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INVESTIGATION OF THE WATER CONTENT OF CH_4-H_2 SYSTEM

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Abstract: Hydrogen, as the clean energy carrier of the future can play a significant role in climate policy efforts in the near future. The study National Energy Strategy 2030 published in January 2020 defines the natural gas network as a seasonal energy storage. Several European countries have investigated whether hydrogen predominantly from renewable sources can be introduced to the natural gas system to reduce GHG emission. One of the important parameters of the natural gas fed into the gas network is the water vapor content, its maximum value of which is regulated by law. In this article, the authors examined whether hydrogen, which differs significantly from the properties of methane, causes a significant change in water saturation. The investigated pressure and temperature ranges cover every state found in the processing and transportation of natural gas. To carry out the calculations the Aspen HYSYS program was used.

1 Introduction

The European Commission's "Hydrogen Strategy for a Climate-Neutral Europe" was published in July 2020, which highlights key priority of hydrogen in achieving the EU's 2050 decarbonization targets [1]. Hydrogen is expected to play a significant role in bridging the current gaps in renewable energy storage and, in addition to reducing greenhouse gas emissions by producing water vapor only when combusted, will also offset seasonal fluctuations in energy needs. According to the communication the hydrogen could be a substitute for fossil fuels and increase the global competitiveness of industries with significant CO_2 emissions. It can also offer an opportunity to reduce GHG emissions in the transport sector. Hydrogen can be produced using electrolysis from electricity which thus can be stored for a longer time period, regardless of the seasonal and periodic fluctuations in the demand for natural gas. The study also mentions the existing natural gas infrastructure as a storage facility for hydrogen produced on a renewable basis, but the basis of the natural gas network use is to make the elements of the existing network technically suitable for continuous contact with hydrogen [2].

The growing interest in hydrogen is underpinned by “A Clean Planet for All” published in November 2018, which sets out the EU's climate-neutral strategic vision that the current share of hydrogen will increase to 14% by 2050 within Europe's energy mix [3]. The advancement of pure hydrogen could help the European Union achieve its goal of reducing GHG emissions by at least 40% by 2030 compared to 1990 levels [4].

Hydrogen differs significantly in its physical and combustion characteristics from methane. Therefore, it is necessary to examine how the parameters that must be met with the public service gas quality standards will change when a hydrogen is mixed with methane. In this paper, the authors refrain from reviewing all parameters influenced by hydrogen, examining only one important characteristic, the change in water saturation as a function of pressure, temperature and hydrogen content.

2 Importance of water dew point of natural gas

The water content of the produced natural gas is determined by the reservoir properties. The significant part of the undesired water content is separated during the treating process of the natural gas to set the water dew point before transfer to the natural gas network.

The risk of water content dissolved in natural gas is that water vapor may condense during transport due to pressure and/or temperature drop and can accumulate at the bottom of the pipeline, reducing the flowing cross-section in either liquid or solid state. In addition, water is corrosive to metals, which is amplified in the presence of CO_2 and H_2S content. The water content present in the natural gas also has a negative effect on the structural elements of the pipeline and on the associated consumer equipment. For this reason, the dew point of the natural gas is set to prevent water condensation.

Gases reach a saturated water content when the partial pressure of the water vapor dissolved in them is equal to the equilibrium vapor pressure of the water at a given temperature. As the temperature of the saturated gas decreases, the precipitation of water dissolved in it begins. The dew point of natural gases is thus the temperature at which the partial pressure corresponding to the water vapor is equal to its vapor pressure. The dew point temperature depends significantly on the pressure; at the same humidity it increases with increasing pressure. A given dew point temperature value has a lower absolute humidity at higher pressures [5,6].

After the water dew point setting, the gas in the domestic natural gas supply system can be considered practically dry gas, because water condensation is not happening at the transport and distribution pressures and corresponding temperatures. In Hungarian practice, the supplied natural gas may contain a maximum of 0.17 g/Nm^3 of water vapor. The standard established by CEN specifies a dew point temperature of -8 °C at the maximum operating pressure, which is stricter than the European average, as it means a maximum water vapor content of 65 mg/Nm^3 at 70 bar (a) [7,8].

