Hydrogen Flow Calibration Facility for Domestic Gas Meters

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Content

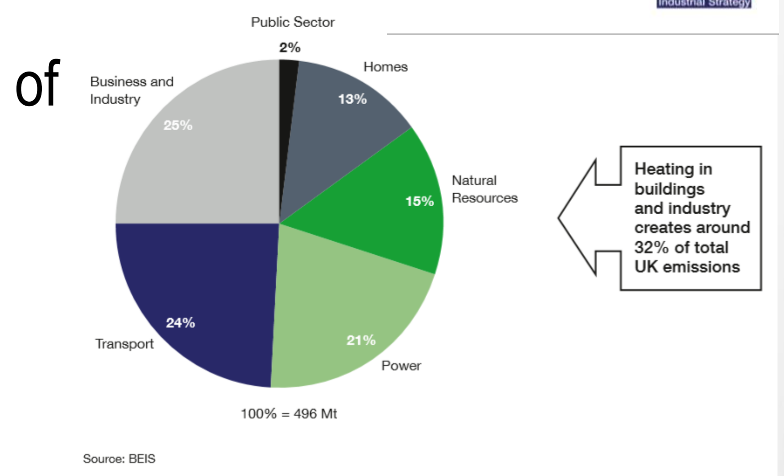
Background

- Drivers for reaching net zero CO_2 emissions
  - Paris Agreement (COP21): Aims to limit global temperature increase to well below 2°C, aiming for 1.5°C
  - Renewable Energy Directive (RED I, RED II): Mandates levels of renewable energy use for individual countries within the EU
  - European Green Deal: Set of policies with overarching aim of making Europe climate neutral by 2050
  - Climate Change Act: Ensure that the net UK carbon account for the year 2050 is zero

Background

- UK Perspective
  - The UK Government Clean Growth Strategy (2017) recognizes
    - The role of electrification (solar, wind, LEVs, heat pumps)
    - The role of biomass and bioenergy
    - The role of hydrogen
    - The role of carbon capture, utilization and storage
  - Huge potential for reducing emissions through decarbonization of heat
    - 32% of total emissions attributed to heating in buildings and industry

Figure 2: UK emissions by sector, 2015[27]



Background

- Decarbonisation of heat
  - Essential if the UK is to meet its ambitious climate target of net zero emissions by 2050
  - Use of alternative gases to natural gas; such as hydrogen; will likely play a key role in this
  - Hydrogen pathway proposes introducing hydrogen to UK gas networks
    - Hydrogen pathway proposes introducing hydrogen to UK gas networks
    - Repurpose existing gas infrastructure and work force
    - Minimise disruption for end users
    - Provide buffer capacity for renewable electricity

Background

- UK Demonstration projects
  - Several UK demonstration projects are considering the use of hydrogen for home heating
  - and more!
  - The projects primarily focus on safety, technical feasibility, public acceptance etc.
  - But there is a recognition that the gas meter performance is not know:
    - with pure hydrogen
    - with hydrogen and natural gas blends

Background

- Fluid property implications, replacing natural gas with hydrogen
  - Decreasing calorific value. 40 MJ/m^3 vs. 12.7 MJ/m^3
    - 3X increase in flow rate required for same energy density with pure hydrogen 6 → 20 m^3/hr
    - Existing flow meters over-ranged
    - Possible measurement errors
    - Increased wear/failure of mechanical meters

4 Normal operating conditions

4.1 Flow range

The values of maximum flow rates and those corresponding values of the upper limits of the minimum flow rates shall be those given in Table 1.

