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Metrology infrastructure for high-pressure gas and liquified hydrogen flows

Alternative fluid calibration

Gregor Bobovnik[1], Bodo Mickan[2], Peter Sambol[1], Rémy Maury[3], Jože Kutin[1]

[1] University of Ljubljana, Faculty of Mechanical Eng., Laboratory of Measurements in Process Engineering, Ljubljana, Slovenia
[2] PTB, Braunschweig, Germany
[3] CESAME-EXADEBIT, Poitiers, France

Introduction

- the idea is to use critical flow Venturi nozzles (CFVNs) as secondary standards (ISO 9300)
- identification of potential alternative gas in calibration of CFVNs used with hydrogen
- the ideal mass flow rate of the fluid through the nozzle is given by:

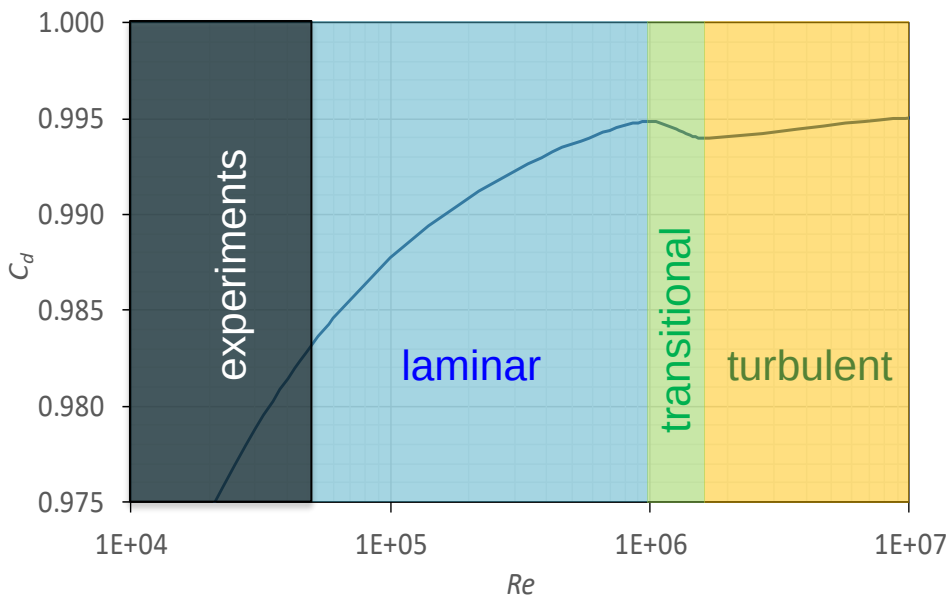
$$q_{m,id} = \frac{AC^* p_0}{\sqrt{R_m T_0}}$$