3 Introduction of the model used in the investigation of water content

The effect of hydrogen mixed with methane, the main constituent of natural gas, on water saturation was investigated using the simulation software Aspen HYSYS. The equation of state used for the model tests was selected by comparing the water saturation values at different temperatures provided by different models with the data obtained from a laboratory measurement, as illustrated in Figure 1 [9].

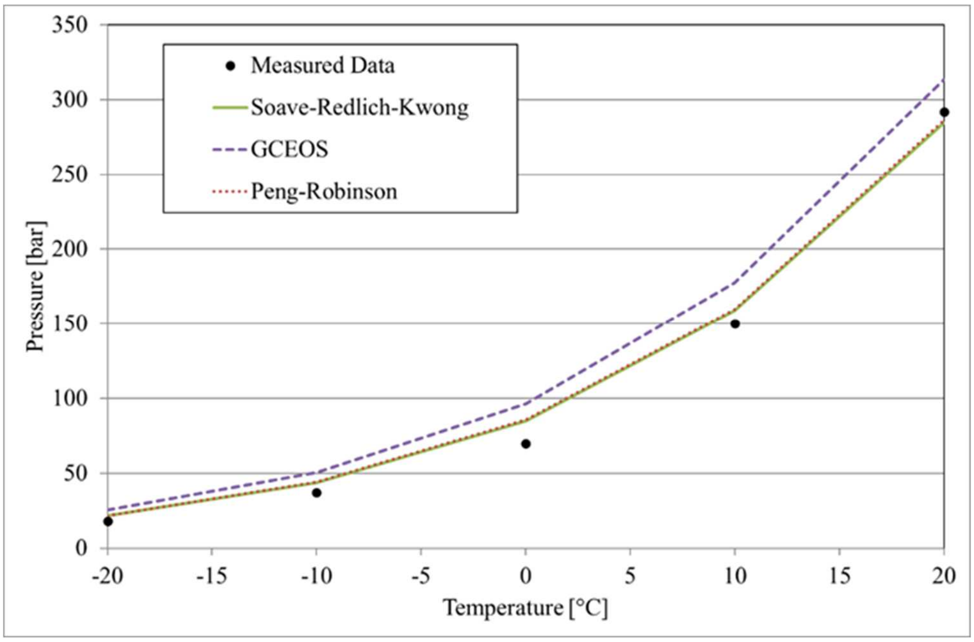

Figure 1 Selection of the equation of state used in the modelling procedure

Figure 1 shows the curves closest to the points generated during the measurement, calculated using different equations of state. Based on a comparison of the measured and software-calculated data, the most widely used Peng-Robinson equation for real gases was used in the model testing for water saturation.

To analyse the effect of the hydrogen content in the methane-hydrogen system on water saturation, the water saturation of 100 V/V% H_2 at different pressures and temperatures was determined. The simulation was performed in the temperature range of (-20)-60 °C and pressure range of 0-70 barg, its graphical representation is shown in Figure 2.

Based on the looking at the hydrogen saturation curves, it can be stated that the highest water content occurs at atmospheric pressure and at 60 °C. The water content dissolved in hydrogen increases with increasing temperature until it decreases with increasing pressure, as a result of which the lowest water saturation occurred in the test range at an overpressure of 70 bar and -20 °C.

The HYSYS model constructed for the water saturation change study under the action of hydrogen mixed with methane is shown in Figure 3.

In the model, hydrogen is mixed with methane through a manifold. The methane-hydrogen gas mixture is then fed to a saturator where it is saturated with water vapor at a

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given pressure and temperature, i.e. it reaches the maximum water content so that no liquid phase develops.

During the simulation, methane and hydrogen introduced to the manifold have the same pressure and temperature. The tests were performed for a gas mixture with 0-100 V/V% hydrogen content, where the test pressure range was 0-70 barg, using 10 bar increments, for which the water saturation values were determined in the (-20)-60 °C temperature range with 10 °C step size.

The objective of the ADJ-1 element placed in the model is to keep the resulting gas mixture at constant volumetric flow rate. As the hydrogen content in the gas mixture increases, the volume flow of methane decreases accordingly. The ADJ-2 element is responsible for keeping the pressure of methane and hydrogen, while the ADJ-3 element is responsible for keeping its temperature constant. The ADJ-4 element eliminates the effect of temperature changes due to the mixing of real gases.

