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OVERVIEW OF SELECTED NATURAL GAS DRYING METHODS

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Abstract

The gas produced from the deposit usually contains various types of pollution. They are the reason for limiting its use, often making its use impossible. Therefore, it requires appropriate treatment. One of the main pollutants in gas is water. Its occurrence causes a lot of problems, especially at the stage of gas transport, such as the formation of hydrates blocking pipelines and apparatus, causes the phenomenon of condensation and corrosion of pipelines, especially if there is carbon dioxide or hydrogen sulphide in the gas. The paper presents a number of methods that enable drying of gas after extraction. Each of them has different parameters that will be achieved for the gas after it is dried. Depending on the required degree of drying, the economics of the process and compatibility with other dependent processes, the individual methods are more or less used in gas engineering. The paper discusses methods of absorption in ethylene glycol solutions, adsorption methods using silica gel, molecular sieves or calcium chloride and low-temperature processes such as Twister® supersonic separator, IFPEX-1® process and DexPro™ process.

Keywords: **Gas drying; Glycol; Adsorption; Absorption; Silica gel; Molecular sieve.**

1. INTRODUCTION

The gas produced from the deposit usually contains various types of pollution. They are the reason for limiting its use, often making its use impossible. Therefore, it requires appropriate treatment. One of the main pollutants in gas is water [1, 2].

Steam saturation is the result of prolonged gas contact with reservoir water. The content of this steam depends on the composition of the gas or the salt content of the deposit water. However, it depends primarily on the thermodynamic conditions of the deposit, i.e. temperature and pressure. The higher the pressure and lower the temperature, the higher the water vapour content of the gas. When these two parameters change, water condenses from the gas or the gas becomes unsaturated in relation to water vapour [3, 4].

Water liquefaction starts at dew point temperature, which is the value to which the gas must be cooled at a specific pressure with a constant water vapour content to become saturated vapour. The result is that, as the pressure increases, the dew point temperature increases, while at constant pressure it is higher the lower the water vapour content of the gas [5, 6].

The presence of water vapour in the gas creates many problems, especially during transport by gas pipelines. Its presence also creates operational difficulties in low-temperature gas processing installations. These difficulties are the result of the above-mentioned condensation and the formation of crystalline hydrates clogging apparatus or pipelines [7]. In addition, it contributes to the phenomenon of condensation, which leads to the formation of so-called corks and erosion, increasing the volume and decreasing the calorific value of gas. In addition, liquid water accelerates the corrosion process and makes it difficult to measure the flow rate, especially when the gas contains carbon dioxide and/or hydrogen sulphide. For the above reasons, it is necessary to dehumidify the gas before transportation or processing [8, 9].

The paper presents and describes a number of methods that enable the drying of gas. Each of them has different parameters that will be achieved for the gas after it is dried. Depending on the required degree of dehumidification, process economics and compatibility with other dependent processes, individual methods are more or less used in gas engineering.

2. GAS DRYING METHODS

The drying process does not have to mean the complete elimination of steam. It is important to remove only the amount that would have been released as condensate at a given temperature. The gas should be dried to such an extent that its dew point temperature is 3–10°C lower than the lowest temperature at which it can be, for example, transported by pipeline. This allows for protection against the reduction of gas pipelines' permeability due to hydrate deposition or ice plugs. It is also important in the operating industry to quickly determine the water vapour content of the transmitted gas [10].

In addition to drying the gas to a sufficiently low dew point temperature, other methods are occasionally used: gas heating, pressure reduction or injection of inhibitors that reduce the hydrate formation temperature. However, their effectiveness is much lower, so they are usually used only as ad-hoc methods [11, 12].

A number of methods of gas dehumidification are available worldwide, and one can distinguish between them:

- absorption methods,
- adsorption methods,
- recommending methods for cooling the gas stream [13].

The method of the gas drying technology depends on the required degree of drying the gas, compatibility with other dependent processes and the economic aspect of the process. Adsorption methods are widely used for the so-called deep gas drying, i.e. to a dew point temperature lower than -40°C (Fig. 1). This type of dehumidification is not a requirement when preparing the gas for transport, but it cannot be avoided when the gas liquefies. Fig. 1 shows the temperature values of the gas dew point, which can be achieved by different dehumidification methods. Their analysis makes it possible to select an appropriate drying method.