Table 1 — Flow range

Q_{max} m³/h	Upper limits of Q_{min} m³/h
2,5	0,016
4	0,025
6	0,040
10	0,060

Ref: BS EN 14236:2018 – Ultrasonic domestic gas meters

Background

- Fluid property implications, replacing natural gas with hydrogen
  - Lowest Gas Density, 8X lower than CH_4
    - ρN_2 = 1.2 kg/m^3
    - ρCH_4 = 0.66 kg/m^3
    - ρH_2 = 0.08 kg/m^3
  - High speed of sound, 3X higher than CH_4
    - cN_2 = 349 m/s
    - cCH_4 = 445 m/s
    - cH_2 = 1304 m/s

A.1 General

Ultrasonic domestic meter technology has been designed almost exclusively for use on second family gases, although it is feasible to use it to measure gases of the other families as well. The meters are typically designed to operate on gases with speeds of sound in the range 300 m/s to 475 m/s.

A.2 Test gas properties

The physical properties of a gas which can change due to variations in gas composition and which are most likely to influence the performance of ultrasonic domestic gas meters are:

Speed of sound range:	min.:	Air
	max.:	100 % CH_4 (with the exception of G 222 as defined in EN 437)
Attenuation:	min.:	Air
	max.:	94 % CH_4, 6 % CO_2 (100 % CH_4 has 3 dB lower attenuation and this level of CO_2 would not be tolerated in a distributed gas)
Viscosity:	min.:	70 % CH_4, 30 % C_2H_6 (100 % CH_4 is within 3 % of the same viscosity and will exercise this parameter sufficiently)
	max.:	Air
Density:	min.:	89 % CH_4, 11 % H_2 (100 % CH_4 is sufficiently close i.e. within 10 % to exercise this parameter)
	max.:	Air

Ref: BS EN 14236:2018 – Ultrasonic domestic gas meters

Background

- Domestic Gas Metering
  - Three meter types currently used:
    - Diaphragm: Errors from internal leakage, degradation of seal materials?
    - Ultrasonic: Speed of sound ranges, timing resolution?
    - Thermal Mass: Well suited for the change in fluid?
  - New test data is required to answer these questions:
    - Need meter test programme for pure hydrogen, and for blends
    - No existing calibration facilities are available
    - Choice and traceability of reference flow device?

Design of Calibration Facility

- Initially designed for pure hydrogen
  - NEL approached by gas network operator to support UK demonstration project
  - Sized for domestic gas meter range
    - Normally 6 m^3/hr at 1 bar, but allowed 20 m^3/hr for hydrogen
  - To calibrate meters to the accuracy requirements of the EU MID
    - MPEs of 1.0% or 1.5%

- Choice of flow reference was critical
  - Device well suited for low gas flow rates
  - Capable of low measurement uncertainty, target $\pm$0.3% at 95% confidence
  - Need a means of calibrating with hydrogen or demonstrating insensitivity to change in gas

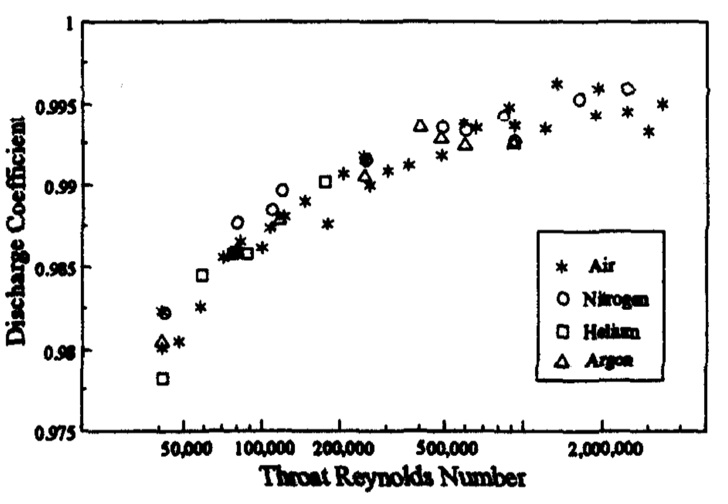
Design of Calibration Facility

- Reference flow device
  - Decided to use critical flow nozzles
  - Widely used secondary flow standard
  - Simple construction, gas is accelerated to sonic velocity at throat
  - Measure upstream T and P, calculate mass flow from thermodynamic properties
  - Very low measurement uncertainty (approx. $\pm$0.2% with air)
  - Available in wide range of sizes

