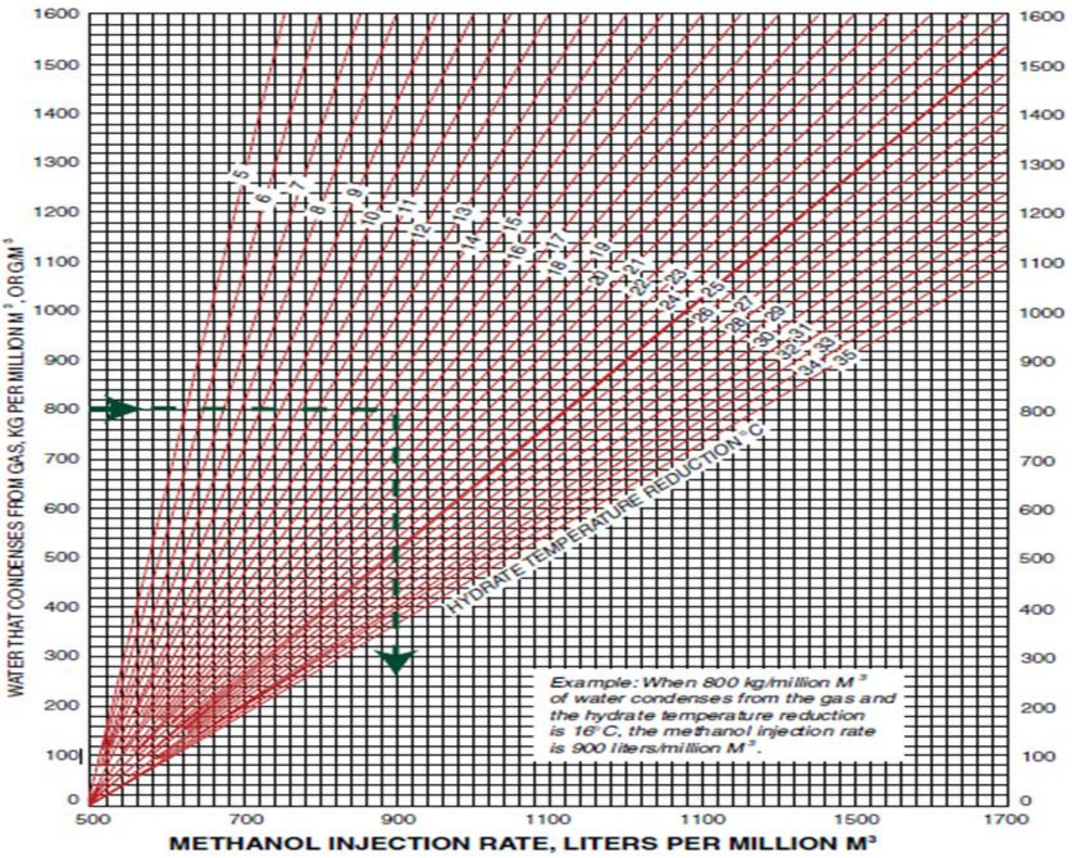


2.9.8. INHIBITOR INJECTION RATE

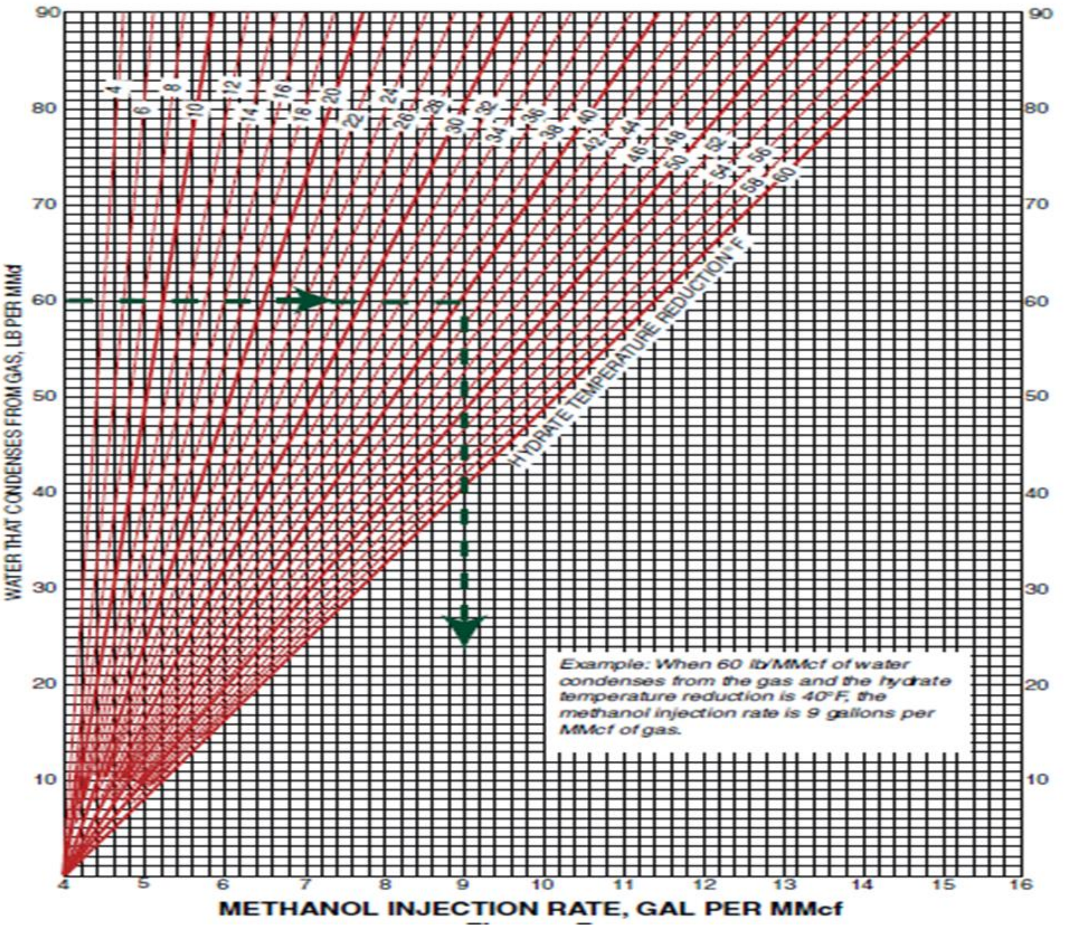
The temperature at which hydrate starts to form is shown in figures on pages 2 and 3. As long as the gas temperature stays above the hydrate formation point, no inhibitor must be injected. However, if the temperature can fall below the hydrate formation point, then inhibitor must be injected or hydrate will form.

Temperature Can Fall Below the Hydrate For Mation Point, Then Inhibitor Must Be Injected		
Pipeline Pressure	**SI UNITS** 10 000 kPa	**ENGLISH UNITS** 1500 psi
Hydrate Formation Temperature	18.5 ºC	66º F
Lowest Temperature In Pipeline	7 ºC	45 ºF
Hydrate Temperature Reduction	11.6 ºC	21 ºF

2.9.9. METHANOL INJECTION RATE SI-UNITS



2.9.10. METHANOL INJECTION RATE - ENGLISH UNITS



Example: When 60 lb/MMcf of water condenses from the gas and the hydrate temperature reduction is 40°F, the methanol injection rate is 9 gallons per MMcf of gas.

	SI Units	English Units
Daily Methanol Injection Rate	630 x 10 = 6300 x L/d	5.0 x 350 = 1750 gal/d
Hourly Methanol Injection Rate	6300 ÷ 24 = 263 L/hr	1750 gal/d ÷ 24 = 73 gal/hr
Glycol Injection Rate (Figure 4A/B)	105 L/million m^3	0.8 gal/MMcf
Gas Flow Rate	10 million m_3/d	350 MMcf/d
Total Glycol Injection Rate	105 x 10 = 1050 L/d	0.8 x 350 = 280 gal/d
Hourly Glycol Injection Rate	1050 ÷ 24 = 44 L/hr	280 ÷ 24 = 11.7 gal/hr

2.9.11. INHIBITOR INJECTION RATE

In order to prevent hydrate from forming in the pipeline when the gas is cooled from 30C to 7C [86F to 45F], methanol must be injected into the stream at a rate of 263 liters/hr. [73 gals/hr.] or glycol must be injected at a rate of 44 liters/hr. [11.7 gal/ hr.]. The actual rate is usually increased about 10% above that calculated for a margin of safety.

2.9.12. HYDRATE PREVENTION TECHNIQUES:

The multiphase fluid produced at the wellhead will normally be at a high pressure and a moderate temperature.

As the fluid flows through the pipelines, it becomes colder, which means such pipelines could experience hydrates at some point in their operating envelope. For this reason, the hydrate formation in gas transmission pipelines should be prevented effectively and economically to guarantee that the pipelines operate normally.

Control of hydrates relies on keeping the system conditions out of the region in which hydrates are stable. It may be possible to keep the fluid warmer than the hydrate formation temperature (with the inclusion of a suitable margin for safety) or operate at a pressure less than the hydrate formation pressure.

