EMPIR
EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

MetHyInfra

EMPIR CALL 2020

Metrology infrastructure for high-pressure gas and liquified hydrogen flows

20IND11

Hans-Benjamin Böckler

Presenting EMPIR

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

- EMPIR = European Metrology Programme for Innovation and Research
- Implemented by EURAMET (European Association of National Metrology institutes)
- It is about improving measurement to drive innovation and competitiveness
- Based on Article 185 of the Lisbon Treaty
- Part of the European Research and Innovation Programme Horizon 2020
- Duration: 10 years with 7 calls launched from 2014 to 2020
- Jointly funded by the EMPIR participating countries and the European Union (budget ~ 600 M€ over 7 years)
- It enables the collaboration of European metrology institutes (EURAMET members), industrial organisations/research centres and academia on Joint Research Projects

internal

external

MetHyInfra

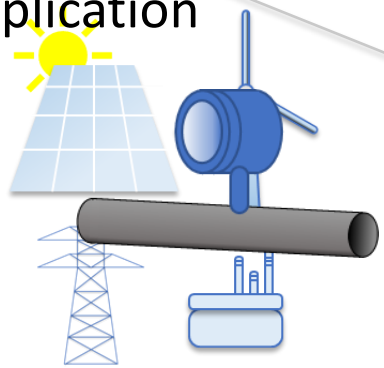
This project (20IND11 MetHyInfra) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

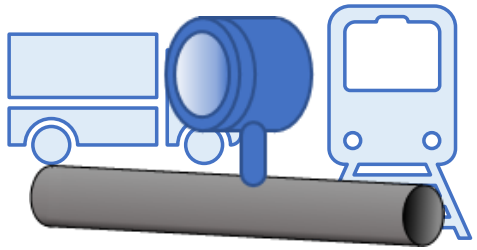
EMPIR EURAMET

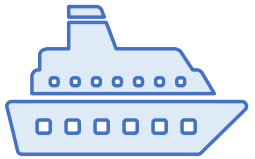
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Metrological need: Traceability Chain

