Hydrogen Commercial Kitchen and Test Facility

Kitchen Overview and Testing Results

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Contents

Executive Summary

The Hydrogen Commercial kitchen at Tyseley Energy Park represents a pioneering initiative to evaluate hydrogen as a sustainable energy source for the commercial catering sector and to support product and standards development for the hydrogen industry. This state-of-the-art facility, developed by National Gas Metering (NGM) in collaboration with Falcon Foodservices and other key industry partners, is the UK's and possibly the world's first hydrogen-powered commercial kitchen. Designed to replicate traditional natural gas kitchens, it serves as both a testing ground and demonstration facility for hydrogen-compatible appliances and metering systems.

Key Achievements

- Facility Design: The kitchen integrates hydrogen metering installations, appliances, and enhanced safety systems, aligning with emerging IGEM and BSI standards. It leverages advanced ventilation, pipework materials, and safety protocols to ensure operational safety and efficiency. It also builds on the certification and development by the Hy4Heat project.
- Testing Outcomes: Extensive tests on hydrogen metering, legacy meters, regulators, valves, and other components have validated their compatibility with hydrogen, providing actionable insights for industry standards and product enhancements.
- Culinary Performance: Falcon appliances have successfully demonstrated reliability and efficiency in a hydrogen environment, offering a compelling case for hydrogen as a low-carbon alternative to traditional fuels.
- Safety and Compliance: The project has set a benchmark in hydrogen safety systems, including the integration of gas detection, emergency shutoffs, and ventilation design tailored for hydrogen's unique properties.
- Stakeholder Engagement: The facility has hosted numerous demonstrations for industry leaders and academic stakeholders, showcasing the practical applications and potential of hydrogen in decarbonising commercial kitchens.

Challenges and Opportunities

The project addressed the absence of formal hydrogen-specific competencies and limited availability of certified components by leveraging existing natural gas standards and developing interim solutions. These efforts have not only demonstrated the viability of hydrogen for commercial kitchens but also laid the groundwork for setting industry best practices and competency frameworks.

Recommendations

The project underscores the need for:

1. Continued refinement of hydrogen safety and operational standards.
2. Expanded testing of diverse appliance configurations and operational scenarios.
3. Industry-wide adoption of the findings to accelerate the transition to hydrogen in commercial catering.

The Hydrogen kitchen initiative provides a critical stepping stone towards decarbonising the catering sector and contributing to the broader hydrogen economy.

1. Introduction

National Gas Metering (NGM) and Falcon Foodservices are spearheading an initiative to establish the UK's first hydrogen-powered commercial kitchen at Tyseley Energy Park (TEP), in collaboration with key industry and supply chain partners. This ground-breaking project has created a state-of-the-art facility for testing and optimising metering installations and kitchen appliances, offering valuable insights into the feasibility, efficiency, and sustainability of hydrogen-based energy solutions in commercial settings.

NGM has selected commercial catering appliances as a load for testing gas meters and equipment due to the wide variability of load profiles they can generate. This allows for robust testing of the integrity and safety of hydrogen meters, ensuring compliance with industry standards (e.g. new IGEM H Standards).

For Falcon Food Services, this facility provides the first opportunity to fully explore the culinary performance of hydrogen appliances developed during Hy4Heat. It also facilitates collaboration with a range of end-users to demonstrate and gather feedback. Presently, caterers seeking to decarbonise their operations can only do so through electrification, which is not always suitable for all kitchen sites or cooking methods. The interest of the catering sector can be observed in various publications and trade association activities.

Gas and electric catering appliances offer complementary benefits and challenges:

- Electric solutions result in dry heat cooking while gas is humid heat cooking. Based on calculations for combustion product mass flow rate per kW of input power, the water content is 53% greater for hydrogen than that for methane gas combustion [IGEM/H/1]. However, dew point for each gas differs. Furthermore, as this is superheated water vapour the real impact on culinary performance is unknown.
- Heat delivery control systems offer different benefits: gas typically has modulated heat delivery; electric controls can more easily be integrated with smart system management features (IoT).
- Electric appliances generally require 3-phase supply and for high induction load set-ups power factor correction may be needed, but some appliance types have greater energy efficiency.
- Local electric and gas grid constraints vary.
- Building type/design may affect equipment choice. Property ownership may affect willingness to change building services required for decarbonisation.

Our facility is designed to cater to a variety of first-generation hydrogen UKCA certified commercial appliances, sourced from Falcon Foodservice Equipment (Falcon), a renowned supplier of kitchen equipment. These appliances include grills, range cookers, and fryers. The facility not only serves these appliances but also incorporates multiple hydrogen metering devices, provided by National Gas Metering (NGM), crucial for testing hydrogen end use products and ensuring safety requirements are met.

This report outlines the key learning points from the design, build and operation of the kitchen facility including an overview of the progress of the testing plan delivered in the initial proposal document.

1.2 Project Description

The kitchen is located within the Shop R building at Tyseley Energy Park (TEP). TEP is a joint venture with University of Birmingham and Webster & Horsfall ltd, which is investing in research, business incubation and high-profile decarbonisation projects to support local and national business and technology development.

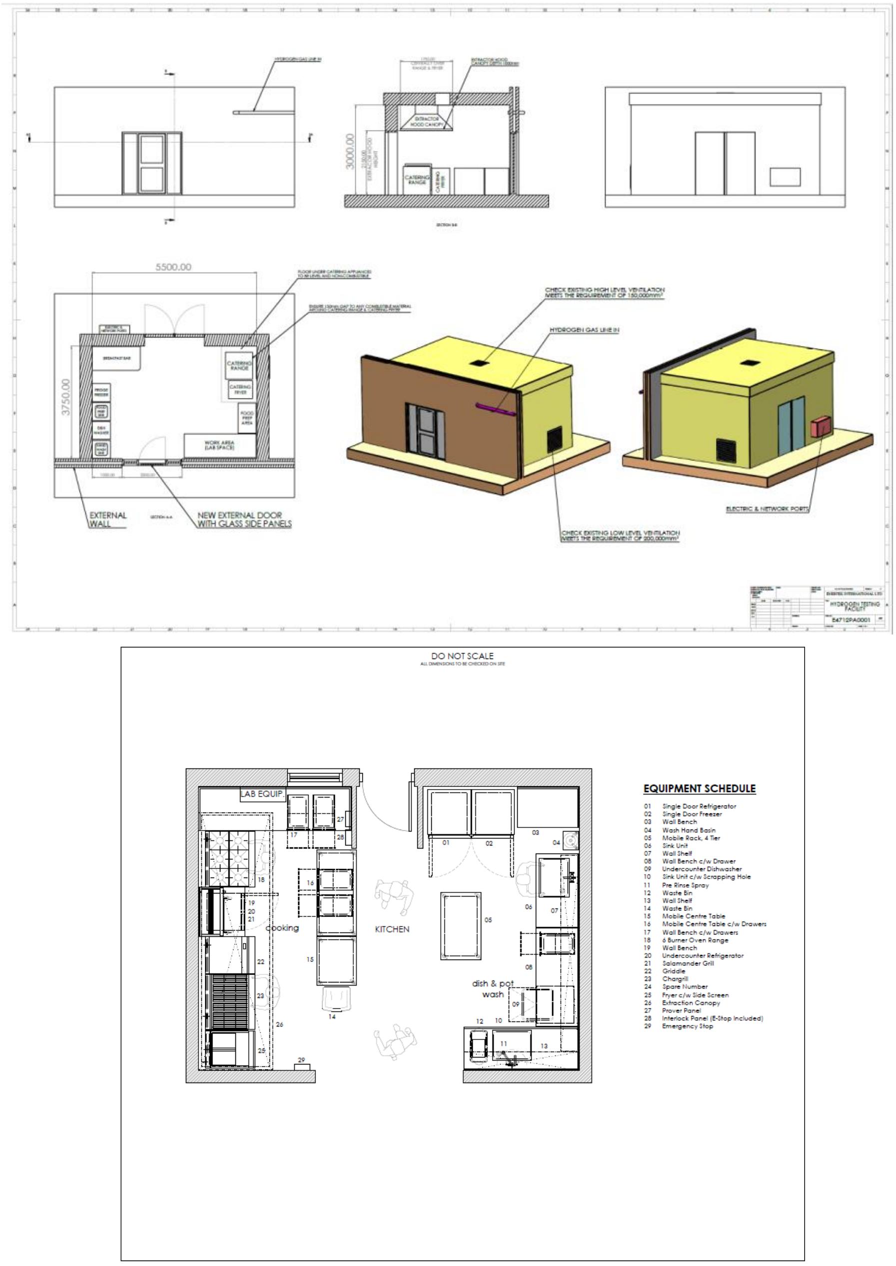

Figure 1 – High level schematic of the kitchen layout proposal

The 22-square-meter kitchen has recently been constructed and commissioned and meets the design specification in the figure above. The kitchen is powered by BOC-supplied Manifolded Cylinder Pack (MCP) hydrogen, which is distributed through a network of hydrogen metering installations equipped with pressure reduction equipment and excess flow valves – based on Hy4Heat recommendations. Subsequently, the hydrogen supplies various commercial kitchen appliances.