2.10. CASE STUDY OF NATURAL GAS DEHYDRATION PROCESS IN BANGLADESH

Md. Mehedi Hasan, 2016

2.10.1. ABOUT THE STADY

Dehydration of natural gas is needed to remove the water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Dehydration prevents the formation of gas hydrates and reduces corrosion. Unless gases are dehydrated, liquid water may condense in pipelines and accumulate at low points along the line and reducing its flow capacity. Several methods have been developed to dehydrate gases on an industrial scale. The three major methods of dehydration are direct cooling, adsorption, and absorption. In Bangladesh 21 out of 26 gas field are producing nearly 2700 MMCFD gas with 13000 BBL condensate. Dehydration method, selected based on the gas property and location of gas field as well as customer demand. Most of the gas Field in Bangladesh are using Glycol (89 %) to dehydrate gas other used solid desiccant (Silica Gel, Molecular Sieve, 9 %) and

(LTS, LTX, 2%). Glycols used for dehydrating natural gas in Bangladesh is, triethylene glycol (TEG)which has universal acceptance as most cost effective due

to its superior dew point depression, operation cost and operation reliability. Solid desiccant (Silica, molecular sieve) type dehydration is a very simple process, ideal for remote locations with limited utilities, environment benefit, easy to install and operate and it also suitable in laboratory scale. Considering economical, gas composition, government rules presently the gas company are facing few problems in both processing, which are need to solve by taking proper action by government.

2.10.2. CONCLUSION

Dehydration of natural gas is important because without dehydration the natural gas may causes a corrosion and erosion problem during transmission and distribution of natural gas. Though the installation of adsorbent type dehydration process is costly with respect to absorbent type process it has benefits during dehydrate natural gas when dew point, foaming and corrosion are main considerable. Considering the gas composition, most of the gas field in Bangladesh are using Glycol based process plant, which are cheaper than silica based process plant but need to continuous recharge. But due to government purchase rules and regulation the gas producing company under Petro Bangla facing some problem during gas dehydration. The government should take necessary steps to resolve the problem during gas dehydration by adsorption and absorption process.

2.11. CASE STUDY OF THE DEHYDRATION PROCESS OF NATURAL GAS IN IRAQI NORTH GAS COMPANY AND THE TREATMENT METHODS OF MOLECULAR SIEVE PROBLEMS

Farman Saeed Abd. Zangana, 2012

2.11.1. ABOUT THE STADY

The purpose of this research is to study the dehydration process of natural gas by adsorption using molecular sieve as it is in the North Gas Company. Dehydration of natural gas is needed to remove the water that is associated with natural gas in vapor form. The natural gas industry has recognized that dehydration is necessary to insure smooth operation of gas transmission lines, dehydration prevents the formation of gas hydrates and reduces corrosion. Unless gases are dehydrated, liquid water may condense in pipeline and accumulate at low point along the line and reducing its flow capacity. Several methods have been developed to dehydrate gases in an industrial scale. The four major methods of dehydration are direct cooling, indirect cooling, absorption and adsorption. This study focuses on the adsorption method which is used to dehydrate the natural gas in North Gas Company and also focuses on the problem of breaking up and aging of the molecular sieve before ending its real life time.

2.11.2. CONCLUSION

From this research it can be concluded that the reason for breaking up, blocking and aging the molecular sieve, is one or more of the following:

1. Amine carry over.
2. Water condensed.
3. The temperature of regeneration.
4. Inlet gas velocity.

So the problem can be treated by one or more of the following:

1) Gas separator must be modified to improve their efficiency to maximize water droplet removal.
2) Filter separator is required if the adsorption unit is downstream from an amine unit.
3) Liquid (particularly amines) carry over in the molecular sieve bed must be prevent by using antifoaming material.
4) It is important to choose the regeneration conditions carefully. Where the higher the regeneration temperature and the higher amount of liquid water present on the sieves, the heavier the damaging of the molecular sieve. Which lead to shorter desiccant life and lower regeneration temperatures lead to insufficient dehydration capacities.
5) A layer of less expensive desiccant (activated alumina) in the upper section of the molecular sieve dehydrator will catch contaminants, such as amines, this is called multi bed technology. The results of this technology improve adsorption capacity purification capability, life time of the adsorbent and extend the bed life.
6) It is better to use glycol dehydration unit to reduce the water content to around 60 ppm v and then using solid desiccant for final drying.

CHAPTER THREE

3. METHODOLOGY

3.1. INTRODUCTION

This project is focusing on Treatment of the gas and select the best technique for removing impurities and dehydration process methods at YLNG Plant-Belhaf, Yemen by Removal of acidic gases (H_2S and CO_2) by amine sweetening process, Removal of water vapor by Dehydration unit, Increase the temperature, decrease the pressure and Making a comparison between the dehydration processes ways in all aspects, especially the economic aspect. Gas processing is like any other science; the value of the interpretations that come from the results is determined by the quality of the data collected, so the higher quality of data, the better results will be achieved.

3.2. TYPE OF DATA THAT NEEDED FOR THE PROJECT

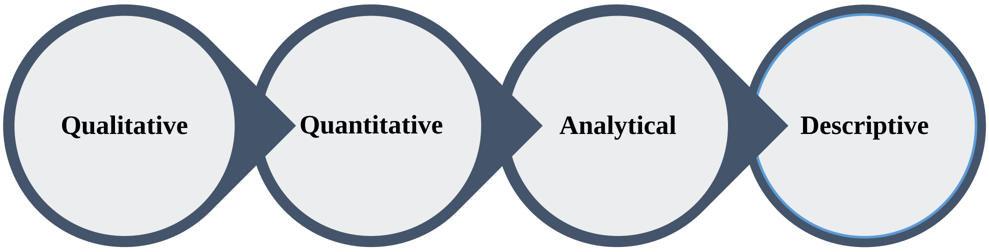
The data required for perfect interpretation is shown in Table 3-1.

Table 3-1 Hydrates Slugging Treatment in Dehydration Unit needs the following data:

No.	Data Required
1	**Feed Gas Composition Of Gas From CPU To KPU Via The Transfer Line.**
2	**P&ID Maps Of Gas Processing Units Especially Dehydration Unit.**
3	**Feed Gas Proprieties**

3.3. ANALYSIS APPROACH

Analysis approach for the available data is Qualitative and Quantitative Analytical and Descriptive approach.



3.4. EXPECTED RESULTS

After the analysis for the available data, we expect to find the solution of treatment the problem of hydrates slugging in dehydration unit at Yemen LNG.

CHAPTER FOUR

4. ANALYSIS AND DISCUSSION

4.1. INTRODUCTION

As mentioned earlier in this research, Treatment of the gas and select the best technique for removing impurities and dehydration process methods has its special importance in oil and gas industry. After the gas arrive to Yemen LNG company. equipment must run to treatment the natural gas This chapter will discuss the ways of Treatment of the gas and select the best economical for dehydration process methods compare with the results of treatment that had been done by the company.

4.2. DEHYDRATION METHODS

4.2.1. ABSORPTION DEHYDRATION USING GLYCOL

all raw natural gas is fully saturated with water vapor when produced from an underground reservoir. Because most of the water vapor has to be removed from natural gas before it can be commercially marketed, all natural gas is subjected to a dehydration process. One of the most common methods for removing the water from produced gas is glycol. we will discuss the types of glycols that may be used, the process used to remove water with glycol, and the control of air emissions from glycol dehydration units.

The basis for gas dehydration using glycol is the absorbent; there are certain requirements for absorbents used in gas treating.

- Strong affinity for water to minimize the required amount of absorbent (liquid solvent).
- Low potential for corrosion in equipment, low volatility at the process temperature to minimize vaporization losses.
- Low affinity for hydrocarbons to minimize their loss during the process.
- Low solubility in hydrocarbons to minimize losses during treating.
- Low tendency to foam and emulsify to avoid reduction in gas handling capacity and minimize losses during regeneration.
- Good thermal stability to prevent decomposition during regeneration and low viscosity for easily pumping and good contact between gas and liquid phases. Off course, the major critical property for a good absorbent is the high affinity for water. The others are used to evaluate potential absorbents practical applicability in the industry.

Glycol dehydration is a liquid desiccant system for the removal of water from natural gas and natural gas liquids (NGL). It is the most common and economical means of water removal from these streams. Glycols typically seen in industry include triethylene glycol (TEG), diethylene glycol (DEG), ethylene glycol (MEG), and tetraethylene glycol (TREG). TEG is the most commonly used glycol in industry.

