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Repurposing Existing Natural Gas Pipelines For Hydrogen Service

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Abstract

In efforts toward decarbonization of the existing energy system, hydrogen has emerged as an attractive option for low carbon fuel. Currently, proposed applications for hydrogen include direct use as a fuel, either in pure form, or blended into natural gas supply, and as an option for long-term energy storage option.

While there are numerous potential opportunities for blending hydrogen into natural gas systems, it is recognized that the introduction of hydrogen into existing natural gas infrastructure may present multiple challenges related to material, operational, and process compatibility.

This paper presents an overview of the technical, operational, and integrity challenges associated with transitioning line pipe to blended hydrogen service. Additionally, it provides a framework and high-level guidance for how to transition natural gas systems to enable safe and reliable operation with hydrogen.

1. Introduction

It is well established that pipelines provide the best option for moving large volume of gas over relatively long distances. In the United States (US) there are approximately 300,000 miles (483,000 km) of large, high-pressure transmission pipelines used for transporting a continuous and robust supply of Natural Gas across the country. Local supply to residential and commercial customers is then achieved using an integrated, low(er) pressure distribution system. In contrast, the current hydrogen pipeline network across the United States is only about 1,600 miles (~2,600 km) of hydrogen specific pipelines, which are primarily owned by merchant producers, and thus isolated to select few regions of the country.

In the US, more than half of the in-service natural gas pipelines were built prior to 1970 using codes, standards and materials specifications that have evolved over time. While the opportunity to use these natural gas pipelines for transmission of hydrogen gas has huge potential cost benefit, it is imperative that the technical challenges and risks associated with introducing hydrogen to the existing infrastructure are identified, and the required engineering assessments are performed to maximize safety.

It is recognized that the introduction of hydrogen in existing carbon steel pipelines may present a myriad of effects including hydrogen embrittlement, increases to fatigue crack growth rate, and reductions in ductility and yield strength when exposed to susceptible steels under stress. These potential effects may vary based on the vintage, strength of steel, weld type, and other specific pipeline characteristics. Additional complications include the variability in steel quality installed and the influence that materials pedigree has on the fracture behavior of carbon steels in hydrogen service. Thus, before introducing hydrogen into a pipeline system, it is important to appreciate the service history in natural gas.

Therefore, when assessing the feasibility of transitioning a natural gas system to hydrogen service, there are several challenges that must be addressed, including:

- Will materials of construction and fabricated joints sustain long term structural integrity?
- What are the risks associated with hydrogen permeation and unintentional releases?

- How should the operating conditions be established?
- How to balance optimization of individual components as well as ensuring compatibility and performance of the integrated system?
- How should the integrity management program (IMP) be developed to maintain the asset integrity throughout the service life of the pipeline?

A pipeline IMP is a set of safety management, analytical, operations, and maintenance processes that are implemented in an integrated, logical and rigorous manner to accurately identify, assess, and mitigate pipeline integrity threats. IMP for existing natural gas service is a mature technical discipline, based on extensive operator experience, as well as analytical, experimental, and empirical data. Yet, even with broad experience, IMPs are constantly developing and improving. Conversely, experience with hydrogen transport for pipelines not originally designed to hydrogen standards is limited. The potential for hydrogen to exacerbate certain defects in carbon steels typically used in natural gas pipelines is well recognized, further increasing this challenge.

Therefore, considering the potential for detrimental impacts of hydrogen on susceptible pipeline materials, it is crucial to assess the suitability of a particular pipeline with hydrogen service on a case specific basis. This assessment should include understanding the existing condition of the pipeline, presence of existing relevant threats, and how exposure to hydrogen can affect the acceptability of the flaws and serviceability of the pipeline to maintain the overall pipeline integrity for hydrogen service.

Establishing a standard methodology for evaluating material compatibility of natural gas systems with hydrogen service is essential to enabling a transition to hydrogen service.

2. Conclusions

The introduction of hydrogen into an existing natural gas system requires consideration of many factors at all aspects of design, operation, and maintenance of the systems. This paper addresses the technical background of many of these considerations, with specific focus on material compatibility, and the integrity and risks concerns associated with hydrogen related threats.

Where possible, this paper provides practical guidance for integrity management considerations, as well as the recommendations for the specific material test methods for obtaining integrity data pertinent to the longevity of a pipeline system. The methods presented describe a set of tests which account for the unique effects hydrogen exposure may have on pipeline materials fracture and fatigue performance, and recommended approach for integrating that data into an overall integrity management program.

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