Construction, conversion and operation of steel gas pipelines for hydrogen: from material testing to approval

The basic requirement for the hydrogen run up is that hydrogen is available in sufficient quantities where it is needed. Therefore, a hydrogen core network as a link between hydrogen feeders and consumers is necessary. The development of an efficient hydrogen infrastructure is not only achieved through new construction, but in particular through the conversion of existing gas infrastructures [1]. At this point, these offer great potential for the supply, distribution and storage of hydrogen. Hydrogen can either be transported in its pure form or blended.

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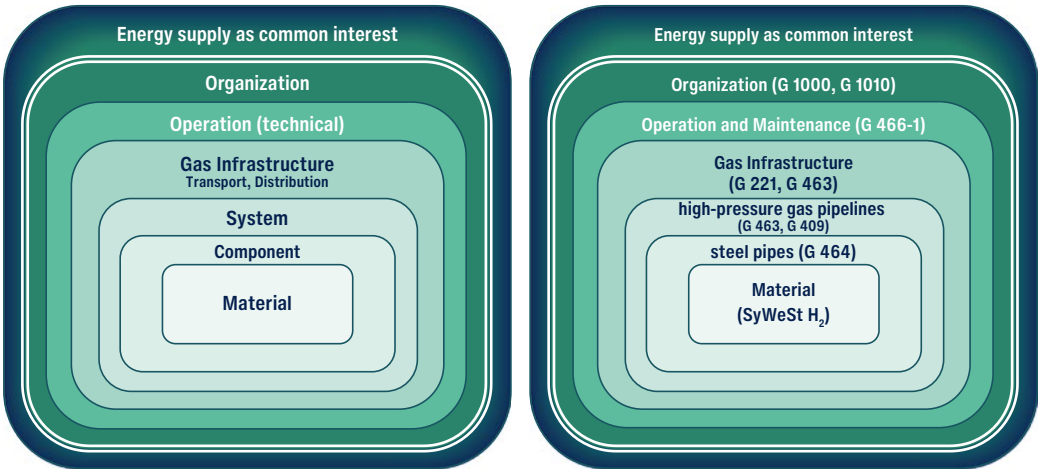
A bird's eye view of gas infrastructures: Existing gas pipelines will play a major role in the injection, distribution and storage of hydrogen in the future.

Source: Kalyakan/stock.adobe.com



Source: DVGW

Fig. 1: Levels for the application of the term "H_2-ready": a) general representation according to [3], b) adaption for high-pressure gas pipelines

The amendment to the Energy Industry Act (EnWG, July 2021) provides the starting signal for a legal basis with the addition of hydrogen in favour of the DVGW regulations for systems for the production, transport and distribution of hydrogen [2], thus the presumption rule regarding compliance with the generally recognised rules of technology for hydrogen networks for pipeline-based energy supply to the general public applies. With the DVGW regulations updated for hydrogen applications, gas pipelines for the distribution and transport of hydrogen can now be constructed, converted and operated. Depending on the object under consideration, different technical and legal assessment principles must be taken into account. In order to be able to safely operate an infrastructure for hydrogen within the meaning of the EnWG, further organizational, legal and economic requirements must also be met. An overview of the requirement for gas pipelines for the distribution and transport of hydrogen is provided here.

Assessment of gas pipelines for hydrogen applications

The assessment criteria for newly constructed or converted gas pipelines are specified in various DVGW regulations. The shell model shown in **Figure 1a**) in accordance with DVGW Information GAS No. 29 [3] is a good way of illustrating the different levels of assessment. Here, the individual levels for the application of the term „H_2 -ready" from the assessment of the material to the steel pipes, the high-pressure gas pipeline and the specifications for operation are brought together to form an integral assessment. The subdivision into the different levels enables a differentiated presentation of the relevant requirements that are to be used as the basis for the respective assessment. The requirements described in DVGW Code of Practice G 221 [4] form the basis for this. Only if all requirements are fulfilled the H_2-readiness is comprehensively given and operation with hydrogen possible. In this context, H_2-ready means that a gas pipeline is prepared for operation with or the use of hydrogen, whereby additional measures may be required that can only be implemented at the time of a conversion to hydrogen. The respective level is only H_2-ready if the levels included have also been assessed as H_2-ready.