NEL reference nozzles, throat diameters 1.25 to 16 mm

Design of Calibration Facility

- Reference flow device
  - Calibration with air transfers to other gases
  - Works for nitrogen, oxygen, hydrogen, helium, argon, methane, natural gas etc.
  - Does not work for CO_2 or SF_6 with small nozzle diameters



Ref: "Correlation of Hydrogen and Air Flow in Critical Flow Nozzles Part 1: Primary Calibration Facility", T. M. Kegel, CEESI 1992

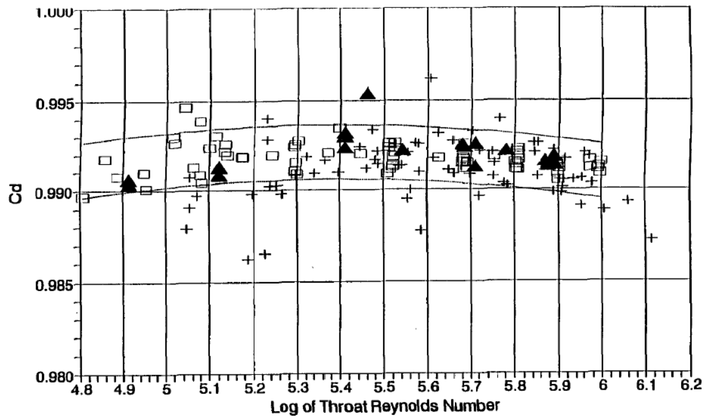


Figure 6. Comparison of hydrogen and air data for CFV 1134.
□ C H_2 Data, - - - t 95 S Limits, + C Air Data,
▲ B Air Data.

Ref: "Correlation of H_2, N_2, Ar and He and Air Flow in Critical Flow Nozzles", G. Corpron, CEESI 1995

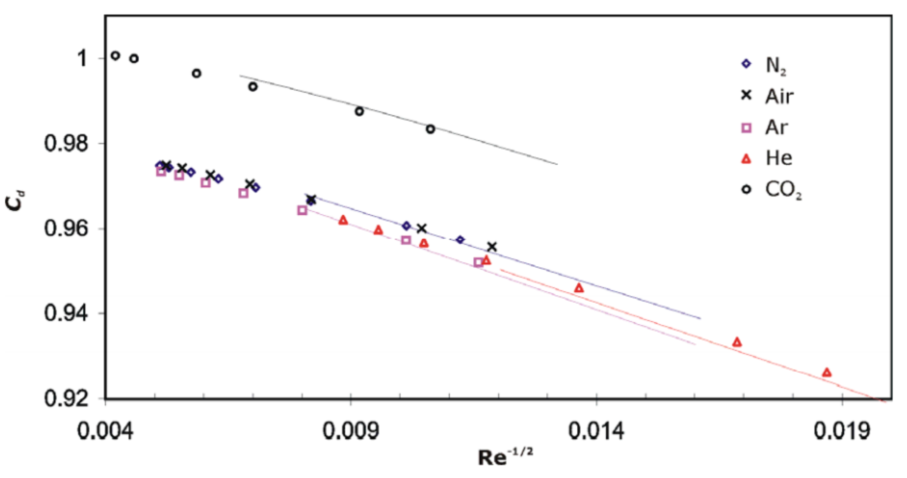
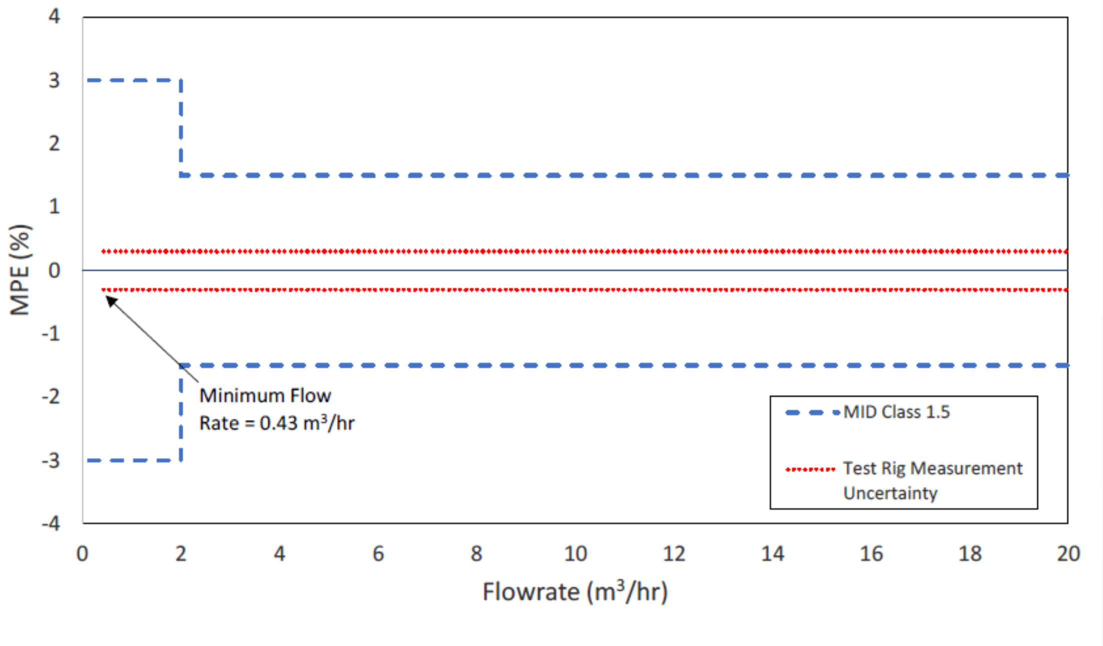


