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Extended Abstract

Initial Findings on Repurposing Existing Natural Gas Networks for Hydrogen

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1 INTRODUCTION

Hydrogen fuel is one of the low carbon solutions which can help the UK achieve its emissions reduction targets in line with 6th Carbon Budget under the Climate Control Act and Net Zero target of 2050. The UK government has made a strategic policy decision to support blending of up to 20% hydrogen by volume into the existing GB natural gas distribution networks which will support the early development of the hydrogen economy.

Kelton has led several hydrogen innovation projects with GB Gas Transmission and Distribution networks. This includes reviewing existing high pressure measurement systems at entry points, offtakes, compressor stations and process flow measurement. The equipment reviewed includes meters, gas analysers, flow computer calculations and supervisory systems and how these may be affected by blends of up to 20% hydrogen as well as 100% hydrogen. Where existing technologies are not suitable, alternative technologies have been assessed.

This paper will discuss Kelton's initial findings on repurposing existing natural gas networks for hydrogen.

2 HYDROGEN ASSESSMENT AT NTS OFFTAKE

The aim of this project was to understand the impact of blends of 2% and 20% hydrogen (H2) with natural gas on the mechanical and E&I equipment as well as software at National Transmission System (NTS) offtake sites. Kelton has undertaken site surveys at one volume controlled site and one pressure controlled offtake to cover as much of the range of the mechanical and E&I equipment as possible.

An initial hazardous area assessment was undertaken using IGEM/SR/25 [1] for natural gas installations. The Hazardous area drawings were updated using IGEM/SR/25 Edition 2 Supplement 1 [2]. For the sites surveyed, some of the kiosks do not have sufficient ventilation for use with 20% hydrogen therefore would be classed as zone 0 internally. Additional ventilation would be required for these kiosks to be classed as zone 1.

The electrical equipment (including portable equipment) was reviewed in terms of ATEX rating. Natural gas is a Group IIA gas whereas pure hydrogen is classified as a Group IIC gas. Group IIB contains up to 20 vol.% of hydrogen with methane. The majority of the electrical equipment on the sites surveyed were ATEX rating group IIC. Some equipment such as valve actuators and instruments in the Local Gas Treatment (LGT) system are rated IIB. As the current UK government strategy is to allow blending without a limit into the gas distribution networks consideration should be given to replacing the IIB equipment with IIC as sites are upgraded.

An assessment of the ultrasonic meters (USMs) installed at the offtakes was undertaken by the manufacturer. The assessment concluded that the meters reviewed are suitable for operation with 2% and 20% hydrogen blends with no modifications, but recommended that during the next service (before blends of hydrogen are introduced) the transducer o-rings are replaced with an extended low-temperature application range (-20°C instead of -15°C), and that the linearisation coefficients and transducer parameters are updated at the next calibration.

The existing calculations in the flow computers currently installed were reviewed for gas mixtures containing hydrogen. Uncertainty improvements could be made by implementing ISO 6976:2016 [3] for calorific value and relative density, ISO 20765-5 [4] for calculation of viscosity and GERG2008 [5] equation of state for compressibility.

The Ofgem approval for the gas chromatograph (GC) does not currently consider hydrogen blends. The approval of calorific value determination devices for use in the FWACV process is unlikely to include hydrogen until Gas Safety Management Regulations (GS(M)R) is changed to allow the conveyance of hydrogen content >0.1%mol. Ofgem will be required to review the approval process in line with changes to GS(M)R, including determining requirements for new calibration gas mixtures and 35-day test gas mixtures to include hydrogen content.

The addition of hydrogen to natural gas would reduce the calorific value (MJ/Sm^3) by ~1.4% for a 2% hydrogen blend and by ~14% for a 20% hydrogen blend. Considering a scenario where gas energy demand remains at current levels, an increase in standard volumetric flow rate would be required to counteract the reduction in calorific value and density. This can be achieved by increasing either the pressure, velocity or pipe area, or a combination of these. The effect on site capacities is significant for offtakes that are already operating close to their capacity limits.

All of the offtakes use DANINT software which is responsible for the CV measurement and attribution process within Flow Weighted Average Calorific Value (FWACV). Once GS(M)R has been updated then Ofgem would be required to review the approval process for DANINT alongside the CVDD approval. A number of files in the DANINT software require an extra data point for hydrogen. The calculation of Carbon Emission factors (CEF) should be updated (BS 8609:2014 [6]) to include hydrogen. DNV recommend that the current GL[7] equation of state should be used in the hydrocarbon dewpoint calculation when hydrogen is present and when hydrogen is absent avoiding any discontinuity in the results.

