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Gas dehydration methods

Abstract

Today, natural gas is one of the most important fuels in our life and one of the principle sources of energy for many of our day-to-day needs and activities. It is important factor for the development of countries that have strong economies because natural gas is the source of energy for household, industrial and commercial use, as well as to generate electricity. It is one of the cleanest, safest, and most useful of all energy sources. It consisting primarily of methane but including significant quantities of ethane, propane, butane, and pentane and other impurities such as carbon, sulfur, nitrogen, water etc at reservoir because of high pressure and temperature.

Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet'. In order to meet the requirements for a clean, dry, wholly gaseous fuel suitable for transmission through pipelines and distribution for burning by end users, the gas must go through several stages of processing, including the removal of entrained liquids from the gas, followed by drying to reduce water content. In order to remove water content, dehydration process is used to treat the natural gas. This paper discusses the various methods of dehydration of natural gas.

Dehydration (hypohydration) is the removal of water from an object. In Physiologic terms, it entails a relative deficiency of water molecules in relation to other dissolved solutes. Gas dehydration is one of the most prominent unit operations in the natural gas industry. In this operation water, content is removed from natural gas streams to meet sales specifications or other downstream gas processes such as gas liquid recovery.

Introduction

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.

Gas dehydration is a process of extracting moisture out of natural gas and gaseous mixtures. It often precedes either a pipeline transportation of gas or a low temperature based gas processing.

By drying we imply removal of moisture or dehydration. Water moisture content is present in every gas. It is the quantity of that content that differs. Most of the raw or feed untreated gases are saturated with moisture – i.e. they hold maximum content at specified pressure and temperature. It is worth noting that we're not talking about free water – drops flying in with the gas that is easily removed in the mechanical separators. Instead we're referring to water vapor that requires more sophisticated processes to be applied.

Dehydration allows for continuous use of downstream process equipment and pipelines by reducing the risk of hydrates cooling down and forming ice plugs in the pipelines. Most of the dehydration methods are based on either absorption or adsorption of moisture or on its

condensation during cooling of the gas. The most important characteristic of the dehydrated gas is its water dew point (measured in deg C or deg F just like temperature).

Typically, dehydration is important in three areas :

- Gas gathering: water must be removed to reduce pipeline corrosion and prevent line blockage caused by hydrate formation;
- Product dehydration: both gas and liquid products have specifications on water content. Sales gas that leaves a plant is usually dry if cryogenic hydrocarbon liquid recovery is used. Liquid and gas streams may be water saturated after amine treatment or coming from underground storage. Most product specifications, except for propane, require that no free water be present.
- Hydrocarbon recovery: most plants use cryogenic processes to recover the C2 + fraction from inlet gas. If acid gases are removed by use of amine processes, the exit gas leaves water saturated. To prevent hydrate formation in the cryogenic section of hydrocarbon recovery, the water concentration should be 0.1 ppmv or less.

Gas dehydration methods.

Natural gas dehydration unit is a facility used to remove water in gas stream. There are at least three commercial methods of natural gas dehydration, which are absorption, adsorption, and condensation.

1. Absorption method

Absorption is the most widely used industrial natural gas dehydration. Absorption is usually performed by using TEG (triethylene glycol). The process consists of absorption (of water in gas stream) and regeneration (of TEG). Absorption occurs at low temperature, while regeneration occurs at high temperature.

Absorption dehydration unit consists of glycol contactor, in form of tray column or packed column. In the contactor, wet natural gas and TEG flow counter-currently. TEG enriched in water flows out the bottom part of contactor, while dry natural gas flows out to the upper part of contactor. At the top part of contactor, filter is sometimes installed. The function is to capture remaining TEG in dry gas stream. TEG enriched in water flows into flash drum, where the flash gases are released. Then, the TEG enters to cold side of glycol/glycol heat exchanger. Then, TEG enters reboiler, where it is heated by heat transfer fluid to regenerate the TEG. Regenerated TEG is pumped back to hot side of glycol/glycol exchanger and gas/glycol heat exchanger to the top of contactor. The cycle begins again.