To meet the ventilation and safety requirements of the kitchen, Enertek International Ltd, ensuring the highest standards of safety, provided crucial ventilation solutions for the facility, and have actively contributed to safety assessments. Based on chemical reaction calculations, water vapour produced by hydrogen is 22% lower than that for methane combustion [IGEM/H/1]. However, there are still knowledge gaps relating to gas leak risks which require real-environment measurements before exact guidance can be formulated, the kitchen tests will be used to assess this.

The facility is designed with the dual purpose of serving as a collaborative laboratory and testing centre, while also ensuring the highest standards of hygiene to facilitate the preparation of food for both consumption and demonstration. Professional commercial kitchen designers WVHowe Ltd have provided the kitchen design and provided a Gas Safe Engineer which led to the commissioning of the hydrogen catering appliances. This is a first-of-a-kind hydrogen kitchen installation.

2. Demonstration Activity

The kitchen has been designed, as far as technically feasible, to replicate an existing natural gas fuelled catering kitchen regarding design, equipment, and operation, to demonstrate that hydrogen can be incorporated without major equipment deviation from current industry standards and components. This is important for the commercial catering industry as it will ensure minimal deviation from current consumers operating requirements, in terms of chef competency and building space requirements etc.

Throughout the design and construction process a strong emphasis was placed upon testing the draft standards for hydrogen in development by IGEM and BSI, for both materials selection, and physical construction and testing procedures.

2.1 Pipework Materials and Design

Initial standards development has already been undertaken by both IGEM (Institute of Gas Engineers and Managers) and the British Standards Institute (BSI), building upon existing natural gas standards. This has provided a strong foundation for the design considerations for residential and small industrial/commercial hydrogen installations which we wanted to put into practical application. The main deviations from the natural gas equivalent standards are additional safety measures to ensure that hydrogen poses no greater risk than natural gas and may be able to be used in a safer way.

Key mitigation factors include:

- Material selection
- Ventilation
- Excess flow restriction
- Hydrogen detection / alarm

Throughout the design phase, both new and existing IGEM and BSI standards were used to ensure that the standards were being utilised. Gaps that are specific to a commercial kitchen had solutions developed in line with natural gas standards, to ensure that the end solution was both familiar, safe and engineered with the correct safety equipment.

Pipework material selection is as per IGEM /GM/6, IGEM/GM8 part 2, BS6400-1, IGEM/H2 (Draft), IGEM/H3 (Draft), PAS4441, PAS4442 and PAS4443, PAS4444 as appropriate. (As per final drafts for PAS standards).The meter installations and pipework were strength tested, tightness tested, and purged as if Natural Gas was being used in line with IGE/UP/1, IGE/UP1b with the addition of the hydrogen supplement requirements stated in section of 10 & 11 of IGEM/H2 & IGEM/H3 sections 14 & 15. The testing showed no leaks or issues (tested via a Gassco seeker suitable for hydrogen) and is continually tested each day of operation. After 8 months of operation no leaks have been detected.

The hydrogen containing parts of the kitchen supply pipework and appliances, are constructed using hydrogen approved or tested components that meet the current published or final draft standards. It was designed this way to assess the standards in operation, challenge the supply

chain on product approval, and to prove the existing natural gas components can either be repurposed or re-engineered for hydrogen compatibility.
As some standards are not currently published for industry, are in final stages of draft, or have gaps in the hydrogen specific standards/specifications, our approach has focussed on mitigating areas of safety concern either in the component selection or fundamental safety system design.

Areas of mitigation:

- Commercial grade hydrogen for the supply is to be used which is un-odorised.
- Confirming hydrogen compatibility with component manufacturers/supply chain.
- Utilisation of industry approved products or products evaluated by the OEM for hydrogen use.
- Minimising mechanical joints in the pipework, to reduce leakage potential.
- External specialist review of hydrogen specific elements, such as ventilation and hydrogen supply design.

2.2 **Training & accreditation**

There are currently no specific hydrogen qualifications or formal industry accreditation for hydrogen catering appliances and low-pressure pipework. We took the opportunity to test how applicable the existing Gas Safe qualifications are in application to this project, supplementing the specifics around pressure testing and purging with the detail in the IGEM H standards where an amendment exists on the applicable calculations and processes.

Pipe work was designed, procured, installed, and commissioned by NGM engineers with the below qualifications.

- Domestic – MET1 CESP1, MET4, REGT1
- Industrial & Commercial - CMET 1, CMET 2, ICPN1, TPCP1

Catering Appliances: Installed by a gas safe engineer with the below qualifications, supplemented with guidance from the appliance manufacturer instructions and in person appliance development engineer.

- CCCN1 - Core Commercial catering
- COMCAT1 – Boiler burners, open/solid ranges, hot plates, and bain-maries
- COMCAT3 - Deep fat fryers, griddles, and grills.

In practice, the supplement documents provide sufficient guidance for a Gas Safe qualified engineer to carry out the installation, testing and purging of pipework in similar way to natural gas. However, there is clarification of purge termination technique required and potentially new products in development which will aid the purging process once formal accreditation is rolled out. Any gaps in accreditation were identified and carried out under a suitable risk assessment.

Regarding the appliance installation and commissioning, there is further work required by the industry to accommodate the difference in hydrogen appliances and burners. However, this will be driven by legislation informing formal certification bodies and will likely form a new set of ACS (Accredited Certification Scheme) alongside those for all areas of the Gas Safe qualification.

2.3 Hydrogen Safety System Methodology

The kitchen has been designed, constructed and commissioned as per existing commercial catering design regulations including DW172 in relation to extraction design and ventilation requirements with all appropriate safety systems and early warning detection in place.

Purpose built ventilation has been designed by Enertek International ensuring ventilation provides adequate mitigation against the risk of hydrogen leak. Thus, ensuring that significant air replacement doesn't allow an explosive mixture of hydrogen to build up.

In the absence of specific ventilation calculations for a commercial kitchen IGEM/ SR/25, calculations have been applied in addition to guidance in IGEM/UP16. This ensures compliance with a zone 2 NE meaning that standard electrical equipment is permitted without the need for ATEX rated equipment.

As is standard industry practice, the safety system logic is centred around automated proving of the pipework integrity and a system check to prove air extraction prior to flow of hydrogen to the appliances being enabled.
Back up protection is provided by hard wired hydrogen gas sensors, CO/CO2 detection and an audible alarm warning with automated isolation of the hydrogen supply at both the 2-bar inlet pipework and at the primary commercial meter.
3x Emergency Shut Down (ESD) buttons are located with easy access around the room at strategic locations with one being located on the main safety system control panel.

2.4 Hydrogen supply

The hydrogen supply to the kitchen has been designed in such a way that it is representative of a traditional gas network supply albeit with cylinders of hydrogen at 175 bar, which are reduced in pressure at three stages before the hydrogen is used as fuel in the kitchen appliances.

The components and methodology used are also representative of the way natural gas network connections work and are configured.

A schematic of the kitchen supply and controls is provided in figures 3 & 4.