For a basic suitability of the material of a component for use with hydrogen, the specific design of the component, the respective operating conditions and, in the case of systems in operation, the current condition (integrity) must be known. For the assessment of gas pipelines for hydrogen applications, the specifications of the assessment levels are described in various DVGW regulations. These regulations for the assessment of gas pipelines are outlined below and summarized for high-pressure gas pipelines in Figure 1b).

The basis for the evaluation of the existing components is meaningful network and system documentation from the operator. The suitability for the respective application must be determined and verified by the operator.

Materials

Materials and the elementary components made from them, e.g., pipes or fittings of the inner level of the model, are ready for operation with hydrogen if they are selected, designed, operated and maintained in such a way that the requirements for integrity and tightness are met over the entire service life. Even though gas pipelines are generally subject to predominantly static loads and therefore only negligible growth of defects occurs, potential crack growth can be greater when operating a high-pressure gas pipeline with the medium hydrogen compared to the medium natural gas. For this reason, the hydrogen suitability of the gas pipeline must be proven for the intended operating time and a fracture mechanics assessment is required for high-pressure gas pipelines made of steel pipes for a design pressure of more than 16 bar in DVGW Code of Practice G 464 [5]. In addition to the safety concept, the fracture mechanics assessment is based on the DVGW research project G 202006 – H_2-Suitability of steels – SyWeSt H_2 [6]. Here, extensive fracture mechanics material tests were carried out on all typical pipe steels used in Germany under the medium hydrogen up to 100 bar test pressure. The test results show that the steels used are basically suitable for hydrogen that complies with DVGW Code of Practice G 260. The assessment in accordance with DVGW Code of Practice G 464 of typical high-pressure gas pipelines with predominantly static loads generally results in a sufficiently high permissible service life.

Further requirements for other materials as well as parts and components for gas pipes for the transport, distribution and feed-in of hydrogen are given in DVGW Code of Practice G 462, G 463, G 265-3 and DVGW Code of Practice G 221 [4, 7, 8, 9].

The hydrogen suitability of individual components can be found in the DVGW's verifHy database [10], which includes the contents of the DBI's H_2 compendia. The database is supplemented by findings from research and science as well as information from manufacturers and is continuously developed further.

Pipelines for the gas infrastructure

The construction of the hydrogen infrastructure with gas pipelines is based on the relevant DVGW regulations, which specify the functional requirements for the system under consideration, e.g., pipelines for distribution, transport or for plants. DVGW Code of Practice G 462, G 463 or G 265-3 and DVGW Code of Practice G 221 are to be applied here. In addition, the requirements of the ordinances [11, 12] and the associated technical regulations must be observed with regard to explosion safety, in particular for the construction and operation of the systems used for pipeline operation.

Qualification requirements for construction companies for pipelines for hydrogen are specified in DVGW Code of Practice GW 301 [13]; DVGW Code of Practice G 493-1 forms the basis for the qualification requirements for construction of hydrogen plants [14].

The basic prerequisite for the use of hydrogen in the existing gas infrastructure is the technical suitability of the system. In particular, the possible changes caused by hydrogen must be considered separately. Above all, the influence on the pipeline material requires precise testing and assessment and forms the basis for converting a gas pipeline to transport hydrogen. DVGW Code of practice G 407 (gas distribution) and G 409 (gas transport) apply to the conversion of gas pipelines for hydrogen [15, 16]. According to the specifications of the underlying DVGW regulations, a conversion to operation with hydrogen can be a significant change. In this case, the corresponding tests must be carried out and certified by experts, specialists or persons authorised to carry out tests in order to provide evidence.

As an overall system of gas infrastructures consisting of transport pipelines and distribution networks, their interfaces to the connected systems must be considered. Transport pipelines and distribution networks are prepared for a conversion to hydrogen operation if, in addition to the pipelines and systems of the network, the systems and facilities of the connected networks and the connected connection users are also prepared for a conversion. The network operator requires precise knowledge of all entry and exit points in its network and appropriate planning for the conversion. At the time of the changeover, all test certificates required in accordance with legal requirements and DVGW regulations must be available [4].