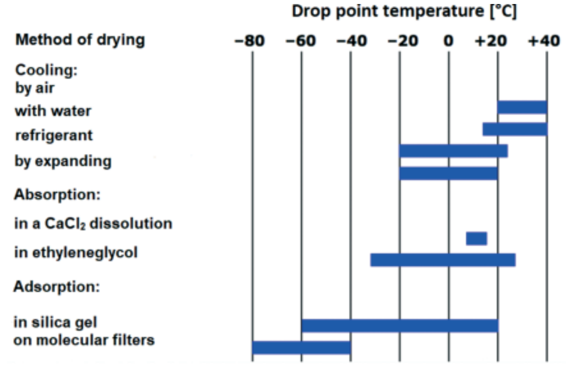

Figure 1.
Reduction of the gas dew point temperature by means of various gas drying methods (own preparation based on [14])

2.1. Drying the gas by a method of water absorption in ethylene glycol solutions

Absorption methods using ethylene glycols enable the gas to be dried to a dew point of -30°C. When preparing the gas for pipeline transport, it is usually sufficient to use so-called medium drying, where the dew point temperature oscillates between -25°C and -15°C, so that glycol drying can be successfully used in this case. An additional positive aspect of this method is the widespread availability of glycols, easy regeneration of glycol solutions during the dehydration process, a slight decrease in gas pressure in the apparatus and, moreover, the method does not require large investment and operating costs. This method allows to dry large quantities of gas at high flow speeds [1, 12].

The process of glycol gas drying is based on the use of absorption properties of glycol, which at the initial stage of the process is injected into the upper section of the contact column, where it flows down under the influence of gravity forces (Fig. 2). Wet gas is directed to the lower section of the column from where it flows upwards. Glycol absorbs water from the gas. The dried gas leaves the installation at the top of the column, while the glycol rich in absorbed water is accumulated on the so-called overflow plate in the column, where it is automatically let off. The glycol in water is directed from the column to the coil located in the upper part of the regenerator column, where it flows into the deaerator in the next stage (Fig. 2). The coil generates growth, as a result of cooling part of the steam produced in the regenerator reboiler. The gas is separated from the glycol in the degasser. The degassed glycol flows through the particle filter and carbon filter and then is injected into the reboiler. The glycol in the reboiler is heated to the extent that water can evaporate from the reboiler. The water-poor glycol flows from the regenerator into the storage tank and, using the injection pumps, is directed to the upper section of the contact column. This technology is characterized by the operation in a closed system, and with a properly conducted process glycol losses are practically unnoticeable. This method can be used with diethylene glycol (DEG) or TEG. The degassed glycol flows through the particle filter and

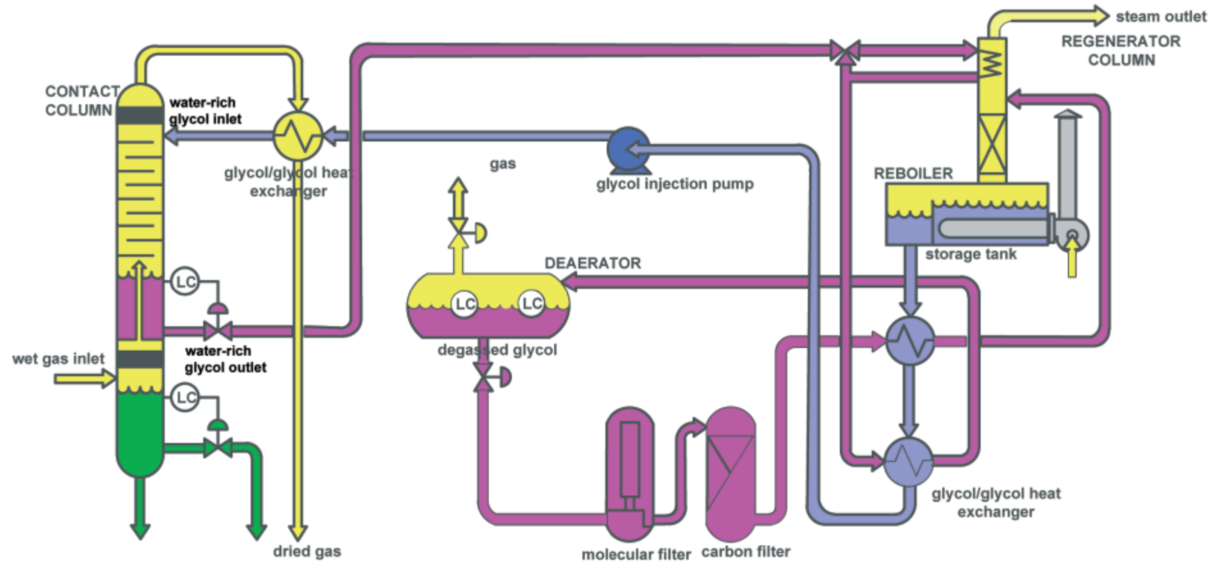

Figure 2.
Operating scheme of the glycol gas dehydration system (own preparation based on [16])

carbon filter and is then injected into the reboiler. The glycol in the reboiler is heated to the extent that water can evaporate from the reboiler. The water-poor glycol flows from the regenerator into the storage tank and, using the injection pumps, is directed to the upper section of the contact column. This technology is characterized by the operation in a closed system, and with a properly conducted process glycol losses are practically unnoticeable [16].