- ✓ Natural gas is dried by absorption, often in a countercurrent scrubbing unit. A liquid having a strong affinity for water is used as an absorbent.
- ✓ A liquid having a strong affinity for water is used as an absorbent.
- ✓ A good absorbent should have;

1. Strong affinity for water

2. Low cost

- 3 Non corrosive
4. Low affinity for hydrocarbons and acid gases
5. Thermal stability
6. Low viscosity

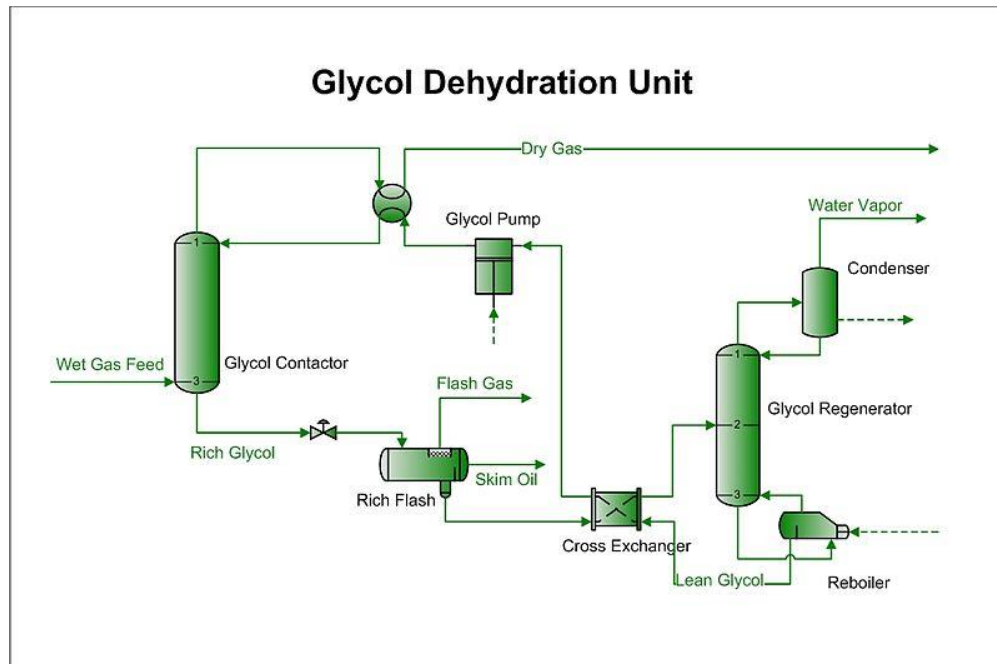


Figure 1. Glycol dehydration unit

Glycol Absorption Unit pros and cons

Pros

- Low initial cost ☐
- Low pressure drop across absorption towers ☐ Recharging of towers present
- no problems Recharging of towers present no problems ☐ Materials that would cause fouling of some solid adsorbents can be tolerated in the contactor

Cons

- ☐ Suspended matter, such as dirt, scale, and iron oxide may contaminate glycol solutions
- Overheating of solutions may produce both low and high boiling decomposition products ☐
- The resultant sludge may collect on heating surfaces, causing some loss in efficiency, or, in severe cases, complete flow stoppage ☐

- When both oxygen and hydrogen sulfide are present, corrosion may become a problem because of the formation of acid material in the glycol solution [2]
- Liquids such as water, light hydrocarbons or lubrication oils in inlet gas may require installation of an efficient separator ahead of the absorber. Highly mineralized water entering the system with inlet gas may, over long periods crystallize and fill the reboiler with solid salts [2]
- Foaming of solution may occur with a resultant carry-over of liquid. The addition of a small if d l l di hi bl l l quantity of antifoam compound usually remedies this problem.

2. Adsorption method

In this method, solid desiccants adsorb water, most often by mole sieve, silica gel or alumina. As a minimum, two beds systems are used

Table 1 comparison of the physical properties of desiccants.