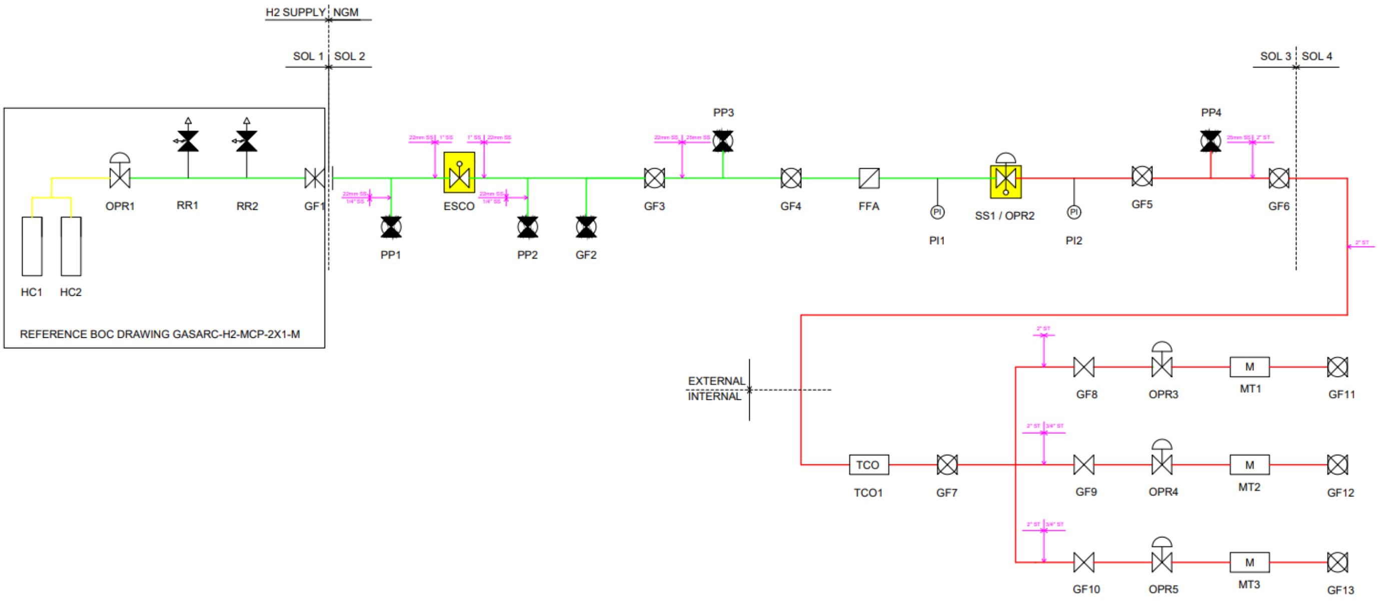

Figure 3 - Engineering line diagram (external supply up to internal meter outlet valves)

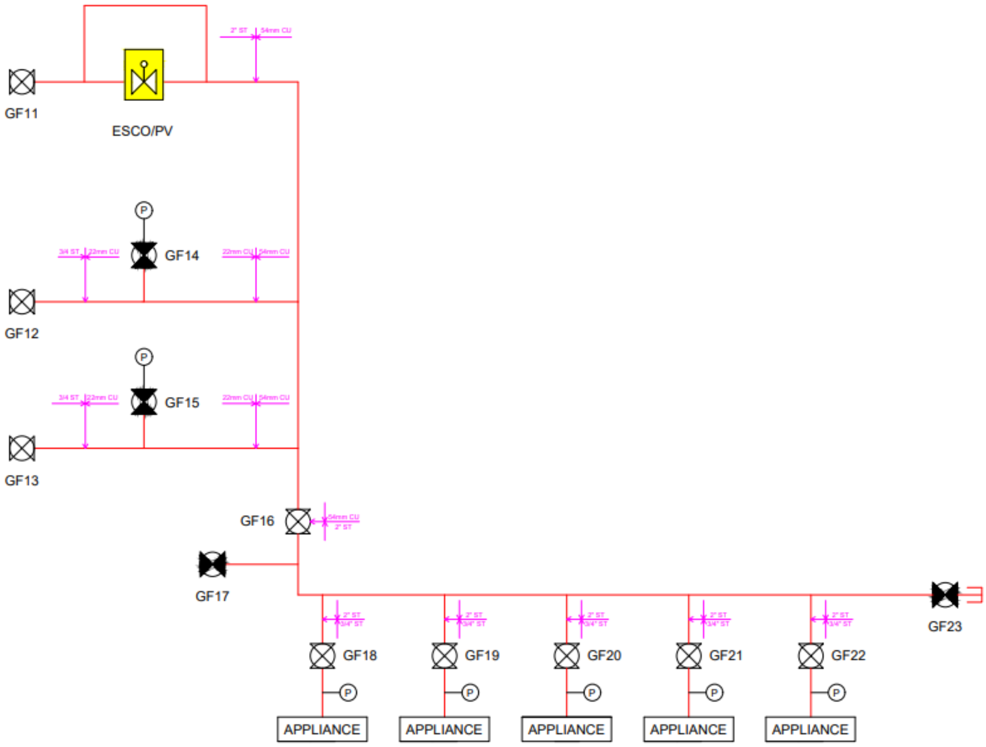

Figure 4 – Engineering line diagram (inside the kitchen - meter outlet to appliances.)

Commercial grade hydrogen is procured in 2 x 15-cylinder MCP's (HC1 &HC2) which are contained in a safe area within a secure compound. These are connected to a standard MCP pressure reduction control panel, which reduces the pressure to 2 bar.

The 2 bar external pipeline wraps around the factory wall to a Medium Pressure/Low Pressure (MP/LP) regulator/slam shut boundary regulator set, which reduces the pressure to 50 mb, which is representative of the current higher end of a low-pressure natural gas supply into a building. (Adjustable from 25-75mb)

The hydrogen feed into the internal room has been designed to not exceed the higher limit of a low-pressure gas network at 75mbar.

The hydrogen meter installations all regulate the pressure down to 21 mbar for the supply to the catering appliances, as is the case with natural gas metering and appliances supplies.

The kitchen appliances all incorporate regulators for the burner supply typically set at 14-15 mbar. Photos of the aspects shown in the engineering line diagrams in Figures 3 and 4 are shown below.

Figure 5 - Multi cylinder pallet (MCP) – 15 cylinders containing ~9kg of H2.

Figure 6 - MCP control panel – reduces the pressure from 175 bar to 2-3 bar.

Figure 7 - 2 bar – 50 mbar boundary regulator.

Figure 8 – View of the kitchen appliances

Figure 9 – View of the internal pipework, metering installation and associated equipment

Figure 10 - View of the other kitchen equipment

Figure 11 – External doors of the kitchen entrance from shop R.

3. Results and Analysis

The testing results below were designed to test the suitability of equipment and to perform engineering studies to provide vital evidence on how future kitchens could be built and operated using hydrogen.

The testing programme is not necessarily designed to verify or certify any equipment performance or manufacturers data sheets. However, it is important that future kitchen or commercial catering facilities understand the configurations of equipment that are best suited to their operational needs as well as performance and safety. The testing programme was broken down into specific elements, the full testing programme is described in appendix 1.

3.1 Hydrogen Metering testing

Components	Test Type and Description	What standard is this aligned to	Date	Data to be Captured	Value (how will this impact our business or industry)
Hydrogen Domestic Meters	• Material suitability • Performance - tightness testing, operation, logical tests, connectivity to other equipment • Software test - AMR Connectivity	BS 6400, IGEM/H2, BSI PAS444	30 September 2024	• Design feedback on operation and engineer use. • Does it meet the standards? • Ease of assembly • Quality assessment (joints made correctly, quality of threads etc)	Technical assessment test. It gives an indication of which manufacturer meter works best for the operational needs, assuming the price is suitable
Hydrogen Commercial Meters		GM/8, GM/6, IGEM/H2, BSI PAS444	30 September 2024		

Installation of two 100% hydrogen domestic capacity meters demonstrating different technology and measurement methods has been carried out against the above table of requirements.

Pietro Fiorentini H2-SSM smart meter

Figure 12 - Pietro Fiorentini H2-SSM smart meter

The **H2-SSM smart meter** by Pietro Fiorentini incorporates the latest ultrasonic measurement technology to measure both natural gases and **100% hydrogen**, switching between gases without any additional interaction.

It is built with a valve inside the meter which can act as Excess Flow Valve to enhance customers and network safety. This device is used for residential applications on low pressure gas distribution networks.

Features

- Body: metal
- Electronic enclosure: plastic polycarbonate
- Precision class: 1.5
- Working temperature: from -25 °C to +55 °C
- Connections: 1’’ BS 746
- Measurement range: from 0.04 m^3/h to 6 m^3/h for natural gas; from 0.13 m^3/h to 20 m^3/h for hydrogen
- Remote communication interfaces: Zigbee 2.4 GHz and 868 MHz
- Compliant to IP65
- ATEX classification II 3G ic IIC T3 GC
- Built in gas volume & temperature compensation.
- Built in excess flow function.

Approvals

The H2-SSM is designed to meet OIML R137, EN 14236, SMETS2. The product is certified according to CPA, European Directive 2014/34/EU (ATEX), European Directive 2014/32/EU (MID) and UKCA.

H2-SSM – summary

The meter has been installed on the test rig for 7 months and meets the draft requirements set out by IGEM for compliance in the UK.

The specification is suitable for the UK market and as a dedicated hydrogen meter, has been designed with suitable materials to withstand hydrogen use within a low-pressure hydrogen network environment. During pressure testing, purging and in use, the meter passed all the standard tests, and has a clear screen and easy to operate menu functionality.

The meter fits the dimensional requirements of a standard meter shelf and meter box.

As a dedicated SMETS2 smart meter there is no functionality for connection to a standalone AMR (automated meter ready) device, however this is not thought to be required for domestic smart meters that are directly connected to the smart network through the DCC (Data Communication Company).

Metersit Domusnext MMU40 – Smart meter

The **MMU40 smart meter** by Metersit incorporates the latest MEMS Micro Thermal flow sensing technology to measure both natural gases, NG/H2 blends up to 23% and **100% hydrogen**, dependent on model ordered.