4 Water content investigation of CH_4-H_2 systems

During the simulation studies, an increasing volume of hydrogen was added to the methane in order to create clear conclusions about its effect on the maximum water saturation.

Figure 4 shows the case in which the hydrogen content is 10 V/V% of the gas mixture, showing the difference in water saturation relative to pure methane. It can be observed that the most significant deviation occurs at the lowest test temperature value, i.e. -20 °C. It can also be observed that as the temperature increases, the deviation from pure methane shows a decreasing trend. In terms of pressures, the most significant difference occurs at a pressure of 40 barg at -20 °C, in this case the amount of saturated water vapor soluble at the given physical state increases by 3.5% compared to the water saturation of 100% CH_4. It can also be observed that at this temperature and at a higher pressure there is a decrease in the saturated water vapor content of pure methane, so that approximately a difference of 2% occurs in the presence of 10 V/V% hydrogen. At 60 °C and in the pressure range of 10-70 barg, there is a 0.2-1.2% difference in the saturated water vapor content compared to the pure methane.

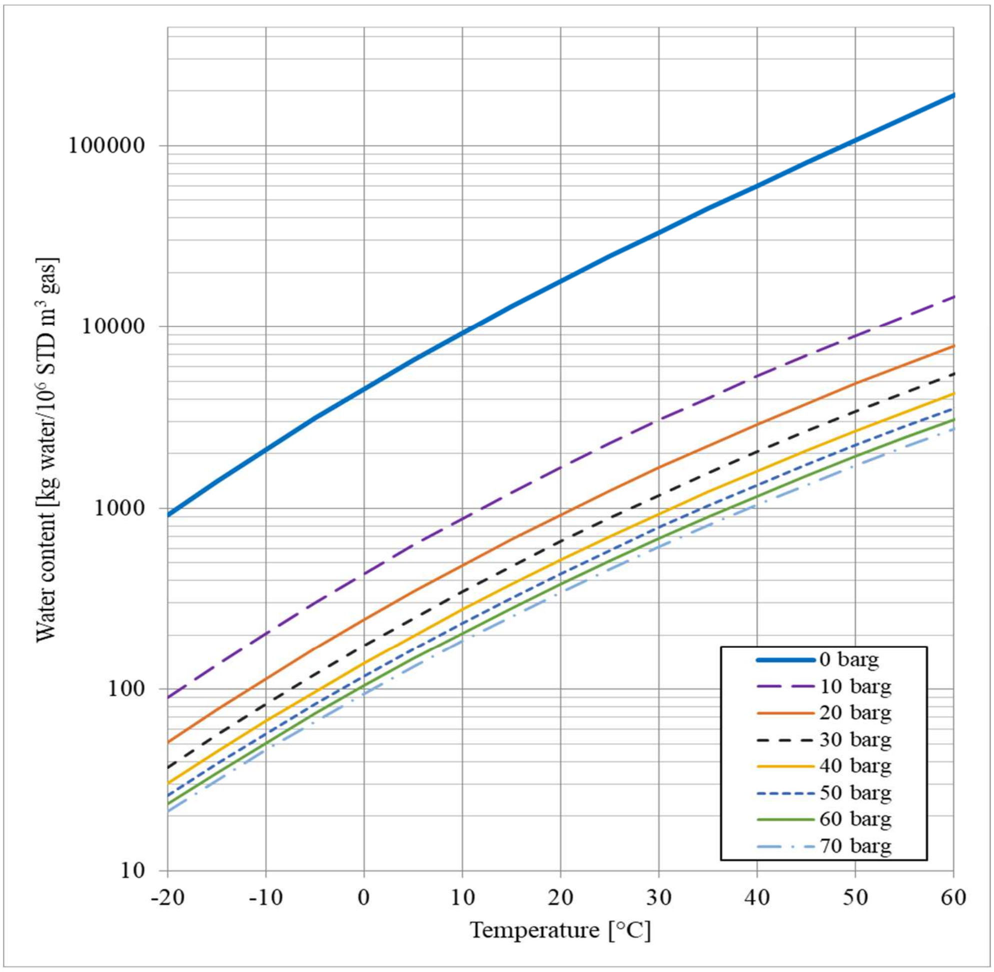

Figure 2 Change in water saturation of pure hydrogen as a function of pressure and temperature

