ANALYSIS OF THE HYDROGEN CONCENTRATION ON NETWORKS FOR GAS SUPPLY

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ABSTRACT. Restrictions on the planet's carbon footprint are becoming a motivating measure to limit the use of fossil fuels in the European Union. One of the measures to decarbonize the economy is to reduce the use of hydrocarbon fuels (oil, gas, coal). Increasing the potential for hydrogen use in energy is a key point in the conversion of fuels into energy. How the concentration of hydrogen is reflected in the gas supply is an analysis that the energy sector must consider to determine the safe operation and quality of operation of the appliances. Increasing the concentration of hydrogen in gas mixtures by up to 5% does not change the key parameters that determine the interchangeability of used gases in the gas industry. At hydrogen concentrations above 10% in the gas mixtures, the gas-dynamic properties of the gas also change, which also affects the design parameters of the gas supply systems.

Keywords: natural gas, hydrogen, gas supply, gas appliances

АНАЛИЗ НА ВЪЗМОЖОСТИ ЗА ИЗПОЛЗВАНЕТО НА ВОДОРОД В ГАЗОСНАБДИТЕЛНИТЕ СИСТЕМИ

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РЕЗЮМЕ. Намалението на въглеродният отпечатък върху планетата, става мотивираща мярка за ограничаване на използването на фусилните горива в Европейския съюз. Една от мерките за декарбонизация на икономиката е намаляване на използването на въглеводородни горива (нефт, газ, въглища). Увеличението на възможностите за използване на водород в енергетиката е ключов момент при конверсията на горива в икономиката. Как се отразява концентрацията на водорода при газоснабдяването е анализ, който енергийния сектор трябва да вземе предвид за определяне на безопасната експлоатация и качеството на работа на газовите уреди. Увеличаване на концентрацията на водород в газовите смеси до 5% не променят ключовите параметри определящи взаимозаменяемостта на използваните газове в газовата промишленост. При концентрации на водорода над 10% в газовите смеси се променят и газодинамичните качества на газа, което се отразява и на проектните параметри на газоснабдителните системи. Предмет на този доклад е възможността за използване и пренасяне на водорода в газоснабдителните системи.

Ключови думи: природен газ, водород, газоснабдяване, газови уреди

Introduction

Protecting the environment and preserving the ecological climate of the planet is society's duty to the next generation and an investment in the future.

Joint multi-layered efforts are needed to achieve a sensitive effect and real benefits for clean air, climate and public health. The extractive and processing industries, together with transport, are the sectors of the economy that will undergo the most profound changes in the realization of the goals set for society to reduce the carbon footprint of the planet.

The main changes are expected to be in the direction of changing the fuel base in the energy and transport sectors. The task is to limit fossil fuels at the expense of an increasing share of hydrogen (green and blue), obtained by electrolysis or reforming, respectively from water or fuels that contain it. The European Community expects that by 2040 the reduction of greenhouse gases will be 5 Gt compared to the current situation.

In the process of replacing fossil non-renewable fuels with hydrogen produced by the two main technologies, at least three problems have been identified. One is related to the production of sufficiently significant quantities of this gas, and the others are related to the transmission, distribution and use by consumers. The last two issues and related issues are addressed in this report.

Possibilities for hydrogen use in gas supply systems

European politicians are increasingly recognizing the important role that hydrogen will play in existing gas networks in order to achieve decarbonization targets with minimal disruption to consumers. Existing gas infrastructure is a vital advantage for energy supply and security of supply, capable of long-term and reliable energy storage. Mixing hydrogen with natural gas in existing gas supply systems is a possible advantage over companies in the gas sector. Some idea of the market can be obtained by studying the theory of imbalance, as a balanced center of gravity presented by (Radev, 2011).
Technologically in the supply chain from the production of hydrogen to its combustion at consumers three technical-technological tasks are distinguished, corresponding to the chain of production and supply to customers (Fig. 1).

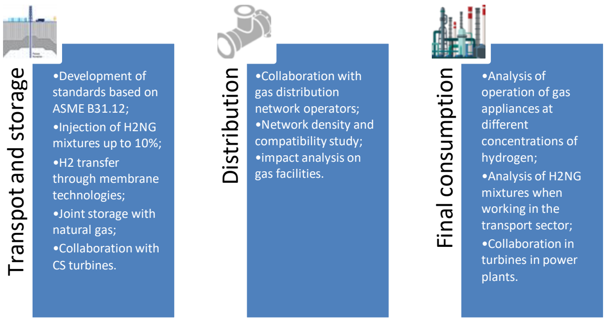

Fig. 1. Technical problems in hydrogen supply

The first problem is related to transport, where the subproblems are divided into the linear (pipeline) part, gas storages and compressor stations. In the transmission network the research is in the direction of: development of standards based on ASME B 31.12, which should prepare specifications of the admissible equipment, technical means for injection of high pressure hydrogen in the transport systems, research and study of membrane technologies for steel protection pipelines of high hydrogen concentration during transmission. A promising direction in storage is the possibility of capturing carbon dioxide from thermal power plants and in combination with hydrogen to obtain methane, which is traditionally stored and used in gas transmission systems. In the case of compressor stations, research is of interest to establish the effect of increased hydrogen concentration during the operation of gas turbine units.