Table 4-1:Physical Properties of Glycols

	Mono-ethylene Glycol (MEG)	**Diethylene Glycol (DEG)**	**Tri-ethylene Glycol (TEG)**	**Tetra-ethylene Glycol (TREG)**
Formula	$C_2H_6O_2$	$C_4H_{10}O_3$	$C_6H_{14}O_4$	$C_6H_{18}O_5$
Molecular Weight	62.1	106.1	150.2	194.2
Boiling Point at 760 mmHg - °C	197.3	244.8	285.5	314.0
Vapor Pressure at 25°C - mmHg	0.12	<0.01	<0.01	<0.01
Vapor Pressure at 50°C - mmHg	0.62	0.06	<0.01	<0.01
Density @ 25°C kg/m3	1110	1113	1119	1120
Density @ 60°C kg/m3	1085	1088	1092	1092
Freezing point - °C	-13	-8	-7	-5.5
Pour Point - °C	-	-54	-58	-41
Viscosity @ 25°C - cP	16.5	28.2	37.3	44.6
Viscosity @ 60°C - cP	4.68	6.99	8.77	10.2
Surface Tension (25°C) dyne/cm	47	44	45	45
Refractive Index (25°C)	1.430	1.446	1.454	1.457
Specific Heat (25°C) kJ/ (kg. K)	2.43	2.30	2.22	2.18
Flash Point - °C (PMCC)	116	124	177	204

4.2.1.1. PROCESS DESCRIPTION

The gas flows through a separator to remove condensed liquids or any solids that might be in the gas. Some absorbers incorporate the separator in a bottom section of the vessel, in which case the gas then flows upward through a chimney tray into the glycol absorber portion of the vessel. The glycol contactor or absorber can contain:

- Trays
- Random packing
- Structured packing

If it is a trayed vessel, it will contain several bubble-cap trays. Lean glycol is pumped into the upper portion of the contactor, above the top tray but below the mist eliminator. The trays are flooded with glycol that flows down from tray to tray in down comer sections.

The gas rises through the bubble caps and is dispersed as bubbles through the glycol on the trays. This provides the intimate contact between the gas and the glycol.

The glycol is highly hygroscopic, and most of the water vapor in the gas is absorbed by the glycol. The rich glycol, containing the absorbed water, is withdrawn from the contactor near the bottom of the vessel above the chimney tray through a liquid level control valve and passes to the regeneration section. The treated gas leaves the contactor at the top through a mist eliminator and usually meets the specified water content. The rich glycol can be routed through a heat exchange coil in the top of the reboiler column called the still. The heat exchange generates some reflux for the separation of the water from the glycol in the top of the still and also heats the rich glycol somewhat. In some installations, the rich solution passes to a flash tank operating at about 15 to 50 psig, which allows absorbed hydrocarbon gas to separate from the glycol. The glycol then flows into the still through a filter and a heat exchanger, exchanging heat with the regenerated glycol. It drops through a packed section in the still into the glycol reboiler vessel,

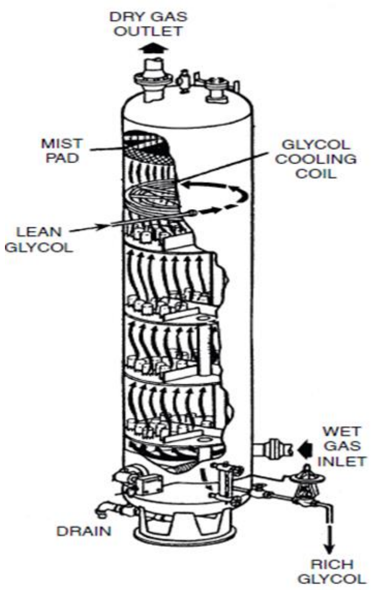


Figure 4-1 Cutaway drawing of contactor

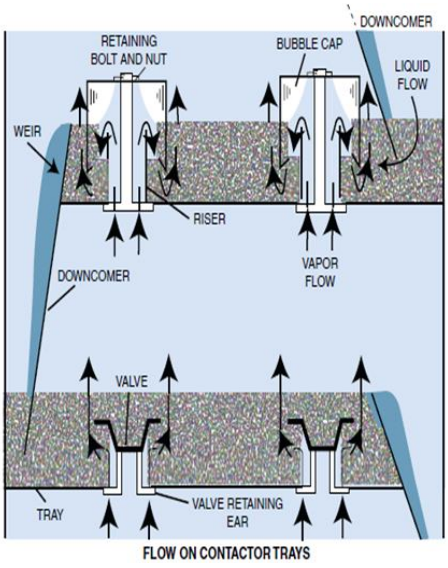


Figure 4-2 Flow On Contactor Trays

where it is heated to the necessary high regeneration temperature at near atmospheric pressure. At the high temperature, the glycol loses its ability to hold water; the water is vaporized and leaves through the top of the still. The regenerated glycol flows to the surge tank, from which it is routed through the lean/rich heat exchanger to the glycol pump. The pump boosts the pressure of the lean glycol to the contactor pressure. Prior to entering the contactor, it exchanges heat with the dry gas leaving the contactor or some other heat exchange medium.

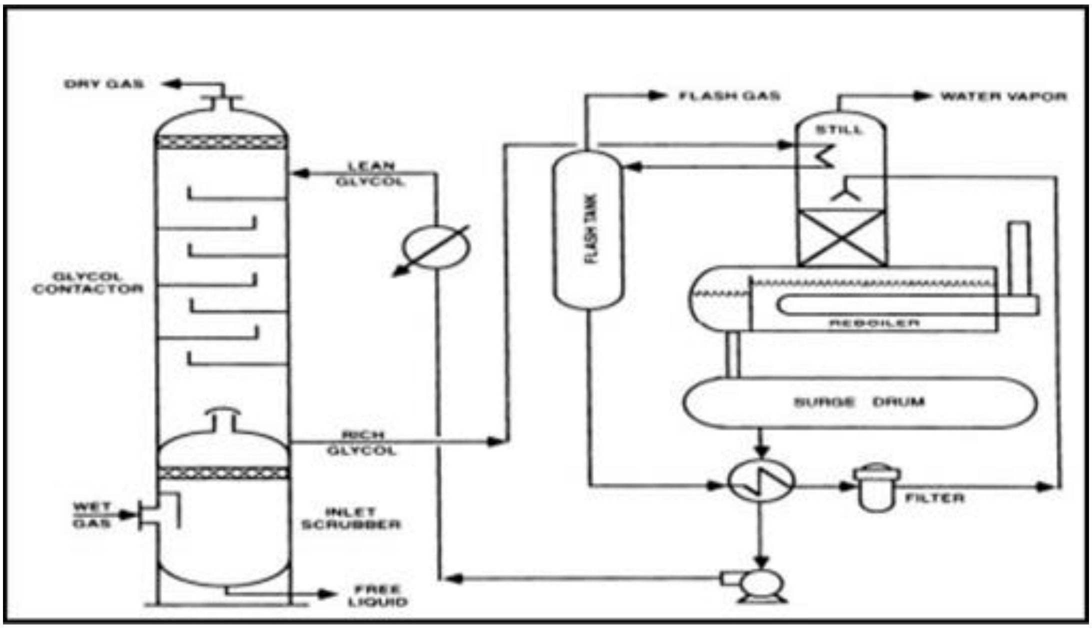


Figure 4-3 Basic Flow Scheme For Glycol Dehydration

4.2.1.2. OTHER GLYCOL OPTIONS

Other options to enhance glycol purity to achieve a high degree of water dew point depression include operation of the regenerator under vacuum, the proprietary Drizo process and the proprietary Cold finger process.

4.2.1.3. ENHANCED STRIPPING METHODS

Most glycol units are fairly uniform except for the regeneration step. Several methods are used to enhance the stripping of the glycol to higher purities (higher purities are required for dryer gas out of the absorber). Since the reboiler temperature is limited to 400F or less to prevent thermal degradation of the glycol, almost all of the enhanced systems center on lowering the partial pressure of water in the system to increase stripping.

Common enhanced methods include the use of stripping gas, the use of a vacuum system (lowering the entire stripper pressure), the DRIZO process, which is similar to the use of stripping gas but uses a recoverable hydrocarbon solvent, and the Cold finger process where the vapors in the reboiler are partially condensed and drawn out separately from the bulk liquid.

Table 4-2 : TEG Technologies Comparison

Method	[TEG] % m/m (max)	Water dew point depression[ºC]
Stripping	99.2 / 99.98	55 / 83
Vacuum	99.2 / 99.98	55 / 83
Drizo	99.99 +	100 / 122
Cold finger	99.96	55 / 83

4.2.2. ADSORPTION DEHYDRATION USING SOLID DESICCANT

There are several solid desiccants which possess physical characteristic to adsorb water from natural gas. Generally, in a simple two-tower system, the dehydration systems consisting of two or more towers and associated regeneration equipment. One tower is on stream adsorbing water from the gas while the other tower is being regenerated and cooled. Hot gas is used to drive off the adsorbed water from the desiccant, after which the tower is cooled with an unheated gas stream. In general, the use of solids desiccant instead of liquids is associated to very low water de w point requirements, applications with high H2S gases content, requirements of simultaneous control of hydrocarbon and water dew point. At cryogenic or very low temperature it is usually preferred the use of solid desiccants than inhibition, to avoid hydrate and/or ice formation

Figure 4-4 : Driers Photo

4.2.2.1. PROCESS DESCRIPTION

The gas is dried in two of the three Driers operating in parallel. At any time, two beds are in adsorption phase and one in regeneration phase.

