

# Different Methods of Gas Dehydration -Compared Analysis on Real Casuistry

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*In order to be transported and used under secure conditions, the natural gas must meet a set of quality requirements that also include a maximum value of the dew point for water from the commercial delivery/pickup point. This assumes the treatment of natural gas in order to reduce the water vapour content, using dedicated equipment, named gas drying or dehydration stations. The materials or substances used for gas dehydration, on an industrial scale and for many years, in the natural gas production areas, are part both of the adsorbent substances category as well as of the absorbent substances category. The paper presents the theoretical and practical aspects regarding the determination of gas humidity and a synthesis of the real casuistry related to exploration of gas dehydration stations by underlining the problems concerning the proper performance of these stations.*

*Key words: humidity, dehydration, glycols, silica gel, salts*

Gas dehydration (drying) is one of the technical procedures of gas purification aiming to avoid atmospheric pollution as well as separating those compounds in the gas flow modifying the quality requirements of these hydrocarbons.

The legislation in the field of natural gas, that is the Network Code of the National Gas Transmission System [1], stipulates in chapter 5 the minimal quality conditions of gas to be traded in the entrance/exit point of the National Transmission System (SNT). Thus, the chemical composition as well as a series of physical properties of natural gas are defining characteristics referring to: gross and net calorific power, Wobbe index, density, relative density, compressibility factor, dew point of water and liquid hydrocarbons [2,3].

Within the context of the same chapter, Article 5.4 (1) states that the chemical composition of natural gas and its physical properties above mentioned are determined by means of a gas chromatography laboratory device and/or gas chromatography line devices, in accordance with the specifications of the Regulation on metering gas quantities traded in Romania and the legal regulations in force [4].

Table 1 below shows the chemical composition of gas, expressed in molar percentage, qualified for transmission from producers to the final customers.

It is known that some of the gas quality parameters are obtained through a responsible operation of the complex technological installation for gas dehydration [5]. The values of these parameters are as follows:

-Dew point temperature of water,  $t_{H_2O} \leq -15^{\circ}C$  related to the pressure at the commercial delivery/ take-over point,

-Dew point temperature of hydrocarbons,  $t_{hidr} \leq 0^{\circ}C$  related to pressure at the commercial delivery/ take-over point [1],

-Gross calorific power,  $P_{cal}^{sup} \geq 7840 Kcal/m^3$ ;

$$P_{cal}^{sup} \geq 10,496 KWh/m^3$$

-Maximum temperature of gas flowing through the delivery/ take-over points,  $t_{max} = 50^{\circ}C$ ,

-Content of mechanical impurities,  $C_{imp} \leq 0.05 g/m^3$ .

## Experimental part

Name and chemical formula of components	Content in molar %
Methane (C <sub>1</sub> )	minimum 70
Ethane (C <sub>2</sub> )	maximum 10
Propane (C <sub>3</sub> )	maximum 3.5
Butane (C <sub>4</sub> )	maximum 1.5
Pentane (C <sub>5</sub> )	maximum 0.5
Hexane (C <sub>6</sub> )	maximum 0.1
Heptane (C <sub>7</sub> )	maximum 0.05
Octane (C <sub>8</sub> ) + higher hydrocarbons (C <sub>9</sub> )	maximum 0.05
Nitrogen (N <sub>2</sub> )	maximum 10
Carbon dioxide (CO <sub>2</sub> )	maximum 8
Oxygen (O <sub>2</sub> )	maximum 0,02
Hydrogen sulfide (H <sub>2</sub> S)	maximum 6.8 mg/mc
Ethyl Mercaptan (C <sub>2</sub> H <sub>5</sub> SH)	minim 8mg/mc
Total sulphur on short term	maximum 100 mg/mc

**Table 1**  
CHEMICAL COMPOSITION OF NATURAL GAS [4]

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It is unanimously recognized that the more reservoir pressure drops, the higher the volume of water entering the well from the porous permeable ore fissured reservoir environment is, hence making the process of gas production more difficult.

The comprehensive data base, built up in a professional manner during many tens of years has contributed decisively to developing the so-called production history for each commercial reservoir under the concession agreement of the largest gas production company in Romania. Interpretation of several production data correlated with geological conditions of reservoir formation has allowed for a good knowledge of gas generation mechanisms in the reservoir and, implicitly, the evolution in time of water volumes as free-water phase as well as vapor phase within the gas flow [6,7].