The meter is built with a factory set valve inside, which can act as Excess Flow Valve to enhance customers and network safety. This device is used for residential applications on low pressure gas distribution networks and could be preset at different values subject to authorised persons and/or manufacturer approval.

Features

- Body: metal
- Electronic enclosure: plastic polycarbonate
- Precision class: 1.5
- Working temperature: from -25 °C to +55 °C
- Connections: 1’’ BS 746
- Measurement range: 0.13 m^3/h to 20 m^3/h for hydrogen
- Remote communication interfaces: Zigbee 2.4 GHz and 868 MHz
- Compliant to IP67, Ik08
- ATEX classification: EX II 3G EX nA IIB T6 Gc
- Built in gas volume & temperature compensation.
- Built in excess flow function.
- Max operating pressure 500mb

Approvals

The MMU40 is designed to meet OIML R137, EN 14236, SMETS2. The product is currently a prototype designed to meet the objectives of Hy4heat which should meet MID/Ofgem, European Directive 2014/34/EU (ATEX), European Directive 2014/32/EU (MID) and SMETS specifications.

MMU40 – summary

The meter has been installed on the test rig for 7 months, and meets the draft requirements set out by IGEM for compliance in the UK.

The specification is suitable for the UK market and as a dedicated hydrogen meter, has been designed with suitable materials to withstand hydrogen use within a low-pressure hydrogen network environment.

During pressure testing, purging and in use, the meter passed all the standard tests, and has a clear screen and easy to operate menu functionality.

- The meter fits the dimensional requirements of a standard meter shelf and meter box.
- As a dedicated SMETS2 smart meter there is no functionality for connection to a standalone AMR device, however this is not thought to be required for domestic smart meters that are directly connected to the DCC.

Hydrogen Commercial meter testing

Metersit Domusnext MMU120

The **MMU120 smart meter** by Metersit incorporates the latest Micro Thermal Flow Sensing (MEMS) technology to measure both natural gases, NG/H2 blends up to 23% and **100% hydrogen**, dependent on model ordered.

Figure 13 - Metersit Domusnext MMU120

Features

- Body: metal
- Electronic enclosure: plastic polycarbonate
- Precision class: 1.5
- Working temperature: from -25 °C to +40 °C
- Connections: 2’’ BS 746
- Measurement range: 0.5 m^3/h to 120 m^3/h for hydrogen
- Remote communication interfaces: Zigbee 2.4 GHz and 868 MHz
- Compliant to IP55, Ik08
- ATEX classification: EX II 3G EX nA IIB T6 Gc
- Built in gas volume Temperature compensation.
- Built in excess flow function.
- Max operating pressure 500mb

MMU120 – summary

The meter has been installed on the test rig for 7 months and appears to meet the requirements for use in the UK.

The specification is suitable for the UK market and as a dedicated hydrogen meter, has been designed with suitable materials to withstand hydrogen use within a low-pressure hydrogen network environment.

During pressure testing, purging and in use, the meter passed all the standard tests, and has a clear screen and easy to operate menu functionality.

The meter is significantly small in proportions than a standard natural gas meter of equivalent capacity, therefore easily fits the dimensional requirements of a standard meter shelf and meter box dimensions.

As a dedicated SMETS2 smart meter there is no functionality for connection to a standalone AMR device, however this is not thought to be required for domestic smart meters that are directly connected to the DCC.

3.2 Testing of legacy Gas meters on Hydrogen

<table>
<tr><th>Testing Type</th><th>Description</th><th>Standard to test to</th><th>Date to be completed</th><th>Comments</th></tr>
<tr><td>Legacy Domestic Meters</td><td rowspan="2">•Material suitability
•Performance - tightness testing, operation, logical tests, connectivity to other equipment
•Software test - AMR Connectivity
•Condition assessment (what conditions we consider can be repurposed in alignment with the H-standards),
•Collaboration with manufacturers to know what they deem acceptable and other tests on material impact beyond visual tests</td><td>BS 6400</td><td>30 September 2024</td><td rowspan="2">Understand if the legacy/gas meters will work on hydrogen and see if it can be repurposed. Data received will help make recommendations on changes that may be required. For domestic, it will help us understand if we can connect with AMR</td></tr>
<tr><td>Legacy Commercial Meters</td><td>GM/8, GM/6</td><td>07 October 2024</td></tr>
</table>

Natural Gas Domestic meters (G4)

To consider general suitability and repurposing of the general portfolio of domestic gas meters for use on 100% hydrogen, the team decided to take a random sample of one of the most common meters in our portfolio, used and refurbished G4 meters, and subject them to in use testing criteria on the hydrogen test rig.

The G4 gas meter that was initially tested was the Itron / Actaris G4 as from a portfolio population perspective they account for a large proportion of the domestic portfolio. These meters are traditional diaphragm meters that are not currently included within the proposed standards; however, it was deemed essential to test the historical meter technology from a safety perspective as some OEM's have approved similar technology for use on hydrogen should the standards evolve to include them.

From a longer-term viewpoint, should residential networks be converted to 100% hydrogen, then there could be significant savings if the G4 type meter could be repurposed rather than replacing with a hydrogen specific or electronic /ultrasonic meter.

An initial sample of 10 Actaris/Itron G4 meters were subject to the same tests as the specific hydrogen meters. Meters ranged in age and condition but were all manufactured between 2006-2012 and are representative of the current NGM portfolio.

The general findings were that across the sample, providing the meter carcass was in good physical condition without damage to the meter body or threaded connections, then the meters would pass the industry pressure test requirements stipulated in IGEM/H2 and were consistent in the measured volume simulating 1 hour's consumption.

We expanded the meter selection to include U6/G4 type electronic pre-payment meters and tested a selection of used GWI ETM – Electronic Token Meters, which all passed the same tests as the standard G4 meters as the internal technology is similar.

It is noted that due to the measured volume not having pressure and temperature compensation like the dedicated hydrogen meters, the volume totalisation would need to be corrected by way of fixed factor correction. This would likely be corrected by the gas shipper/supplier at point of billing the volumetric consumption.

Based on limited testing of G4 meters, there doesn't appear to be any significant reason why this meter technology could not be retained on future hydrogen networks, subject to approvals and manufacturer testing.

Natural gas E6 Ultrasonic domestic meters

An initial sample of 10 Landis & Gyr E6 ultrasonic meters, were subject to the same tests as the specific hydrogen meters. Meters ranged in age and condition but were all manufactured between 2018-2021 and are representative of the current NGM portfolio.

For consistency with our portfolio, we expanded the E6 meter selection to include older E6 meters from Siemens and Eurometers ranging from 1995-1998 which were all subject to the same tests.

It was quickly confirmed that although the E6 type meter was capable of remaining hydrogen tight from a leakage perspective, the existing natural gas version of E6 ultrasonic measurement is not capable of measuring hydrogen due to the differences in speed of sound calibration.

The conclusion for existing legacy E6 meters would be that they would need to be replaced with hydrogen specific versions of either ultrasonic or thermal mass technology and could not be repurposed without OEM recalibration and testing. This is consistent with other testing conducted as part of other hydrogen projects such as Hydeploy.

3.3 Regulator testing

Low pressure hydrogen gas network applications are a recent development and therefore there has been limited development work by OEM's on low pressure regulators. There are only a couple of products available on the market that would suit hydrogen metering applications of which most were developed for the domestic network village trials.

Testing Type	Description	Standard to test to	Date to be completed	Test Detail	Comments
LP Regulators	• Gas tightness • Performance • Lock-up test. • Aging and mechanical life • Torsion and bending test. • Accuracy testing	GM/8; BS EN 334	31 July 2024	•Setpoint accuracy •Response time •Longevity •Environmental resistance (how to reacts external environment)	Cross product testing will inform NGM approved products and industry product gaps.
MP Regulators			31 July 2024		Cross product testing will inform NGM approved products and industry product gaps.
MP Slam shuts	• Closing behaviour • Gas tightness	GIRS/V9, BS EN 14382	30 November 2024		Cross product testing will inform NGM approved products and industry product gaps.

The kitchen has used the products below to demonstrate both domestic and commercial use applications of differing pressure requirements.

Continental – Mesura H2 domestic regulator
Pietro Fiorentini – Dival 500H Commercial medium pressure regulator.
Speryn – G1000 Commercial low-pressure regulator

Domestic regulator testing

Mesura R1 -R2

The **R1** and **R2 series regulators** are a line of direct-action type pressure governors, normally used for domestic applications, generally installed directly to the meter or in installations in gas grids for natural and manufactured gas, LPG, or other non-corrosive preliminarily treated stable gas.
R1 and R2 regulators are KIWA certified for 100% hydrogen use.

