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FLOMEKO2019
18th International Flow Measurement Conference
Portugal | Lisbon | LNEC | 26-28 june 2019

EXPLORATION OF HYDROGEN INFLUENCE ON PHYSICAL PROPERTIES OF NATURAL GAS AND METROLOGICAL CHARACTERISTICS OF ITS METERING SYSTEMS

ISO 9001
141101

Due to the predicted exhaustion of oil and natural gas resources by the end of this century, all industrialized countries are taking steps to find alternatives for hydrocarbon fuels.

Among other sources of energy, the use of which can be possible in the nearest future, hydrogen is the most promising one. The advantages of using hydrogen as a fuel can be summarized as follows:

1. Using hydrogen as fuel can be one of the comprehensive solutions to the problem of environmental protection.

2. Hydrogen is an excellent energy carrier.

3. Hydrogen has great potential as one of the main energy sources of the future. Future supplies of hydrogen that do not affect the global climate can be derived from sustained primary sources such as wind, solar and geothermal energy.

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Taking into the possibility of using a mixture of hydrogen and natural gas as a source of energy, the research has been aimed in the following directions:

-**Influence of hydrogen impurities on the physical properties of natural gas;**

-**the effect of adding hydrogen into natural gas on the metrological characteristics of metering systems.**

To determine the effect of hydrogen on the above list of factors, research is aimed at solving the following problems:

1. **Conducting studies on the effect of hydrogen injection in natural gas on the physical properties of the mixture requires determining the dependence of the following gas parameters on the percentage of hydrogen in the natural gas: density, dynamic viscosity, compression factor, the highest calorific value, Wobbe index, sound speed, adiabatic index.**
2. **Determining the permissible fraction (permissible concentration) of hydrogen in natural gas in modern gas-transport and gas-consuming systems.**
3. **Examining the effect of hydrogen injection on metrological characteristics of measuring equipment and gas custody transfer metering systems.**

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Analysis of the following physical characteristics of these gas compositions and calculations of their physical criterion were carried out:

-adiabatic index and speed of sound

$$k = 1{,}556(1 + 0{,}074 x_a) - 3{,}9 \cdot 10^{-4} T (1 - 0{,}68 x_a) - 0{,}208 \rho_b + (p/T)^{1{,}43} \left[384 (1 - x_a)(p/T)^{0{,}8} + 26{,}4 x_a \right]$$

$$u = 18{,}591 \left(\frac{T \cdot Z \cdot K}{\rho_b} \right)^{0{,}5}$$

-relative density

$$d(t, p) = \frac{d^\circ \cdot Z_{air}(t, p)}{Z_{mix}(t, p)}$$

-compression factor

$$z_{mix}(t_2, p_2) = 1 - \left[\sum_{j=1}^{N} x_j \cdot \sqrt{b_j} \right]$$

-the highest calorific value

$$\overline{H}[t_1, V(t_2, p_2)] = \frac{\overline{H}^\circ(t_1)}{Z_{mix}(t_2, p_2)}$$

-Wobbe index

$$W[t_1, V(t_2, p_2)] = \frac{\overline{H}_S[t_1, V(t_2, p_2)]}{\sqrt{d(t_2, p_2)}}$$

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The results of the analysis of the physical parameters of four natural gas samples

	Gas 1				Gas 2			
Hydrogen	0	2	10	23	0	2	10	23
Methane	93.031	91.170	83.728	71.634	90.779	88.963	81.701	69.900
Ethane	3.541	3.470	3.187	2.727	4.555	4.464	4.100	3.507
Propane	0.835	0.818	0.752	0.643	1.056	1.035	0.950	0.813
i - Butane	0.105	0.103	0.095	0.081	0.110	0.108	0.099	0.085
n - Butane	0.136	0.133	0.122	0.105	0.174	0.171	0.157	0.134
neo - Pentane	0.013	0.013	0.012	0.010	0.002	0.002	0.002	0.002
i - Pentane	0.029	0.028	0.026	0.022	0.045	0.044	0.041	0.035
n - Pentane	0.023	0.023	0.021	0.018	0.038	0.037	0.034	0.029
Hexan	0.008	0.008	0.007	0.006	0.034	0.033	0.031	0.026
Nitrogen	1.125	1.103	1.013	0.866	1.519	1.489	1.367	1.170
Carbon Dioxide	1.149	1.126	1.034	0.885	1.684	1.650	1.516	1.297
Oxygen	0.008	0.008	0.007	0.006	0.008	0.008	0.007	0.006
Calorific value MJ/m^3	38.650	38.116	35.980	32.516	38.811	38.273	36.124	32.638
Shift, %	-	-1.38	-6.91	-15.87	-	-1.39	-6.92	-15.90
Wobbe index	49.8571	49.611	48.623	47.015	49.428	49.184	48.205	46.613
Shift, %	-	-0.49	-2.48	-5.70	-	-0.49	-2.47	-5.70