Properties	Silica gel	Alumina	Mol. sieves
Specific area [m ² /g]	750 – 830	210	650 – 800
Pore volume [cm ³ /g]	0,4 – 0,45	0,21	0,27
Pore diameter [Å]	22	26	4-5
Design capacity [kg H ₂ O/100 kg desiccant]	7-9	4-7	9-12
Density [kg/m ³]	721	800 - 880	690 – 720
Heat capacity [J/kg/°C]	920	240	200
Regeneration temperature [°C]	230	240	290
Heat of desorption [J]	3256	4183	3718

. Natural gas adsorption is usually consists of two towers, where adsorption occurs in one tower, and regeneration occurs in the other one. Hot gas is used to drive off the absorbed water from the desiccant. A comparison of the physical properties of desiccants are shown in the table above.

The amount of adsorbed water molecules increases with the pressure of the gas and decreases with its temperature. These facts are taken into account when the process parameters are designed. Adsorption dehydration columns always work periodically. A minimum of two bed systems are used. Typically one bed dries the gas while the other is being regenerated. Regeneration is performed by preheated gas, or by part of the dehydrated NG as depicted in Figure 2.

This method is known as temperature swing adsorption (TSA). Regeneration can also be performed by change of pressure - pressure swing adsorption (PSA). However, PSA is not industrially applied for NG dehydration.. A combination of those two methods (PSA and TSA) seems to be a promising future option for adsorption dehydration of NG. This idea is still in the research process. In classical applications, the TSA heater is realized as an ordinary burner or as

a shell and tube heat exchanger warmed by steam or by hot oil. The regeneration gas warms in the heater and flows into the column. In the column passes through the adsorbent and the water desorbs into the regeneration gas. The water saturated regeneration gas then flows into the cooler. The cooler usually uses cold air to decrease the temperature of the regeneration gas. When the water saturated regeneration gas is cooled, partial condensation of the water occurs. The regeneration gas is led further into the separator, where the condensed water is removed.