primary standard
→ transfer standard
→ application







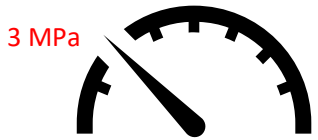
mobility

gene

ll

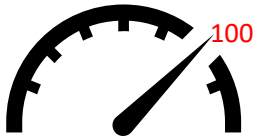
Calibration service

LH2



3 MPa

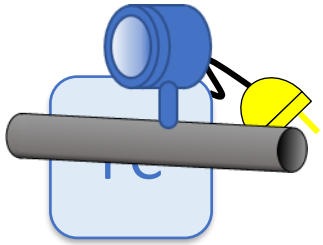
Middle pressure H2

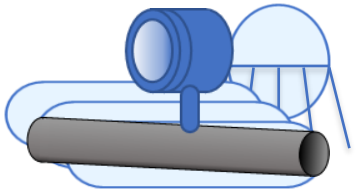


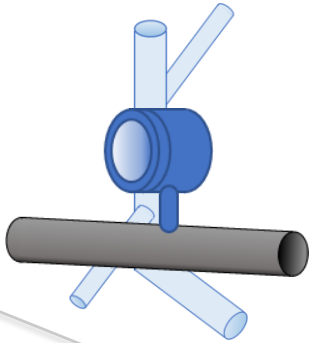
100 MPa

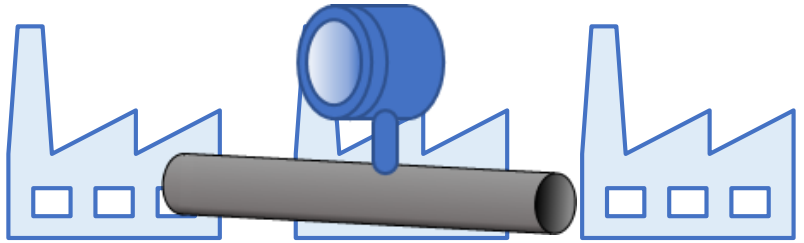
high pressure H2

sto



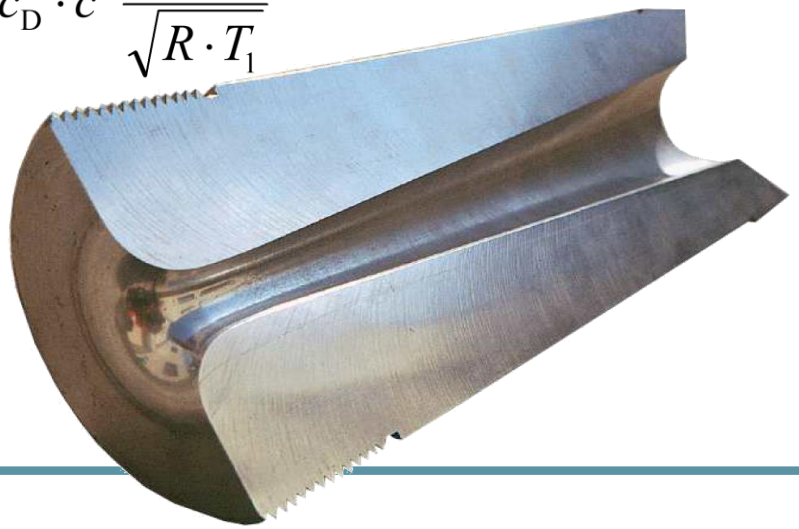






The Project

- Facts of CFVN
- Long term stability
- Well known
- Flow rate depends on
  - Dimensions
  - Kind of gas (SOS)
  - Real gas effects (c*)
- $Q_m = \frac{\pi}{4} d^2 \cdot c_D \cdot c^* \frac{p_1}{\sqrt{R \cdot T_1}}$

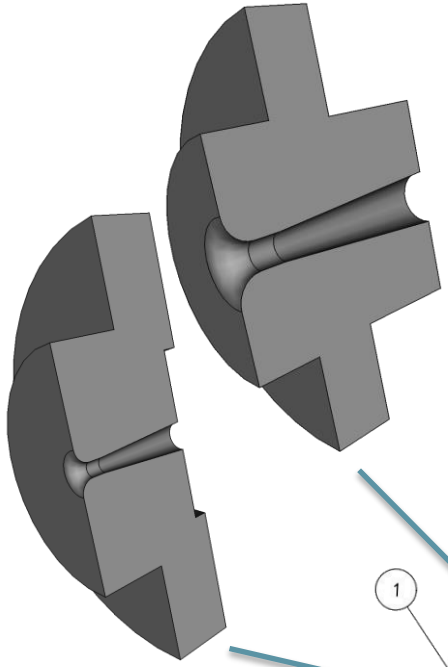


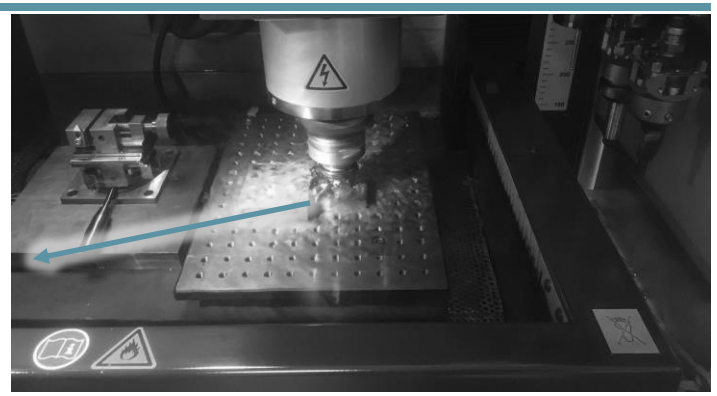
Work Packages (WP)

- WP1 High Pressure Measurement Hydrogen
  - WP-Leader: METAS, Switzerland
- WP2: Alternative Fluids
  - WP-Leader: Cesame, France
- WP3: Computational Fluid Dynamics (CFD)
  - WP-Leader: PTB, Germany
- WP4: Medium Pressure and Liquified Hydrogen
  - WP-Leader: VSL, Netherlands
- WP5: Impact
  - WP-Leader: RISE, Sweden