This method can be used with diethylene glycol (DEG) or triethylene glycol (TEG). TEG is widely used because of the best compromise between the cost of glycol and its losses due to evaporation and interception by gas [12].

When designing the process of gas drying with TEG, it is worth to refer to a few correlations that will improve the whole process: the greater the number of shelves in the contact section, the greater the reduction in the water dew point of the gas at a given intensity and concentration of glycol circulation; moreover, the number of shelves in the contact section may have a greater effect on the reduction in the dew point than the glycol circulation intensity itself. An increase in the glycol concentration significantly lowers the dew point for a given intensity of the circulation and number of shelves. The glycol concentration in the plant is modified by temperature and pressure in the reboiler. The higher the temperature in the reboiler, the higher the concentration and the higher the glycol concentration, the more water will be removed [17] It is important to note, however, that the highest concentration of TEG that can be obtained during regeneration under atmospheric pressure and at 204°C is 98.7–99% by weight. No regeneration processes are carried out at higher temperatures, due to the fact that TEG decomposes at 207°C. In addition, if the entire process were carried out at a pressure higher than atmospheric, this could significantly reduce the concentration of glycol and contribute to a decrease in gas drying capacity [18, 12].

With a typical glycol dehydration process, glycol regeneration reaches a maximum of 98.6% by weight. At a gas temperature of +10°C to +25°C, this allows a dew point in the gas of -28°C to +2°C. In industrial practice, these parameters are sufficient to meet the relevant gas transport requirements. When it is necessary to obtain a lower temperature of the water dew point, this installation is not able to generate better parameters. One of the solutions to achieve a higher purity of TEG glycol than 98.6% by weight is to apply the principle of reducing the effective partial pressure H_2O in the area of glycol reboiler steam. This allows to obtain a lower dew point of the dried gas. Currently the most frequently used method is the use of stripping gas. It uses the phenomenon of srtipping. This is a physical separation process in which one or more syntaxes are removed with a steam jet. In this method, srtipping gas is injected into a striping column that connects the reboiler to a storage tank. The gas is injected in the lower section of the column, where it then flows upwards through the filling inside the column. In the counterflow to the gas flows regenerated glycol from the reboiler into the storage tank. The gas introduced into the reboiler increases the evaporation from the surface of the regenerated glycol, which makes its concentration reach 99.9% by weight. Glycol regenerated in this way, at the temperature of the gas dried from +10°C to +25°C, allows to obtain a dew point of water in the gas in the range from -66°C to -22°C. The use of this method is characterized by a certain structural modification, which has a minimal impact on the increase of the costs of construction of such an installation, but the achieved effects give almost three times lower dew point [1].

2.2. Adsorption gas drying method

The adsorption methods allow a very low dew point temperature (below -40°C). Not all gas applications require such deep drying. Often the use of absorption methods is sufficient. In most cases, the use of adsorption methods is necessary when the dried gas is to be subjected to low-temperature separation or condensation. Usually, an absorption pre-drying is then applied first, followed by dehumidification on solid adsorbents, which allows the load on the adsorbents to be significantly reduced [11].

The below formula (1) is used to select the appropriate mass of adsorbent needed for drying the gas:

$$m_a = \frac{Q_v(W_1 - W_2)t}{24a} \tag{1}$$

where:

m_a – mass of adsorbent [kg],

W_1 – absolute humidity of the gas before drying [kg/m^3],

W_2 – required absolute humidity of the gas after drying [kg/m^3],

Q_v – gas volume flow rate to the dehumidification plant [m^3/s],

t– time [s],

a – the activity (adsorption capacity) of the adsorbent typically 0.04-0.05 [14].

The whole process of adsorption is presented in the Fig. 3. Raw gas coming from well enters inlet receiving (1) after mixing with gas which is coming back from the previous process. After removing the liquids it coming though the valve and enters operational bed (2). In this moment the vapor is removed by adsorption. The valves may be adjusted so that beds operate and regenerate in turns. Extracted gas is heating up in heater (3), so it will desorp water from dessicant more efficiently. Heated gas goes to regenerated bed (4). There the water is removed and, as wet gas, enters condenser (5). In this place gas is cooled down and water vapor condenses. Liquid is taken out in water knock out (6). After that gas is compressed in a compressor (7) to compensate losses in the unit and equalize pressure with raw gas. At the end it is reinjected to the stream coming from well [15].