In adsorption phase, as the gas passes downward through the Driers, the water is adsorbed by the molecular sieves.

The Driers shall be designed for a period of at least three years of continuous operation

(without replacement of the molecular sieves).

The Driers operate on an 18-hour cycle time. This time is divided into the following steps

(to be confirmed by supplier):

- Adsorption time 12 hours.
- Regeneration time 6 hours.

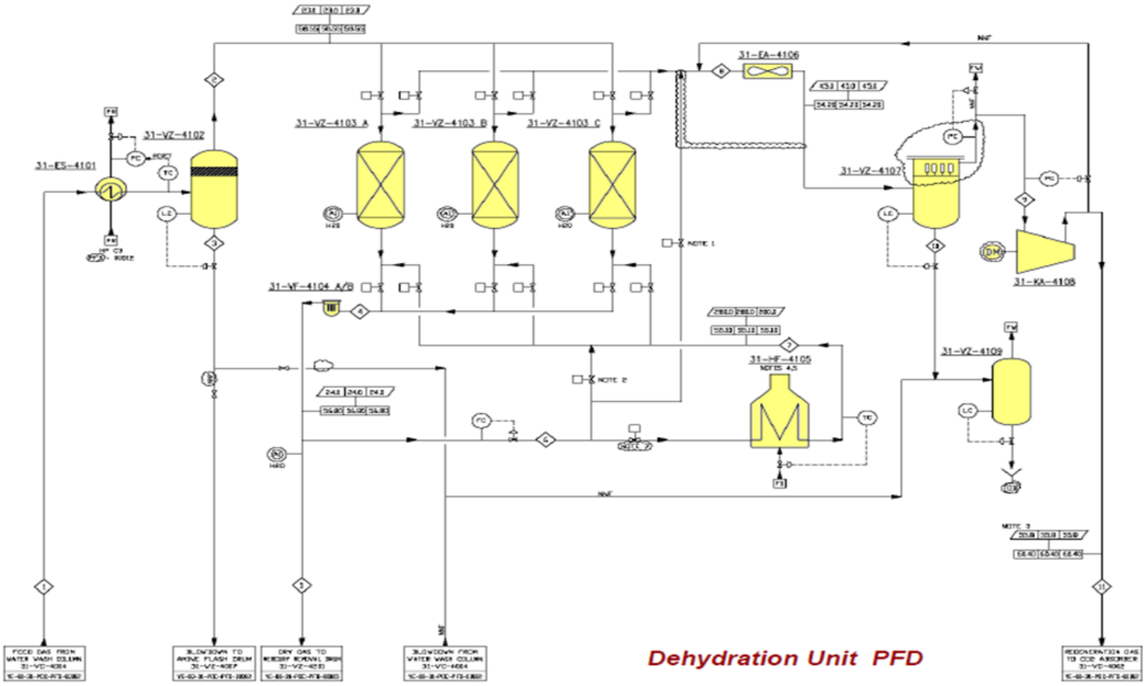


Figure 4-5:Dehydration Unit PFD

4.2.2.2. DRIERS REGENERATION

When a Drier is water saturated after 12 hours of adsorption, it is taken off adsorption mode and is regenerated to remove the residual water. Another Drier, which has completed the regeneration steps, replaces the previous Drier in the adsorption mode.

Each Drier is equipped with water content analyzers to monitor bed performance and detection of water breakthrough.

The regeneration time is divided into the following steps (to be confirmed by supplier):

- heating 4 hours including 0.5 h ramp-up.
- cooling 1.5 hours including 0.5h ramp-down.
- standby 0.5 hour.

4.2.2.3. EQUIPMENT AND UNITS DESIGN

If not otherwise mentioned in the following paragraphs, the system is designed to allow operation between 60% and 100% of the Very Lean Capacity.

Material selection for equipment and lines is made in such a way that immediate re-pressurization of the unit at full design pressure is possible in cold conditions i.e. just after a depressurization. This is an exception, justified by a marginal extra cost and higher operating flexibility, to the general philosophy applied on the plant design.

4.2.2.4. COMPRESSOR: DRIERS REGENERATION COMPRESSOR

The compressor is a centrifugal type and is designed to recompress the regeneration gas back to the inlet of the CO2 Absorber.

The suction lines are electrically trace heated to prevent liquid dropout from the saturated feed gas exiting.

The compressor is not spared, upon compressor shutdown pressure increases in the upstream drum leading to opening of and flaring the regeneration gas is flared automatically.

4.2.2.5. REGENERATION GAS AIR COOLER:

The design of the Air Cooler is determined based on the greatest between either dry regeneration gas cooled from 300°C to 45°C (corresponding to the end of regeneration heating phase) or wet regeneration gas with average water content cooled from 280°C 45°C. Since water peak, representing 5 to 7% of regeneration gas flow rate according to molecular sieves suppliers, takes places around 150°C it does not result in a sizing duty for air cooler. Regeneration gas air cooler is a forced draft type air cooler.

4.2.2.6. HP/C3 FEED GAS CHILLER:

The design duty of the exchanger is based on a gas outlet temperature of 23°C, with a minimum of 5°C above the hydrate formation point, with an inlet temperature of 38°C. This is the maximum operating temperature from Acid Gas Removal based on

the absorption for design CO_2 content in the Feed Gas (0.56% mol for the feed gas mixed with regeneration gas.

4.2.2.7. Driers After Filters

The filters are of the cartridge type, and are designed to remove all entrained solid particles from the Driers down to 6 μm. The pressure drop through the fouled filter shall not exceed 0.5 bar. The filters are provided with 6 μm filtration installed cartridges, however 10μm and 2 μm filtration cartridges are suitable to be installed, if required.

4.2.2.8. DRIERS REGENERATION FURNACE

Regeneration heat is provided by a cylindrical fired heater. The designed regeneration gas outlet temperature is 300°C. As there is no regeneration gas flow during cooling and bed switching steps, during these steps burners are stopped and pilots are operating.

Automatic restart of burners is provided. The relevant flame detection devices are provided (UV detection for burners and ionization rod for pilots).

4.2.2.9. VESSELS

Driers Inlet Separator:

To minimize the carryover of liquid droplets into the Driers that can subsequently

lead to deactivation of the molecular sieve beds, the separator is designed with the

following basis:

- Design flow rate: 100% of Very Lean Case operating flowrate based on design CO_2 content (0.6% mole) at System 40 inlet plus 40000 Nm^3/h of regeneration gas.
- High efficiency gas/liquid mesh separator is installed with the following performance specification 100% of droplets with diameter larger than 5 μm to be removed, Maximum liquid content in outlet gas: 5 ppmV at conditions.
- Schoepentoeter or equivalent inlet flow distributor is installed to improve efficiency of separation.

4.2.2.10. DRIERS:

The Driers are designed to accommodate the different molecular sieve inventory as stated proposed by the main suppliers such as Zeochem, Ceca, Grace and UOP.

4.2.2.11. SYSTEM DESCRIPTION

The adsorbent material is supported on a fixed grid, with layers of ceramic balls at the top and bottom of the bed. The Driers are externally insulated (heat and cold conservation).

An additional guard bed (alumina or silica) shall be installed above the molecular sieve bed in order to remove during normal operation any free water and amine traces and avoid deterioration of the molecular sieve. Adsorbed products shall be desorbed during the regeneration step and guard bed characteristics shall not be subject to deterioration during regeneration mode.

As the Driers will be cycling through the adsorption and regeneration sequences, mechanical design of the Driers shall take into account the effects of thermal fatigue.

Bed support is designed to ensure sudden pressurization with the transfer from regeneration mode to adsorption mode.

Depressurization of the driers is performed in a downward direction with an acceptable depressurization flow rate (to be checked by the selected supplier).

The following process guarantees shall be provided by the molecular sieve supplier:

- The water content of the dry gas shall be guaranteed,
- The molecular sieve lifetime shall be guaranteed to be at least three years,
- The pressure drop across the drier during adsorption step shall be guaranteed to be a maximum of 0.7 bar,
- The adsorption and regeneration duration shall be guaranteed,
- The regeneration gas flow rate shall also be guaranteed.