- the discharge coefficient

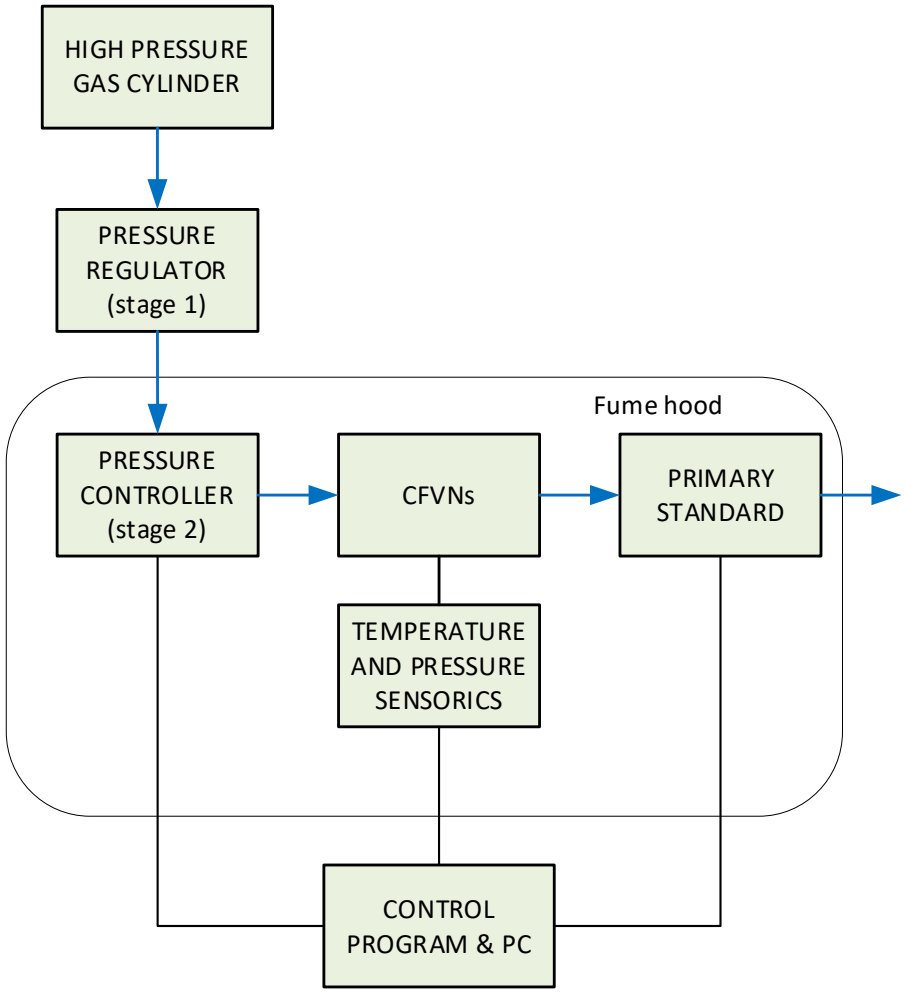
$$C_d = \frac{q_m}{q_{m,id}} \approx a\left(1 - \frac{b}{\sqrt{Re}}\right)$$

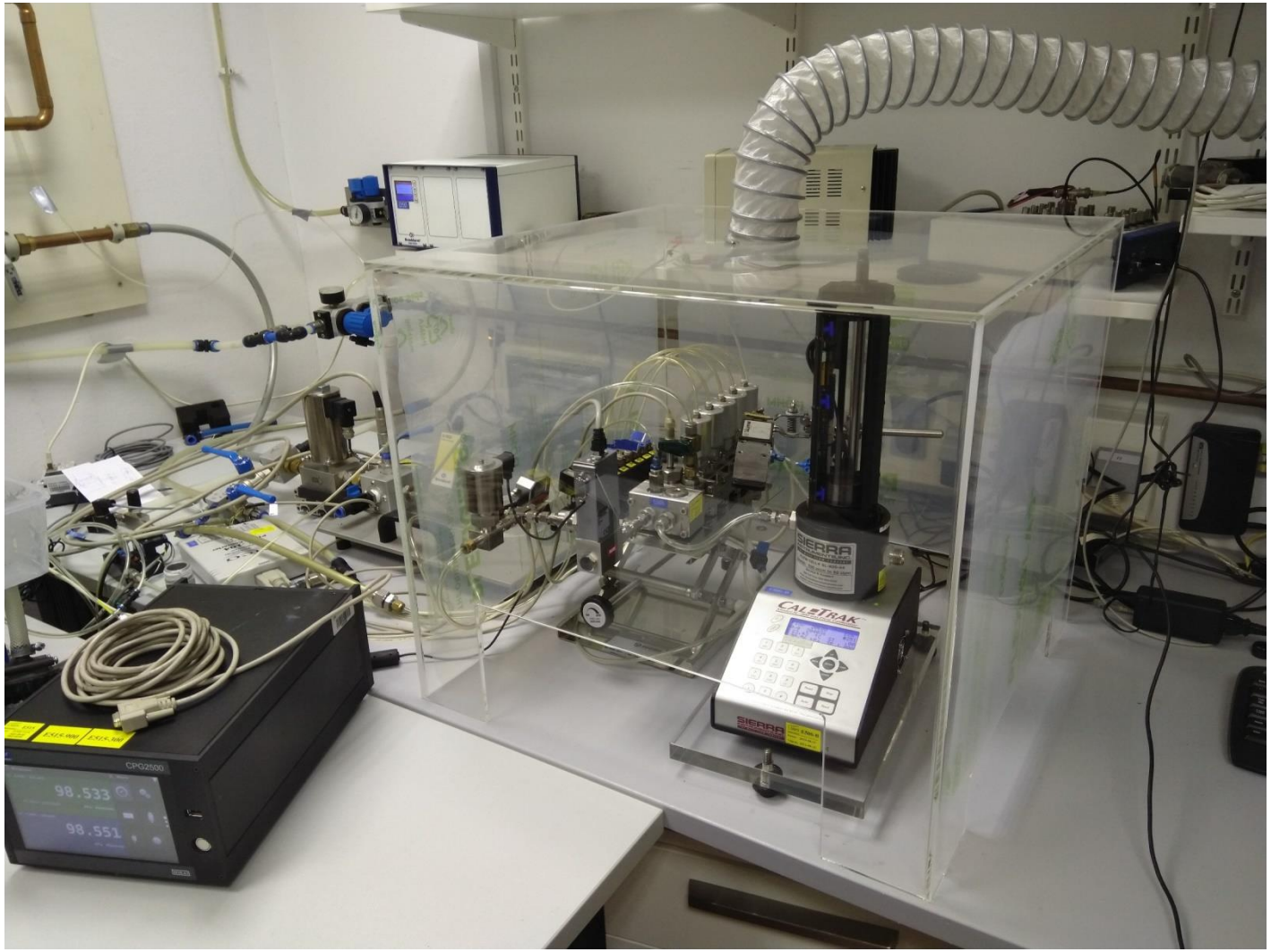
- ISO 9300 (toroidal nozzle):