In the distribution of gas, the analysis of the intensity of the diffusion processes of hydrogen in the pipes is in principle important for establishing the criteria for limiting the amounts of hydrogen used in urban networks. A separate type of research is devoted to its impact on gas facilities.

In the use of hydrogen gas mixtures (H2NG) by consumers, the efforts of the scientific community are aimed at establishing the impact of the mixture on the combustion process in order to maintain the design power of gas appliances and the quality of the combustion process. The possibility of using hydrogen in transport also belongs to this segment of research. The models adopted there are based on internal combustion engines using hydrogen as fuel or on the basis of hydrogen cells to generate electricity for electric vehicles and heavier vehicles. The well-known technology for obtaining hydrogen-oxygen mixtures in our country at the beginning of the new millennium, known as "brown gas" on behalf of its developer, is a third form, but is not based on scientific and theoretical popularity and is currently not widespread and applicable.

Hydrogen injection into gas supply systems

Hydrogen is a gas that differs greatly in its physicochemical characteristics from natural gas and other biogases that are compatible in the gas network. Its pure use, in concentrations above 90%, can impair the mechanical properties of steel pipelines, gas storage facilities and customer installations. It can definitely be argued that pure hydrogen is not compatible with existing networks. However, hydrogen may be transferred to the gas networks if it is in quantities at the network entry point mixed with natural gas which do not adversely affect the interoperability of the gas supply network. This follows from the interpretation of Articles of Directive (EU) 2018/2001 of the European Parliament of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. These possibilities are to be described in detail in standards and working documents of the network operators, so that other gases can be supplied to the network as "additional gas" to natural gas ("main gas") in existing gas supply networks. In addition, the supplementary gas must be injected in a manner that meets the requirements for the public natural gas supplier at the point of entry. This means that hydrogen can be supplied as far as permitted and as far as possible to ensure the safety and interoperability of the input network in question, of each transmission network along the chain, and of the storage facilities connected to the affected sections along it.

On the other hand, the network operator is not required to increase the hydrogen resistance of the existing network. In this case, the rules on minimum availability and minimum injection capacity do not apply. Nor are measures requiring the network operator to take action to increase the capacity of its network. This means that while there may be sufficient gas capacity in the system, the gas injected into the system may not necessarily be compatible with that system.

Network connection

In Directive 2014/94/EU, hydrogen is classified as an alternative fuel and Art. 6 allows its transmission on available infrastructure. This assessment does not contradict the inclusion of hydrogen in the definition under Art. 171, para. 5 of the Energy Act. This can be seen by comparing the legal situation applicable to the supply of raw biogas (called raw biogas), which may also be incompatible when injected into gas systems. The rules for the supply of biogas also apply to the injection of raw biogas, as the definition of biogas covers for raw materials any possible form of biogas, ie. gas obtained from biomass, gas from waste water treatment plants, landfill gas and mine gas, regardless of the degree of treatment in each case, its specific composition or its compatibility with the system. On the other hand, if, contrary to the current legal situation, the connection requirements of network operators are required to ensure that the injected biogas meets the requirements of the system and is compatible, then in the case of injected hydrogen, crude biogas or other non-compliant gases, which fall within these definitions are incompatible with the network. In these cases, the network operator would be required to either improve its network or, if technically impossible or economically unprofitable, to build and operate the necessary biogas or methanization plants itself. However, this is not the purpose and intention of Art. 6 of Directive 2014/94 / EU. As the comparison specifically with raw biogas shows, it is not the purpose or intention to include renewable hydrogen and renewable synthetic methane. An interpretation in this direction would be in breach of the principles laid down in the provisions for the connection of gas sources to transmission systems, according to which the supplier should ensure that the gas injected into the system is compliant and compatible with it.