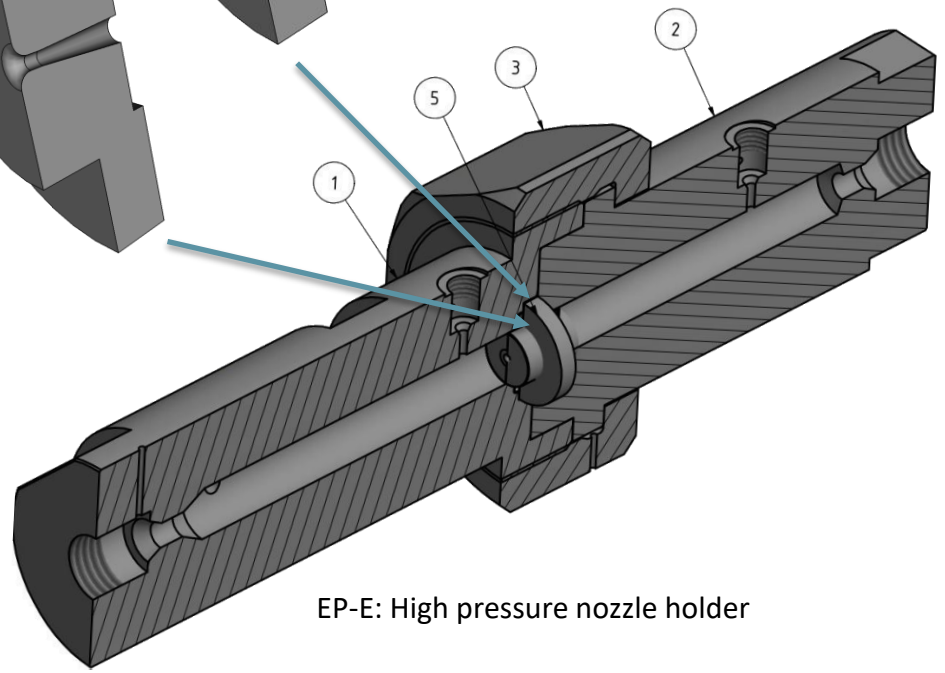
The Equipment

- Designing/ realisation of nozzle equipment
  - Nozzle set A
    - 2 nozzles for high pressure
    - 2 diameters and 2 shapes
  - Nozzle set B
    - 12 nozzles
    - 2 diameters, 3 roughnesses an 2 shapes (toroidal & cylindrical)
  - Nozzle holders
    - for high pressure





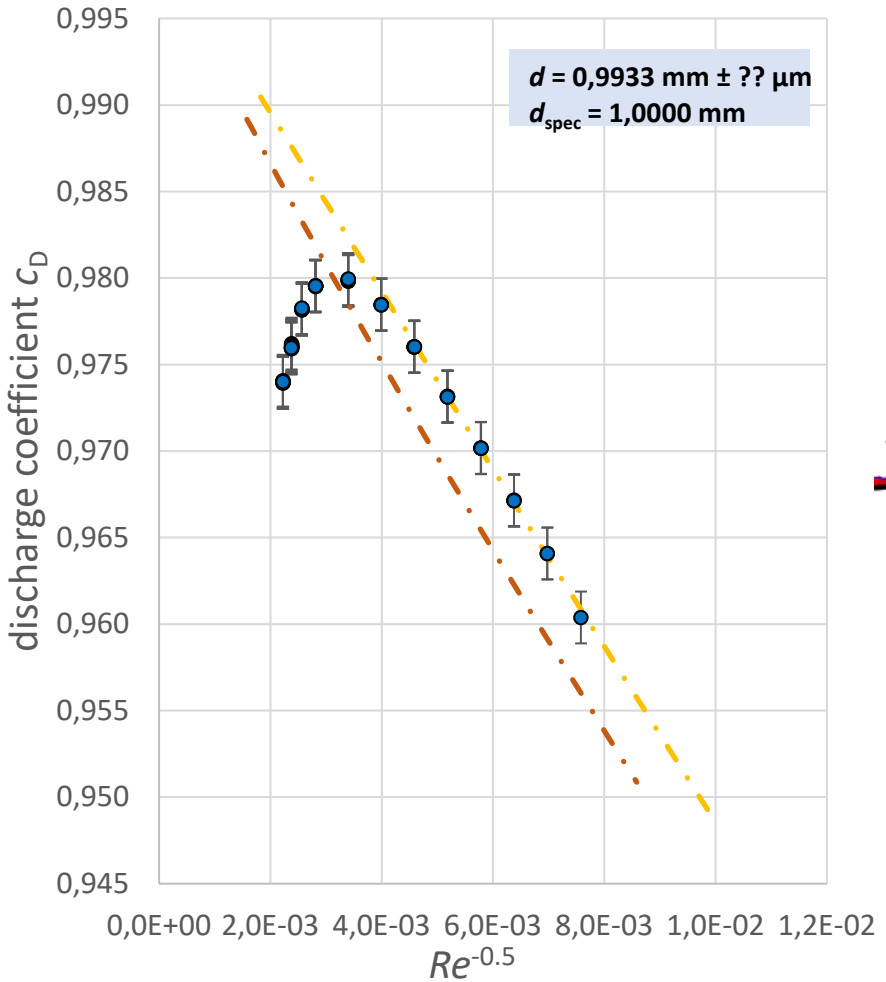
PTB: Nozzle production by electro-erosion machining