Numerous determinations and researches performed in the specialized laboratories of the company have reiterated that gas pressure, temperature, nature, composition and content of impurities exert influence upon gas humidity. Thus, the presence within natural gas of CO<sub>2</sub> and H<sub>2</sub>S, in a certain percentage, for instance higher than the values shown in table 1, implies an increase in humidity, while the presence of nitrogen tends to lower the humidity of natural gas.

An interesting observation is that, under the same conditions, humidity of natural gas is higher than that of air.

It is also to be noted that humidity is influenced by the molecular mass of natural gas, meaning that an increase in molecular mass leads to less humidity. A relevant example is gas low in C<sub>3+</sub> (gasoline) component, having a higher humidity than the C<sub>3+</sub>-rich hydrocarbons.

In engineering calculations determining the size of a gas dehydration station, it is very important to assess the value of gas humidity, especially as this parameter is related

to the assessment of the dew point temperature, which has to comply with the value required by legal regulations in the related field [8,9].

One way to calculate gas humidity is presented below, assuming that the respective fluid is a mixture, in equilibrium, formed of water and gas vapors at low pressure (4÷5) atm.

Gas humidity may be calculated from the equation at equilibrium expressed as [10]:

$$P_{H_2O} = P \cdot Y_{H_2O} = P_{H_2O}^t \quad (1)$$

where:

- $P_{H_2O}$  - partial pressure of water vapor in the gas phase,
- $P$  - system pressure,
- $Y_{H_2O}$  - molar fraction of water vapor in gas phase,
- $P_{H_2O}^t$  - water vapor pressure at temperature  $t$ .

Experiments have proven that for pressures within the range of tens of bars, the equation (1) is no longer valid because the external pressure affects the water-gas fluid, i.e. the water vapor pressure.

The humidity of a gas, or the saturation humidity or equilibrium humidity, also known as absolute humidity is expressed as:

$$U_g = \frac{m_{H_2O}}{m_g}, \text{ Kg}_{H_2O}/\text{Kg}_{\text{gaz dry}}, \quad (2)$$

or:

$$U_g^1 = \frac{m_{H_2O}}{m_{\text{total gaz}}}, \text{ Kg}_{H_2O}/\text{Kg}_{\text{gaz dry}}, \quad (3)$$

where:

- $m_{H_2O}$  - water vapor mass,
- $m_g$  - dry gas mass,
- $m_{\text{total gaz}} = m_{H_2O} + m_g$ , total mass of humid gas

Assuming that the gas + water vapor fluid is in the low pressure range and by applying the gas laws for the two components as well as for the entire mixture (fluid), the following equations result:

$$P_g V = \frac{m_g}{M_g} R_n T, \quad (4)$$

$$P_{H_2O} V = \frac{m_{H_2O}}{M_{H_2O}} R_n T, \quad (5)$$

$$P_{am} V = \frac{m_{am}}{M_{am}} R_n T, \quad (6)$$

where:

- $m = m_{H_2O} + m_g$ , mass of mixture or fluid
- $M_{H_2O}^{\text{am}}, M_g^{\text{am}}$  - molecular mass of water vapor, and gas, respectively
- $M_{\text{am}}$  - average molecular mass of the mixture
- $R_u$  - universal gas constant,
- $T^u$  - temperature of fluid or mixture

If the equation (5) is divided by (4) and (6) and bearing in mind the equation (1), Dalton's law as well as the equation of the average molecular mass, that is:

$$P_{H_2O} = P \cdot Y_{H_2O}; \quad P = P \cdot Y_g; \quad P = P_{H_2O} + P_g, \quad (7)$$

$$M_{am} = M_{H_2O} \cdot Y_{H_2O} + M_g \cdot Y_g = M_{H_2O} \cdot \frac{P_{H_2O}}{P} + M_g \cdot \frac{P_g}{P}, \quad (8)$$

the gas humidity equation results under the following form:

$$U_g = \frac{m_{H_2O}}{m_g} = \frac{P_{H_2O}^t}{P - P_{H_2O}^t} \cdot \frac{M_{H_2O}}{M_g} \quad (9)$$

Expressing the term  $P_{H_2O}^t$  from the equation (9), we obtain:

$$P_{H_2O}^t = P \cdot \frac{U_g + a}{U_g + a + 1}, \text{ where } a = \frac{M_{H_2O}}{M_g}. \quad (10)$$