System compatibility assessment

Upon receipt of a request for connection, the network operator, as part of the analysis of the current situation and possible changes in the operator's system already foreseeable at the time of the request, must first determine the maximum volume of hydrogen that its network can will take over. According to accepted principles in the EU, the costs of this assessment are always borne by the connecting party, provided that the assessment does not relate to capacity building measures within the meaning of the provisions of the Energy Act. As part of the assessment of connectivity, the network operator must in particular calculate the maximum permissible hydrogen content in its network and the permissible supply volume or capacity. To do this, the network operator must determine the factors of its network and other networks in the chain that could limit the amount of hydrogen that can be injected. In this context, a distinction must be made between restrictions that arise in relation to total gas supply and restrictions that relate only to the requirements of specific customer groups (eg the use of natural gas as a production material in the chemical industry). In practice, the provisions only protect the requirements related to the total gas supply. The requirements for the total gas supply and hence the interoperability of the gas supply network also cover the requirements for the system and storage activities, and the general and normal use of gas in the production of heat and electricity. This relates in particular to the quality of gas and hydrogen concentration required for gas turbines, cogeneration engines and gas storage installations, as well as the non-capture of hydrogen concentrations by gas chromatographs (GC).

Exceptions in this context are HGs used in the calibrated measurement of fuel value for the purposes of correct gas charging. According to European standards, the network operator is required to exchange the HTG if this is necessary to meet the gas charging requirements under the Connection and Trade Rules for Natural Gas and if the associated costs do not make the whole connection economically unjustified. The costs incurred in this connection shall always be borne by the network operator in whose network they are incurred, even if such costs arise as a result of a transformation in an upstream network area. This means that if new GCs have to be deployed in a network at customer entry points as a result of hydrogen injection, this is the responsibility of the downstream operator. On the other hand, this operator may pass on these costs where this would be economically justified and subject to cost-effectiveness considerations in the company's annual investment programs.

It is not normatively determined whether it is necessary to set further requirements for the quality of gas for charging stations with compressed natural gas (CNG) before the provisions on the interoperability of the gas supply network. It is unclear given the relatively small volumes of natural gas currently consumed as automotive fuel compared to the volumes used to generate heat and even electricity. The current situation, not future or expected developments, is crucial in this regard. On the other hand, the protection in the form of interoperability of the gas supply network is supported by the fact that in the presence of about 100 charging stations a large number of end customers are directly affected, and in the presence of more than 69,000 cars powered by natural gas in Bulgaria. , and about one million such cars in Europe as a whole, even more end customers are indirectly affected. A final assessment of the hydrogen injection situation remains to be considered in more detail, taking into account that the requirements for existing CNG charging stations should in any case be taken into account when setting the maximum permissible hydrogen content. As pure hydrogen is not compatible with the system and can only be supplied after it has been sufficiently mixed with natural gas, a current customer who is not protected by the interoperability requirements of the gas supply network must be able to at least rely on receiving of gas compatible with the system, which meets the thresholds provided in the working documents of the Bulgarian legislation.

After identifying the hydrogen-sensitive applications in the system, the network operator must - taking into account the binding data from the hydrogen supplier and in the connection request for the planned injection purposes - determine the required data from its network and whether and to what extent degree hydrogen may come into contact with sensitive applications or interconnection points in downstream or upstream networks (in the case of reverse feed). If this is the case, it may be necessary for the network operator to assess, where applicable with the affected customer, whether the application or the affected customer (eg storage or power plant operator) may exceptionally be able to accept higher hydrogen content or a larger volume of hydrogen (for example, very short-term excesses); on the other hand, the customer concerned is not required to accept a higher hydrogen content for a short period if damage cannot be completely ruled out, even if such content is only increased for a very short period of time. If this is not the case, the network operator must calculate the amount of hydrogen that can be injected at the requested connection point. If hydrogen is to enter downstream or upstream networks, the network operator must determine how much hydrogen can enter the network up or down the chain through the relevant interconnection point and must report this finding to the relevant network operator. It must then make a separate assessment to determine whether, in anticipating that it is possible to supply higher levels of hydrogen at certain times, the network operator must allow the supplier to do so. If this requires the installation of a chromatograph with a hydrogen reading column, the costs should be borne by the network operator.

The network operator needs to assess whether the replacement of hydrogen-sensitive equipment with hydrogen-compatible equipment or the modification of existing facilities to withstand higher hydrogen concentrations will be able to increase the hydrogen mixture without to disrupt or jeopardize the fulfillment of its obligation to operate a secure, reliable and efficient system.

On one hand, the network operator is not required to modify or install new equipment or accept the costs involved, but on the other hand it must provide the provider with all the information that will enable it to decide whether it would be more efficiently from a business point of view to transform customer installations in order to optimize the injection of hydrogen at the expense of the supplier, and not to carry out the required increase of the hydrogen mixture or not to use additional installation for methanization.