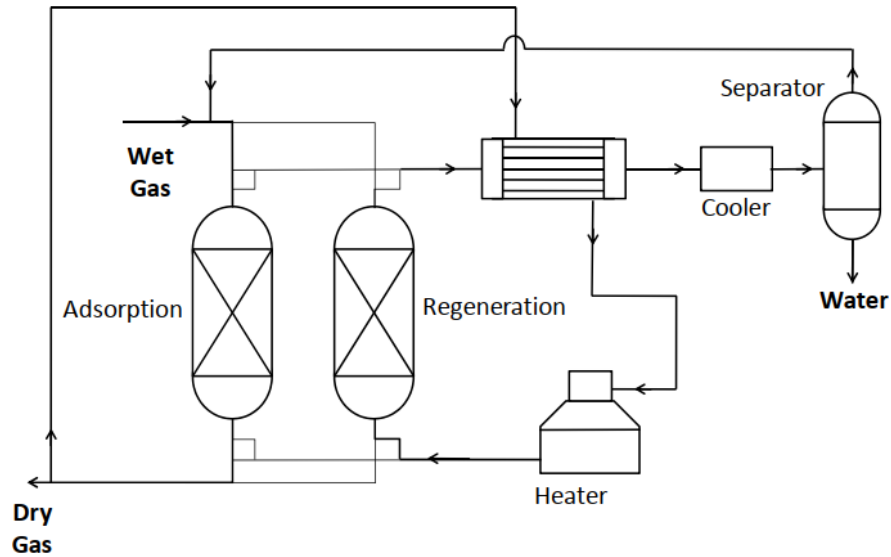


Figure 2. Schematic drawing of adsorption natural gas dehydration unit

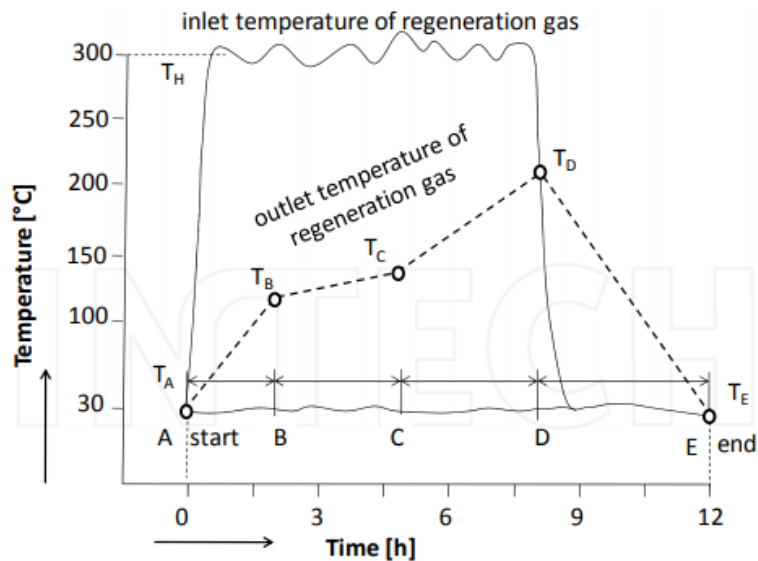


Figure 3 . Typical temperature course for 12 h TSA regeneration of molecular sieves

A downstream flow of wet NG through the adsorption column is usually applied. In this way, floating and channeling of an adsorbent is avoided. Regeneration is performed by countercurrent flow in order to provide complete regeneration from the bottom of the column, where the last contact of the dried NG with the adsorbent proceeds. The typical temperature course for 12 h regeneration of molecular sieves is shown in Figure 3 above.

In figure 3 the shape of the curve representing the course of the outlet regeneration gas temperature is typically composed of four regions. They are specified by time borders A, B, C and D with appropriate border temperatures T_A , T_B , T_C and T_D . Regeneration starts at point A. The inlet regeneration gas warms the column and the adsorbent. At a temperature around 120°C (T_B) the sorbed humidity starts to evaporate from the pores. The adsorbent continues warming more slowly, because a considerable part of the heat is consumed by water evaporation. From point C, it can be assumed that all water has been desorbed. The adsorbent is further heated to desorb C_5+ and other contaminants. The regeneration is completed when the outlet temperature of the regeneration gas reaches $180 - 190^\circ\text{C}$ (T_D). Finally, cooling proceeds from point D to point E. The temperature of the cooling gas should not decrease below 50°C , in order to prevent any water condensation from the cooling gas. Part of the dehydrated NG is usually used as the regeneration gas. After regenerating the adsorbent the regeneration gas is cooled, and the water condensed from it is separated. After water separation, the regeneration gas is added back to the inlet stream or alternatively to the dehydrated stream. The total energy used for regeneration is composed of heat to warm the load (30%), heat for desorption (50%) and heat going into the structure (20%). With proper internal insulation of the adsorption towers, the heat going to the structure can be minimized and around 20% of the invested energy can be saved. So-called LBTSA (Layered Bed Temperature-Swing Adsorption) processes are an upgrade of the TSA method. Here, the adsorption column is composed of several layers of different adsorbents. Hence the properties of the separate adsorbents are combined in a single column. For example, in NG dehydration a combination of activated alumina with molecular sieve 4A is used. Alumina has better resistance to liquid water, so a thin layer is put in first place to contact the wet NG. This ordering supports the lifetime of the molecular sieve, which is placed below the alumina layer. The effect of adsorbent lifetime extension is shown for two cases in Figure 6. It can be seen that contact with liquid water dramatically decreases the lifetime of the molecular sieve.

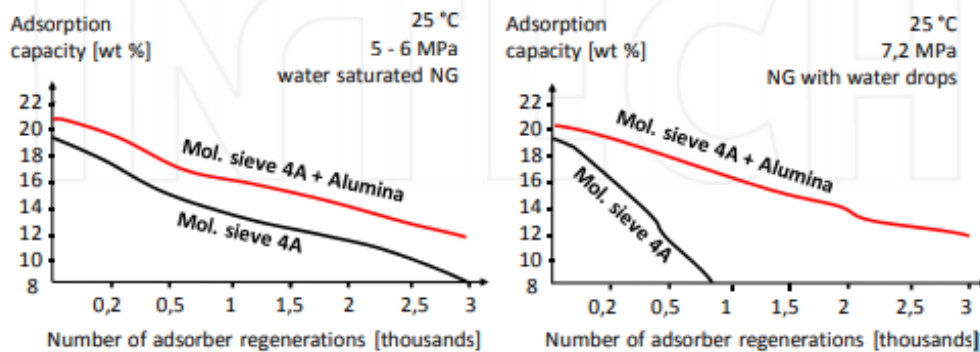


Figure 4. Effect of layered bed adsorption on the lifetime of the adsorbent

Advantages of Molecular Sieves:

- Very low dew point and water content can be obtained [2]
- Best suited for large volumes of gas under very high pressure
- Dehydration of very small quantities of natural gas at low cost [2]
- Insensitive to moderate changes in gas temperature, flow rate, and pressure. [2]
- They are relatively free from problems of corrosion, foaming, etc. [2]
- Some types can be used for simultaneous dehydration and sweetening

Disadvantages of Molecular Sieves:

- The most expensive adsorbents [2]
- The regeneration temperature is very high (operating cost). [2]
- Pressure drop is too high [2]
- High space and weight required [2]
- Mechanical breaking and contamination of liquid, oil and glycol are possible

3. Condensation method

The third conventional dehydration method employs gas cooling to turn water molecules into the liquid phase and then removes them from the stream. Natural gas liquids and condensed higher hydrocarbons can also be recovered from NG by cooling. The condensation method is therefore usually applied for simultaneous dehydration and recovery of natural gas liquids. NG can be advantageously cooled using the Joule-Thompson effect (JT effect). The JT effect describes how the temperature of a gas changes with pressure adjustment. For NG, thanks to expansion, the average distance between its molecules increases, leading to an increase in their potential energy (Van der Waals forces). During expansion, there is no heat exchange with the environment, and no work creation. Therefore, due to the conservation law, the increase in potential energy leads to a decrease in kinetic energy and thus a temperature decrease of NG. However, there is another phenomenon connected with the cooling of wet NG. Attention should be paid to the formation of methane hydrate. Hydrates formed by cooling may plug the flow. This is usually prevented by injecting methanol or monoethyleneglycol (MEG) hydrate inhibitors before each cooling. Figure 5 depicts an industrial application of dehydration method utilizing the JT effect and MEG hydrate inhibition.

The wet NG is throttled in two steps inside the flash tanks. The lower temperature (due to the JT effect) of the gas stream in the flash tanks leads to partial condensation of the water vapors. The droplets that are created are removed from the gas stream by a demister inside the flashes. In cases where cooling by the JT effect is insufficient (the usable pressure difference between the inlet and outlet of the gas is insufficient), the air pre-cooler and the external cooler are turned on.

Since dehydration is normally applied to large volumes of NG, the external coolers need to have high performance, so this type of cooling is very energy expensive. For dehydration of

low pressures NG the external coolers consumes up to 80% of total energy of dehydration unit. However, if the usable pressure difference is high, the JT effect inside the flashes is so strong that internal heating of the flashes is required to defreeze any methane hydrate or ice that may form. A condensation method is applied when suitable conditions for the JT effect are available.