EP-E: High pressure nozzle holder

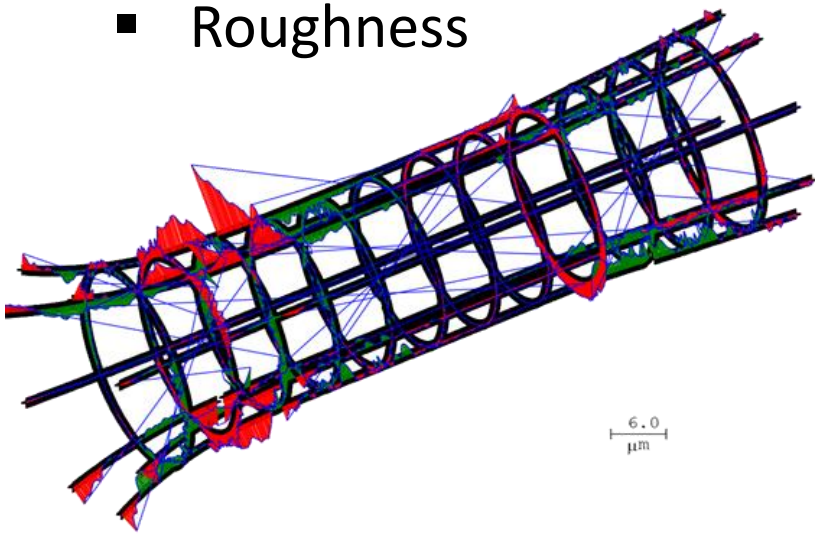
The Nozzles

- Prequalification



PTB: first tests on nozzle behavior

- Dimensional calibration
  - Inner shape
  - Roughness



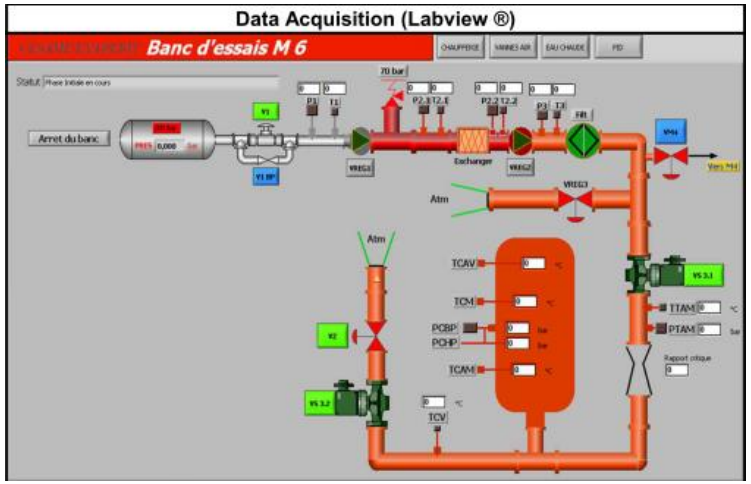