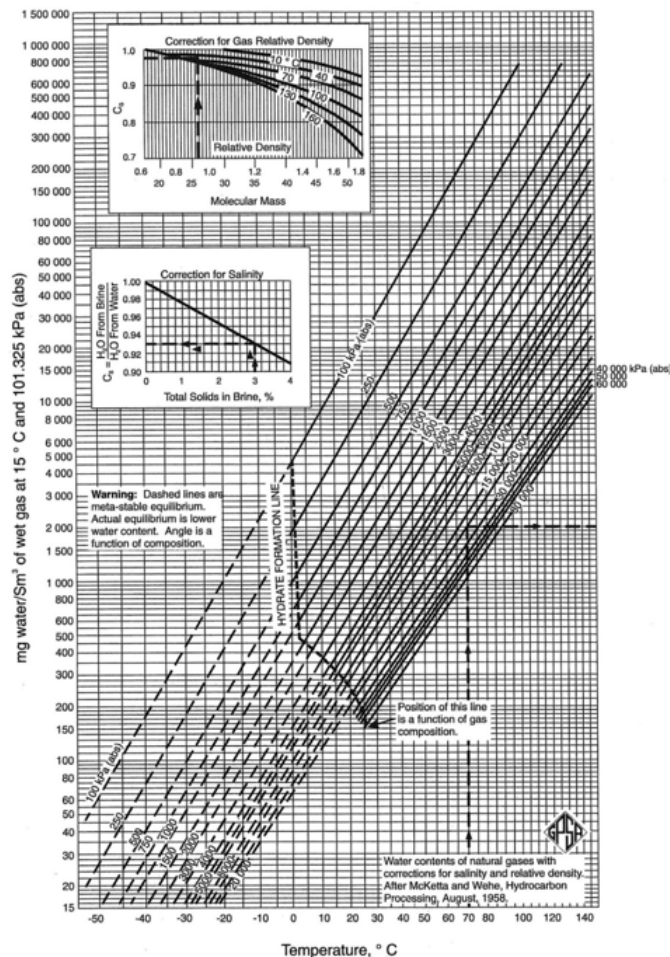


Fig. 1 Humidity of natural gas vs temperature and pressure [11]

This equation is important for it allows determination of  $P_{H_2O}^*$ , and then, the dew point temperature related to this pressure can be read from the water vapor pressure graph.

Using the diagram in figure 1, the gas humidity  $U_g$  can be determined depending on the pressure and temperature of the fluid or the gas+water vapor mixture [11].

## Results and discussions

The fundamental parameter of a gas dehydration/drying station is the dew point temperature of water, the value of which should be below or equal to  $-15^\circ\text{C}$  at the exit point of gas from the station, according to the standards in force.

Materials or substances used at industrial scale and for many years in the natural gas production area are adsorbents (table 2) as well as absorbents (table 3). One of the advantages of using this type of adsorbent and absorbent substances is that they are renewable, ensuring thus the continuance of the process in time, within the range of years, if regeneration temperature intervals and the fluid proportion within the gas flow are observed [12].

In this case, we are considering the reservoir water in excess, foamed into the gas flow and which cannot be retained by the liquid separator placed upstream the drying station.

Among the desiccants shown in table 2 above, silica gels have been mostly used during the last decades in gas treating/ drying, having the best price/quality ratio as compared to other desiccants.

For information only, it is specified that silica gel is a granular product, of different sizes, with high porosity obtained by dehydration of silicon dioxide gels in certain conditions. Remarkable is the fact that during the gas drying process, spectacular values of about  $-40^\circ\text{C}$  have been frequently obtained for the dew point temperature of water, thus, resulting a truly monophasic gas flow. Equally good results have been obtained for gas flows containing water vapor as well as condensate, the last one being recovered and measured after each regeneration cycle of silica gel.