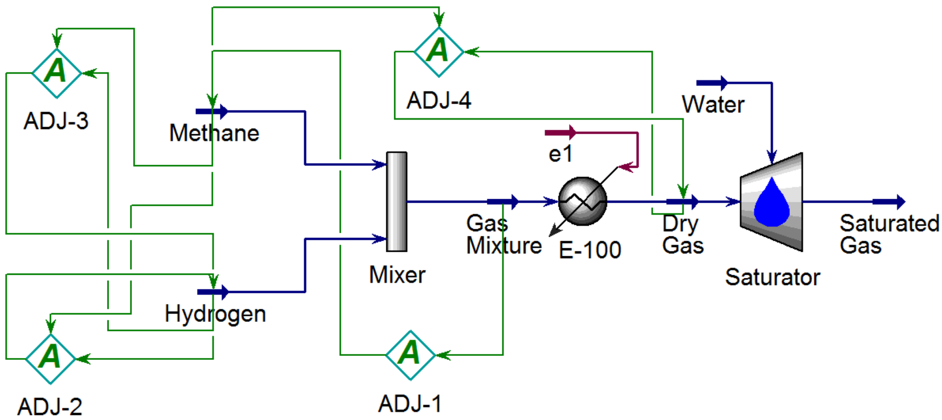

Figure 3 Structure of the model used for simulation studies

Tests were performed at every 10 bar pressure stage, but the presentation of the results is limited. For this reason, the Figure 5 shows the change in water saturation for 100% hydrogen relative to the saturated water vapor for pure methane. Based on Figure 5, the change in saturated water content shows a similar trend as in the case of 10 V/V% hydrogen content. The largest deviation occurs at the lowest temperature tested at a pressure of 40 barg, where the deviation is close to 5%. It can also be said that with increasing temperature, a nearly linearly decreasing trend is observed in the change relative to the water saturation of pure methane gas.