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	Gas 3				Gas 4			
Hydrogen	0	2	10	23	0	2	10	23
Methane	89.425	87.637	80.483	68.857	89.213	87.428	80.291	68.694
Ethane	5.179	5.075	4.661	3.988	5.114	5.012	4.603	3.938
Propane	1.191	1.167	1.072	0.917	1.163	1.140	1.047	0.895
i - Butane	0.115	0.113	0.104	0.089	0.118	0.115	0.106	0.091
n - Butane	0.185	0.181	0.167	0.142	0.209	0.205	0.188	0.161
neo - Pentane	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.002
i - Pentane	0.047	0.046	0.042	0.036	0.059	0.058	0.053	0.046
n - Pentane	0.040	0.039	0.036	0.031	0.047	0.046	0.042	0.036
Hexan	0.054	0.053	0.049	0.042	0.05	0.049	0.045	0.039
Nitrogen	1.646	1.613	1.481	1.267	1.509	1.479	1.358	1.162
Carbon Dioxide	2.111	2.069	1.900	1.625	2.510	2.460	2.259	1.933
Oxygen	0.007	0.007	0.006	0.005	0.0055	0.005	0.005	0.004
Calorific value MJ/m^3	38.904	38.364	36.208	32.709	38.809	38.271	36.122	32.636
Shift, %	-	-1.39	-6.93	-15.92	-	-1.39	-6.92	-15.91
Wobbe index	49.156	48.913	47.940	46.359	48.905	48.665	47.701	46.135
Shift, %	-	-0.49	-2.47	-5.69	-	-0.49	-2.46	-5.66

The results of calculations allow to draw conclusions that when adding hydrogen to the natural gas in an amount from 2 % to 23 % physical parameters of the obtained mixture vary accordingly in the following ranges:

-the speed of sound increases in the range (1 - 13,5) %;

-density (relative density) of the mixture is reduced in the range (1,7 - 20,5) %;

-compression factor at atmospheric pressure varies within the limits (0,01 - 0,1) %;

-the highest calorific value decreases in the range (1,4 - 16) %;

-the Wobbe index decreases in the range (0,49 - 5,7) %.

According to the European standard EN 437 Tested gases - Test pressures - Appliance categories, natural gas is classified into “H” and “L” groups depending on the Wobbe index values. Simulations showed that with the addition of hydrogen in a volume of up to 23%, all four samples of natural gas remained in the “H” group