METAS: Dimensional calibration of CFVN

- A specific Equation of State (EoS) for high pressure hydrogen

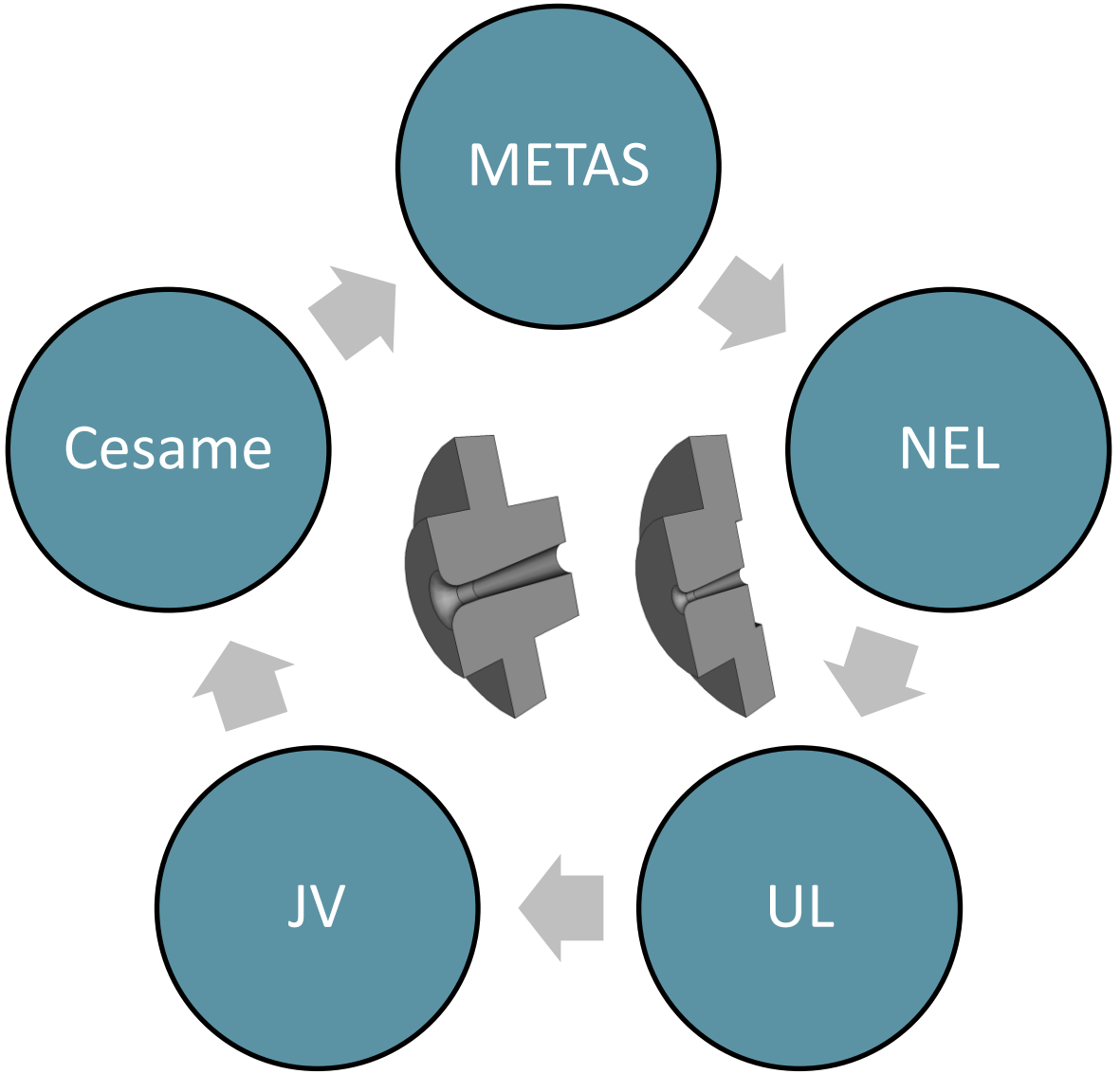
Imperial College London: ultrasonic cell and high-pressure vessel