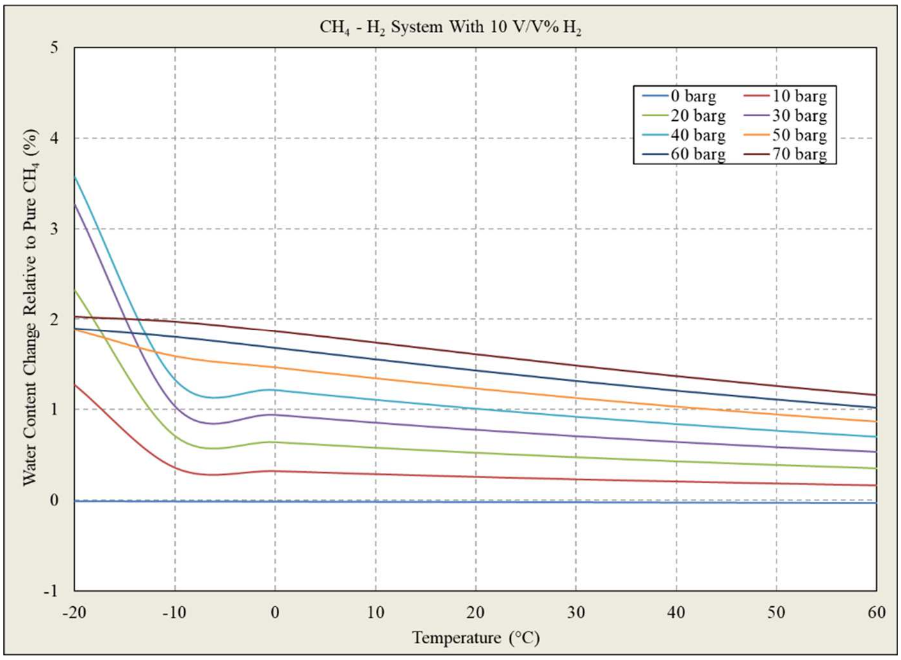

Figure 4 Water content change in case of 10% H_2 in the gas mixture

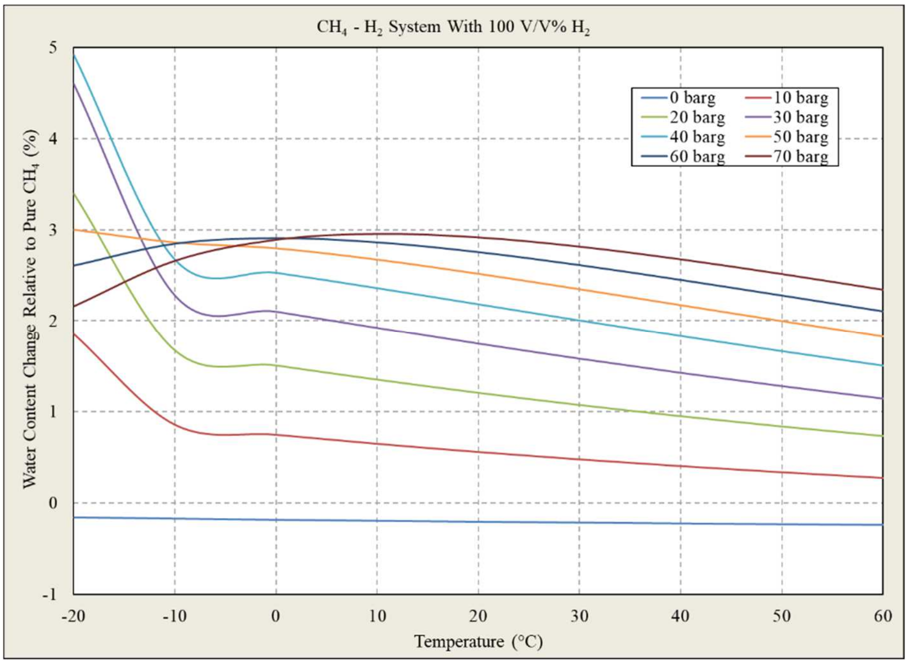

Figure 5 Maximum water content of hydrogen compared to pure methane

We also extended our investigation to see how the saturated water vapor content of the methane-hydrogen system changes compared to pure methane at constant temperatures for different hydrogen concentrations, the results of which are illustrated in Figures 6 and 7.