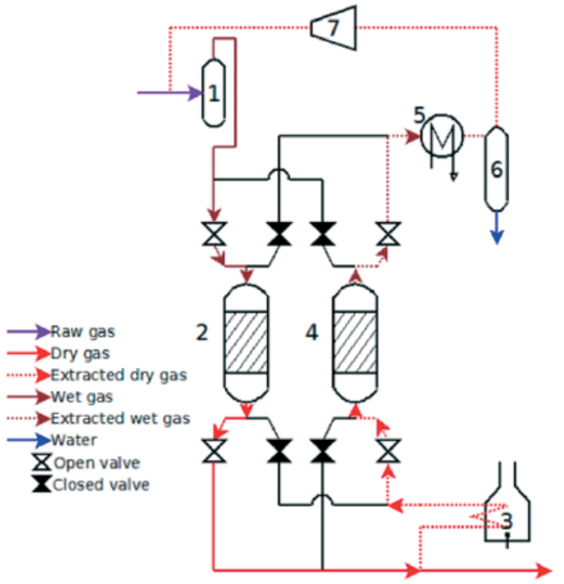

Figure 3.
Scheme of adsorption drying process (source: [15])

The most commonly used adsorbents in gas drying processes are silica gel (SiO_2), molecular sieves (zeolites) and much less frequently used calcium chloride.

The adsorbents that are used in industrial gas dehumidification plants must exhibit some characteristic properties. Among them, it stands out:

- high adsorption capacity, depending on the surface area and pore volume,
- a lot of selectivity,
- no toxic or corrosive effects,
- mechanical strength, which will prove to be resistant to the influence of the layer mass during the adsorption process and temperature during regeneration,
- resistance to liquid water,
- resistance to long-term use [11].

Among the advantages of this process can be distinguished:

- possibility of obtaining very low dew point temperatures,
- dehumidifying small amounts of gas,
- no corrosion,
- simplicity of installation,
- low sensitivity to changes in temperature, pressure and gas flow rate [1].

2.2.1. Silica gel

One of the most commonly used adsorbents is silica gel. It is a solid with the general formula SiO_2*nH_2O. Its special characteristics are: high porosity, with a specific pore surface area of up to 700 m^2/g, appropriate pore size, among which micropores 1–1.5 nm, mesophores 1.5–50 nm and macrophores – above 50 nm and high hydrophilicity. The absorbed water vapour is maintained on the surface of the crystalline lattice of the silicone-ammonium gel due to hydrogen bonds formed between its hydroxyl group and this surface [11, 17].

Silica gel is mainly used where the water vapour content of the wet gas exceeds 1% mole and where a low water content of the dried gas is not necessary [17]. It is easy to regenerate, but if repeated at temperatures above 200°C, some under-adsorption occurs. This is the result of a decrease in the number of hydroxyl surface groups. As a result of deactivation with hydrogen sulphide, the adsorption activity of the silica gel decreases dramatically; hence, it is not really useful for sulphated gas drying processes. The dynamics of the silica gel gas drying process depends on the diameter of the grains, on the speed of gas flow and on the initial water vapour content of the gel after its application and regeneration. This is directly dependent on the regeneration temperature [11].

2.2.2. Molecular filters

The second type of adsorbent that is often used to dry gas is molecular sieves. These are crystallised, synthetic aluminosilicates (zeolites), which are characterised by a network of pores of a strictly defined diameter. About half of the total volume of the crystal is made up of free spaces (chambers). Their internal surface is between 600 and 1200 m^2/g of zeolite. Thanks to these chambers, particles of various compounds can penetrate into the crystal through so-called windows in the zeolite's crystal network [20]. The particles of various compounds have characteristic sizes and shapes. The cross-section is of particular importance here, as only particles whose cross-section is smaller than the windows in the crystal lattice can penetrate the crystal. On this principle, using a properly selected zeolite, it is possible to separate a mixture of different compounds. Separation consists in passing a liquid or gaseous mixture through a suitably selected layer of zeolite. However, only those particles whose size is smaller than that of the window penetrate. This separates the mixture and the zeolite acts as a kind of sieve that traps the respective particles. The term molecular sieve is derived from this possibility of sieving particles. This is a feature that distinguishes molecular sieves from other adsorbents such as silica gel or activated carbon [21]. The operation of the adsorption gas drying system on molecular filters is in Fig. 4.