a = 0.9985, b = 3.412 and n = 0.5

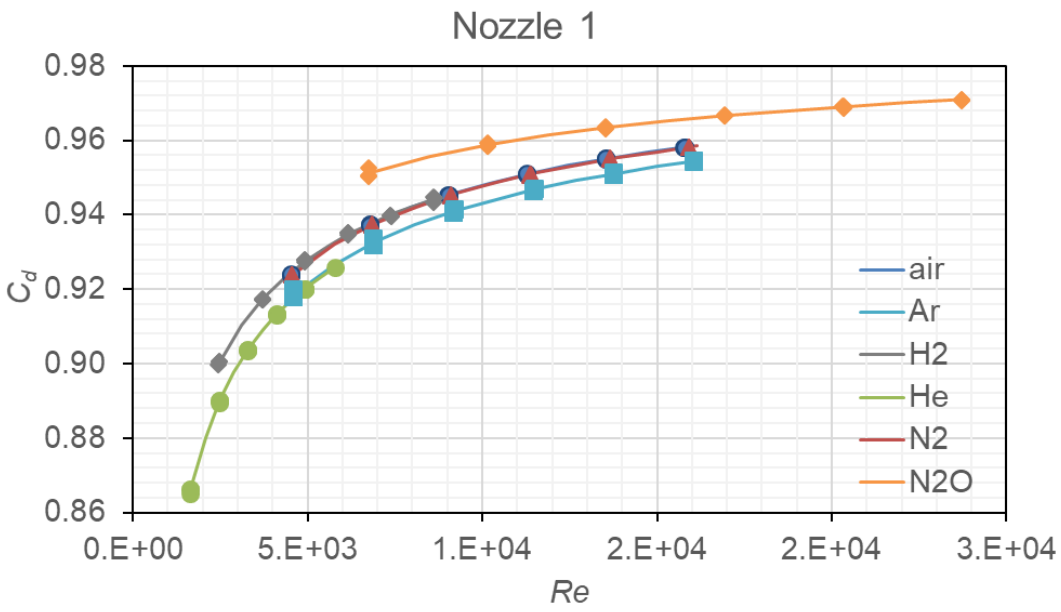


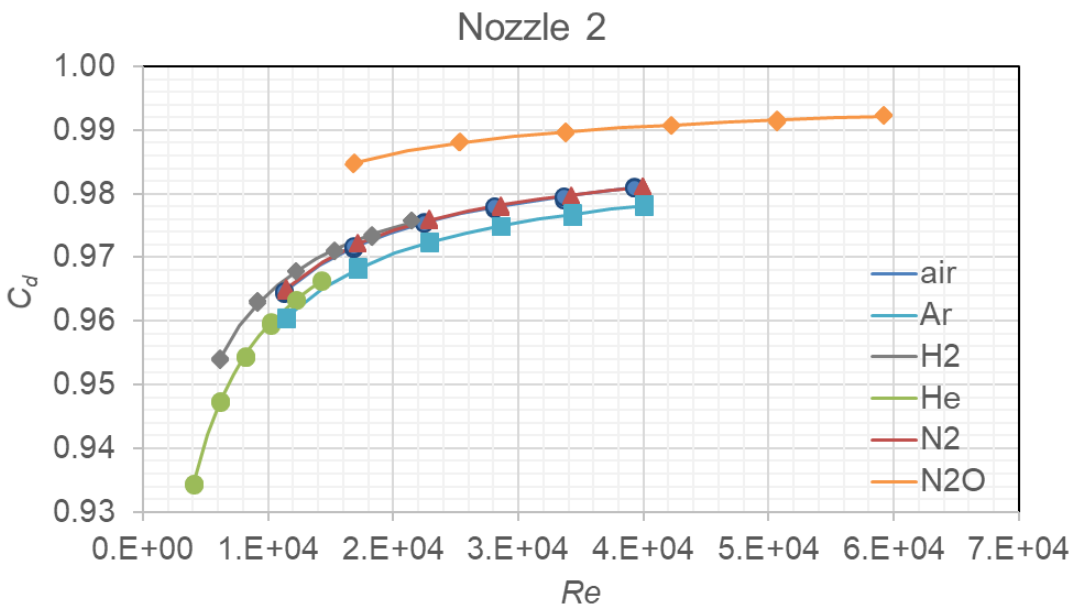
Test setup & test procedure





Experimental results



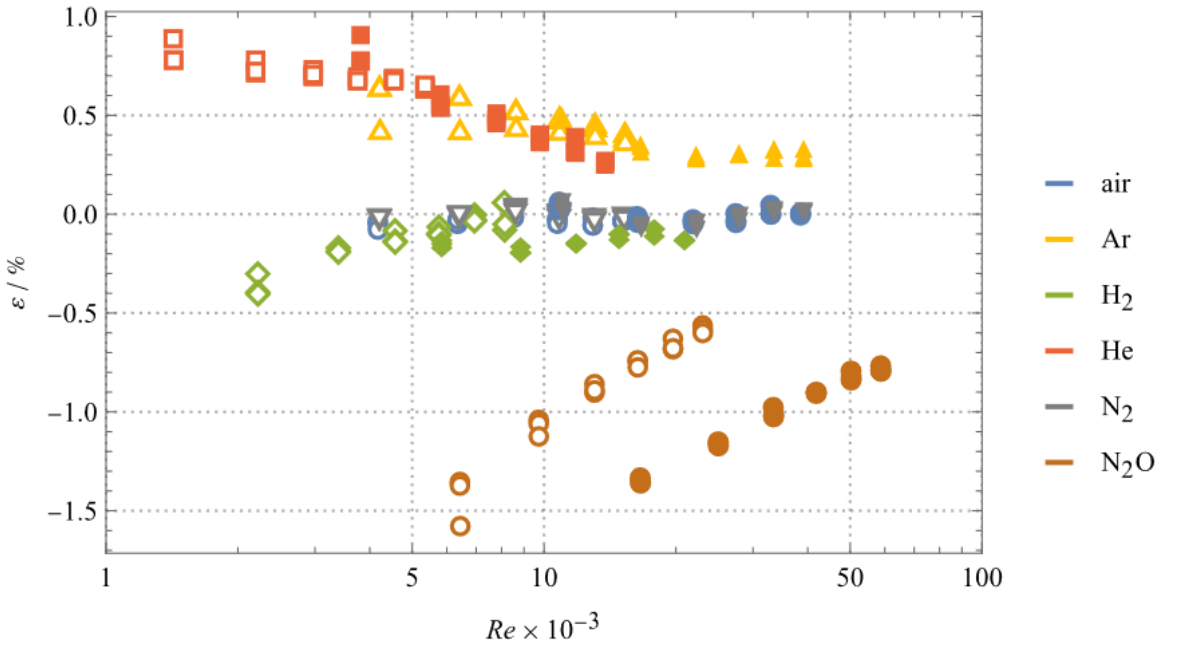


- similar trends of C_d for different gases are observed for both nozzles
- C_d for air, N_2 and H_2 almost overlap
- based on the experimental results the gases can be classified into three groups:
  - (i) He and Ar (κ=1.67) (ii) air, N_2 and H_2 (κ=1.4) (iii) N_2O (κ=1.3)