Alternative Fluids

- Supplementary calibration of CFVN with alternative fluids
- Intercomparison of test rigs in use
  - With set B

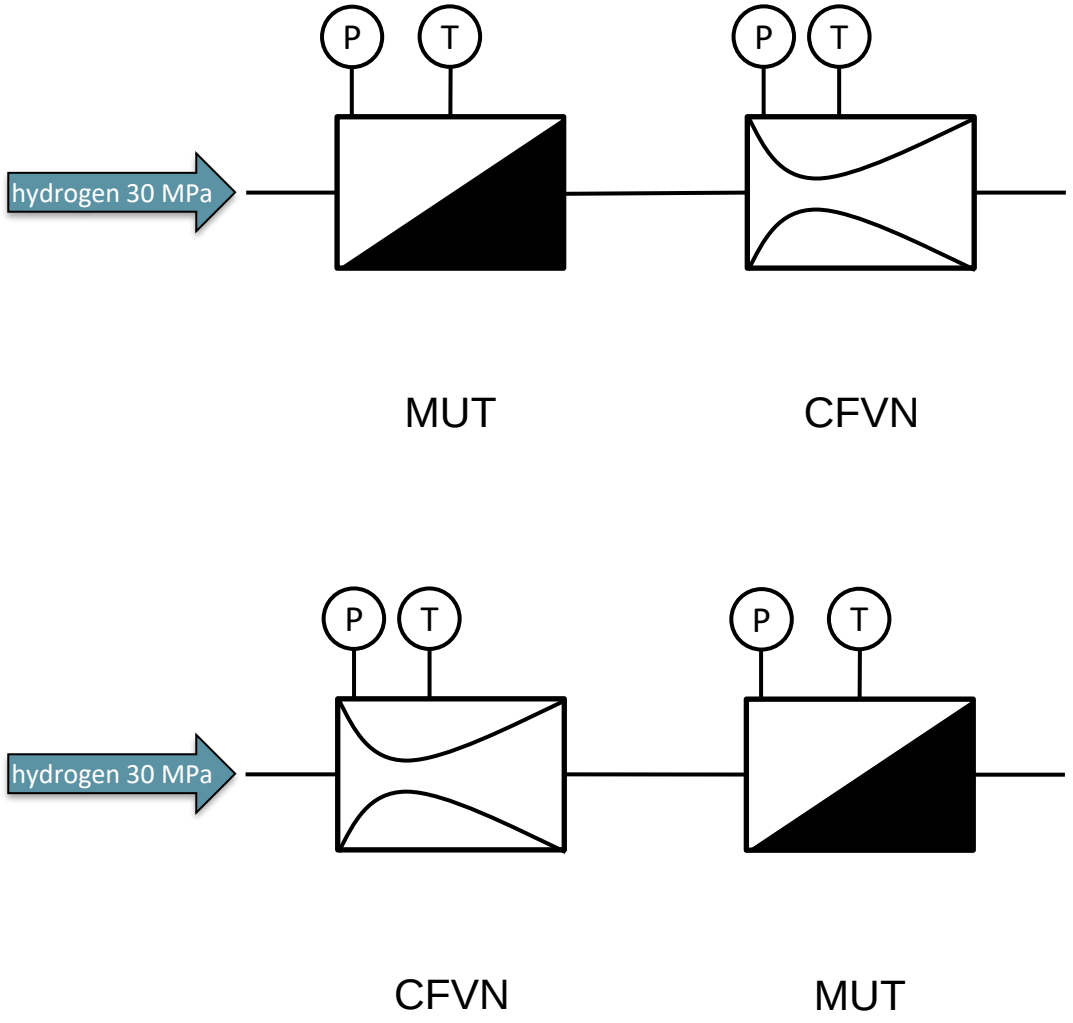


Cesame Exadébit: Primary nozzle calibration facility



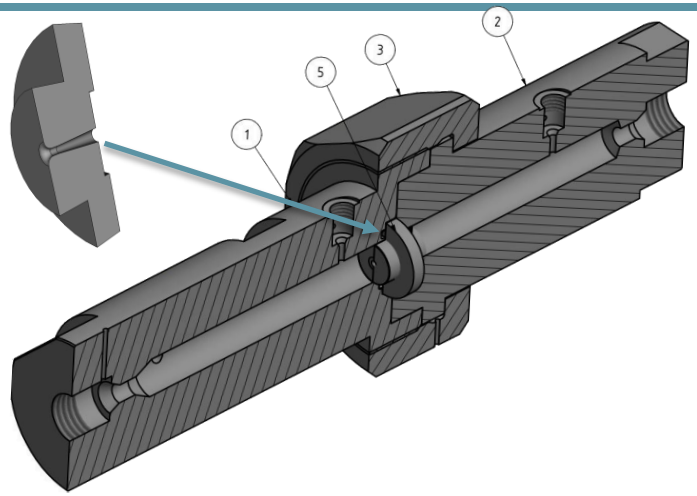
Calibration Facility for Hydrogen Flow Measurement

- Flow rate up to 4 kg/h at up to 3 MPa
- Calibration of meter under test (MUT) upstream or downstream of the nozzle
- MUT: Coriolis, thermal mass and ultrasonic types

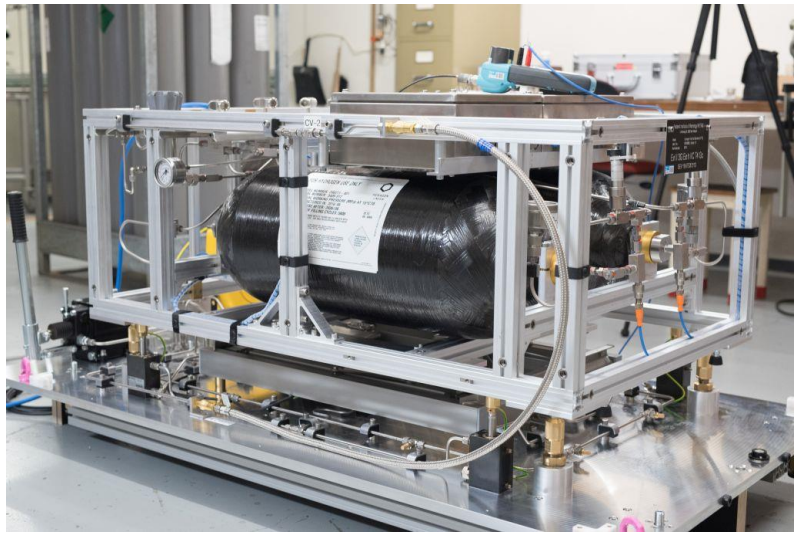


High Pressure Measurement

- High pressure calibration campaign
  - Calibrating a master meter
  - Using the master meter for CFVN calibration
- Goal: pressure up 80 MPa
  - Facility max pressure: 93 MPa
  - Certification of components: up to 105 MPa