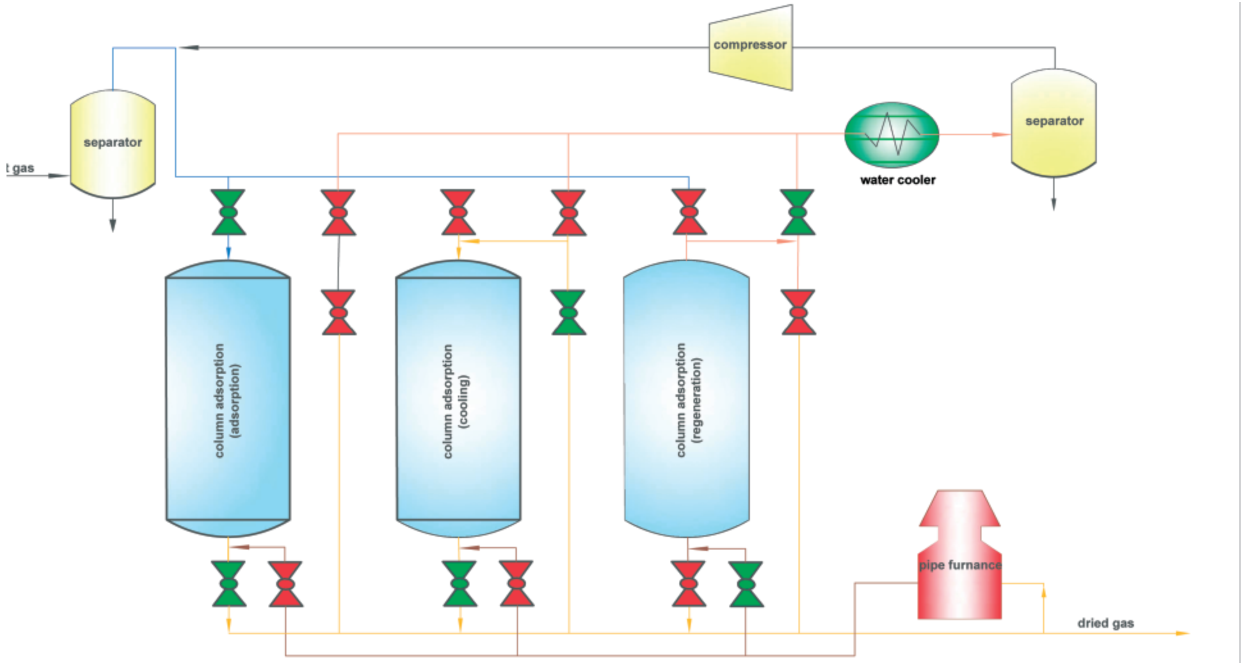

Figure 4.
Scheme of molecular filter gas adsorption drying system (green color – open valves; red color – closed valves) (own preparation based on [14])

The gas drying process is carried out in three stages [1]:

1) adsorption (approximately 12–24 h),
2) adsorbent regeneration (4–6 h),
3) cooling of the adsorbent (1–2 h).

A part of the dried gas flow is directed to regeneration and cooling of the adsorbent. Usually, the automatic adsorber switching is set in such a way that for a certain period of time the adsorption takes place simultaneously in two adsorbers, while in the third, regeneration or cooling takes place at the same time [11].

To understand the process exactly, Fig. 4 shows the three adsorbers, each having a different role in the drying process at that time. The adsorption column on the left-hand side acts as an adsorber, the middle column is in the cooling phase and the right-hand column will be regenerated as it acted as an adsorber at an earlier stage. The figure also shows the flow directions of the streams, and the valves that are currently closed (red) and open (green), so that the gas flows to the appropriate columns. After separating the liquid water in the separator, the gas is directed to proper dehumidification, i.e. steam adsorption. The gas is directed to the adsorption column on the left-hand side of the diagram, where it is injected from above and dry gas is collected at the bottom of the apparatus. Thanks to this type of flow, this layer of adsorber is prevented from loosening, the adsorber molecules rise from it and additionally its faster mechanical wear is prevented. In the regeneration stage, which takes place in the right-hand column, the dried gas, previously heated in the tube oven at a temperature of approximately 250–350°C, is directed by the adsorber in the reverse direction, i.e. 'from bottom to top'. This ensures better regeneration of the lower part of the layer, which enables the gas to be dried much more thoroughly in the next stage of adsorption drying. During regeneration, the hot gas from the tube furnace is saturated with desorbed steam due to the high temperatures of the adsorbent layer in the column set aside for regeneration. The gas flow is then directed to a cooler, where water is condensed and then separated in a separator. The separated water is collected at the bottom of the separator, while the gas is combined with a gas stream directed to drying in the column that has already been cooled [1].

Molecular filters adsorb much more water than silica gel and are used if the wet gas content is not high. The high water content of the input gas makes drying the gas using molecular sieves highly expensive, due to the high energy consumption for adsorbent regeneration. In order to carry out the regeneration process in an appropriate manner, more than 50% of the energy used in the gas dehumidification process is consumed. To reduce the amount of water present in the molecular filter gas, another drying process can be used before using the molecular sieves, or silica gel can be used to remove significant excess water and only then use the molecular filters to remove the remaining water [17].