An odorant risk assessment will be required as the rate of odorant may need to be increased. The current typical injection rate to achieve an odour intensity (OI) of 2° for a 1% gas in air (GIA) concentration is currently 6 mg/m^3. The H100 project in Fife has carried out a T/PM/GQ/8 [8] measurement risk assessment for supplying 300 homes with 100% hydrogen and is recommending an odorant injection rate of 7.3 mg/m^3 due to the lower flammability limit of hydrogen. A report [9] investigating odorant for 20% hydrogen blends suggest that a value of 6.25 mg/m3 would be required to achieve an OI of 2°. In practice this will vary across the network as gas composition and therefore the lower flammability limit varies.

3 HYDROGEN ASSESSMENT OF NTS METER TECHNOLOGIES

The objective of this study was to understand the impact of hydrogen scenarios on existing measurement assets at National Transmission System (NTS) entry points, exits points, compressor fuel gas metering and process metering sites. Metering at entry and exit points is done at a typical NTS pressure of up to 70 barg and at compressor stations is typically at a pressure of 30-40 barg.

3.1 Ultrasonic Meters

Ultrasonic meters (USM) use Reynolds number (Re) correction algorithms based on natural gas in the electronic processing. Hydrogen has significantly different properties to natural gas, and this introduces small errors in the flow rate output due to changes in the flow profile compared to that expected of natural gas (as hydrogen % is increased, the speed of sound increases). These errors are small and decrease with flow rate but are considered a systematic bias. With existing ultrasonic meters, when the concentration of hydrogen in natural gas changes, it would be necessary to recalibrate the meter (at an ISO 17025 accredited facility) to minimise bias from the change in performance due to the addition of hydrogen. In the future, it is anticipated that corrections will be automatically applied within the ultrasonic meter electronics based on a hydrogen input signal (similar to existing pressure and temperature corrections that are carried out within the ultrasonic meter electronics).

3.2 Turbine Meters

Turbine meters are currently used in the measurement of cryogenic liquid hydrogen, therefore measurement of hydrogen blends should not present a technical challenge. Turbine meter performance is characterised during initial calibration and corrected with errors that vary with flow rate. Turbine meter performance is inherently related to the Reynolds number, which will decrease with hydrogen content. The certified calibration performance of a turbine meter (on a flow rate basis) will not be transferrable between natural gas with varying levels of hydrogen. Recalibration of the meter for the current concentration of hydrogen would be required to minimise bias from performance change. Alternatively, using the method of correcting the calibration errors against Reynolds number (instead of flow rate) would allow the calibration to be transferrable for any concentration of hydrogen.

3.3 Calibration Facilities

The RMA Group has the first high pressure 100% hydrogen calibration test facility (located at Rheinau in the south of Germany) certified by PTB Germany for calibrating custody transfer meters such as rotary, turbine and ultrasonic meters from 2" up to 12" at pressures up to 51 bar absolute and flowrates up to 6,500 m^3/h. The facility offers measurement uncertainty for the calibration value of a test item ≤ 0.3%. The Force Technology MEGA loop in Denmark is another calibration facility for blends of natural gas with up to 25% hydrogen content. This is a large test facility for 2" to 60" meters up to 65 bar gauge with flowrates of up to 60,000 m^3/h. DNV in the Netherlands also have a calibration test facility that can operate at 100% hydrogen for smaller meters (1"- 6") up to 40 bar absolute and for flowrates up to 500 m^3/h.

3.4 Orifice Plate Meters

Orifice plate meters are typically manufactured from 316 stainless steel. Nitrile or Viton rubbers typically used in orifice plate seals are suitable for use with hydrogen . Standard orifice plates shall only be used in accordance with ISO 5167-1:2003 [10] for fluids with specific Reynolds numbers (i.e. Re > 1260β2D). According to ISO 5167-2:2003 section 5.3.1 (Limits of Use) Reynolds number is limited by the pipe internal roughness (Ra) to Diameter (D) ratio. This limit is required as the orifice plates discharge coefficient equation was determined from a database collected from pipes with a specific range of roughness.

The introduction of hydrogen into natural gas is anticipated to reduce the gas viscosity thus decreasing the Reynolds number for a fixed gas velocity. The decrease in viscosity and Reynolds number is greater as the pressure increases. Considering a scenario where gas energy demand remains at current levels, this Reynolds number effect is likely to be mitigated by a higher velocity or density through the meter to maintain the energy throughput.