This may be relevant if several hydrogen suppliers would benefit from such measures and if retrofitting costs are shared between them.

Changes in parameters after connection evaluation

Hydrogen injection may also be subject to change after the assessment of connectivity as a result of a change in gas flow at the network entry point. This may be due to changed import / export flows or commissioning / decommissioning, changed mode of operation of gas storage installations, changed reception structure (such as loss or attraction of customers), conversion of L-type gas into type H gas, market conversion from L gas to H gas and decentralized supply or reverse supply of gases (such as biomethane), or the injection of hydrogen at a later stage (if the permissible injection is to be distributed between several installations).

Imposing restrictions on hydrogen injection may result in additional hydrogen injection being linked at a later stage. On the other hand, limiting hydrogen injection on the basis of injection at a later stage would run counter to the principle of priority of earlier coupling or request for coupling. By deviating from the priority principle, it would be possible to achieve a higher (overall) level of hydrogen injection, as feed points that would be technically and commercially acceptable would not be neglected simply due to the existence of earlier submission projects. On the other hand, the operator of an installation that is connected earlier would make its investment decision based on arguments that will be undermined if the priority principle is disregarded. In this respect, the legitimate expectations of an earlier connecting party must be protected and take precedence over technically optimized maximum injection into a network or part of a network. Finally, this should also apply to connection requests, the network of this operator has applications that are sensitive to hydrogen, and must calculate how much hydrogen can be fed to the relevant point. The conclusion of the evaluation should be communicated to the network operator. The network operator (on supply) must then use this information to assess how much hydrogen can be injected at the required connection point. As part of this assessment, the network operator (where applicable in cooperation with the downstream or downstream network operators concerned) should also take into account foreseeable changes that may occur during the year. If it can be done at an earlier stage, in cases where the connection assessment has not yet been completed

In addition, the network operator must take into account any subsequent changes in the framework conditions under which hydrogen is injected. In particular, the network operator is not entitled - if a change in gas flow is expected at a later stage as a result of the supply or re-supply of a system-compatible gas (such as biogas that has been improved to natural gas quality) - to refuse such changes to facilitate unchanged hydrogen injection. Any such refusal may be based only on technical impossibility, economic unreasonableness or lack of compatibility with the system. On the other hand, such grounds for refusal do not apply in the circumstances described.

If circumstances arise that the network operator must take into account, the network operator should assess whether this would also have an effect on hydrogen injection. The evaluation should be undertaken in the same way as the evaluation of a request for connection. The assessment may lead to an increase or decrease in the amount of hydrogen injected. If the network operator concludes that the hydrogen injection needs to be reduced in order to maintain the interoperability of the gas supply network, the network operator must check whether alternative measures (change in transmission settings, change of installation) would provide a way to reduce to avoid. On the other hand, the costs of such measures that may be required are borne by the hydrogen supplier. If these measures would be extremely costly for the hydrogen supplier, the network operator has the right, as a last resort, to reduce the amount of hydrogen injected or to stop the injection altogether if necessary. Therefore, the network operator has the right to retain the right of limited injection if the technical framework conditions change or, as a result of such changes, it becomes necessary to reduce the amount of hydrogen injected on the grounds of safety and interoperability of the gas network.

As the potential for change in gas flows as a result of changing supply and consumption patterns increases, it is becoming increasingly important for the hydrogen supplier to choose a location that fully guarantees the planned injection or gas flow that can be reliably planned on an ongoing basis. year and the network operator to notify the connecting party as soon as it becomes aware of even the slightest possibility of a negative change in gas flows and then to support the connecting party, as far as its knowledge and ability allow, to minimize the risk of damage that comes from stopping or reducing the injection. The allocation of risks in this way will make it possible to create energy-related business incentives for the relocation of hydrogen injection installations to such grid locations that provide high and reliable levels of long-term hydrogen compatibility. At network topological positions where there is a high probability of injection limitation, the risk distribution is such that it creates incentives in favor of methanization.

Influence on the operation of gas appliances

To ensure safety and determine the operation of a system with increasing hydrogen concentration, an effort is needed to develop regulatory studies and constraints.

The University of Mining and Geology, together with the gas sector, has launched a number of studies relate to this. These projects aim to develop and publish a detailed study of the impact of mixtures of natural gas and hydrogen on end-use applications, in particular in the household and commercial sectors.

Our task is to study the possibility of widespread use of H2CH4 (hydrogen in natural gas) mixtures and their impact on household and commercial gas appliances.