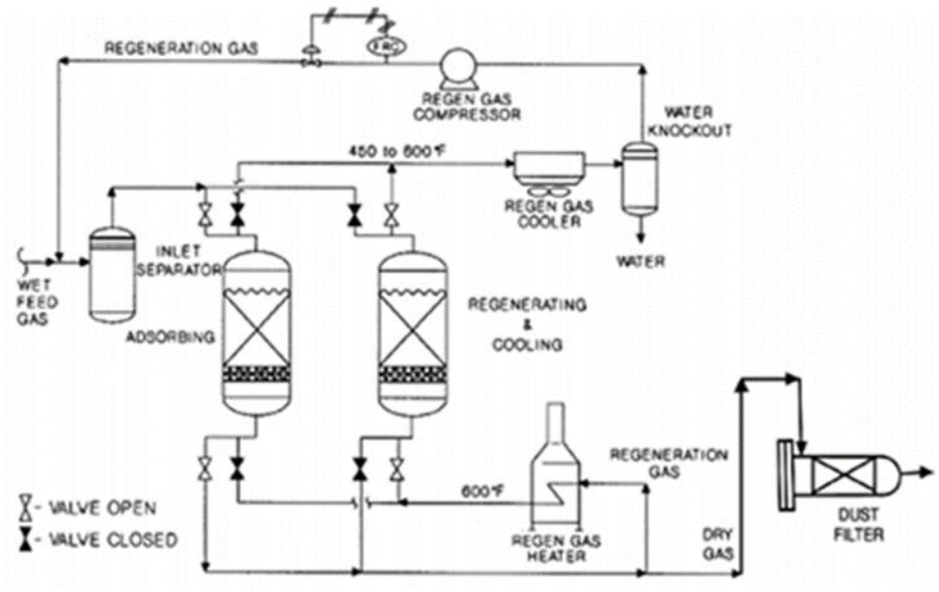


Figure 4-6 Basic Flow Scheme For Solid Desiccants

4.2.2.12. MARIB BLOCK 18 RICH GAS FOR BASIC DESIGN

Table 4-3 Raw Wet Inlet Gas Composition For the New Cryogenic Unit.

Component	**Mole %**
Methane	87.739
Ethane	6.420
Propane	3.299
i-Butane	0.511
n-Butane	1.045
i-Pentane	0.180
n-Pentane	0.346
n-Hexane	0.203
Heptane+	0.000
Nitrogen	0.000
Carbon dioxide	0.257
Water	Saturated
Total	**100.000**

4.2.2.13. COMPRESSION BETWEEN FEED GAS VS. LNG PRODUCT

Table 4-4 Feed Gas Composition

Component	Mole %		LNG Product Specs	Mole %
CO_2	0.17 – 0.31		CO_2	(1)
C1	93.2 – 93.6		C1	90.0 mini
C2	5.1 – 5.7		C2	(3)
C3	0.5 – 1.5		C3	
C4	0.02 – 0.37		C4	
C5+	0 – 0.19 (4)	**Plant** **Proceses**	C5+	0.1 max
C_6H_6 (Benzene)	100 ppmV max (4)		C_6H_6 (Benzene)	1ppm V max
H_2S	3 ppmV max		H_2S	3ppm V max
Total Sulfur	30 mg/Nm^3		Total Sulfur	30 mg/Nm^3
Hg (Mercury)	50 mg/Nm^3		Hg (Mercury)	Less than 10 mg/Nm^3
H_2O (Water)	100 ppmV max		H_2O (Water)	(2)

1) No specific requirement on LNG product, but **50 ppm** max (Acid Gas Removal Unit) @ MCHE inlet (freezing)
2) No specific requirement on LNG product, but 1 ppm max (Dehydration Unit) @ MCHE inlet (freezing)
3) No specific requirement on HHV for LNG product / C1 to C4 in LNG product similar to Feed Gas compo
4) Rich case only (upset in Marib upstream facilities) – Spec in LNG product is 1ppmV to avoid freezing in MCHE

4.2.2.14. REGENERATION OF ADSORBENT

Regenerating the adsorbent is the most important and least understood phase of an adsorption plant operation. It is the most expensive part of the operation because fuel is consumed in heating the regeneration gas.

Regeneration consists of a heating phase to boil out the adsorbed material, and a cooling phase to lower the adsorbent temperature to approximately that of the process inlet stream. Cooling is essential because the adsorbent will not remove as much material from the process stream at a high temperature.

Refer to the flow diagram for the 2- tower plant shown below. Tower 2 is adsorbing and Tower 1 is regenerating. During the heating phase of regeneration, the regeneration gas flows through the heater prior to entering Tower 1. During the cooling phase, the heater is by-passed and the regeneration stream flows directly to Tower 1. This gas flow should cool the ad- sorbent to within about 20ºC [35ºF] of the temperature of the process inlet fluid

The heating phase of regeneration includes 3 parts:

1. Heat the adsorbent to the boiling temperature of water.
2. Add enough heat to vaporize most of the water. About 90% of the water will boil off at this point.
3. Heat the adsorbent to drive off the remaining 10% of the water.

The last step is the most important and most difficult. Any adsorbed material that remains on the adsorbent after regeneration obviously reduces the capacity of the adsorbent. It also lowers the efficiency of the adsorbent, which results in a higher dew point of treated gas in a dehydration plant. About 25% of the total heater fuel is required to drive off the last 10% of adsorbed material, so it is the most expensive part of regeneration.

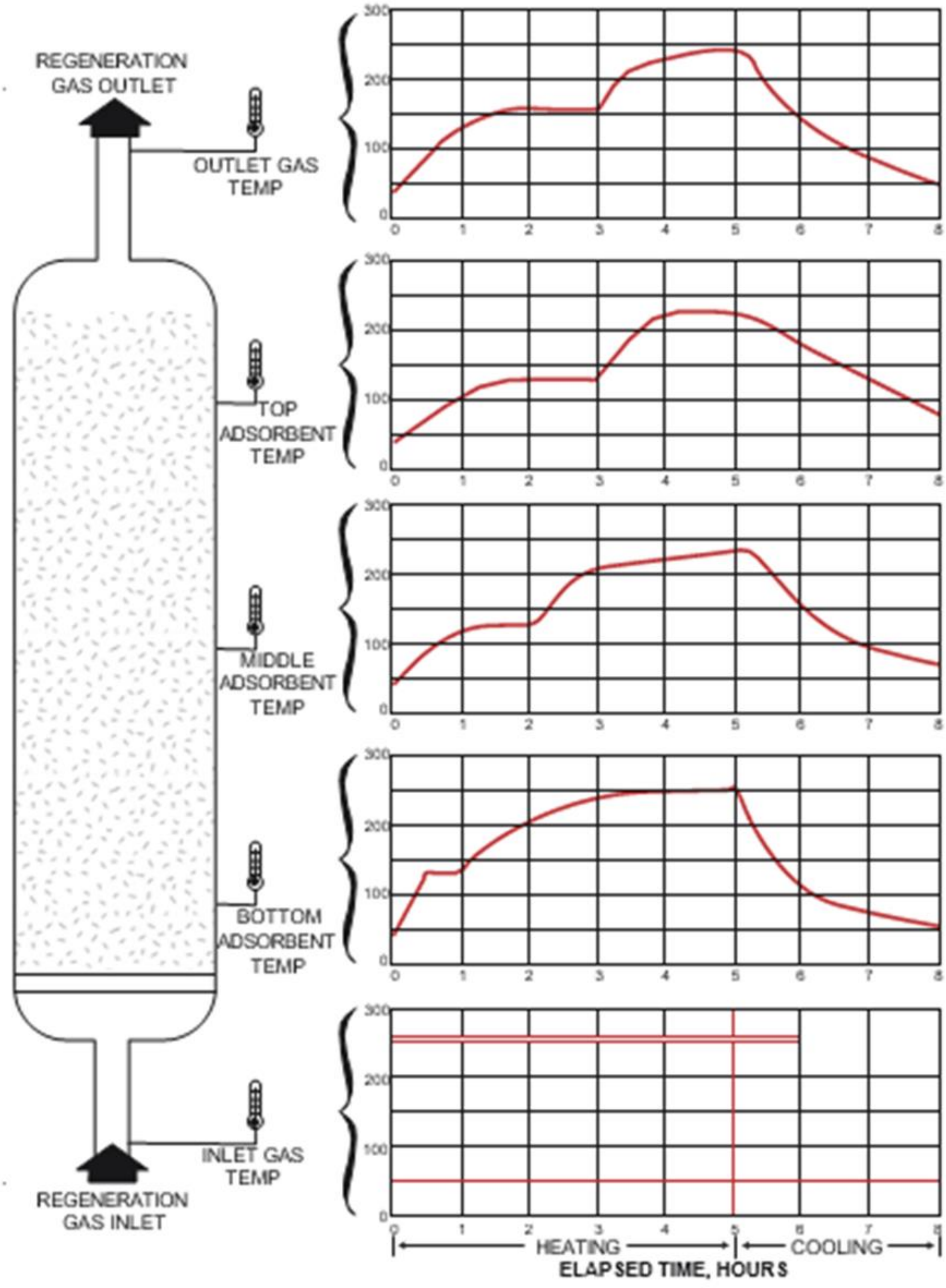


Figure 4-7 Temperature Profile In Adsorber During Regeneration.

4.2.2.15. NUMBER OF ADSORBENT REGENERATION FOR VARIOUS CYCLE TIMES

Table 4-5 Capacity Of Adsorbent Plants.