In the practice of gas drying, other solid desiccants have also been used, such as activated coal, volcanic tuff,

Desiccant	Form	Specific weight $\text{kg/m}^3$	Particle size
Activated alumina	Granules	830	6-2 mm
Silica gel – R	Spherical granules	785	5-2 mm
Silica gel – H	Spherical granules	720	7-2 mm
Molecular meshes	Spherical granules	670-720	5-2 mm

**Table 2**  
CERTAIN COMMERCIAL  
CHARACTERISTICS OF  
ADSORBENTS

	Diethylene Glycol	Triethylene Glycol
Chemical formula	$C_4H_{10}O_3$	$C_6H_{14}O_4$
Molecular mass	106.1	150.2
Boiling temperature ( $^\circ\text{C}$ ) @ 760 mmHg	244.8	285.5
Vapor pressure (mmHg) @ $25^\circ\text{C}$	< 0.01	< 0.01
Density @ $25^\circ\text{C}$	1.113	1.119
60 $^\circ\text{C}$	1.088	1.092
Freezing point, $^\circ\text{C}$	-8	-7
Viscosity @ $25^\circ\text{C}$	28.2	37.3
60 $^\circ\text{C}$	6.99	8.77
Surface tension, dyne/cm	44	45
Boiling temperature, $^\circ\text{C}$	244.8	285.5
Flash point temperature, $^\circ\text{C}$	143	166

**Table 3**  
PHYSICAL  
PROPERTIES OF  
DIETHYLENE GLYCOL  
AND TRIETHYLENE  
GLYCOL [10,11]

Code of drying station	Substance (material) used in gas dehydration	Production Parameters				
		$P_i$ bar	$P_e$ bar	$Q_g$ $\cdot 10^3 \text{m}^3/\text{zi}$	CT $\cdot 10^3 \text{m}^3/\text{zi}$	$t_{\text{roua}}$ $^\circ\text{C}$
Station 1	Silica gel	4.5	3.1	360	0.89	-30
Station 2	Silica gel	19.6	15.6	735	0.55	-32
Station 3	Silica gel	6.0	5.9	90	0.14	-37
Station 4	Silica gel	16.9	15.7	216	0.8	-25
Station A	Triethylene glycol TEG	28.98	28.80	796	0.59	-22
Station B	TEG	30.37	30.21	1887	0.98	-26
Station C	TEG	24.16	24.11	329	0.45	-19
Station D	TEG	13.6	13.5	166	0.63	-31
Station E	TEG	13.0	12.9	63	0.21	-27
Station $\alpha$	Deliquescent salts	7.5	7.4	4.1	-	-21
Station $\beta$	Deliquescent salts	7.6	7.5	3.9	-	-20
Station $\gamma$	Deliquescent salts	13.0	13.0	6.0	-	-26
Station $\Delta$	Deliquescent salts	10.1	10	10.4	-	-27

**Table 4**  
TABLE OF  
COMPARED  
PRODUCTION  
PARAMETERS OF  
SEVERAL GAS  
DRYING STATIONS  
IN ROMANIA

$P_i$ ,  $P_e$  : drying station inlet pressure and outlet pressure, respectively;  $Q_g$  : total gas flow (dehydrated); CT: technological gas consumption;  $t_{\text{roua}}$  : dew point temperature of treated gas

activated alumina and molecular meshes. The last ones, although the most expensive ones, allow for values of  $-100^{\circ}\text{C}$  to be obtained for the dew point of water.

Among the liquid desiccants included within the absorbent category, triethylene glycol (TEG) is being currently most widely used due to its superior drying capacity, as well as its higher breakdown resistance as compared to diethylene glycol (DEG).

Laboratory researches have demonstrated that breakdown of desiccants starts at temperatures significantly lower than their boiling point. Thus, the approximate values of breakdown temperatures are  $164^{\circ}\text{C}$  for DEG and  $207^{\circ}\text{C}$  for TEG, respectively. Furthermore, the recommended regeneration temperature interval is  $(149-163)^{\circ}\text{C}$  for DEG and  $(177-197)^{\circ}\text{C}$  for TEG. By comparing only these values it can be easily noted that TEG is superior to DEG as regards the gas drying process.

Table 4 shows, comparatively, the base parameters reflecting a clear image of proper operation of these facilities in accordance with the design parameters. These three types of gas dehydration facilities operate in several gas fields in Romania, and are located upstream to compressor stations or at the producer - transmission operator interface. The oldest dehydration stations are the silica gel ones, some in operation for more than 30 years, a period during which they were repaired and revamped several times. The newest facilities are the deliquescent salt drying stations, located at the exit from gas fields with a small production not exceeding  $(10-11) \cdot 10^3\text{m}^3/\text{day}$ . The TEG station category is very well represented at national level as well as worldwide, and it is to be mentioned that where high amounts of gas are treated, in the range of tens of millions cubic meters per day, silica gel dehydration facilities are still being used [13].