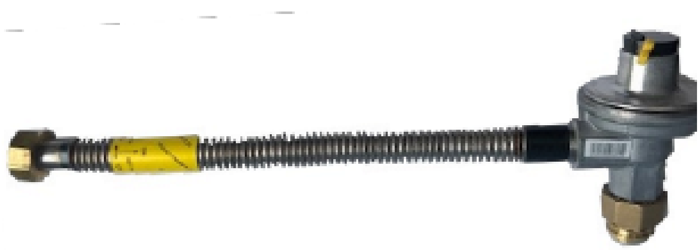

Figure 14 - Mesura R1 -R2 domestic regulator

Specifications R1

- Body Material: Aluminium / Painted
- Inlet Pressure: 0.4
- Outlet Pressure: 12 to 55 mbar
- Nominal Capacity: 6 – 12.5 (m^3/h)
- Working temperature: -40 ÷ +96 °C
- Inlet Connections: 3/4” 7/8” 1”
- Outlet Connections: 3/4” 7/8” 1”

Specifications R2

- Body Material: Aluminium / Painted
- Inlet Pressure: 0.2
- Outlet Pressure: 12 to 37 mbar
- Nominal Capacity: 6 (m^3/h)
- Working temperature: -20(-40) ÷ +60
- Inlet Connections: 3/4” 7/8” 1”
- Outlet Connections: 3/4” 7/8” 1”

Testing of Mesura R2 regulator and flexible pipework, has been carried out by Continental product engineering ltd as part of the BEIS Hy4Heat work package 4b-lot1.

The kitchen utilised the ¾” hydrogen specific Mesura R2 supplied by Continental, fitted as a traditional domestic meter regulator fitted on two installations feeding different meter technology and flow rates. The regulators see a typical inlet pressure of 50 mbar and are both set at 21 mbar for the metering pressure. During the 7-8 months of testing there have been no detection of leakage or failure of seals from the valves.

The regulator has been installed on the test rig for 8 months, and meets the draft requirements set out by IGEM for compliance in the UK.

GWM SR100 regulator

Another OEM regulator manufacturer is working on repurposing an existing domestic regulator for hydrogen use that is currently going through internal testing and due to be submitted for industry approval. The GWM SR100 regulator is currently used within the gas industry for low pressure domestic use on natural gas with large quantities in general use throughout the UK. At the time of testing the regulator approval had not been formally granted on the prototype, so could not be included in the tests. However, this does show that there are already OEM companies that have modified/repurposed existing equipment for hydrogen use and that there is potentially already competition in the market which will drive technological advancement further.

I&C regulator testing

Speryn G1000 (2”) Natural gas low pressure regulator

Specification: PRS35

- Inlet range 23.5-75mbar
- Outlet range 17.5 -25mbar
- Set point 21 mbar

Figure 15 - Speryn G1000 (2”) Natural gas low pressure regulator

Summary

At the time of construction there was no dedicated industrial & commercial low pressure regulator demand. As such there is currently no supply in the UK for small commercial low-pressure regulators for the metering market. However, in discussion with the UK distributer for Sperryn G100 regulators, it was agreed that the existing natural gas regulator should be capable of regulating hydrogen with no adverse material concerns in the regulator construction.

Although no formal testing had been carried out of the G1000, we agreed to trial the regulator on the Kitchen Installation under strictly monitored usage.

The regulator has been installed on the test rig for 7 months, and meets the draft requirements set out by IGEM for compliance in the UK. Next steps would be for the OEM’s to formally develop, test and approve regulators specifically for hydrogen use in low and medium pressure applications. The restriction in development is relating to applicable legislation and standards that are not yet defined for the UK hydrogen market.

Pietro Fiorentini Dival 500H MP regulator/slam shut

The Dival 500 H is a lever-operated gas pressure regulator controlled by a diaphragm and contrasting regulated spring action. This device is suitable for 100% hydrogen applications. It is used for medium and low-pressure gas distribution networks, as well as commercial and industrial applications. According to the European Standard EN 334, it is classified as Fail Open.

Features:

- Accuracy class AC: up to 10
- Nominal sizes DN: 1″ x 1″, 1″ x 1″ 1/2
- Lock-up pressure class SG: up to 20 (depending on version and set point)

- Design pressure: up to 10 bar for BP, up to 20 bar for MP and TR
- Design temperature: from -20 °C to +60 °C
- Minimum differential pressure: 0.1 bar
- Range of downstream pressure Wd: from 13 to 100 mbar for BP, from 100 to 300 mbar for MP, from 300 to 2500 mbar for TR
- Inlet pressure range bpu: from (Pd + 0.1) bar to 10 bar for BP
  from (Pd + 0,1) bar to 20 bar for MP and TR

Figure 17 - Pietro Fiorentini Dival 500H MP regulator/slam shut

Summary

The Fiorentini Dival 500H is installed in the kitchen supply as the 2 bar – 50 mbar regulator, which simulates a traditional boundary regulator set up for natural gas.

The regulator has been installed on the test rig for 7 months in the 1” x 1” version for capacity up to 50m3hr and appears to meet the planned requirements for use in the UK.
During operational use the regulator has performed well, passed all testing criteria and appears to be suitable for the application.

3.4 Materials assessment

Material testing is important to ensure compatibility with hydrogen, this area of testing was to ensure that the equipment used in the kitchen were able to contain the hydrogen as required.

Testing Type	**Description**	**Standard to test to**	**Date to be completed**	**Test Details**	**Comments**
Pipework Materials & Fittings	•Material suitability •Resistance against internal pressure •Validating copper fittings	BS 6400, UP/1, UP/1B, UP/2, UP/16	31 August 2024	•Pressure containment, •Seal accuracy, •Longevity •Environmental resistance	Test industry standards and provide industry best practice.

Joint types & Materials	• Material suitability • Leak tightness		30 September 2024		

Material	IGEM/H2/3 & PAS approval	certified Design p	standard tested	test pressure	pass /fail	restrictions
copper tube	PAS4442	3 bar	BSEN 1057	82.5 mbar	Pass	
copper press fit fittings	PAS4442	200 mbar		82.5 mbar	Pass	
malleable iron pipe				82.5 mbar	Pass	
Brass ball valves				82.5 mbar	Pass	
Brass test points		300 mbar		82.5 mbar	Pass	
welded steel tube	PAS4442			1.5bar	Pass	
stainless steel fittings	PAS4442			2 bar	Pass	
stainless steel tube	PAS4442		ASTM269 -316	2 bar	Pass	
Stainless steel ball valves		1000 PSI		2 bar	Pass	
stainless steel flexible connectors			BS EN 15266	75 mbar	Pass	
Rubber washers				21 mbar	Pass	
Boss white	PAS4442		BS6956-5	21 mbar	Pass	S/S threads
PTFE tape	PAS4442		BS EN 751-3	175 bar, 2 bar	Pass	S/S threads
Permabond 201H	PAS4442				Pass	
domestic regulators 21 mbar				21 mbar	Pass	
I&C regulators	not yet certified			21 mbar	Pass	
soft solder	PAS4442	N/A	BS EN 29453			
Flux	PAS4442	N/A	ASTM B813			

Table 1 – list of components and approval standard

3.5 Valves

Throughout the design and build of the kitchen, the approach was to source and utilise a thorough selection of different valve types and manufacturers models. Typically, hydrogen rated valves have a design pressure of 1000PSI or greater for use in chemical, process or industrial gases applications which is much greater than the pressure the kitchen would see as a typical low-pressure installation (<50mBar)

For low pressure applications, the BSI 444 series of documents permits the selection and use of valves conforming to BS 1552, BSEN 331, PRS1/E or GIS/7. This selection is caveated by the requirement that the manufacturers have proven the valves fit for purpose for use with hydrogen a as a 4th family gas.

In practice it was difficult to find many OEM's who produce valves that had been approved or tested for use on hydrogen in low pressure applications outside of the work carried out by the Hy4heat work packages.

Typically, in the gas transportation industry and certainly for metering installations, BS1552, BS EN 331 and GIS/V7 are the commonly specified valves.

Testing of emergency control valves to BSEN 331/ GIS/V7, has been carried out by Continental product engineering ltd as part of the BEIS Hy4Heat work package 4b-lot1.

These products have been checked for material suitability, leak tightness, angular seal, operation and mechanical life and have been deemed suitable up to 300 mbar.

Waverly Brownall BV1000 ball valve - stainless steel

Currently installed and tested within the kitchen at sizes ranging from ½”-2” on both the low and medium pressure parts of the kitchen supply system.
the BV1000 is an industrial gasses /liquids rated ball valve that meets the requirements of BS EN 331:1998. With sealing performance that meets BS6755 pt1

The valve is constructed of 304 stainless steels with a pressure rating of 1000psi (68 bar), with a PTFE sealing seat.

There have been no issues during 8 months of use, with hydrogen containment and sealing surfaces for isolation performing well.