DAYS ADSORBENT IN SERVICE	NUMBER OF REGENERATIONS PER TOWER FOR TOTAL CYCLE TIME FOR 1 TOWER (TOTAL CYCLE TIME = HRS ADSORBING + HRS REGEN)									
	6 hrs	**8 hrs**	**10 hrs**	**12 hrs**	**14 hrs**	**18 hrs**	**16 hrs**	**20 hrs**	**22 hrs**	**24 hrs**
25	100	75	60	50	43	38	33	30	27	25
50	200	150	120	100	86	75	67	60	54	50
100	400	300	240	200	171	150	133	120	109	100
150	600	450	360	300	257	225	200	180	164	150
200	800	600	480	400	343	300	267	240	218	200
250	1000	750	600	500	429	375	333	300	273	250
300	1200	900	720	600	514	450	400	360	327	300
350	1400	1050	840	700	600	525	467	420	382	350
400	1600	1200	960	800	686	600	533	480	436	400
450	1800	1350	1080	900	771	675	600	540	491	450
500	2000	1500	1200	1000	857	750	667	600	545	500
550	2200	1650	1320	1100	943	825	733	660	600	550
600	2400	1800	1440	1200	1029	900	800	720	655	600
650	2600	1950	1560	1300	1114	975	867	780	709	650
700	2800	2100	1680	1400	1200	1050	933	840	764	700
750	3000	2250	1800	1500	1286	1125	1000	900	818	750
800	3200	2400	1920	1600	1371	1200	1067	960	873	800
850	3400	2550	2040	1700	1457	1275	1133	1020	927	850
900	3600	2700	2160	1800	1543	1350	1200	1080	982	900
950	3800	2850	2280	1900	1629	1425	1267	1140	1036	950
1000	4000	3000	2400	2000	1714	1500	1333	1200	1091	1000

The following three types of solids desiccants are usually used:

Silica Gel

Silica Gel basically, is a silicon dioxide, SiO_2 and is used for gas and liquid dehydration. Also, it can be used for hydrocarbon recovery from natural gas. Dew point of approximately -60 ºC can be achieved in hydrocarbon removal units that are commonly called HRUs (Hydrocarbon Recovery Units) or SCUs (Short Cycle Units)

Alumina

Alumina (manufactured or natural) is a hydrated form of alumina oxide, Al_2O_3 which can be used for dehydration of liquid and gases and get water dew points of about -70ºC

Advantages: In comparison with molecular sieves, alumina needs less regeneration heat because its regeneration temperature is lower.

Disadvantages: Heavy hydrocarbons tend to get adsorbed in the alumina, making the alumina impossible to be regenerated. Alumina can also react with mineral acid.

Molecular Sieves

The molecular sieves are alumina silicates (manufactured or naturals) having the highest selectivity and water capacity and consequently can get the lowest values of water dew point. These technology is commonly used upstream a NGL recovery plant, or in process where very cold temperatures are presents, to prevent hydrate and ice formation. Water dew point of about -100ºC is possible to achieve with molecular sieves. With same changes on design or in operating parameters lower temperatures can be reached. To get a continuous process, a lead-lag arrangement is required, while one bed is operating, the other bed is getting regenerated and cooled. Cycles between 8 and 24 hours are usual. Molecular sieves are non-toxic, non-corrosive and available in different pore sizes

Advantages: Main advantage is the lower water dew point than can be reached.

Disadvantages: They are usually more expensive than the other alternatives.

Table 4-6 Typical Types Of Adsorbents

	Description	Cost	Water content depression	Regeneration	Adsorption of heavy hydrocarbons / regeneration	Advantage	Disadvantage
Alumina	From of aluminum oxide (Al_2O_3)	Least Expensive	5ppm	Requires more heat for Regeneration	Yes / hard	Excellent dew point depression	Alkaline, cannot be used in the presence of acid gases
Silica Gel & Silica Alumina Gel	Manufactured from sulfuric acid and sodium silicate, combination of silica and alumina gels	Medium	10ppm	Easy	Yes / hard	Handle sour gases	Sulfur can deposit, can't handle caustic or ammonia
Molecular Sieves	Crystalline from of alkali metal (calcium or sodium)	Most expensive	1ppm	Requires more heat for Regeneration	No / -	Don't absorb heavy hydrocarbons Best choice For sour gases, highly porous and very high surface area	Expensive

Table 4-7 Representative Properties Of Commercial Silica Gels, Activated Alumina, And Molecular Sieve 4A

	Silica Gel	**Activated Alumina**	**Molecular Sieve 4A**
Shape	Spherical	Spherical	Pellets (extruded cylinders) and beads
Bulk density Lb/ft^3 (kg/m^3)	49 (785)	48 (769)	40 -45 (640 – 720)
Particle size	4 – 8 mesh 5 – 2 mm	7 – 14 mesh, 1/8 inch, 3/16 inch, ¼ inch diameter (3 mm, 5 mm, 6 mm)	1/16 inch, 1/8 inch, ¼ inch diameter cylinders (1.6 mm, 3.2 mm, 6 mm)
Packed bed % voids	35	35	35
Specific heat Btu/lb $^{\circ}$F (kJ/kg K)	0.25 (1.05)	0.24 (1.00)	0.24 (1.00)
Surface area m^2/g	650 – 750	325 – 360	600 – 800
Pore volume cm^3/g	0.36	0.5	0.28
Regeneration temperature, $^{\circ}$F ($^{\circ}$C)	375 (190)	320 to 430 (160 to 220)	400 to 600 (200 to 315)
Average pore diameter (Å)	22	NA	3, 4, 5, 10
Minimum dew point temperature of effluent, $^{\circ}$F ($^{\circ}$C)	-80 (-60)	-100 (-75)	-150 (-100)
Average minimum moisture content of effluent gas, ppmV	5 – 10	10 - 20	0.1

Table 4-8 Solid Desiccants (Adsorption Dehydration) Advantages / Disadvantages

Advantage	**Disadvantage**
• Dew point as low as -150°F • They are less affected by small changes in gas pressure, temperature and flow rate. • They are less susceptible to corrosion or foaming.	• Higher capital cost and higher pressure drops • Desiccant poisoning by heavy HC's, H_2S, CO_2, etc. • Mechanical breaking of desiccant particles. • High regeneration heat requirements and high utility costs.

Table 4-9 Comparison Of Glycol And Molecular Sieve For Gas Dehydration

Glycol	Molecular Sieve
Glycol units have a single high pressure absorber tower	Molecular sieves require a minimum of two high pressure absorbers, sometimes more, depending on flow rates and regeneration cycles
Lower CAPEX	Higher CAPEX
Glycol units have lower peak utility consumption as the glycol reboiler operates continuously	Molecular sieve regeneration gas heater is a cyclic service; therefore, have higher peak utility consumption.
Glycol units operate at maximum temperature of 204°C. The equipment that operates at high temperature in a glycol unit is at low pressure.	Molecular sieves operate at maximum temperature of >315°C. The high temperatures occur at high pressures.
Lower pressures may result in a lower pressure piping class for glycol unit equipment and piping e.g. class 600 RF.	The combination of high temperature and high pressure may dictate the use of a higher pressure piping class for the molecular sieve equipment and piping e.g. class 900 RTJ. This may require an additional range of spare parts not found elsewhere on the plant.
Glycol units employ simple control loops only.	Molecular sieves require relatively complex valve switching logic and critical sequence timing.
Gas pressure drop < 0.3 bar	Gas pressure drop = 1.0 – 1.5 bar.
Liquid phase water droplets do not affect glycol units.	Molecular sieve desiccant material is intolerant to liquid phase water droplets. Impact of droplets on the sieve causes severe degradation of the desiccant producing fine solid particles, which migrate through the bed and entrained in the gas. Additional filters require maintenance and carry an attendant risk of non-performance.
No fine particles present in Glycol unit.	Attrition of desiccant creates fine particles of molecular sieve material, which entrained, in the dry gas. A fine gas filter is required downstream adding to the overall pressure drop of the system.

Table 4-10 Comparison Of Liquid And Solid Desiccants

Absorption using liquid desiccants	Adsorption using solid desiccants
Low installation cost	High installation costs
Low pressure drop: 5-10 psi	High pressure drop: 10-50 psi
Continuous process	Process in parallel
Low ratio of heat regeneration / removed water	High ratio of heat regeneration / removed water
Minimum water dew point = -40ºC	Minimum water dew point = -100ºC
For low water dew points other regeneration methods are needed: Stripping, Drizo, etc.	The reactive are poisoned in contact heavy hydrocarbons.
Low operating cost	High operating cost
Glycols are corrosive when are degradated or contaminated	Less susceptible to corrosion or foaming.
Highly affected due to changes of flow, pressure and temperature of the gas flow	Not highly affected due to changes of flow, pressure and temperature of the gas flow

Table 4-11 Typical Process Requirements For Dehydration Plants

				REGEN GAS		**REGENERATION HEAT**			
ADSORBENT		MOISTURE REMOVED FROM INLET GAS %	DEW POINT OF TREATED GAS	SOURCE OF GAS	FLOW DIRECTION IN TOWER	TEMP TO HEAT ADSORBENT		HEATER FUEL GAS	
TYPE	CAPACITY Wt%					°C	°F	m3/kg of ADSORBENT	cu ft/lb of ADSORBENT
Mol Sieve	10.0	99.9%	Below -62C [-80F]	Treated Gas	Up	232°	450°	0.062	1.0