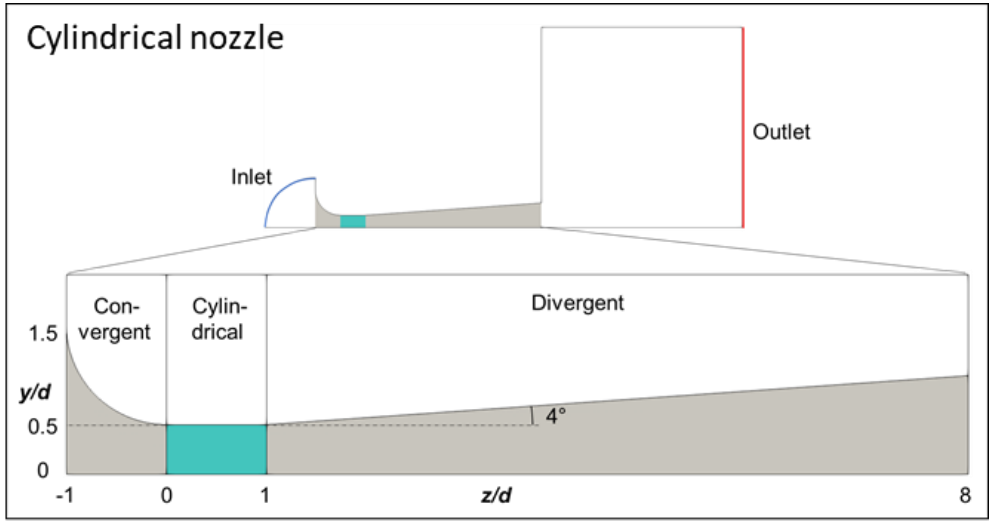
EP-E: High pressure nozzle holder



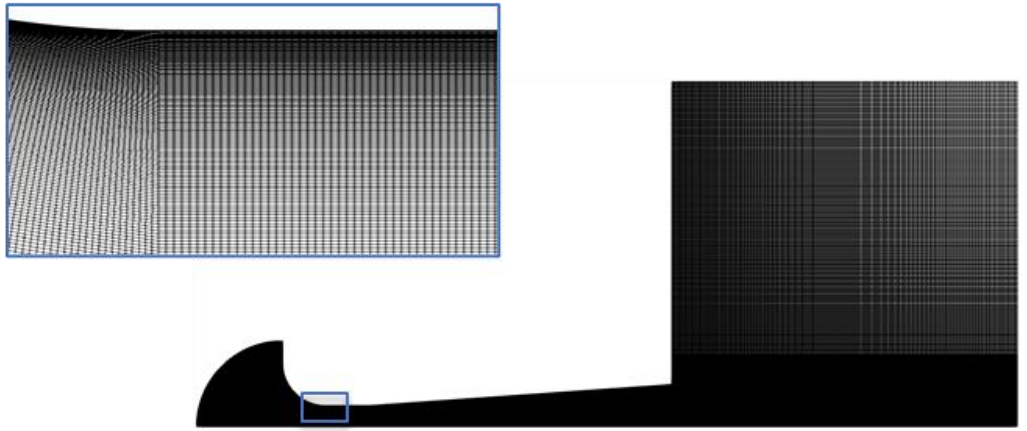
METAS: Gravimetric primary standard

Computational Fluid Dynamics (CFD)

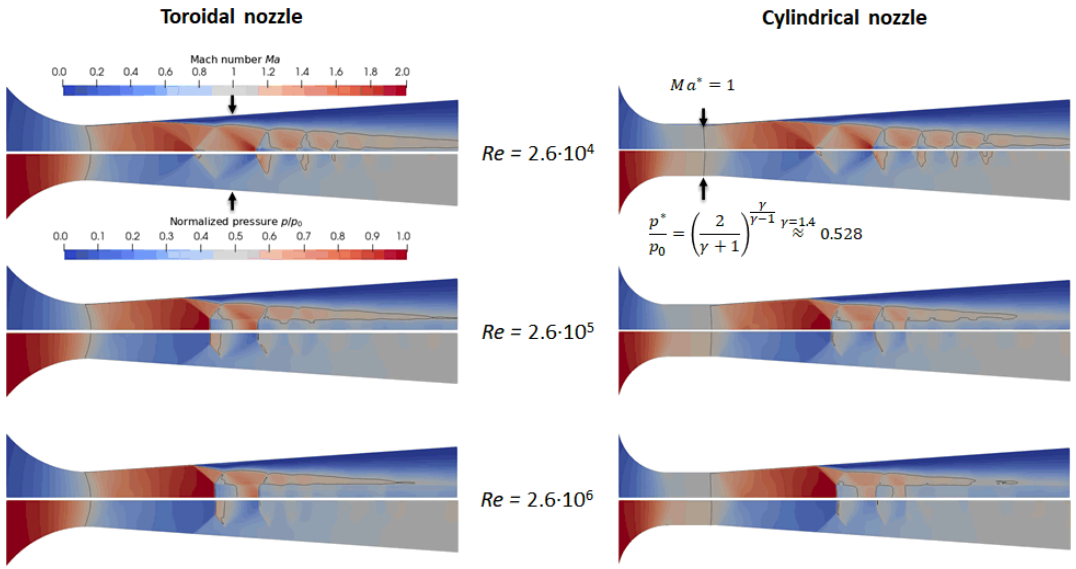
- Development of a CFD model for CFVN
- Extension to high-pressure
- Simulation of wall roughness and non-adiabatic wall influences
- Experimental check of selected simulation results