According to the European standard EN 16726: 2015 "it is not possible to determine a hydrogen limit value valid for all parts of the European gas infrastructure, therefore a case-by-case analysis is recommended". Eligibility limits vary for the United Kingdom from 0.1% to 6 and 10% in France and Germany respectively. The current levels of hydrogen in mixtures of hydrogen with natural gas do not indicate the need for additional safety requirements. For increased hydrogen concentrations, the prospect is to increase the requirements for monitoring, sensors and safety rules in installations. There are additional restrictions related to national provisions or areas of application. For example, the calorific value of the gas changes after the injection. In Germany, there is a formal agreement for the monitoring and invoicing of H2NG mixtures, where the calorific value can be determined with gas quality measuring instruments (gas chromatographs are currently used).

The EU Gas Appliances Directive 90/396/EEC and derivative Gas Appliances Regulations (EU) 2016/426, which cover all Member States, already sets out (in a common format) the requirement to prove the safety of any gas appliance that will be sold in the EU.

The regulations for gas appliances apply equally to all gaseous fuels that will be used in a gas appliance - hydrogen, biogas, natural gas, propane and / or butane. The conducted research showed that at the moment the operation of gas appliances with the used mixtures of hydrogen and natural gas up to 10% by volume of hydrogen is possible without adaptation of the devices.

Table 1. *Influence of hydrogen concentration*

% H2	d, kg/m3	Hlcv kWh		Hgcv kWh	Wlcv MJm3	Wgcv MJ/m3
0	0,67	9,156		10,165	43,73	48,546
5	0,641	8,69		9,65	42,547	47,235
10	0,608	8,22		9,13	41,333	45,89
15	0,575	7,75		8,61	40,08	44,5
20	0,542	7,29		8,09	38,793	41,59
25	0,51	6,82		7,57	37,46	41,59
50	0,345	4,48		4,979	29,93	33,23

The table presents the results of a study of the concentration of hydrogen in a methane mixture. The step is 5 percent, and the variations studied are from 0 to 50 percent hydrogen content in a methane mixture. Indicators such as: density, d (kg / m3), upper and lower limit of combustion heat, H (kWh) and lower and upper value of the Wobbe number, W (MG / m3) were evaluated. The calculations are based on the methodology and requirements of the BDS ISO 6976 standard, and software used for these purposes by the Natural Gas Association.

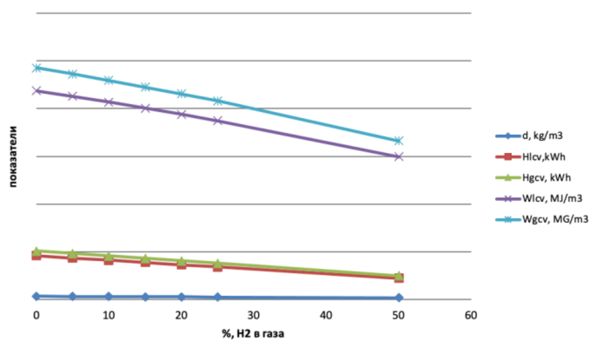

Fig. 2. Change in gas mixture parameters due to increase in hydrogen concentration

Due to the lower density of hydrogen and volumetric heat of combustion with increasing its concentration, the values of the studied parameters of the gas mixture also decrease.

Conclusion

The requirement for the use of 32% renewable energy, defined in the Renewable Energy Directive and the requirement for an annual increase in the share of renewable energy sources in heating and cooling compared to what was achieved in 2020. by 1.3%, puts the issue of hydrogen use in an important position for their implementation. There are many technical, legislative and other barriers that need to be overcome for this implementation.

An example of this we can, as usual, take from Germany. What has been achieved there shows that some of the pan-European barriers can be overcome quicker at a national level, before waiting for the EU Directives.

Gaps and inconsistencies at the regulatory level relate to:

- The lack of a uniform definition of renewable gases of non-biological origin - the only existing definition applies only to fuels in the transport sector. To overcome this barrier, Germany includes hydrogen produced by electrolysis of water with renewable energy in the definition of biogas (Energy Industry Act).
- The existence of a single Guarantee of Origin system for renewable gases of non-biological origin would encourage end-users to buy renewable hydrogen. In this regard, Regulation № RD-16-1117 of 14 October 2011 is a good basis that can be applied in such future situations.
- Adoption of standards for permissible concentration of hydrogen in the gas mixture. Based on the current study and future projects in this direction, definitions of gas quality can be developed at national level to be allowed, including norms for the concentration of hydrogen in gas mixtures.

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We gratefully accept the suggestions for follow-up activities and results, believing that real results in scientific activity can be obtained only if they are related to applied projects that will benefit society as a whole.

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