Formal testing and approval would be required for hydrogen use, however valves to BS EN 331 are approved under the BSI PAS4444 standard (subject to testing).

Crane D191 ball valve – brass

Currently installed and tested within the kitchen at sizes ranging from ½”- 2”, the D191 is a natural gas rated ball valve that meets the requirements of BS EN 331:1998.
It has not formally been tested for hydrogen use, however materially it is very similar to the approved Cero EMS valve in materials and construction.

There have been no issues during 8 months of use, with hydrogen containment and sealing surfaces for isolation performing well.

Formal testing and approval would be required for hydrogen use, however valves to BS EN 331 are approved under the BSI PAS4444 standard (subject to testing).

Figure 18 - Crane D191 ball valve – brass

CPE & Cerro EMS Emergency control valve.

Figure 19 - CPE & Cerro EMS Emergency control valve

Both the ¾” and 2 “version of the Cerro ECV supplied by Continental were fitted in the kitchen as a traditional emergency control valve, which sees a typical pressure of 50 mbar. During the past 7-8 months of testing there have been no signs of leakage or failure of seals from the valves.

Both size valves contain a BSP thread on the inlet, which is sealed with a semi liquid paste such as Boss white or Rocol, and a BS746 upper thread which is sealed with a rubber/neoprene washer to form the seal.

For low pressure application both jointing methods have been tested and have performed satisfactorily.

3.6 EFV – Excess flow valves and Thermal cut off valves

The future enabling standards produced by IGEM for the provision of field trials of 100% hydrogen (IGEM /H2 & H/3), contain allowances that account for planned operating pressure differences for low pressure metering installations. These also account for the differences between natural gas and hydrogen from an energy content perspective and allow for the additional componentry required within the network, meter installation, downstream pipework and appliances that provide safety mitigations against leakage.

It is envisaged that one of the most suitable mitigations against a significant leak within a domestic property or on a section of commercial pipework would be excess flow valves. The purpose of which is to automatically mechanically isolate the leaking section by way of a spring-operated poppet type valve that is designed for a given maximum flow / leak rate.

The issue with the addition of these valves is that they have a small inherent pressure drop across the valve due to the internal structure of the spring and valve arrangement, which is not currently factored into the natural gas standards for both meter installations and pipework pressure and flow calculations.

We worked closely with Maxitrol GMBH & co, an OEM manufacturer of EFV and thermal cut of valves currently supplying the natural gas market in the UK & wider European market, who have also developed hydrogen rated versions of these products.
Factory testing of the Excess flow valves (EFV) and thermal cut off valves (TCO), shows that providing the valves are correctly sized, the pressure drop across the valve is minimal and should not make a material difference to the overall sizing calculations.

However, as part of the kitchen design we factored in the placement and assessment of both EFV's and thermal cut offs to provide the required safety mitigation, test the technology and standards application, and test the performance as part of a functioning real life use case.

The kitchen contained the below combination of EFV's and TCO's in order to physically test the pressure drop and operation against the pipe sizing calculations and activation accuracy.

- 2" TCO model GT50114, fitted as primary thermal protection on the main incoming hydrogen pipe at entry to the building.

- ¾" EFV model GS20HH1.6AIZ, fitted to the ¾" supply pipe to the smooth Griddle
- 1" EFV model GS25HH6AIZ, fitted to the supply pipe feeding the Range

- ¾" EFV model BV34EF to demonstrate and test a traditional BS746 meter point connection, fitted to one of the domestic gas meter installations at the outlet of the emergency control valve.
- ¾" combined EFV & TCO model GS20HT6AAZ, to demonstrate and test a traditional BS746 meter point connection, fitted to one of the domestic gas meter installations at the outlet of the emergency control valve.

Testing to date has confirmed that the pressure drop across the components is acceptable within the new enabling standards with no significant pressure drop witnessed that would cause an issue with the pipework flow rate if sized correctly.

The domestic meter testing was limited to the currently available natural gas versions of the EFV and EFV /TCO as there is currently not a hydrogen specific version available, however the OEM had provided assurance that the products were suitable for hydrogen use in their standard form.

The most significant pressure drop was witnessed on the supply to the range when on full rate operation, this showed a pressure drop of 0.3mbar. The pressure drop was acceptable for the size of pipework and did not adversely affect the supply pressure to the appliance regulator and subsequent burner pressure.

The overall conclusion is that the EFV and TCO components do provide an additional level of protection from significant leakage over and above what is currently installed on natural gas installations, if sized and installed correctly.

Figure 20 - Excess flow valves (2nd from left onwards) and Thermal cut off valves (far left)

4. Engineering Studies

4.1 Safety Systems

In the absence of specific standards, specifications, and policy for using hydrogen as a fuel for commercial catering, the design philosophy was to utilise the existing guidance and standards available and understood for natural gas. The project applied hydrogen specific mitigations that were either appropriate in draft form or where no suitable guidance was available, applied an engineering risk assessment approach.

Utilising IGEM/UP/19 ed 2 and cross referencing DW172 & BS6173 the team applied the applicable ventilation and interlock requirements currently utilised for natural gas catering kitchens to provide a base requirement for the minimum safety system required. A layer of mitigation that these standards don't currently consider was added, in the form of additional ventilation, hydrogen solenoids for a proving system and emergency shut off valve at the supply cylinders. A proving system prevents dangerous situations occurring by preventing the gas supply from being turned on until all appliances isolation valves are closed.

The basic requirements were also supplemented with a commercially available fully interlocked alarm system that added in hydrogen sensors, CO2 sensor and warning beacons.

Working with Duomo ltd, an existing supplier to the commercial gas industry, we were able to take a commercially available catering safety system and exchange the solenoids for hydrogen specific versions. This meant the system was as close to standard as possible but accounted for the additional mitigation required for the potential of hydrogen leakage and provided a safer system than is currently required for natural gas at an affordable cost.

Equipment utilised in the kitchen:

Canopy Interlock system & Proving system.

- KS22 safe start controller with ESD button.
- FP-45 current monitor / or ADP10 air pressure switch.
- VMR – solenoid x 2

Gas detection – GS300MC gas detection controller.

- SG895 gas sensors x 2.
- KOB21 Emergency Shut Down button. x 2.
- CO2 monitor controller.
- AF126- audible flashing alarm x 2

Figure 21 – Prove system (far right), control system (middle) and power system (left)

During the assessment of equipment phase of the design it was discovered that the existing supply chain for gas detection and safety equipment was well developed to cater for the use of hydrogen. Several suppliers were able to offer applicable equipment ranging from basic catering/office specific safety systems all the way up to sophisticated highly rated ATEX rated equipment that would be suitable for a range of commercial / industrial use applications.

The commonality with this equipment is that the detection sensors need to be exchanged for hydrogen specific sensors, but much of the control equipment was still suitable and commercially available off the shelf.

4.2 Hazardous Area Assessments

The 2 bar pipework located on the side of the building falls within the existing scope of IGEM/SR/25 and with the addition of the hydrogen supplement can be deemed to be classed as zone 2 NE due to being in an open environment. However, we did minimise the diameter of pipework and chose to run the 2 bar pipework in welded stainless steel around the external walls of the building so as to minimise the risk of leakage from joints over time as the pipework is located above head height.

The external 2 bar – 50m boundary regulator kiosk located on the wall outside the kitchen, was positioned in accordance with IGEM/SR/25, so that the potential release radius (0.5m) from the ventilation grills of the kiosk would not interact with the ventilation grills supplying air into the kitchen and redundant extraction fan from another room.

The creep relief regulator fitted to the boundary regulator installation has its relief pipework positioned 1.5m above roof height to account for the wind speed and surrounding buildings heights, with an integrated weather cap to prevent water ingress. Again, this was designed to IGEM /SR/25 rather than the standard British Compressed Gasses Association CP33 standard and provides a more onerous solution but one which is arguably in a safer position with better protection than standard.

IGEM/SR/25 calculations used internally have proven to be overly cautious for a kitchen space, as they are designed for a room containing gas pressure reduction equipment and far higher-pressure pipework than is utilised within the commercial kitchen. However, as the current standards do not consider hydrogen within a commercial kitchen space, the calculations provide a safe level of ventilation to prevent an explosive atmosphere in the event of a hydrogen leak.

4.3 Labelling Requirements

The exact labelling requirements for a domestic or industrial / commercial metering installation have not yet been agreed by the industry. However, we took the approach to supplement the existing natural gas labelling requirements in BS6400 part 1, IGEM/GM/6 and IGEM/GM/8 with labels in development for the Fife 100 hydrogen trial by collaborating with Scotia Gas Networks (SGN)
In practice, the additional hydrogen specific labelling is suitable, visible and provides the supplementary information required for use of hydrogen within a commercial setting.

Further standardisation is required by the industry as required depending on roll out of hydrogen networks, however as an interim solution the SGN labels are fit for purpose.