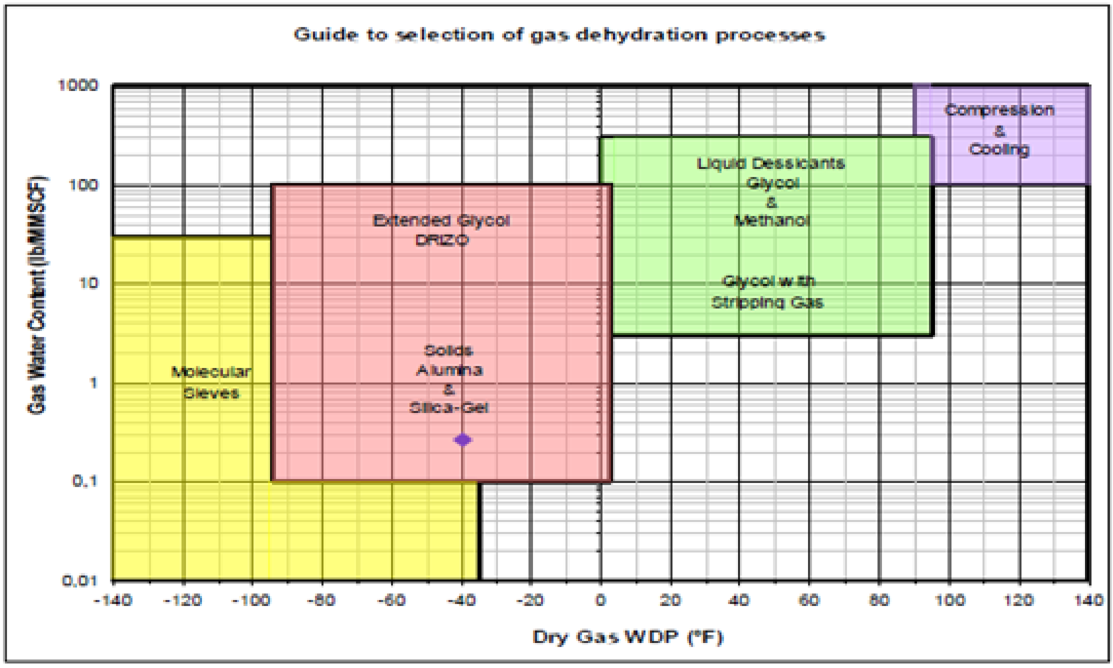


Figure 4-8 Gas Dehydration Technology Selection Chart

4.3. CAPEX OF MOLECULAR SIEVE AND TEG SYSTEMS

Fig. (4.3.1) plots the cost indicator for molecular sieve systems against CO_2 flow rate and shows the maximum and minimum cost lines. There is a wide spread in molecular sieve capital cost data from different vendors for a fixed operating pressure. The differences are due to several factors

The materials of construction proposed.

- The number and size of the individual adsorption beds proposed.
- The number of parallel dehydration trains proposed.

Operating pressure has an effect on the equipment capital costs of molecular sieve systems. Limited available data indicates that equipment capital cost passes through a minimum at 25–30 bara.

There is no difference between the capital costs of the molecular sieve equipment for target moistures of 550 ppm, 50 ppm and < 10 ppm. Media suppliers and package vendors all advised that it is normal to design for the removal of water from the gas stream to achieve < 1 ppm, irrespective of the target moisture required. However, at lower target moisture, the cycle time of each bed becomes shorter.

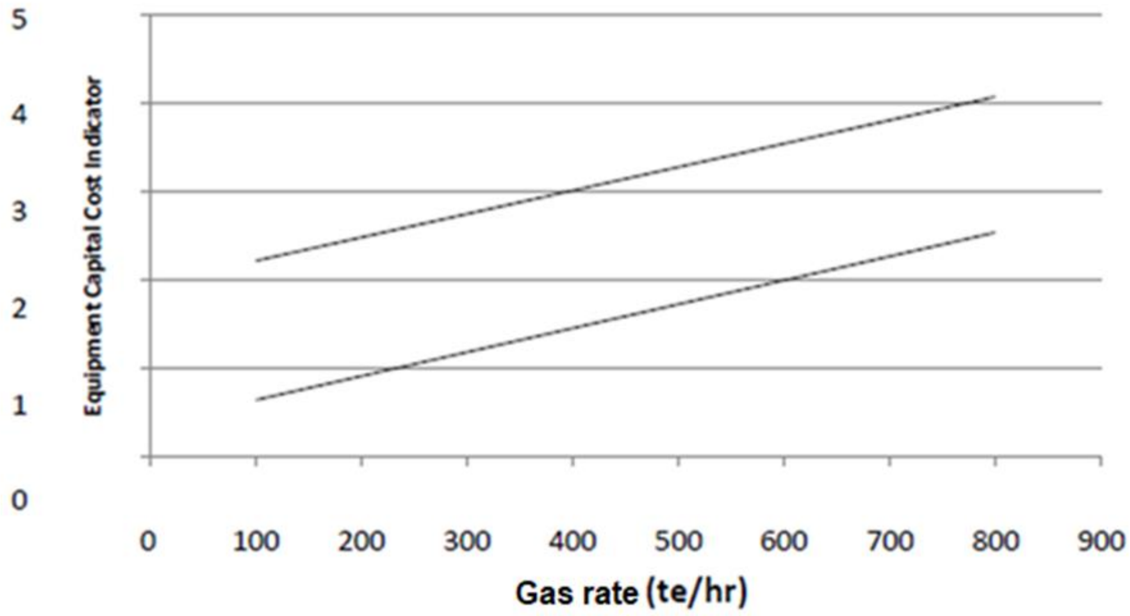


Figure 4-9 CAPEX Indicator For Molecular Sieve.

The circulation rate of TEG and the equipment in the TEG circulation loop will therefore increase. Similar, molecular sieve systems will require larger media volumes. This results in a higher capital cost for both systems.

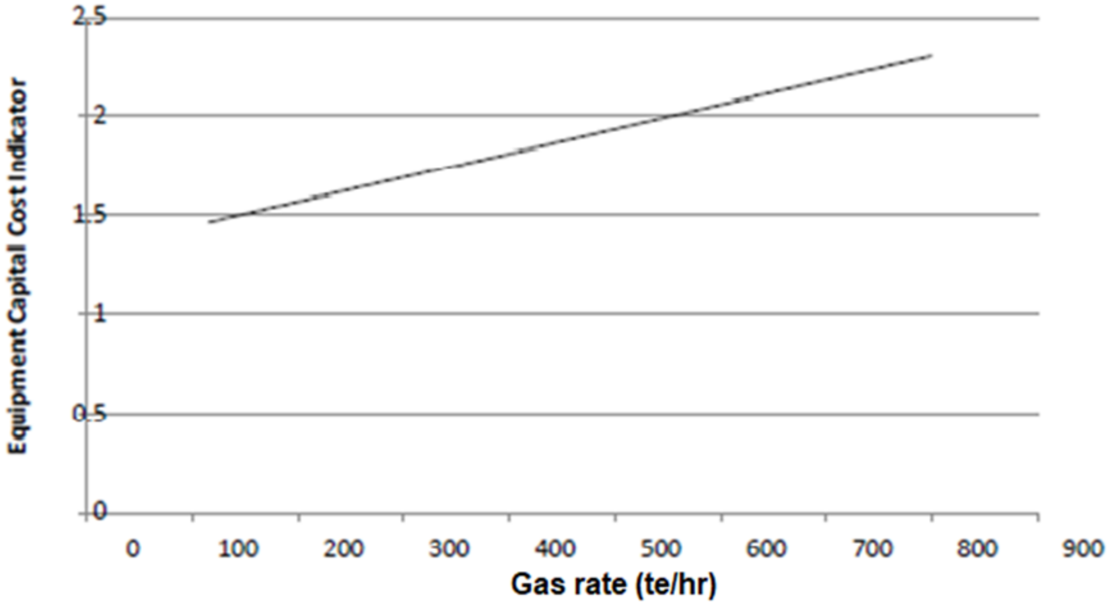


Figure 4-10 CAPEX Indicator For TEG.

Presents the results of the operating cost estimation for the following cases, both assuming a desiccant lifetime of 3 years:

- Molecular sieve at 265 te/hr. Options from two different vendors, one using low pressure regeneration with atmospheric air (minimum CAPEX case) and another using CO2 at pressure for regeneration (maximum CAPEX case).
- TEG at 265 te/hr. Only a single vendor (who also provided the molecular sieve maximum CAPEX case data) has provided information.