Figure 9. The discharge coefficient versus Reynolds number for various pure gases. Solid lines are fits to data of Nakao et al. (1997) and symbols are NIST data.

Ref: "What is the "best" Transfer Standard for Gas Flow" J. D. Wright, NIST 2003

Design of Calibration Facility

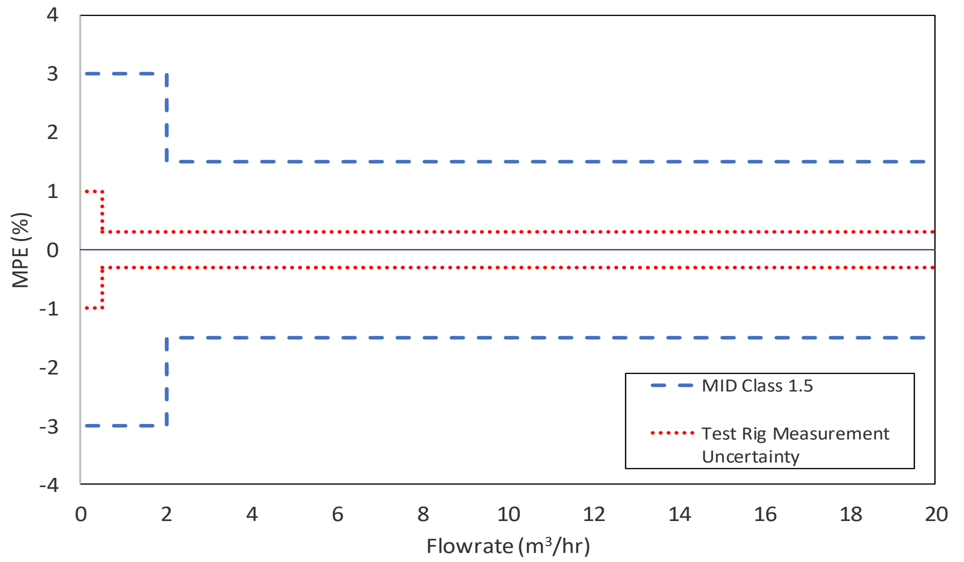
- Operating ranges
  - Designed for pure hydrogen, could also operate with nitrogen
  - Reference nozzles calibrated with air, target uncertainty 0.2% with nitrogen, 0.3% with hydrogen
  - Flow rates 0.43 to 38 m^3/hr at 1 bar (limited by minimum nozzle size)



