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Managing the **safe introduction of hydrogen**

Climate change is one of the biggest challenges facing humanity in the 21st century. The Paris Agreement goal to limit the global temperature increase to well below 2 degrees requires deep decarbonisation. At the same time, ensuring a sustainable, reliable and affordable energy supply during the energy transition introduces new challenges. Addressing these challenges requires long-term energy system planning and a shared determination for all involved in the energy system.

Electricity and gas will continue to fulfil complementary roles in the future integrated energy system. The major primary sources of renewable energy are wind and solar power; these can be used either directly to generate electricity or indirectly to generate renewable gases. Transporting electricity directly to sectors where electrification is technically and economically feasible avoids energy conversion losses. For those sectors where electrification is more difficult, renewable gases such as hydrogen enable decarbonisation and can be transported in existing infrastructures. As the energy transition advances, the gas infrastructure will provide efficient transportation and storage capacity for renewable energy in the form of gaseous energy carriers and will make the overall energy system more flexible and more resilient.

For practical and economic reasons, the future renewable gas infrastructure will mainly be based on the conversion of existing natural gas transmission pipelines, either to 100% hydrogen or to a blend of hydrogen and natural gas. While the concept of hydrogen pipelines is not new or inherently impossible – there are already thousands of kilometres of hydrogen pipelines in service – the introduction of hydrogen into existing natural gas transmission and distribution networks creates unique challenges.

These challenges need to be taken into account to ensure safe and efficient operation. The vast majority of existing hydrogen pipelines have been purpose built and designed to hydrogen-specific codes and standards, which tend to be significantly more restrictive than their natural gas equivalents. However, if existing natural gas pipelines are repurposed to transport high amounts of hydrogen, this can introduce new threats compared to their previous service, and the management, control and mitigation of these threats can be challenging.

To support pipeline operators in this process, the ROSEN Group has developed a holistic hydrogen integrity framework to provide a roadmap for the safe and efficient conversion of existing gas grids to hydrogen and for the reliable operation of hydrogen pipelines in order to extend the lifetime of valuable assets beyond the decarbonisation of the energy system. This comprehensive framework is based on the integrated asset management approach and is shown graphically in Figure 1.

Every transmission and distribution pipeline is certainly unique and will have its own specific set of circumstances. However, this structured approach is generic enough to be widely applicable while allowing sufficient flexibility so that tailored integrity management plans can be developed for each pipeline. This integrity approach is founded on extensive, already completed research on issues such as material susceptibility to hydrogen embrittlement or accelerated fatigue cracking, as well as diagnostic technologies that are already available to map material properties, geometry and deformation features where stress levels are elevated, and features that may be starting points for fatigue cracks.

The first stage of the integrity framework consists of understanding the potential threats. This aspect is fundamental and requires careful judgement. In essence, the potential threats can be divided into three main categories.

First, threats that exist regardless of the medium being transported, such as external corrosion or third-party mechanical damage. Second, direct threats caused by hydrogen, such as cracking. Finally, hydrogen-induced changes to the pipeline material properties, such as embrittlement and increased fatigue susceptibility. These threats should then be assessed against existing knowledge about the pipeline material properties and welding procedures used during the construction, current pipeline conditions and any known features as well as the historical and planned operating envelope. A major outcome of this assessment will be the identification of any knowledge gaps regarding current pipeline conditions.

These identified knowledge gaps can then be filled using a combination of existing in-line inspection tools and destructive testing techniques. Of particular relevance for in-line inspection services in the conversion process of existing natural-gas pipelines to hydrogen are crack detection and material property determination. Material property determination is particularly important since in "traditional" natural gas pipelines, a stronger material was almost always better, leading to pipe mills and operators historically producing and using pipes of significantly higher strength or grade than absolutely required.

In hydrogen service, this "advantage of excess strength" is not always the case, with existing construction codes tending to limit the maximum permissible strength. ROSEN's material property inspection tools include an in-line technology that can non-destructively measure the strength of each joint along the length of the pipeline, and a technology to identify martensitic hardspots (Figure 2). These services are able to identify areas of particularly high strength or martensitic hard spots, which may act as focal points for hydrogen-related degradation. Existing features or defects arising either from construction or from in-service damage can be identified and characterised using crack detection and metal loss tools; this data can then be correlated with material property data to allow a more accurate assessment of the true threats to the pipeline.