2.2.3. Calcium chloride

The drying of gas with calcium chloride is a kind of characteristically crystalline process which combines the adsorption of water vapour on the solid $CaCl_2$ with its absorption in a solution of this salt. The advantage of this adsorbent is its widespread availability and low cost as well as low operating and investment costs. This results from the simplicity and ease of use of the equipment, and additionally from the fact that little heat and electricity is used in the basic technological process. The disadvantage of the process is the corrosive effect of $CaCl_2$ solutions, which is intensified when the oxygen content of the dried gas increases. The efficiency of the process decreases after each course of the system operation cycle. In the initial stages of the cycle, it is possible to achieve a very large reduction in the dew point temperature of the dried gas, even to -50°C, but at the end of the cycle, the reduction in this temperature reaches only several degrees [4]. The installation dehumidifying gas with $CaCl_2$ uses a three-section column (Fig. 5).

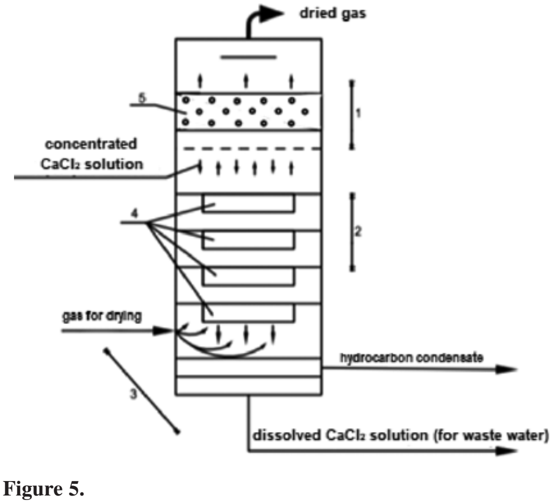

Figure 5.
The principle of operation of the adsorption-absorption column in the process of gas drying with $CaCl_2$
(1 – adsorption section, 2 – absorption section, 3 – separation and separation section, 4 – shelves, 5 – pills)
(own preparation based on [11])

In the absorption section (2) there is counter-current contact between the gas being dried and a $CaCl_2$ solution flowing from the upper section of the column. The process takes place on special shelves called injectors (4). The gas moving upwards flows at high speed through a kind of nozzle called a nozzle tip, and captures the solution, lifting it into the chamber where the rapid flow of the two-phase stream contributes to a very good mixing. In the next stage, the liquid is separated from the gas by tiles and flows back to the bottom of the shelf through troughs and a pipe. Based on this algorithm, the solution flows several times with the dried gas through the nozzle and the chamber, which enables high efficiency of water vapour absorption. Circulation of the solution on the shelf allows to supply these shelves with the solution by appropriate dosing of small portions, determined by the intensity of supply to the central part of the column through concentrated $CaCl_2$ solution, which flows from the adsorption section. On each of the shelves, the solution is kept for about 25 minutes, where it flows down to the lower shelf in the next stage. During the flow from shelf to shelf, the solution is gradually diluted with the absorbed steam, which contributes to its density decrease. Thanks to the absorption on the shelves, about 60% of the water vapour is removed from the gas, which is to be removed during the entire drying process. In the adsorption section (1), the gas already partially dried in the middle of the column flows into the solid layer of $CaCl_2$, which is located in the upper section as tablets (5). During steam absorption of $CaCl_2$, hydrates of $CaCl_2*H_2O$, $CaCl_2*2H_2O$, $CaCl_2*4H_2O$ and $CaCl_2*6H_2O$ are formed. The hydrate molecules, which have a smaller number of water molecules, continue to absorb water vapour, thus becoming more hydrated hydrates, which are largely located in the lower part of the layer. From the hydrate which is most hydrated over time a concentrated aqueous solution of $CaCl_2$ is formed which moves down the column to the middle section. In the separation and separation section (3) part of the water and hydrocarbon condensate is condensed from the gas. In addition, a diluted solution of $CaCl_2$ flows into it from the absorption section described above. The result is the separation and delamination of the two liquid phases, which are discharged at an appropriate rate, which is adjusted according to their levels in the lower part of the column [11, 4].

The drying of the gas with calcium chloride is most commonly used in areas with cold climates. This is due to the fact that low ambient temperatures make it very difficult to use glycols. This is an attractive alternative to TEG dehumidification in remote borehole areas, where it is necessary to dehumidify gas at low flow rates. 0.3 kg $CaCl_2$ [17] is used to absorb 1 kg of water.

2.3. Cooling the gas through a compression process with cooling

The method of drying the gas through a compression with cooling is a relatively easy process to carry out, using the relationship that the higher the pressure, the lower the water content of the gas at a constant temperature. Assuming that the gas is compressed and then cooled in interstage air coolers, this process will result in water dropping, which will then be separated from the gas in interstage scrubbers as well as in a separator during the final compression and cooling stage [17].