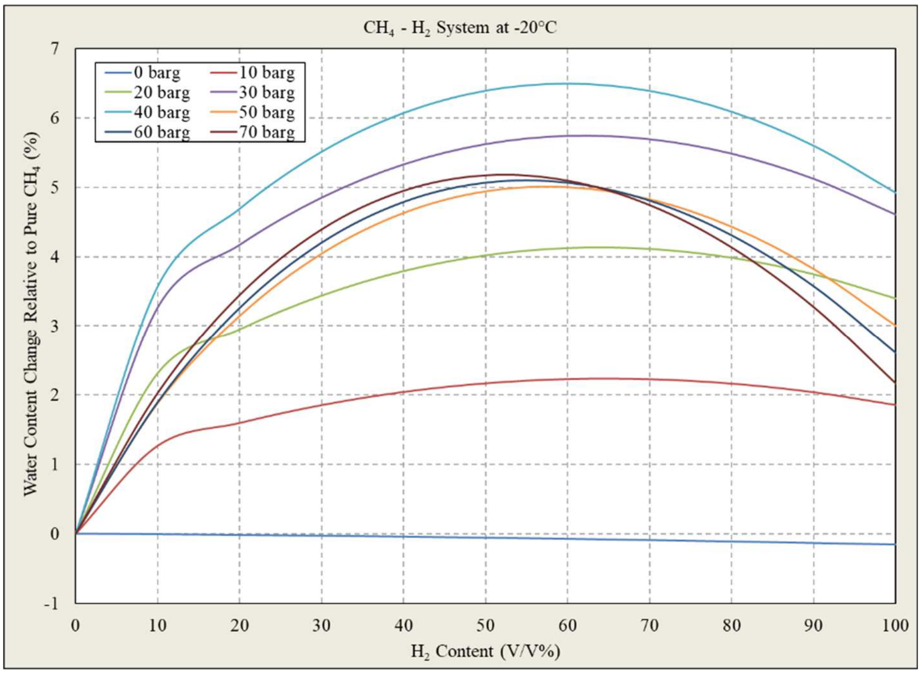

Figure 6 Water content change at -20 °C

It can be seen that the most significant change occurs at approx. 60 V/V% hydrogen content, which is increasing by a decrease in temperature. Until 60 V/V% hydrogen content, a strong upward trend can be observed for the change in saturated water vapor content at every investigated temperature, and then with a further increase in hydrogen content, the rate of change in saturated water vapor relative to pure methane decreases consistently.

At -20 °C and 40 barg pressure a gas mixture with 60 V/V% hydrogen content, the increase is 6.5%, while at the same hydrogen content and at 10 barg pressure, there is only a 2.2% difference. With increasing pressure, it can be

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observed that at 70 barg the saturated water vapor content of pure hydrogen gas differs by 2.2% compared to methane gas, i.e. the increase of pressure above 40 barg shows that the change in water saturation compared to methane gas at the same temperature. At a temperature of 60 °C, which is illustrated in Figure 7, there is already a clearer picture of the change in water saturation. At this temperature, as the pressure increases, the change in saturated water vapor content increases to a hydrogen content of 60 V/V%, and then, as a further increase in H_2 content, a decrease begins until a H_2 content of 100 V/V% is reached. Based on the simulation studies, the increase in water saturation of pure hydrogen gas was only 0.3% at 10 barg and 2.3% at 70 barg.