In this context, it is also important to note that synergistic benefits can be gained from running multiple inspection technologies,

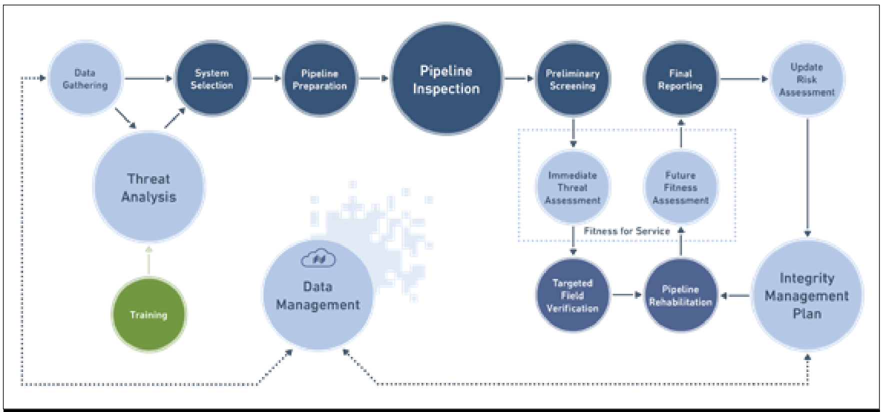

Figure 1 – ROSEN's Hydrogen Integrity Framework

since the information can be overlaid and analysed to assist with improvements of the probability of identification as well as feature classification. Depending on existing knowledge and the current conditions of the pipeline, it may be prudent to run this appropriate combination of diagnostic tools as a baseline inspection in order to facilitate efficient comparison and monitoring of any signs of damage or material degradation in the future.

Once the appropriate pipeline inspection runs have been identified and successfully performed, the gathered information can then be analysed and assessed. These integrity assessments should both identify immediate threats, which will require targeted verification and rehabilitation activities, and provide data for input into fitness-for-hydrogen service activities. Finally, these results will need to be reflected in an updated risk assessment that serves as input for robust future integrity management plans and processes.

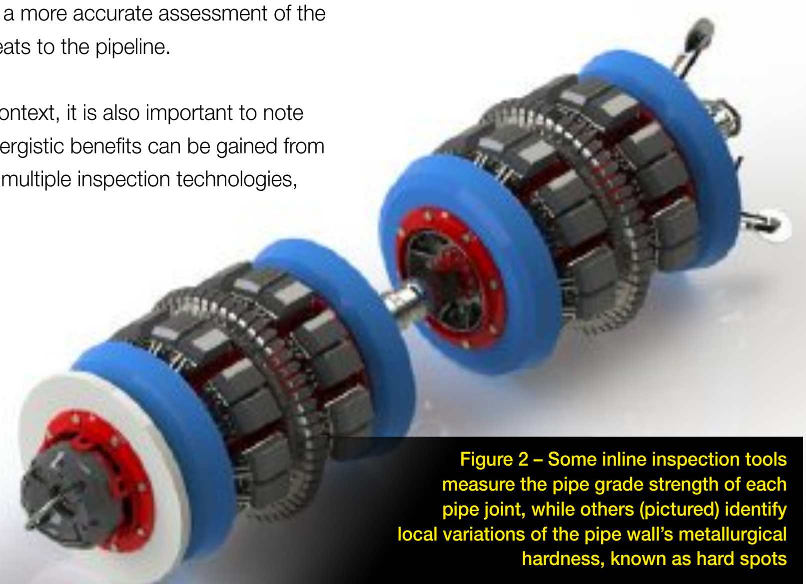

Figure 2 – Some inline inspection tools measure the pipe grade strength of each pipe joint, while others (pictured) identify local variations of the pipe wall's metallurgical hardness, known as hard spots

A holistic approach like the presented hydrogen integrity framework – involving a sound understanding of potential threats with best practice inspection data – enables the safe introduction of hydrogen into the existing natural gas network and continued efficient operation of the pipeline for transporting large amounts of hydrogen. ■

About the authors

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