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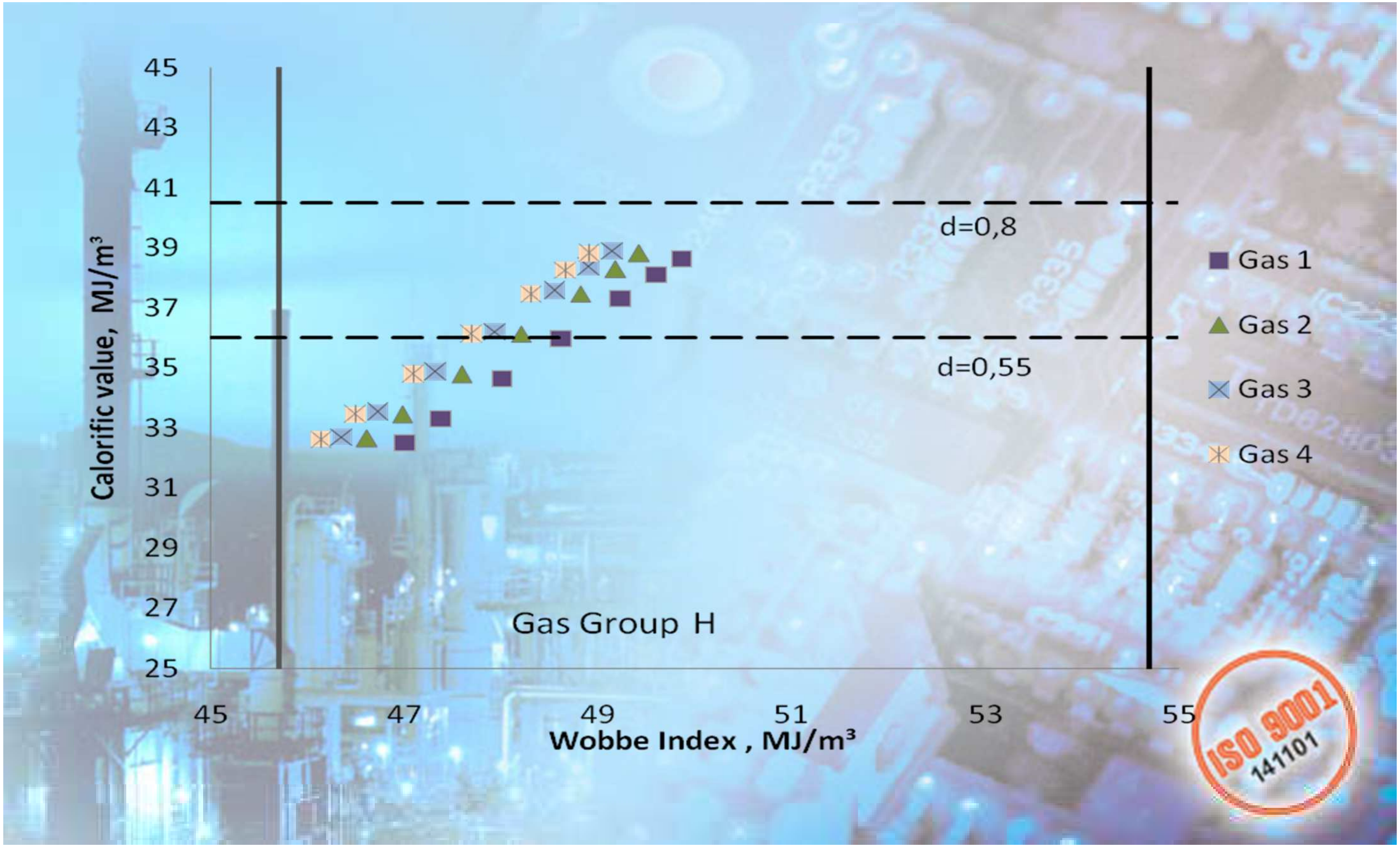

The simulation results showed that, by the criterion of permissible values of the relative density, the fraction of hydrogen in natural gas should be in the range from 0 to 10%.

In accordance with the requirements of the international standard ISO 12213-3: 2006 "Natural gas – Calculation of compression factor – Part 3: Calculation using physical properties", restrictions are imposed on the use of natural gas for domestic purposes according to the following parameters:

-**absolute pressure (from 0 to 12 MPa)**

-**the molar fraction of hydrogen (from 0 to 10%)**

-**relative density (from 0.55 to 0.8)**

Further increase in the proportion of hydrogen (up to 23%) depends on the quality (Wobbe index) of natural gas and requires the search and use of other algorithms for calculating the physical parameters of gas (described by other regulatory documents).

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Considering current trends in the transition of gas metering systems in power plants, i.e., switching to natural gas metering based on its energy value (caloric content), the effect of hydrogen additives on the heat of combustion of the mixture was analyzed.

The results of the analysis of the calculations showed that with the addition of hydrogen up to 10%, the highest calorific value of the mixture decreases by about 7%, while the Wobbe index decreases by no more than 3%.

This allows us to conclude about the possibility of adding hydrogen to natural gas in the amount of up to 10% without any modifications of both gas transmission and gas-consuming systems and algorithms for calculating the physical parameters of gas.

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Conclusion

Adding hydrogen to natural gas in a volume of up to 10% allows to operate existing gas-transport and gas-consuming systems without any reconstructions, modifications, changes in algorithms for calculating the physical parameters of the gas mixture and (volume) volumetric flow rate for custody transfer purposes.

Adding hydrogen in the volume of more than 10%, and also, the use of the mixture at high pressures requires additional study and the development of new algorithms.

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Thank you for your attention!

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