Summary of Engineering Report for Gazifère Hydrogen Blending

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This letter summarizes the work that has been completed as part of the engineering report and recommendations of areas requiring further work.

Engineering Report's Objectives

The report was completed to evaluate system suitability for hydrogen blending and encompasses Gazifère's gas distribution network, and customers' natural gas piping, appliances, and equipment. The report was divided into four interdependent areas of focus:

1. Gas distribution network and customer piping,
2. End-user appliances and equipment,
3. System capacity and operations, and
4. Pipeline system integrity, and risk review

The outcome of the report identified key decisions, internal and external engagements, areas of study, field work prior to and after hydrogen blending, and documentation developments and updates. As the field of research on hydrogen blending is rapidly evolving, the report's recommendations may require re-evaluation for validity and application in the future.

Gas distribution network and customer piping

This section discusses the hydrogen compatibility of the existing pipeline distribution system, including mains, services, and stations, as covered by CSA Z662, and customer piping included within the scope of review. The review covers the design basis, materials and design, manufacturing process, construction, and testing. It also identifies differences between CSA Z662 and CSA B149.1 requirements for piping downstream of customer meters. Areas covered include service fluid, operating and design pressure range and stress levels, operating and design temperature range, valve spacing, pipeline and equipment design service life, pipe specifications and properties, component specifications and properties, non-metallic elements, equipment specifications and properties, gas meters, branch reinforcement, welding and fusion requirements, mechanical joining requirements, minimum depth of cover, crossings and proximity to other facilities, visual examination, inspection, and non-destructive testing.

End-User Appliances and Equipment

There are over 45,000 residential/commercial natural gas customers and 7 large commercial/industrial natural gas customers. A natural gas versus blended hydrogen-natural gas comparison ('interchangeability analysis') was performed to determine the maximum amount of hydrogen that can be blended into the existing natural gas stream without violating Gazifère's contractual requirements for gas quality, while simultaneously ensuring no adverse effects on

combustion performance and emissions for end-use equipment. Based on gas interchangeability, compressed natural gas tanks limit hydrogen blending to a maximum of 2 vol%; as none are expected to exist in Gazifère, blending much beyond this is feasible but maybe most limited by gas engines. Based on appliance testing from other jurisdictions, hydrogen blending may be permissible up to 30 vol% in general appliances, after which appliances may need to be retuned or possibly replaced. Appliance testing will be required to verify whether existing equipment at Gazifère suitable for higher and varying blends of hydrogen.

Gazifère via its affiliate company, Enbridge Gas Inc is involved in a Joint Industry Project (JIP) for appliance testing with several other utilities companies across Canada that represent over 95% of Canada's gas customers. The JIP will provide available testing data to date that has been completed on numerous Canadian residential gas appliances and will further test these appliances along with a larger variation of appliances to observe short term and long term effects of hydrogen blending. This variation along with the most common type of domestic appliances will test the effects on generator powered by internal combustion to ensure stationary generators are able to maintain rated performance. These test focus on the safe and efficient operation of the appliances to allow the adoption of hydrogen in a manner seamless to the appliance or generator end user.

System Capacity & Operations

Due to the lower volumetric energy density of hydrogen compared to natural gas, hydrogen blending will result in an increase in total gas volumes to meet current customer energy demand. A hydraulic assessment of the current system indicates that from a capacity standpoint, hydrogen blending is possible up to 5 vol% before gas meters may require recalibration and recertification with Measurement Canada. The existing system is expected to have adequate capacity for low hydrogen blends before requiring upsizing of some services. In addition, assured security of hydrogen supply will be critical to ensuring continued system and operational reliability, particularly if meters, equipment, and end-use appliances are recalibrated. New storage solutions will be required to balance temporal variability in energy demand in relation to future hydrogen supply and demand.

Integrity, and Risk

Materials in the existing distribution system, stations, and customer piping were reviewed for compatibility with hydrogen blending. Soft goods in elastomeric seals, mechanical connections, and some metals such as cast and black malleable iron, non-austenitic stainless steels, and high-alloy steels are more susceptible to increased brittle failure under hydrogen exposure than other metals present in the system. Current knowledge indicates that hydrogen is inert to plastic; however, there is limited validation of the long-term effects of hydrogen on plastic.

The embrittling effects of hydrogen on steel manifest primarily through a reduction in material toughness and a resulting increase in fatigue crack growth rates. The extent of this degradation is highly dependent on material microstructure, effective hydrogen partial pressure and material stresses. In theory, any concentration of hydrogen could result in a reduction in toughness such that could have negative effects on pipeline system integrity.

Additional study and material testing will be required to ensure the effects of hydrogen on materials will not pose an unacceptable risk and to validate the conservative assumptions used in the probabilistic study. Sampling will require physical investigative digs on portions of the system. Some material testing may be possible to in-situ on in-service pipe, while other samples will require isolation and removal from the system for lab analysis. Partial system replacement and upgrades may be required to mitigate these effects. This work is part of the Engineering Assessment Phase 2.

Risk assessments for blending hydrogen have found a modest increase in risk when considering end-user equipment and house piping, and from external releases at services and mains. Individual specific risk remains below the broadly tolerable risk threshold for individuals.

The behaviour of blended hydrogen-natural gas mixtures up to 20 vol% is not expected to materially change compared to pure natural gas. Further risk assessments and testing will be required for the proposed pure hydrogen assets, in addition to understanding cross-sensitivity and suitability of existing equipment.

Conclusions

The report focuses on the feasibility of blending hydrogen into the existing natural gas distribution system at Gazifère. It is concluded that up to 5 vol% hydrogen can be blended into the low pressure and intermediate pressure networks without major changes, but additional studies, records validation and testing will be required to exceed this limit.

The upper limit for blending hydrogen will be dictated by the results from additional studies and testing. The behaviour of the blended gas mixture is expected to be sufficiently different from conventional natural gas once hydrogen concentrations exceed approximately 30 vol%, which would require system reinforcement, calibration of equipment, and possibly full conversion to pure hydrogen. Company standards and procedures will need to be updated for hydrogen-readiness as hydrogen blending progresses. In all hydrogen blending scenarios, six station rebuilds, a producer station, pure hydrogen pipeline, hydrogen blending station, management of change, risk assessment, updated company documentation, training, new tools, and equipment will be required. It is important to note that additional action items may arise during implementation and the management of change process.

Areas of Further Study

The engineering report identified key areas of further study. Any concentration of hydrogen in the high pressure and extra high pressure section of the gas network will require additional studies, validation, and testing to rule out concerns with hydrogen-induced failure and to identify the required mitigation.

To better understand the higher risk assets and the potential impacts of blending, a probabilistic/sensitivity study for the likelihood of failure of possible existing flaws and potential effects of external loading was identified in the engineering report. Additionally, investigative digs and sampling will be performed to verify pipe characteristics and/or the condition of assets. The testing may be performed on in-service pipe or by performing cut outs to obtain pipe samples. These results are required to help verify the initial material assumptions and presumed effects of hydrogen on material used in the calculations in the probabilistic study.

Field work and surveys will be completed before the introduction of hydrogen to provide a baseline condition of physical assets. Surveys will also identify higher risk features or hazards that require correction before blending.