Operations

The organization and equipment for operation and maintenance for hydrogen applications includes, among other things:

- Qualification of the specialists and the service providers used,
- Adaptation of technical processes, including operating and maintenance strategies, taking occupational health and safety into account,
- Adaptation of equipment and operating resources,
- Adaptation of the risk assessments and the defined protective measures for the protection of employees and corresponding instruction of employees,
- Organisational security – Technical Security Management (TSM).

Specifications for this can be found in DVGW Code of Practice G 466-1, G 465-1 and G 221 [4, 17, 18].

The requirements for the qualification and organization of companies for the operation of pipelines and systems for the pipeline-based supply of gas and hydrogen to the general public are described in DVGW Code of Practice G 1000 and G 1010 [19, 20] within the framework of technical safety management.

The qualification requirements for gas infrastructure experts have been incorporated into the DVGW worksheets and technical bulletins of the G 102 series [21] and included in the training and further education programs.

Summary

With the new definition of the 2nd and 5th gas family in DVGW Code of Practice G 260 [22], the boundary conditions for the use of hydrogen are anchored in the DVGW regulations. The DVGW is revising its gas regulations accordingly. DVGW rules and regulations documents are now labelled „H_2-ready“ if they are applicable for gases of the 2nd and/or 5th gas family according to DVGW Code of Practice G 260.

Based on the explanations of the term H_2-ready in DVGW Information Gas No. 29, the aspects for gas pipes have been explained in more detail in this technical publication in order to demonstrate the complexity and nevertheless a feasible approach.

As part of DVGW research projects, further knowledge on the suitability of assemblies and products for operation with hydrogen, for example, are constantly being developed and incorporated into the regulations accordingly. ■

Literature

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[2] Electricity and Gas Supply Act (Energy Industry Act - EnWG).

[3] DVGW Information GAS No. 29, Explanations on the term „H_2 -ready“ for gas supply networks and gas applications in accordance with DVGW regulations.

[4] DVGW Code of Practice G 221, Guidelines on the application of DVGW regulations to the pipeline-based supply of hydrogen-rich methane gases and hydrogen to the general public.

[5] DVGW Code of Practice G 464, Fracture mechanics assessment concept for steel gas pipes with a design pressure of more than 16 bar for the transport of hydrogen.

[6] DVGW research project G 202006 - H_2- Suitability of steels / SyWeSt H_2.

[7] DVGW Code of Practice G 462, Gas pipes made of steel pipes up to 16 bar operating pressure; design and construction.

[8] DVGW Code of Practice G 463, High-pressure gas pipelines made of steel pipes for a design pressure of more than 16 bar; design and construction.

[9] DVGW Code of Practice G 265-3, Systems for feeding hydrogen into gas and hydrogen networks: Planning, production, installation, testing, commissioning and operation.

[10] VerifHy database available at www.verifhy.de.

[11] Ordinance on Protection against Hazardous Substances (Hazardous Substances Ordinance - GefStoffV).

[12] Ordinance on Safety and Health Protection in the Use of Work Equipment (Ordinance on Industrial Safety and Health - BetrSichV).

[13] DVGW Code of Practice GW 301, Companies for the installation, repair and integration of pipelines - Requirements and tests.

[14] DVGW Code of Practice G 493-1, Qualification criteria for planners and manufacturers of gas systems.

[15] DVGW Code of Practice G 407, Conversion of gas pipes made of steel pipes up to 16 bar operating pressure for the distribution of hydrogen-containing methane-rich gases and hydrogen.

[16] DVGW Code of Practice G 409, Conversion of high-pressure gas pipelines made of steel pipes for a design pressure of more than 16 bar for the transport of hydrogen.

[17] DVGW Code of Practice G 465-1, Inspection of gas pipe networks with an operating pressure of up to 16 bar.

[18] DVGW Code of Practice G 466-1, Gas pipes made of steel pipes for a design pressure of more than 16 bar; operation and maintenance.

[19] DVGW Code of Practice G 1000, Requirements for the qualification and organization of companies for the operation of systems for the pipeline-based supply of gas and hydrogen to the general public.

[20] DVGW Code of Practice G 1010, Requirements for the qualification and organization for the operation of gas systems on factory premises.

[21] DVGW Code of Practice G 102, Qualification requirements for gas infrastructure experts.

[22] DVGW Code of Practice G 260, Gas quality.

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