PTB: Geometrical model of a cylindrical nozzle according to ISO 9300

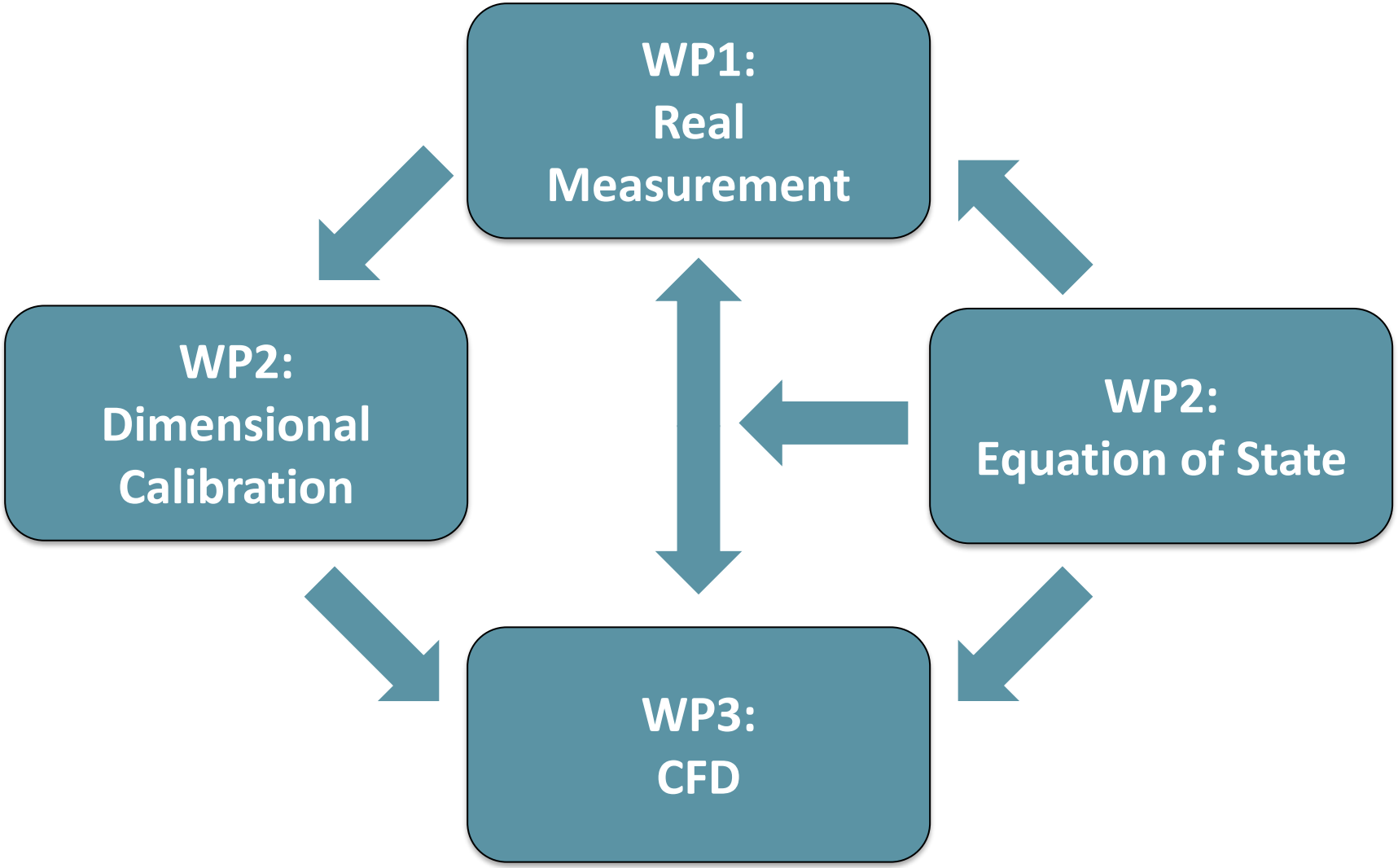


PTB: mesh with 350,000 hexahedral cells



PTB: first results

Comparing results



Liquified Hydrogen Flow Measurement

- Uncertainty model for liquified hydrogen measurement
- three-pronged approach:

1. assessment of transferability of water and Liquefied Natural Gas (LNG) calibrations to liquefied hydrogen conditions
2. cryogenic Laser Doppler Velocimetry (LDV) adapted to liquefied hydrogen flow applications
3. assessment of transferability of water, liquefied nitrogen, and liquefied helium calibrations in the vaporisation method to liquefied hydrogen conditions

1.

VSL's LNG Research and Calibration facility in the port of Rotterdam, the Netherlands.

2.

Cesame Exadébit: LDV cryogenic standard installed in ELENGY terminal

3.

PTB: vaporisation rig for small flow rates

Impact

Standardisation
- Input for: ISO TCs, CEN TC, OIML, WELMEC
- special focus: ISO 9300, ISO 5167, ISO 10790

Metrology
- Methods for the metrological analysis of measurement systems
- Fundamental scientific knowledge about nozzle hydrogen flow physics
- Validated equation of state for hydrogen based on experiments

Industry
- availability of measurement systems and methods for SI-traceable calibration of CFVNs and other flow meters in whole pressures up to 100 MPa
- Free CFD code including all applications
- Experimental SoS and equation of state
- CFVN calibration with alternative fluids or “dry calibration”
- Calibration service for liquified hydrogen

Environment
- decarbonise industrial processes

Dissemination
- Stakeholders: advisory board, collaborators, workshops, questionnaire, communication
- Presentations at international conferences and peer-reviewed journal publications
- Workshops for the industry, website, social media, tutorials, good practice guides, technical reports

Impact

Visit us:

https://www.linkedin.com/in/methyinfra-an-empir-project

https://www.methyinfra.ptb.de/the-project/

MetHyInfra

Hans-Benjamin Böckler

Physikalisch-Technische Bundesanstalt
Bundesallee 100
38116 Braunschweig

Telefon: 0531 592-1335
E-Mail: hans-benjamin.boeckler@ptb.de