Unfortunately, this method does not allow the removal of water vapour in such a quantity that the gas can be fed into the pipeline. Even if the amount of water in the compressed gas will be lower than the water content of the inlet gas, the compressed gas will still be saturated at the temperature to which it was cooled down and will not meet the parameters suitable for transportation through the pipeline. Therefore, after using the cooling compression method, the dried gas must be dried with one of the previously described methods. This combination of the two methods enables the installation of a smaller and cheaper drying system behind the compressor [24].

2.4. Gas drying using low-temperature processes

Among the technologies using low-temperature processes, we can distinguish:

- IFPEX-1® proces,
- supersonic separator Twister®,
- DexPro™ proces.

2.4.1. IFPEX-1® proces

The IFPEX-1® process enables both water and hydrocarbon dew point temperatures to be achieved simultaneously. The wet gas is mixed with methanol and then cooled to the required dew point using a suitable method such as a throttling valve, turboexpander or external cooling circuit. The liquefied mix-

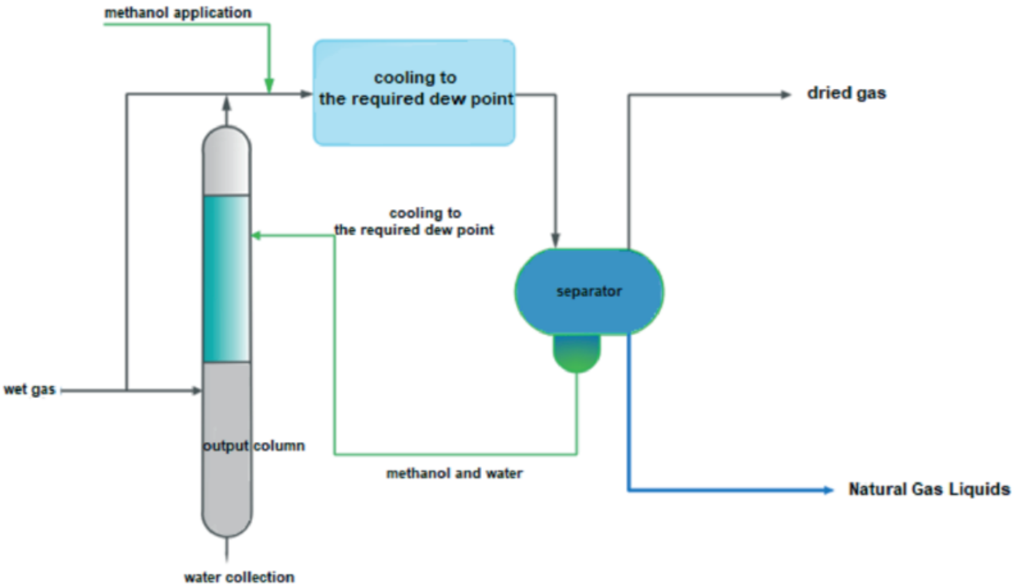

Figure 6.
Operating diagram of a gas drying installation using IFPEX-1® technology

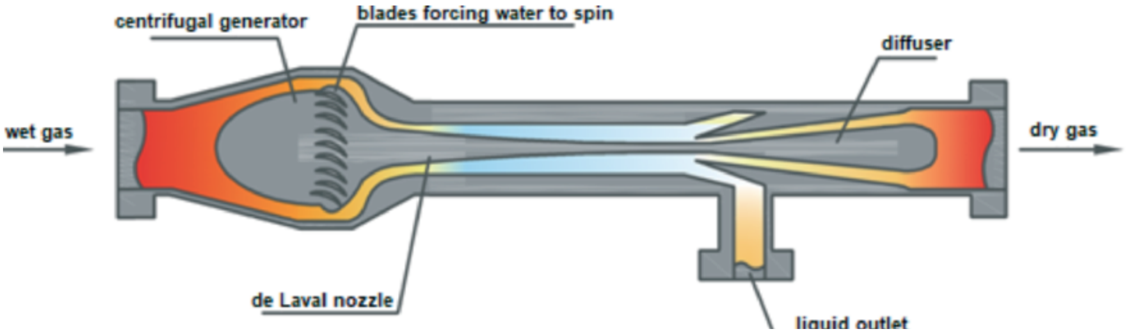

Figure 7.
Cross section of the TWISTER® supersonic separator (own preparation based on [17])

ture of methanol and water is separated in a gas separator and then directed to a drive column. Methanol is recovered in the column. Water with a methanol content below 100 ppm [17, 25] is collected at the bottom of this column. The diagram of the gas drying process using this technology is presented in Fig. 6.

The application of this process allows to obtain a dew point from -100°C to -70°C and at the same time reduce hydrocarbon vapours and does not require heat supply. It is competitive with glycol processes as the required dew point is -30°C and the capital expenditure is approx. 30% lower [22, 26].