Original Test Rig Operating Envelope 100% H_2

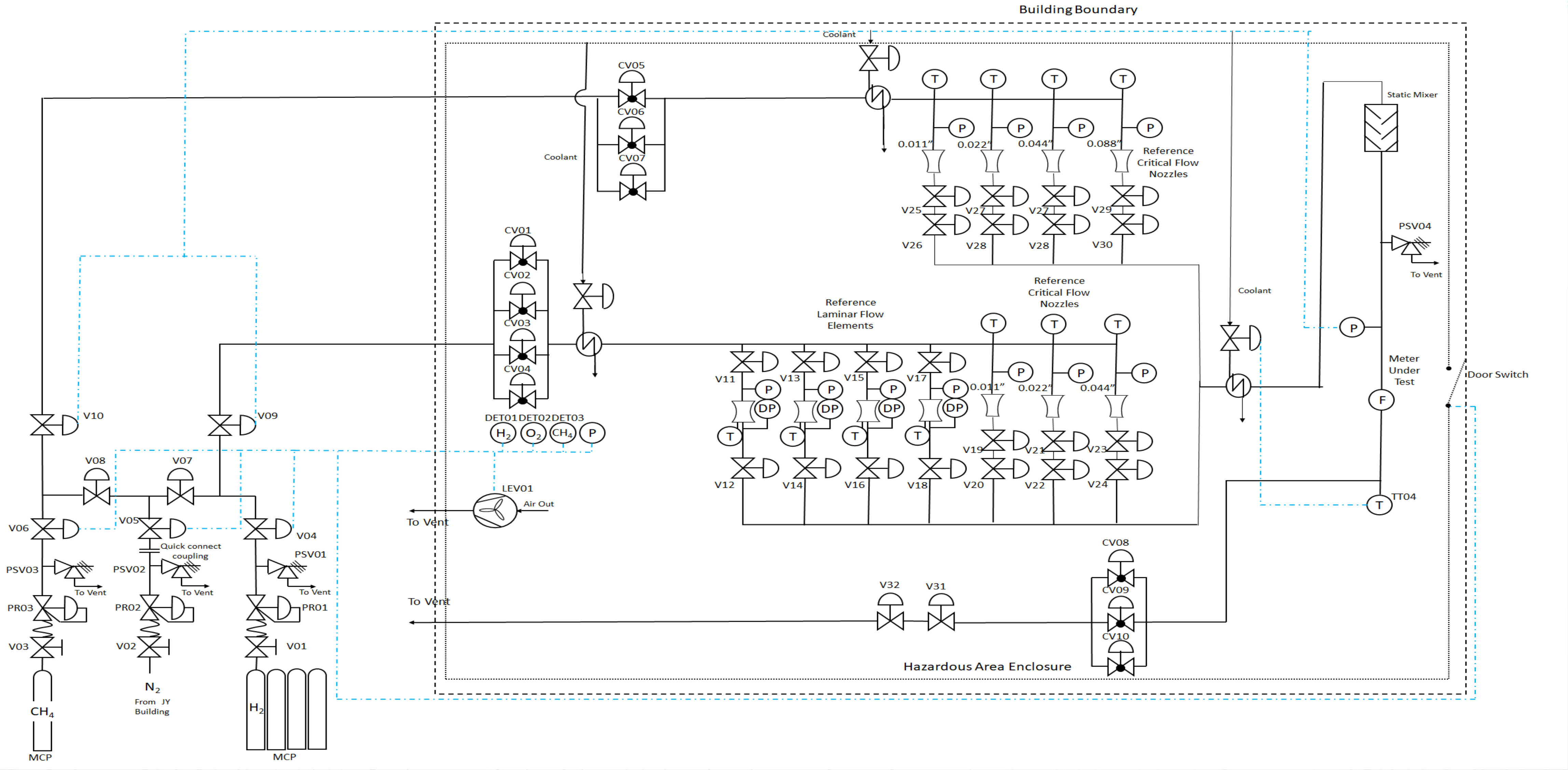
Design of Calibration Facility

- Operating ranges (revised)
  - Design was revised to allow testing with mixtures (H_2 with CH_4 or N_2)
  - Flow rates 0.1 to 38 m^3/hr, 0 to 100% H_2
  - Critical flow nozzles used for H_2, N_2, CH_4
  - Laminar flow elements used for H_2 flowrates below 0.5m^3/hr
    - Calibrated with H_2, estimated uncertainty 0.5 – 1%
  - Build and commission Q3/Q4 2020



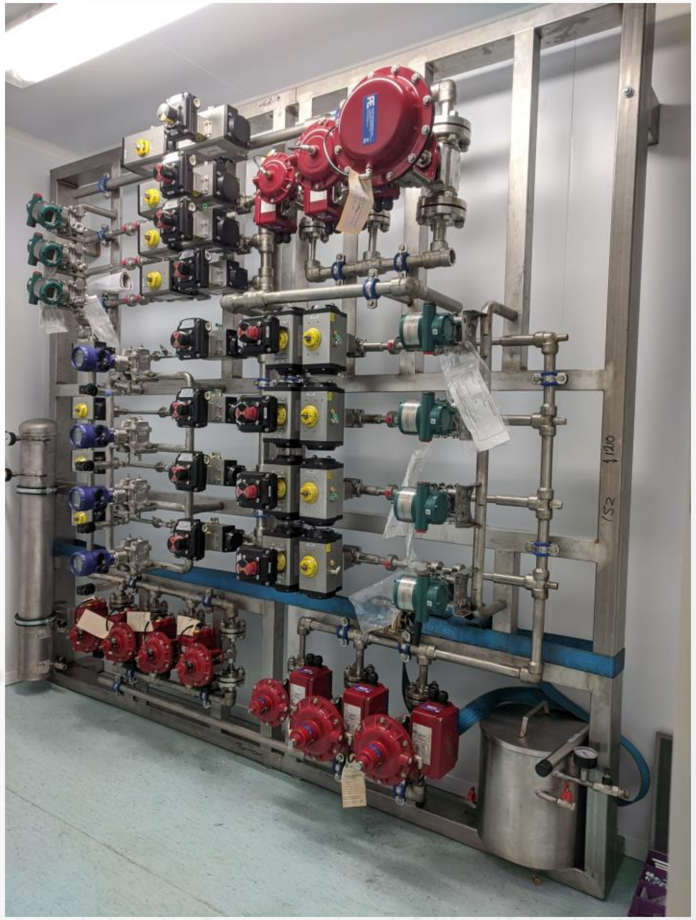
Revised Test Rig Operating Envelope 100% H_2

Design of Calibration Facility



Progress to Date

- All equipment, instrumentation received
- Hazardous area enclosure constructed
- Reference Metering sections built
- Installation of gas bottle station in progress
- Electrical connections in progress
- Commissioning in November, followed by test programme for domestic gas meters, hydrogen/methane blends



Planned Activities

- UK H_2 demonstration project (Q4 2020/Q1 2021)
  - Testing domestic gas meters with H_2 blends
- EMPIR NEWGASMET (2021)
  - Testing domestic gas meters with pure H_2
  - Facility intercomparison with PTB, VSL, CMI, MeterSit using N_2, H_2, CH_4
- NEL internal projects (2021/2022)
  - Building a hydrogen primary flow standard
    - Reduce facility uncertainty, improve traceability
  - Test programme for various meter types
    - e.g. Coriolis, turbine, DP, with pure H_2 & blends

NewGasMet

http://newgasmet.eu

NORTH SEA FLOW MEASUREMENT WORKSHOP
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