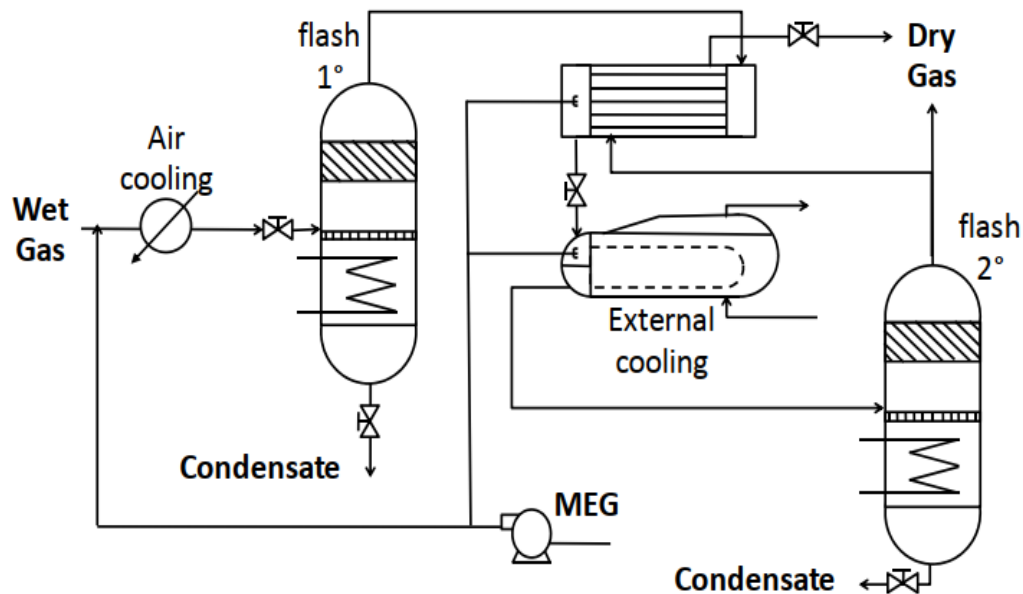


Figure 5 . Schematic of natural gas dehydration utilizing JT effect and monoethylene glycol inhibition

Supersonic separation

The principle of this method lies in the use of the Laval Nozzle, in which the potential energy (pressure and temperature) transforms into kinetic energy (velocity) of the gas. The velocity of the gas reaches supersonic values. Thanks to gas acceleration, sufficient temperature drops are obtained. Tdew of water vapor in NG is reached, and nucleation of the droplets proceeds. Figure 8 depicts the basic design of a supersonic nozzle

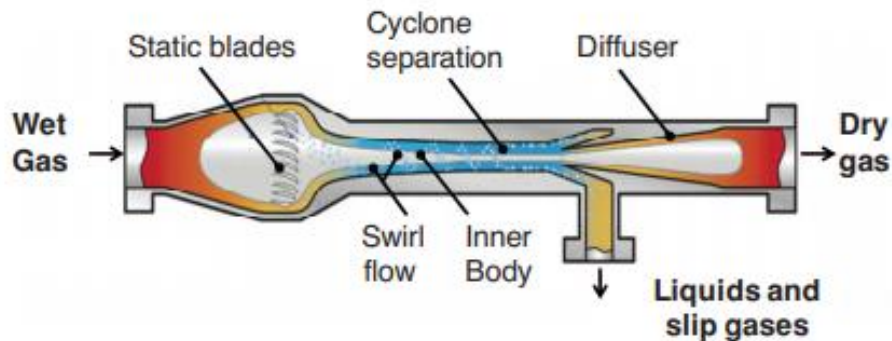


Figure 6. Design of a supersonic nozzle for NG dehydration

At the inlet to the nozzle there are static blades which induce a swirling flow of the gas. The water droplets that form are separated by the centrifugal force on the walls. The centrifugal force in the supersonic part of the nozzle can reach values up to 500 000 g . The thin water film on the walls moves in the direction of flow into the separation channel. The separation channel leads into the heated degas separator. From here, the slip gas is returned back to the main stream and the water condensate is removed. After separation of the water it is important to recover the pressure of the gas from its kinetic energy.

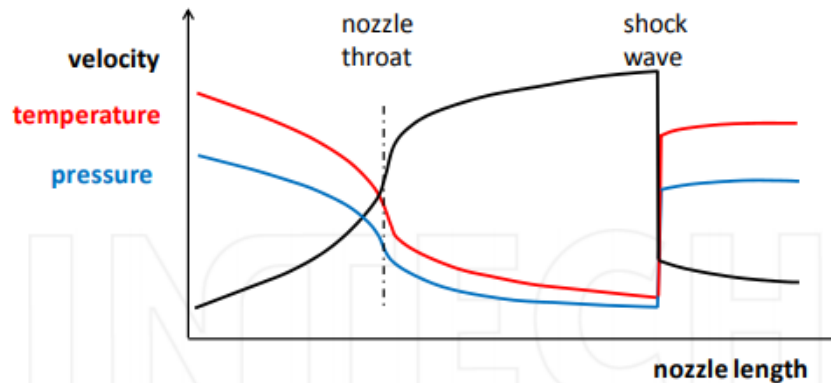


Figure 7. Profile of pressure, temperature and velocity of a gas passing through the supersonic nozzle

The scheme of a supersonic dehydration line working on the principle introduced here is depicted in Figure 8.