2.4.2. Supersonic separator Twister®

The Twister® process uses a supersonic nozzle, often referred to as the de Laval nozzle, in which pressure is reduced by isentropic expansion at constant entropy, which contributes to temperature drop and water condensation. At the inlet to the nozzle there are blades that cause the gas to swirl (Fig. 7). The centrifugal force pushes the liquid droplets onto the nozzle wall, where they are then discharged to the liquid outlet port (Fig. 7). The gas itself reduces its speed in the diffuser, which is equal to the speed of gas in the pipeline after the Twister separator. In the nozzle, a pressure drop of up to 30% of the gas inlet pressure occurs, while in the diffuser, a pressure recovery of up to approximately 70–80% of the cylinder pressure occurs [17, 27].

The liquid, which will be removed by the outlet stub, is directed to the separator, where water and liquid hydrocarbons are separated. If hydrates are formed, a centrifugal separator is usually used to separate the hydrates and liquid from the gas. The hydrates themselves are melted by the use of a heating coil. The use of this technology requires certain conditions during gas drying. First of all, the gas intensity should be ≥ 200 m^3/h and the pressure drop should be ≥ 25%. This process makes it possible to reduce the temperature by 60°C with a pressure drop of 30 bar [28]. The big advantage of this technology is that the gas residence time in the Twister separator is so short that it prevents hydrates from forming. In addition, the separator has no moving parts and is very compact. It also requires no maintenance and is therefore also used on offshore platforms [17, 23].

2.4.3. DexPro™ proces

The DexProTM process technology is used for the additional drying of acidic gas, in addition to mechanical drying, during its multi-stage compression before injection into the field. In order to best remove water from the gas, this process is combined with the compression process. Part of the gas flow in the final stage is passed through the temperature control valve to the DexProTM apparatus installed in front of the scrubber on the suction of the final compression stage. This equipment allows the streams to mix properly without creating conditions for hydrates to grow [29]. Mixing cold, dry acid gas with warm, wet acid gas contributes to the cooling of the mixture in such a way that the expected amount of water is condensed. It is then separated in the suction scrubber during the last compression stage. DexPro™ is a process with many advantages, which contribute to its increased use in drying systems. The unit itself is very compact, occupies a very small space and has minimal running costs. The DexPro™ process is a cost effective investment as the cost of purchasing it is approximately 30% lower than that of a glycol installation. It does not require the use of any kind of chemicals and is also emission free [17].

3. CONCLUSIONS

The most frequently used gas drying technology is the method of water absorption in ethylene glycol solutions with some modification in the form of striping gas. It is characterized by a simple structure. It translates into low costs of the installation itself in comparison to the obtained effects of increasing glycol concentration. Additionally, it is an easy to use technology, which contributes to low failure rate and thus much lower costs [8, 3].

Being at the stage of selecting an appropriate method of gas drying, the basic criterion to be taken into account is the required degree of dehumidification of this gas. Moreover, it should be taken into account whether the selection of a given technology will be compatible with other dependent processes and whether the whole process will be an economic solution for the potential investor [30]. Of the range of methods discussed, usually the most effective and cost-effective is the method of water absorption in ethylene glycol solutions. However, it happens that limitations of a given system, such as its high energy consumption, may dictate the choice of another technology [12].

Installations that use liquid dryers have the advantage of being small in size, flexible in operation, continuous operation and usually cheaper than installations using solid dryers [17].

Installations using solid dehumidifiers have the advantage of being much more efficient than a glycol installation because they can dry the gas to a water content of <0.1 ppmv. In order to minimize the size of these installations, a frequent solution is to pre-dry the glycol to about 60 ppmv water. These types of installations require much higher financial and operating costs [17].

Molecular sieve technology is also a proven method. Its advantage is the ability to remove water, CO_2 and mercaptans at the same time. They are characterized by the highest water vapour absorption and durability. Silica gel, on the other hand, is better compared to molecular sieves if the gas to be transmitted by pipeline needs to be dried, because it requires much less gas for regeneration compared to other adsorbents [21].

Among the low temperature methods, the IFPEX-1® process is the most promising as it can compete with glycol processes (which are currently the most commonly used) when the required dew point is below -30°C. At this point, the capital expenditure is reduced by approximately 30% compared to glycol processes [24].

The Twister® supersonic separator, thanks to the lack of moving parts and mobile dimensions, enables maintenance-free operation, eliminating some of the costs. In addition, the gas stays there for milliseconds and therefore prevents the formation of hydrates. This process also allows more liquid gas to be produced than in the IFPEX-1® process [17].

In Poland, water absorption in ethylene glycol solutions is currently the most frequently used method. This is the most advantageous solution not only in economic terms, but also because it meets all technological requirements in gas engineering [31]. This method meets all the parameters required for gas transmission in Poland [13].

However, the development of gas dehumidification facilities should be continuously improved in order to diversify methods as much as possible. This will allow better control over the quality of gas transmission.

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