By analyzing the data shown in table 4, it can be noted that at similar flows (station 1 vs station C, station 2 vs station A), the silica gel drying stations obtain very low dew point temperatures of water (station 3). As regards the technological consumption they are quite similar for the two groups, with a slight advantage of TEG stations.

It should be noted that the facilities 2, 3 and 4 have captured, during their operating period, hundreds of liters of condensate. Currently, such amounts are smaller due to the reservoir pressure decrease. This petroleum product, the condensate, if in a critical proportion within the gas flow, may deteriorate the annular burner in the combustion chamber of those drying facilities using this eco-friendly method of burning evaporation gas. This is a mixture made up of stripping gas, water vapor and condensate vapor.

Figure 2 shows an operational and reusable burner, while figure 3 shows a completely destroyed burner as a result of a violent combustion and detonations in the combustion chamber.

As regards behavior in time of silica gel, it can be said that its life span depends on the strict observation of the

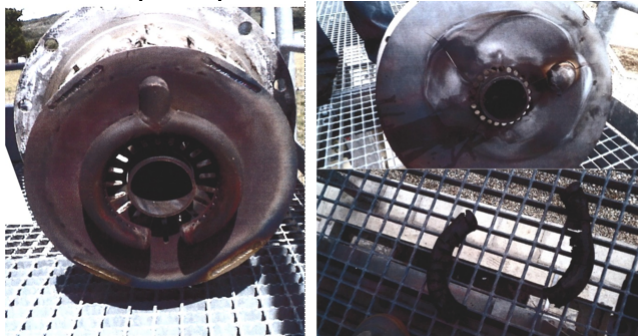


Fig. 2 Operational and reusable burner [14]

Fig. 3 Broken burner due to detonations in the combustion chamber

gas regeneration temperature that should not exceed  $180^{\circ}\text{C}$ . Repeated exceed of recommended temperature results in size degradation of silica gel granules, and the resulted dust may pass through the textile filters, entering then into the gas compressor units, leading to a premature deterioration of the compressor components. The effect of deterioration is amplified when the silica gel dust combines with the fluid resulted by excessive foaming of the reservoir water, having a specific gravity less than 1.

Contamination of TEG with this foamed fluid represents, may times, a real issue as concerns functioning in conformity with the operational parameters of those facilities. When such desiccant combines with the above mentioned fluid (foamer, as used in the field jargon), the color of the desiccant changes, as well as its physical-chemical properties, and it also will be foamed, having as consequences the shut-down of the station and, obviously, TEG replacement. The adsorbent volume in a station treating  $(200-300) \cdot 10^3\text{m}^3/\text{day}$  of gas amounts to 9400 l.

At last, another inconvenient related to an excessive foamer within the gas flow is stimulation of brine vapor resulted from reservoir water in contact with the hot parts of the hot gas/ TEG heat exchanger, forming in time a salt crust that reduces significantly the performance of the heater (fig. 4).



Fig. 4 Deteriorated TEG by foaming, inside the expansion vessel of the facility [14]



Fig. 5 Heat exchanger piping affected by salt crust [14]

The life span of TEG can be significantly increased by injecting defoamers into the gas flow (there are facilities that used TEG for up to 10 years).

### Conclusions

Gas dehydration and, implicitly, control of dew point temperature of water has represented a subject of study, research and finding practical solutions for more than 75 years.

Professional technical documents at the time recorded that the first procedure in gas dehydration used calcium chloride, having the advantage of being cheap but with the downside of being corrosive as well as the fact that the designed dew point was obtained in conditions of low operating temperature.

Usage at a large scale of absorbents within the glycol category, as well as those adsorbents within the silica gel category, for instance, has represented a huge qualitative

leap in terms of gas quality transmitted through the national transmission system and the distribution system.

Among the glycol category, triethylene glycol remains the most widely used absorbent due to its higher drying capacity and a better breakdown resistance as compared to diethylene glycol.

Usage of liquid absorbents, such as triethylene glycol, renders continuance to the dehydration process for the regeneration of such substances is made within a regeneration unit that is part of the drying facility.

Adsorbent substances (such as silica gel) can actually remove all the water within the gas flow (table 4).

Gas dehydration facilities using adsorbents operate in alternating cycle, meaning that while one battery of adsorbents is in the gas drying cycle, silica gel in the other battery is in the regeneration cycle + cooling, afterwards reentering the treatment cycle, etc.

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