A shock wave is used to achieve this. Generally, shock waves form when the speed of a gas changes by more than the speed of sound. In supersonic nozzles, the shock wave is created by rapid enlargement of the nozzle diameter. This part of the nozzle is called the diffuser. Thanks to the diffuser 65 - 80% of the inlet pressure is recovered. This section might also include another set of static devices to undo the swirling motion. The profile of pressure, temperature and velocity of a gas passing through the supersonic nozzle is depicted below.

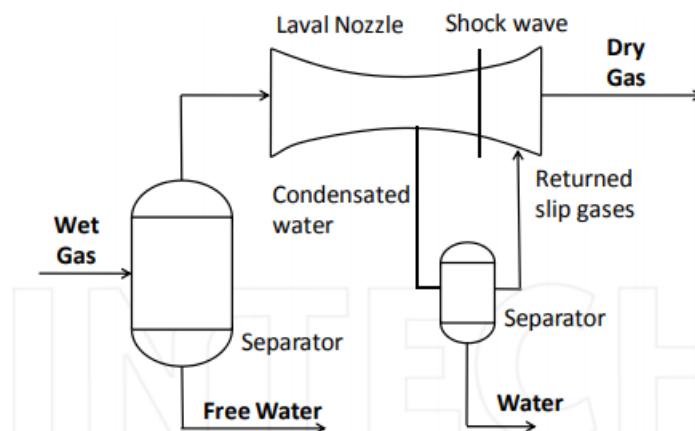


Figure 8. Scheme of a supersonic dehydration line

Comparison of conventional dehydration methods

Each of the methods presented here has its advantages and disadvantages. Absorption by TEG is nowadays the most widely used method. Outlet Tdew around -10°C is usually reached and this water concentration is sufficient for pipeline distribution of NG. Indeed, with improved reboiler design (Vacuum Stripping, Drizo, Coldfinger), the outlet Tdew is even 2 - 3 times lower. However TEG has a problem with sulfur, and with gas contaminated with Splitter Flow meter Wet gas Dry gas Water Degas separator Slip Gas 16 Natural Gas – Extraction to End Use higher hydrocarbons. The TEG in the reboiler foams, and with time it degrades into a “black mud”. BTEX emissions (the acronym stands for benzene, toluene, ethylbenzene and xylenes) in the flash gases and in the reboiler vent are a further disadvantage. Adsorption dehydration can achieve very low outlet water concentration Tdew $< -50^{\circ}\text{C}$, and contaminated gases are not a problem. Even corrosion of the equipment proceeds at a slower rate. However, adsorption requires high capital investment and has high space requirements. The adsorption process runs with at least two columns (some lines use three, four, or as many as six). Industrial experience indicates that the capital cost for an adsorption line is 2 - 3 times higher than when absorption is used. In addition, the operating costs are higher for adsorption than for absorption. Expansion dehydration is the most suitable method in cases where a high pressure difference is available between UGS and the distribution connection. However, the difference decreases during the withdrawal period and becomes insufficient, so that an external cooling cycle is needed. A cycle for regenerating hydrate inhibitor from the condensate separated inside the flashes is also required. The general overview of areas suitable for application of target dehydration method is depicted on the following Figure 9.