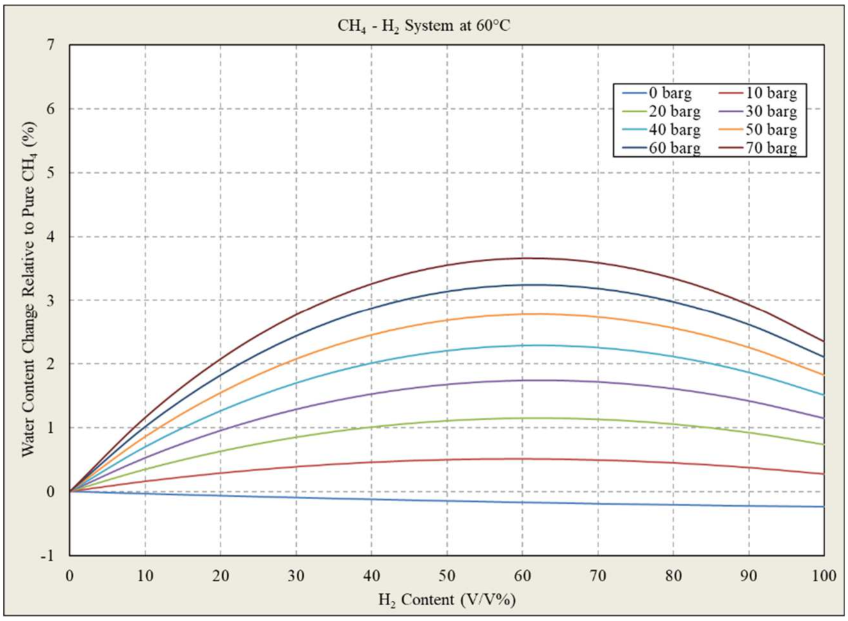

Figure 7 Water content change at 60 °C

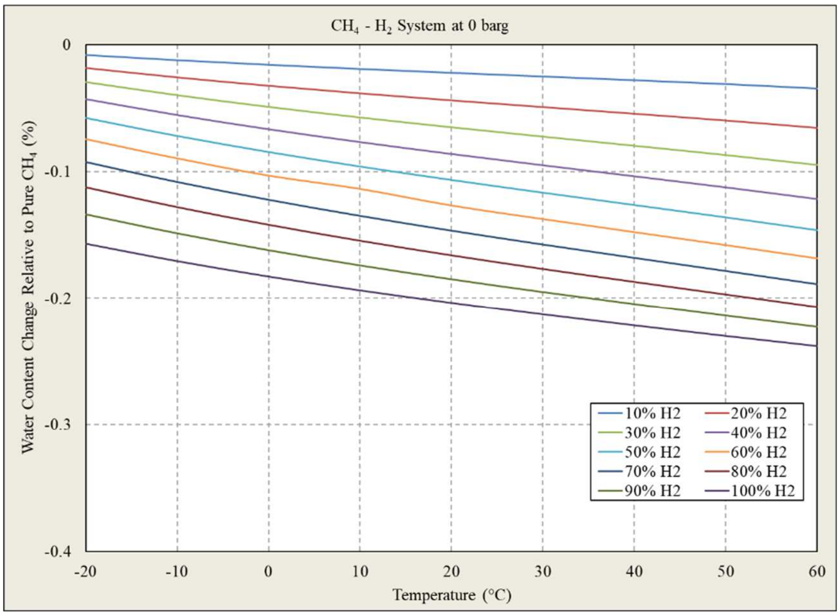

Figure 8 Water content change at 0 barg

In Figure 8 the pressure of the methane-hydrogen system is kept at atmospheric, its temperature and composition varied in the intervals introduced previously. At 0 barg pressure the changes in water content are well approximated with linear function in the investigated interval. With increasing hydrogen content, the maximum water content decreases, this effect is further enhanced with increasing temperature. The greatest change we found at 60 °C and assuming 100% hydrogen. In this case the maximum water saturation dropped by 0.23%.

The behaviour of the investigated gas mixture changes significantly with increasing pressure. Figure 9 uses data at 70 barg pressure. In this figure the relationship between the temperature and the hydrogen concentration will influence the maximum water content in a more complex way. In the lower hydrogen concentrations below 60 V/V%, an increasing hydrogen content will increase the maximal water saturation in the gas mixture. Above this concentration the water saturation will drop if more hydrogen is introduced into the mixture. This effect is valid for the temperature range investigated. The peak difference compared to pure methane occurs at -8 °C using 60 V/V% hydrogen, resulting in 5.3% water content increase relative to pure methane.

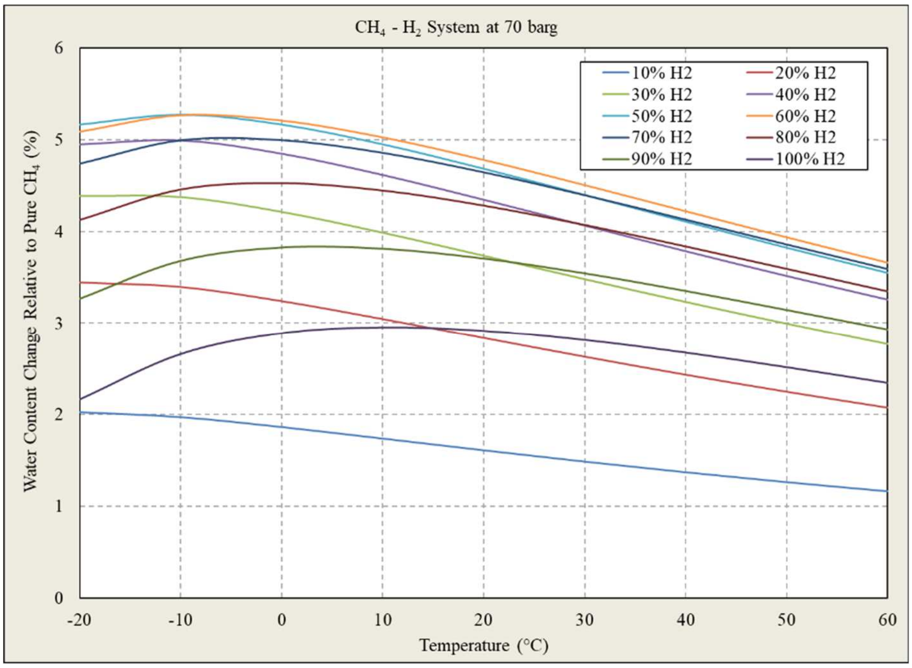

Figure 9 Water content change at 70 barg

5 Results and discussion

The authors conducted a study to determine the effect of the emergence of hydrogen as the energy carrier of the future on the natural gas network on one of the important parameters of natural gas, the dew point. The simulation was performed with Aspen HYSYS, which is widely used in the oil and gas industry. During the tests, various pressure and temperature ranges were investigated to describe the hydrogen-methane system, which represent any degree of variation in the hydrogen content of the main constituents of natural gas, the pure methane.