4.4 Flow and Pressure Drop testing

The kitchen installation, hydrogen supply, pipework design and material selection were designed to test the emerging standards from IGEM and BSI in a practical application using off the shelf products where possible and incorporating any applicable safety mitigations in the form of additional componentry.

Using different calculations, materials, components always have the possibility of creating unexpected results when considering flow and pressure drop testing of both a domestic and industrial/commercial pipework system. This is especially the case when the industry work force is familiar with a standard set of procedures for natural gas throughout industry training and qualifications.

The planned IGEM/H Standards already contain significant guidance around pipe sizing, pressure drop allowances and calculations that are well defined. These amendments are in accordance with the current guidance being utilised in the natural gas industry and would be easily understood by a gas safe engineer who had undertaken transition or updated training.

In practical applications within the kitchen, the draft standards provide sufficient guidance to design, build, purge, pressure test and operate the pipework. The sizing calculations have not caused any issues with poor flow or excessive pressure drop restrictions that would prove problematic if rolled out formally.

The pressure testing carried out so far is specific to the application of a low pressure supplied catering equipment, where the appliances have individual burner regulators incorporated in the appliance. Further work would be required for other industrial applications where the flow characteristics are more susceptible to inlet pressure.

5. Visits and Kitchen Use

Over the course of the 8 month test period, the kitchen has been utilised in its operational capacity as a fully functioning catering kitchen for testing products, networking events and to help feed vulnerable people in the community to ensure the most is made from use of the hydrogen purchased and that consumed hydrogen has added value.

NGM have established a partnership with The Active Well Being Society, a local charity that provide food for people in need within the local community and school age children who require free school dinners.
Where possible, we also utilise The Active Wellbeing Society to cater for our events, with food cooked in the Hydrogen kitchen, using ingredients from local charities and supermarkets that would ordinarily go to waste.

The Active Wellbeing Society

In conjunction with Tyseley Energy Park & Birmingham University's BEIC facility we are regularly involved in innovation tours of Tyseley Energy Park, showcasing the Hydrogen Commercial kitchen as a case study for how hydrogen can be used to decarbonise the industrial and commercial sector, and our metering and network capability can feed into and supplement other hydrogen use cases.

From qualitative information gathered from the chefs who have used the kitchen and appliances, they have indicated there has minimal differences to natural gas and potentially the hydrogen appliance cooked the food slightly faster. This may indicate that hydrogen could provide improved yield of cooking as well as the established sustainability benefits.

Shanue Hall the development chef at Falcon foodservice commented:

"The Hydrogen Hub kitchen sets the benchmark not only for a greener carbon neutral directive and potential hydrogen kitchen set up, but it is also a very well equipped, efficient area to conduct product presentations, hydrogen cooking introductions, training, and catering."

6. Challenges and Opportunities

The challenges in developing the hydrogen-powered kitchen facility extended beyond technical and supply chain hurdles to include workforce competency issues. As hydrogen is an emerging fuel source, standardised competencies for engineers and technicians specific to hydrogen systems have not yet been formally established. This gap presented a challenge, requiring National Gas to proactively upskill team members and establish interim competencies based on existing natural gas standards, along with enhanced safety training. Additionally, the limited availability of certified hydrogen-compatible components and the need to adhere to stringent IGEM and DSEAR standards added further complexity, especially in adapting existing ventilation and safety systems for hydrogen's unique properties.

On the opportunity side, the project has created a framework for establishing best practices in hydrogen competency, safety, and performance. By developing work instructions, verifying operational reliability, and creating a foundational set of skills, this facility has paved the way for other commercial kitchens to transition to hydrogen safely. These advancements underscore National Gas's role in setting industry standards for hydrogen adoption in catering and securing a competitive edge in the emerging hydrogen economy.

There are also opportunities to study yield and potential cost benefits of using a hydrogen kitchen which are recommended studies for the future.

7. Success Criteria and Implications for the Industry

The hydrogen kitchen project at Tyseley Energy Park was established with specific success criteria to assess its viability and impact. This review evaluates progress against these criteria, demonstrating the achievements and areas for ongoing development as the project advances.

1. **Demonstrating Falcon Appliances' Performance**

Falcon appliances were rigorously tested in the hydrogen environment to confirm their reliability and suitability for commercial kitchen demands. The appliances performed robustly, validating their capacity to meet the operational rigors of hydrogen-fuelled cooking. This success builds confidence in hydrogen's suitability as a fuel for the catering industry and marks a step forward in diversifying fuel sources for commercial kitchens.

2. **Ensuring Seamless Installation and Compliance of Metering Products**

Installation processes for hydrogen metering products adhered closely to IGEM 'H' standards, achieving consistent performance under hydrogen conditions. This validation establishes a benchmark for hydrogen metering systems, ensuring that these products meet high industry standards. The project's success in this area demonstrates National Gas's ability to maintain safety and regulatory compliance in hydrogen applications, with potential for scaling in similar environments.

3. **Providing Actionable Insights for Product and Safety Standards**

The project generated valuable feedback on appliance and meter installations, aligning closely with IGEM standards and identifying areas for improvement. Insights from testing highlighted both the strengths and limitations of current hydrogen-compatible products, providing direction for future product developments and refinements in safety and efficiency. These findings have proven essential in shaping practical, real-world standards that can guide broader industry use.

4. **Establishing Hydrogen as a Reliable Fuel Source**

Testing in a real-world kitchen environment has successfully demonstrated hydrogen's viability as a low-carbon fuel option. This accomplishment offers caterers an alternative to traditional fuels, encouraging the decarbonisation of commercial kitchens. By proving hydrogen's reliability and practicality, the project has set a compelling precedent for small commercial settings to consider hydrogen as part of their energy mix.

5. **Engaging Key Stakeholders to Showcase Viability**

National Gas leveraged the facility to host demonstrations for major industry players, including hospitality leaders, showcasing hydrogen as a viable and advantageous alternative to electricity. This engagement has fostered interest and support within the industry, encouraging a broader shift towards hydrogen-powered solutions in the catering sector. Images from the day are shown below.

Figure 22 – photos from the network event on the 18th of September 2024, Food from the hydrogen kitchen (top left), cooked by the excellent Shaune (top right), attendees seeing the kitchen in action (bottom left) and networking in the breakout room (bottom right)

8. Conclusion

The Hydrogen Commercial kitchen at Tyseley Energy Park has successfully demonstrated that hydrogen can be a safe, efficient, and viable fuel for the commercial catering sector. Through rigorous testing and innovative design, the facility has validated the performance of hydrogen-compatible appliances and metering systems while addressing the unique safety and operational challenges posed by hydrogen as a fuel.

This project has gone beyond proving technical feasibility; it has created a blueprint for industry-wide adoption. By leveraging existing natural gas standards and developing interim safety measures, the initiative has bridged critical gaps in competencies, standards, and supply chain readiness. The findings are already starting to inform informed best practices, shape future standards, and highlighted key areas for further development.

The hydrogen kitchen is more than a testbed; it is a catalyst for change. It showcases hydrogen's potential to decarbonise commercial kitchens, provides actionable insights for scaling up hydrogen use, and strengthens stakeholder confidence in adopting hydrogen as a mainstream energy solution.

Building on the successes of the Hydrogen Commercial kitchen initiative, the following recommendations can guide future efforts to expand hydrogen adoption in the commercial catering sector and beyond:

1. **Refinement of Standards and Competencies**
   - Develop formal certification and training programs to address the current gap in hydrogen-specific engineering competencies.
2. **Expanded Testing and Validation**
   - Conduct further testing under diverse operational conditions, including varying hydrogen purity levels, appliance configurations, and load profiles.
   - Explore emissions impacts, particularly NOx and water vapour production, to refine environmental and culinary performance assessments.
3. **Product Development and Supply Chain Innovation**
   - Work with manufacturers to accelerate the development of hydrogen-compatible components such as regulators, valves, and meters.
4. **Scaling the Concept**
   - Pilot hydrogen kitchens in varied commercial settings, such as schools, hospitals, and restaurants, to showcase adaptability and gather real-world data.
   - Investigate the integration of hydrogen kitchens with other renewable technologies, such as on-site solar generation and battery storage.
5. **Stakeholder Engagement and Education**
   - Continue hosting demonstrations and workshops for decision-makers in the catering and energy sectors to build confidence in hydrogen as a viable alternative fuel.
   - Launch educational campaigns to raise awareness of hydrogen's benefits among end-users, including chefs and facility operators.
6. **Exploration of Alternative Applications**
   - Expand testing to non-catering uses, such as industrial kitchens, food processing facilities, and combined heat and power systems, to explore hydrogen’s versatility.
   - Investigate the potential for integrating hydrogen into broader decarbonisation strategies, such as local hydrogen networks and virtual pipelines.