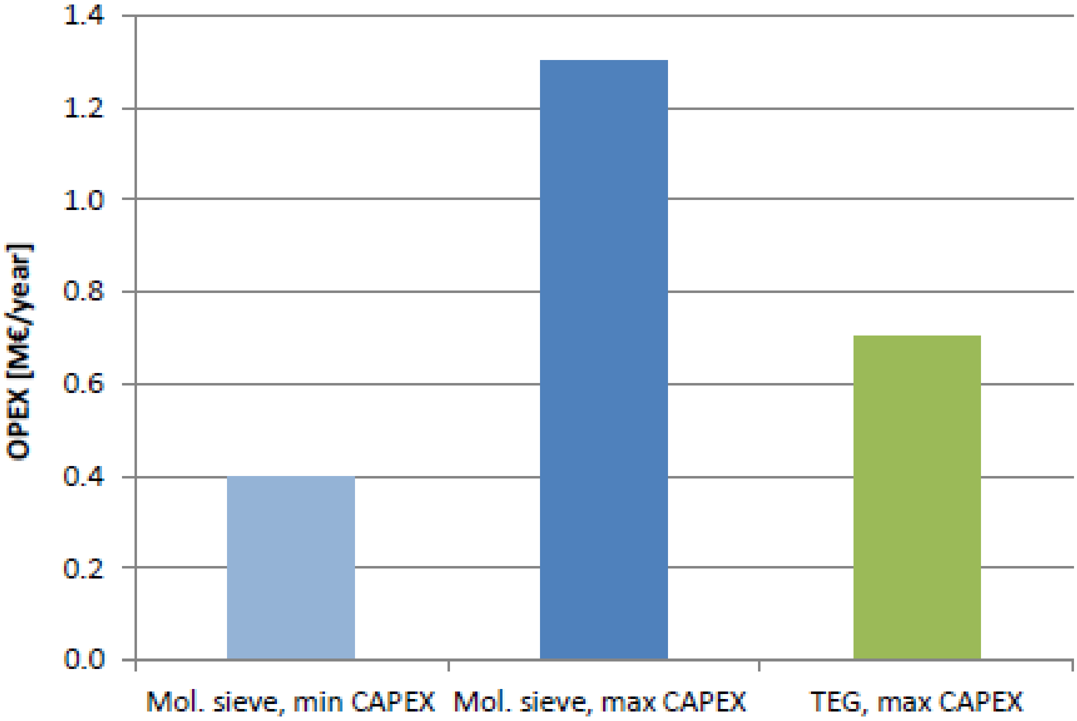


Figure 4-11 OPEX Estimates For Different Dehydration Systems.

Figure 4-11 Comparing data from the same vendor indicates that the annual operating cost of the TEG system is significantly lower than that for the molecular sieve package. However, the more basic molecular sieve package, from a different vendor, but for the same raw gas conditions, indicates that the annual operating costs for molecular sieve systems can also be significantly lower than those for a TEG system. The estimated minimum operating costs for molecular sieve packages as a function of CO_2 flow rate follow a linear trend, comparable to the CAPEX indicators in Fig. 3 and 4. They span a range from 0.27 M€/yr. for a capacity of 265 te/hr. and 0.72 M€/yr. for a unit size of 800 te/hr.

Figure 4-12 provides relative cost data for moisture monitoring equipment. The cost indicator values exclude the sampling system and analyzer housing/building, as these requirements are very project specific. The figure shows that P_2O_5 cells are the least expensive moisture measuring technique, although the cost can vary significantly between different vendors. Quartz crystal sensors and CRDS are the most expensive techniques (i.e. when omitting the dual silicon sensor set-up).

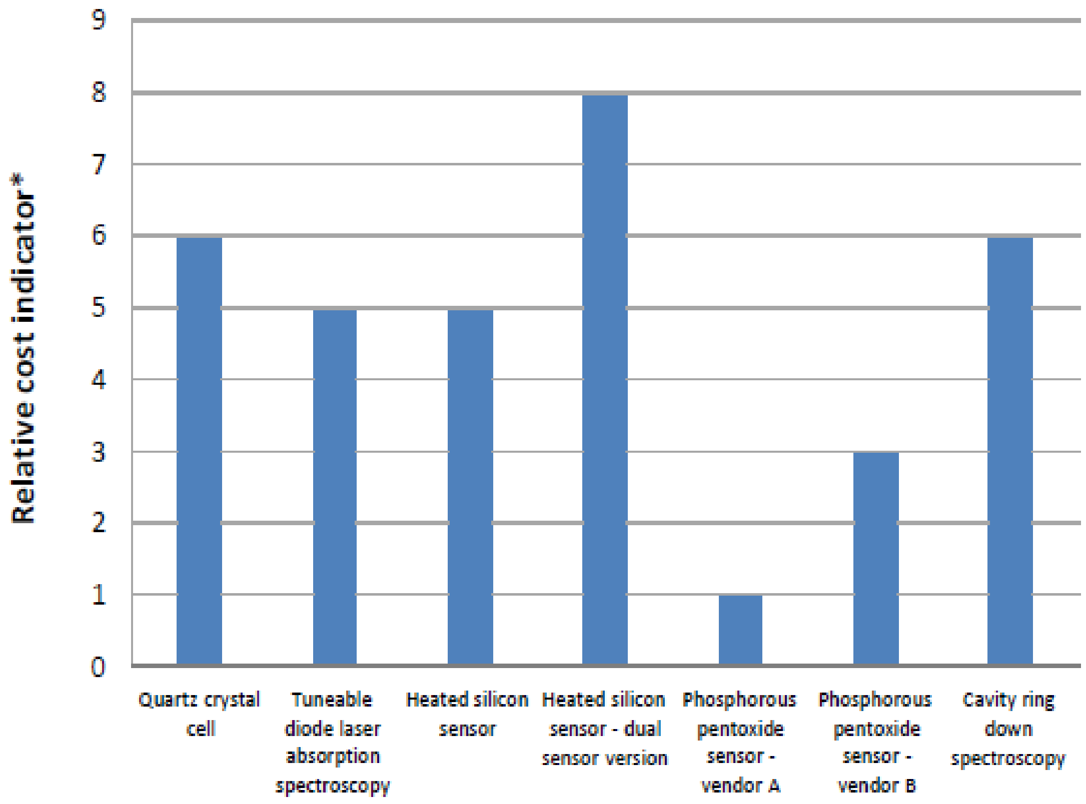


Figure 4-12 Relative Cost Indicators For Different Moisture Monitoring Techniques.

(*where, e.g., 5 indicates that the item price is 5 times as costly as the baseline price of 1)

4.4. MEASURING PRINCIPLE

Design and operation of dehydration units come along with several challenges. This work identified that it is usually beneficial in terms of economics to consider a series of dehydration techniques in order to offload the main system. Besides, removal of impurities by application of guard beds and upstream treatment can offer protection for sensitive desiccants.

The minimum CAPEX and OPEX for both molecular sieve and TEG systems depend mainly on operating pressure and type of regeneration. For a fixed operating pressure, there is a wide spread in CAPEX data. In case of high inserts, the CAPEX will increase for both molecular sieve and TEG systems. Presence of impurities, i.e. NO_2, SO_2 and

H2S, leads to a 7% higher CAPEX but no difference in OPEX for molecular sieve systems. At this time, it is not possible to quantify the effect of impurities on the costs of TEG systems.

Areas requiring further work are, for example, the effect of inserts and impurities on the physical properties of the CO_2 stream.

CHAPTER FIVE

5. CONCLUSION, RECOMMENDATIONS, AND LIMITATIONS

5.1. INTRODUCTION

In this project it was made a comparison between the ways of dehydration process and select the best economical for removing impurities from dehydration process methods in chapter 4.

5.2. CONCLUSION

Comparing data from the same vendor indicates that the annual operating cost of the TEG system is significantly lower than that for the molecular sieve package. However, the more basic molecular sieve package, from a different vendor, but for the same raw gas conditions, indicates that the annual operating costs for molecular sieve systems can also be significantly lower than those for a TEG system. The estimated minimum operating costs for molecular sieve packages as a function of gas flow rate follow a linear trend, comparable to the CAPEX indicators in Fig (4-9) and they span a range from 0.27 M€/yr. for a capacity of 265 te/hr. and 0.72 M€/yr. for a unit size of 800 te/hr.

Therefore, the molecular sieves way of gas dehydration unit was selected in the Yemen LNG company for the following reasons:

- High efficiency up to 0.1 ppm.
- Easy control.
- Clean industry.
- Easy maintenance.
- If we need to dry the gas very large as in the coefficient that the gas temperature must be reduced to a large score in cryogenic here is preferred to use molecular sieves.

5.3. RECOMMENDATIONS

- Establishment of a unit for the production of molecular sieves that's capex for this project is approximately the net value 400k euro according to Yemen gas utilization study prepared by Ramboll company from Denmark. We need only 16 MMscf of natural gas to produced 400 tone of the raw material for molecular sieves and 10 megawatts for power

- It recommends that government and the Ministry of Oil work to establish this unit whose construction price ranges the one mentioned above instead of importing molecular sieves every two years at an amount close to the price of establishing this unit

5.4. LIMITATIONS

1) One of the goals was to conduct a 3D simulation video that shows how the drying and processing of gas is carried out in the Yemen Liquefied Gas Company, but due to the lack of basic data such as drawings and illustrative measurements of the equipment from the company, this goal was limited to only explaining the operations in theory. With a limited number of data as well.
2) Difficulties such as the Coronavirus crisis during data collection resulted in delaying the completion of the project on time.
3) The absence of a unit for the manufacture of molecular sieves led to the development of recommendations on the proposal to build this unit according to the study carried out by the Danish company, Ramboll.

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