As a result of the tests, it can be determined that as the temperature increases, the ratio of the water saturation change of the saturated water vapor content of the methane-hydrogen system relative to the pure methane decreases. Using pure hydrogen, the most significant difference is at the lowest test temperature and 40 barg pressure, which resulted in an increase of nearly 5% relative to the saturated water content of the pure methane. In the presence of 10 V/V% hydrogen content, only a difference of 3.6% was observed under the same conditions.

It was also found that an increase in temperature reduces the change relative to pure methane. In our studies, it was found that with the same hydrogen content and with increasing pressure above 0 °C, the change in water saturation increases consistently.

When testing a methane-hydrogen system with different volume fractions of H_2, the largest difference was at 40 barg pressure and at 40 V/V% hydrogen concentration, resulting in a 6.5% change in the maximum water content compared to pure methane. A further increase in H_2 concentration content results in a decrease in the change in water saturation.

Examining the methane-hydrogen system at atmospheric pressure, it can be observed that in all cases with a volume fraction of H_2 there is a slight decrease in the saturated water vapor content compared to pure methane.

Based on the results of the simulation studies, it can be determined that the appearance of hydrogen in the natural gas network does not necessitate a technological change in the gas treating procedure of a natural gas with high methane content with regard to the setting of water dew point. This finding is valid for both current and future stricter requirements, as this amount of hydrogen content does not cause a significant difference in terms of maximum water saturation.

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References

[1] SZUNYOG, I., GALYAS, A. B.: A földgáz hidrogénnel történő helyettesítésének potenciálja Magyarországon, *Műszaki Földtudományi Közlemények*, Miskolci Egyetemi Kiadó, Vol. 89, No. 1, pp. 227-233, 2020. (Original in Hungarian)

[2] HYDROGEN STRATEGY FOR A CLIMATE-NEUTRAL EUROPE, *Communication from the Commission to the Europen Parliament, the Council, the Europen Economic and Social Committee and the Committee of the Regions*, European Commission, COM(2020) 301 final, Brussels, 8.7.2020. Available: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf [05. Nov 2020] 2020.

[3] A CLEAN PLANER FOR ALL – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 773 final, European Commission, Brussels, 28.11.2018, Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0773 [05. Nov 2020] 2018.

[4] AMANATIDIS, G.: *Combating Climate Change*, European Parliament, Fact Sheets on the European Union – 2020, [Online], Available: https://www.europarl.europa.eu/factsheets/en/sheet/72/az-eghajlatvaltozas-ellen-kuzdelem [05. Nov 2020], 2020.

[5] MESSER, Gases for Life, [Online], Available: https://www.messer.hu/documents/20598/615088/1_6_fejezet.pdf/2430679e-52fc-4b38-bc08-fc122702405a [05. Nov 2020], 2020.

[6] CAMPBELL, J. M.: *Gas Conditioning and Processing*, Vol. 1.: The Basic Principles, 9th ed., Second Printing, J. M. Campbell and Company, Norman, Oklahoma, 2014.

[7] GALYAS, A. B., SZUNYOG, I., TIHANYI, L.: Az egységes európai gázminőségi előírások hatása a hazai földgázellátó rendszerbe betáplált gázminőségekre, *Műszaki Földtudományi Közlemények*, Vol. 86, No. 1, Miskolci Egyetemi Kiadó, pp. 129-137, 2017. (Original in Hungarian)

[8] SZUNYOG, I.: *A biogázok földgáz közszolgáltatásban történő alkalmazásának minőségi feltételrendszere Magyarországon*, PhD dissertation, 2009.

[9] Statoil, GASSCO: Water content of high pressure natural gas, [Online], Available: https://www.sintef.no/globalassets/project/trondheim_gts/presentasjoner/water-content-of-high-pressure-natural-gas.pdf [05. Nov 2020], 2009.

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