By pursuing these recommendations, National Gas and its partners can sustain their leadership in hydrogen innovation, unlocking new opportunities to decarbonise commercial operations and contribute to the transition to a low-carbon economy.

Moving forward, the focus must remain on expanding testing parameters, refining standards, and fostering collaboration across industry stakeholders. By continuing this trajectory, National Gas and its partners will remain at the forefront of the hydrogen revolution, driving innovation and setting new benchmarks for sustainable energy in commercial applications.

Appendix 1: Testing Timeline

Test Category	Components	Test Type and Description	What standard is this aligned to	Date	Data to be Captured	Value (how will this impact our business or industry)
Product Testing	Hydrogen Domestic Meters	• Material suitability • Performance - tightness testing, operation, logical tests, connectivity to other equipment • Software test - AMR Connectivity	BS 6400, IGEM/H2, BSI PAS444	30 September 2024	• Design feedback on operation and engineer use. • Does it meet the standards? • Ease of assembly • Quality assessment (joints made correctly, quality of threads etc)	Technical assessment test. It gives us an idea of which manufacturer meter works best for our operational needs, assuming the price is suitable
	Hydrogen Commercial Meters		GM/8, GM/6, IGEM/H2, BSI PAS444	30 September 2024		
	LP Regulators	• Gas tightness • Performance • Lock-up test. • Aging and mechanical life • Torsion and bending test. • Accuracy testing	GM/8; BS EN 334	31 July 2024	•Setpoint accuracy •Response time •Longevity •Environmental resistance (how to reacts external environment)	Cross product testing will inform NGM approved products and industry product gaps.
	MP Regulators			31 July 2024		Cross product testing will inform NGM approved products and industry product gaps.
	MP Slam shuts	• Closing behaviour • Gas tightness	GIRS/V9, BS EN 14382	30 November 2024		Cross product testing will inform NGM approved products and industry product gaps.
	Valves	• Gas tightness • Sealing test		31 July 2024	•Pressure containment, •Seal accuracy, •Longevity •Environmental resistance	Cross product testing will inform NGM approved products and industry product gaps.

	EFV	•Gas tightness •Material suitability •Leak tightness •Pressure drops •Closing behaviour •Torsion and bending	IGEM/G/5	31 August 2024	•Accuracy •Temperature impact •Jointing Compatibility	Determine suitability for domestic/industrial application, and drive innovation from supply chain.
	Pipework Materials & Fittings	•Material suitability •Resistance against internal pressure •Validating copper fittings	BS 6400, UP/1, UP/1B, UP/2, UP/16	31 August 2024	•Pressure containment, •Seal accuracy, •Longevity •Environmental resistance	Test industry standards and provide industry best practice.
	Joint types & Materials	• Material suitability • Leak tightness		30 September 2024		
	Appliance Testing by Falcon	TBC by Falcon		30 September 2024		
Engineering study	Legacy Domestic Meters	•Material suitability •Performance - tightness testing, operation, logical tests, connectivity to other equipment •Software test - AMR Connectivity •Condition assessment (what conditions we consider can be repurposed in alignment with the H-standards), •Collaboration with manufacturers to know what they deem acceptable and other tests on material impact beyond visual tests	BS 6400	30 September 2024		Understand if the legacy/gas meters will work on hydrogen and see if it can be repurposed. Data received will help make recommendations on changes that may be required. For domestic, it will help us understand if we can connect with AMR
	Legacy Commercial Meters		GM/8, GM/6	07 October 2024		
	Safety Systems	•Testing configurations for safety systems including ventilation and metering installation design. •Dispersion test (proving the ventilation using smoke to confirm the dispersion rate of hydrogen for a given amount of hydrogen in relation to the ventilation provided) •Performance testing (do they go off when they need to) •Try other equipment managers. •Manage scaling back overengineered sections when we prove they are not needed (understanding what is required to get this done)	IGEM /UP/16 & DW172	31 October 2024	• NOx volume data • CO emissions, • Ventilation requirements, • Effects of long-term operation • Sensor’s accuracy	Test industry standards and provide assessment of available suitable products whilst driving innovation in the hydrogen market.

	TCO - Thermal Cutoffs	Temperature tests - testing what temperatures at which the TCO get triggered and how long the shutoff lasts	IGEM/G/5	30 November 2024	• Temperature accuracy • Seal accuracy (when it activates does it shut off the gas supply) • Sealing time (time of fire proofness fire containment time)	Check suitability of this as a safety system. Drive industry innovation and test standards detail around such products.
	Hazardous Area Assessments	Test against standards	IGEM, DSEAR	30 November 2024	Development work around standardizing hazard area drawings for DSEAR assessments	Test industry guidance and standards and where applicable highlight how we mitigate against gaps in the standards in practical applications
	Labelling requirements	•Identify additional labelling requirements if applicable. •Confirming labels are in the right wording and colours. •Performance of the labels (waterproof, opportunity to make the labels better and choose different materials where possible)	GM/8	30 November 2024	Standard for domestic and commercial labelling for hydrogen	Help drive standardisation of labelling for hydrogen installations, with minimum requirements best practice.
	Flow and pressure drop testing	Whole system test for flow and pressure configuration – this is to test for pressure losses across the entire system and individual components and ensuring they meet the standards	PAS 444, IGEM H standards 1/2/3, BS 6400, GM/8, GM/6	30 November 2024	Pressure drop analysis for each component and whole system, across multiple flow rates and pressures.	• Identify gaps in product availability • Make recommendations on the components in the whole system approach (identifying what is needed and what isn't or what is missing)

Appendix 2 – Standards document reference

Document Reference	**Document Title**
IGEM H/1	Reference standard for low pressure hydrogen utilisation
IGEM/H/2	Hydrogen enabling standard domestic
IGEM/H/3	Hydrogen enabling standard non-domestic
IGEM/G/5 Edition 3	Gas in multi-occupancy buildings
IGEM/GM/6	
IGEM/GM/8 Pt 2 Edition 2	Non-domestic meter installations Location, housings and compounds
IGEM/GM/PRS/1	Meter installation fittings
IGEM/UP/1 Edition 2	Strength testing, tightness testing and direct purging of industrial and commercial gas installations
IGEM/UP/2 Edition 3	Installation pipework on industrial and commercial premises
IGEM/UP/16 Edition 2 with amendments	Hazardous area classification of installations using Hydrogen or blends of up to and including 20% by volume Hydrogen in Natural Gas
IGEM/UP/1B Edition 3	Tightness testing and direct purging of small liquified petroleum gas/air, natural gas and liquified petroleum gas installations
IGEM/SR/25 Edition 2 with amendmants 2013 Hydrogen supplement 1	Hazardous area classification of installations using Hydrogen or blends of up to and including 20% by volume Hydrogen in Natural Gas

ASTM B813-16	Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
ASTM 269-316	Stainless stell tube seamless
BS 6400 Pt 1	Specification for installation, exchange, relocation, maintenance and removal of gas meters with a maximum capacity not exceeding 6 m³/h. Low pressure (2nd family gases)
BS EN 331	Manually operated ball valves and closed bottom taper plug valves for gas installations for buildings
BS EN 334	Gas pressure regulators for inlet pressure up to 10 MPa (100 bar)
BS EN 1057	Copper and copper alloys. Seamless, round copper tubes for water and gas in sanitary and heating applications
BS EN 15266	Stainless steel pliable corrugated tubing kits for gas installation pipework with an operating pressure up to 0,2 MPa (2 bar)
BS EN 29454	Soft soldering fluxes. Classification and requirements
BS EN 751-3	Sealing materials for metallic threaded joints in contact with 1st, 2nd and 3rd family gases and hot water - Unsintered PTFE tapes and PTFE strings
BS 6956-5	Jointing materials and compounds - Specification for jointing compounds for use with water, low pressure saturated steam, 1st family gases (excluding coal gas) and 2nd family gases

BS EN 14382	Gas safety shut-off devices for inlet pressure up to 10 MPa (100 bar)
BS EN 14236	Ultrasonic domestic gas meters
BS EN 1552	Specification for open bottomed taper plug valves for 1st, 2nd and 3rd family gases up to 200 mbar
PAS 4441	Components used in hydrogen gas metering (specifaction)
PAS 4442	Material requiremetns for pipework and fittings used in hydrogen gas installations (specifaction)
PAS 4443	Assessment Criteria: Ancillary valves, devices and components used in hydrogen gas installations
PAS 4444	Hydrogen-fired gas appliances (guide)
OIML R137	The International Organisation of Legal Metrology (gas meters)
SMETS 2	Smart Metering Equipment Technical Specifications Version 2
GIS/F7	Specification for steel welding pipe fittings 15mm to 450mm inclusive nominal size for operating pressures not greater than 7 bar
GIS/V6	Steel valves for use with natural gas normal operating pressure above 7 bar and sizes above DN15