3.4 Differential Pressure Transmitters

Differential pressure (DP) transmitters are used in metering systems where differential pressure is measured i.e. orifice plate meters, venturi meters, pitot tubes and elbow metering systems. For hydrogen applications historically the approach is to apply a gold surface coating on the wetted diaphragm face which helped extend the life of the device considerably compared to standard materials. This is because the gold coating reduces the rate of permeation. Metals should be used with low content of nickel avoiding tantalum or Hastelloy C.

3.5 Alternative Meter Technologies

Coriolis flow meters are a well established technology for measurement of hydrogen and are direct mass flow measurement devices which are relatively insensitive to the gas contamination or flow profile. The preferred material type for Coriolis meters is stainless steel rather than nickel alloy due to hydrogen embrittlement. Advantages include the lack of upstream lengths required for installation though the physical size of the meter tends to be larger compared with ultrasonic meters. A coriolis meter has been chosen as the reference meter for the HyNTS FutureGrid 100% H2 metering skid project which will be calibrated on 100% hydrogen. The coriolis meter will be installed in series with a USM and turbine meter for comparison.

4 HYDROGEN ASSESSMENT OF NTS ANALYSER TECHNOLOGIES

4.1 Gas Chromatograph

The gas chromatograph (GC) currently used for natural gas uses a single carrier gas such as helium and is not suitable for blends of hydrogen with natural gas. It can however be upgraded for use with blends of up to 100% hydrogen with natural gas. An additional column, TCD and flow control would be required for hydrogen measurement. An additional carrier gas would be required for hydrogen therefore space for additional gas bottles would be required in the GC kiosk. Helium is not recommended as a carrier gas for hydrogen (because the thermal conductivity of hydrogen does not differ much from that of helium), but argon or nitrogen ensures a correct linear response. The calibration gas and Ofgem test gas (where applicable) which currently contain a typical natural gas composition should be modified to allow for a suitable proportion of hydrogen in the list of components. The calibration gas and Ofgem test gas (where applicable) should also be certified and supplied by an ISO 17025 accredited laboratory. The analyser would also require an ISO 10723 [11] performance evaluation with hydrogen.

4.1 Water dewpoint

The water dewpoint is currently measured at NTS entry points using a moisture sensor. The sensors are suitable for 20% hydrogen blends without affecting the accuracy of the instrument. At 100% hydrogen the existing sensors would need to be recalibrated as the current calibration for natural gas would not apply. The models may vary corresponding to detailed gas composition.

4.1 Oxygen

An oxygen transmitter is used to measure the level of oxygen at NTS entry points. The sensors are suitable for 20% or 100% hydrogen however they would need to be recalibrated above 20% hydrogen.

4.2 Alternative Hydrogen Gas Analyser Technologies

When hydrogen is produced there are typically additional impurities, so the hydrogen content is never 100%. Hydrogen produced from an electrolyser will also contain oxygen and moisture. Hydrogen produced from a reformer will contain carbon dioxide, carbon monoxide and methane impurities. Therefore gas analysers dedicated to measuring hydrogen are available as well as separate analysers for the impurities listed above.

5 REFERENCES

[1] IGEM/SR/25 Hazardous Area Classification of Natural Gas Installations

[2] IGEM/SR/25 Edition 2 with amendments August 2013 (communication 1748) - Hazardous Area Classification of Natural Gas Installations

[3] ISO 6976:2016 Natural Gas – calculation of calorific values, density, relative density and Wobbe Indices from composition

[4] ISO 20765-5 Natural Gas – Calculation of thermodynamic properties – Part 5: Calculation of viscosity, Joule-Thompson coefficient and isentropic exponent

[5] GERG2008 Wide Range Equation of State for Natural Gases and Other Mixtures: An expansion of GERG-2004

[6] BS 8609:2014 Natural gas. Calculation of carbon dioxide emission factors from composition

[7] Previously known as LRS (British Gas, London Research Station). A modified Redlich-Kwong-Soave (RKS) equation of state with DNV parameters

[8] T/PM/GQ/8 Management procedure for assessing the Requirement for Gas Quality, Calorific Value and Flow Measurement Systems

[9] D.F. Lander. Technical report for Functional Specification for Hydrogen Blending Infrastructure Project: Odorisation

[10] ISO 5167-1:2003 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full. Part 1:General principles and requirements

[11] ISO 10723 Natural Gas – Performance Evaluation for analytical systems