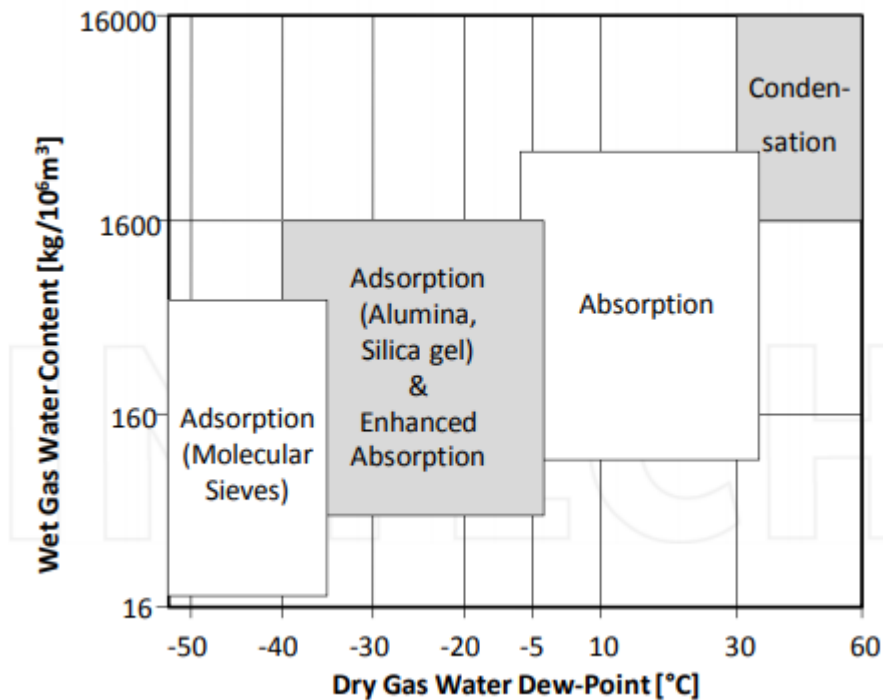


Figure 9. Overview of areas suitable for application of target dehydration method

Table 2 Comparison of conventional dehydration methods

Natural Gas Dehydration Method	Applicability	Advantages	Disadvantages
Absorption	Typically used where dew point depressions 60°-120°F are required	Low operating and capital investment	TEG in reboiler can cause foam
Adsorption	<ul style="list-style-type: none"> a. Limited to application, such as high H₂S content gases b. Limited to very low water dewpoint requirement (required simultaneous control of water and hydrocarbon dew point) c. Suitable for subsequent cryogenic process d. Suitable for drying and sweetening of NGL liquids 	<ul style="list-style-type: none"> a. Can achieve very low water concentration, T_{dew} < -50°C b. No problem with contaminated gas 	<ul style="list-style-type: none"> a. High capital investment (2-3 times of investment of absorption for the same capacity) b. High space requirement c. High operating cost
Condensation	Suitable when gas pressure difference between gas source and required product pressure is high	Low energy consumption at relatively high operating pressure	a. The difference between gas pressure at source and spec will be reduced during operation time.

REFERENCES

1. Gas infrastructure Europe (2011) Map Dataset in Excel-format Storage map. Available: http://www.gie.eu/maps_data/storage.html. Accessed 2011 Mar 8.
2. Foss M (2004) Interstate Natural Gas Quality Specifications and Interchangeability. Center for Energy Economics.
3. NET4GAS (2011) Gas quality parameters. Available at: http://extranet.transgas.cz/caloricity_spec.aspx. Accessed 2011 Mar 8.
4. Gandhidasan P, Al-Farayedhi A, Al-Mubarak A (2001) Dehydration of natural gas using solid desiccants. Energy 26: 855-868.
5. Gandhidasan P (2003) Parametric Analysis of Natural Gas Dehydration by Triethylene Glycol Solution. Energy Sources 25: 189-201.
6. CHEM Group, Inc. (2012) Triethylene Glycol - Liquid Density Data. Available at: <http://www.chem-group.com/services/teg-density.tpl>. Accessed 2012 Mar 6.
7. CHEM Group, Inc. (2012) Triethylene Glycol - Kinematic Viscosity Data. Available at: <http://www.chem-group.com/services/teg-viscosity.tpl>. Accessed 2012 Mar 6.
8. Bahadori A, Vuthaluru H.B (2009) Simple methodology for sizing of absorbers for TEG gas dehydration systems. Energy 34: 1910-1916
9. Hubbard R.A, Campbell J.M (2000) An appraisal of gas dehydration processes. Hydrocarbon Engineering 5: 71-74.
10. Tagliabue M, Farrusseng D, Valencia S, Aguado S, Ravon U, Rizzo C (2009) Natural gas treating by selective adsorption: Material science and chemical engineering interplay. Chemical Engineering Journal 155: 553-566