Analysis of the results

- deviations relative to N_2

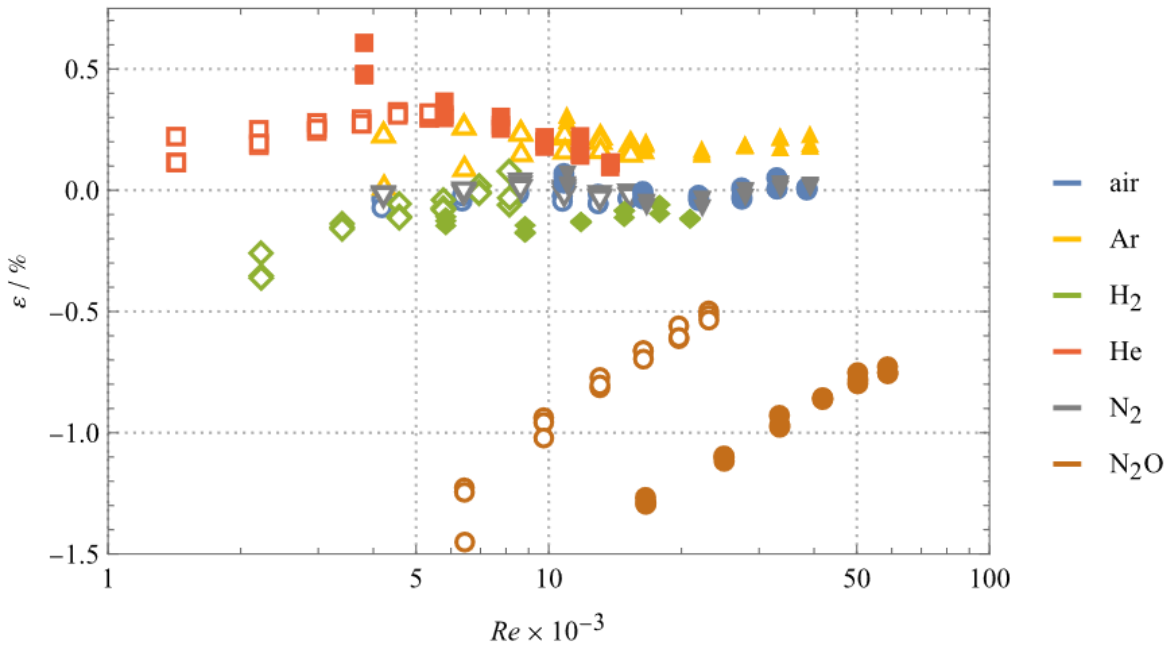
$$\varepsilon = C_d^{(\text{predicted})} / C_d^{(\text{actual})} - 1$$



□ - nozzle 1

■ - nozzle 2

- prediction of C_d based on N_2 calibration
- using analytical models (e.g. Kligel-Levine & Gerop), which take into account κ and *Pr*



Conclusions

- C_d for H_2 agrees well with C_d of air and N_2
- C_d was found to be dependent on isentropic coefficient (κ)
- **difference can be explained using analytical models taking into account the actual properties of gases (except N_2O)**

- in the laminar boundary layer regime the CFVN can potentially be calibrated with alternative gases $\rightarrow$ **first choice air and N_2**
- second option is to use other gas (e.g. helium) and then use the theoretical models to predict the behaviour (higher uncertainty)

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Contact:
Gregor Bobovnik
University of Ljubljana, Faculty of Mechanical Engineering, Laboratory of Measurements in Process Engineering, Aškerčeva 6, Ljubljana, Slovenia
e-mail: gregor.bobovnik@fs.uni-lj.si

MetHyInfra website: https://www.methyinfra.ptb.de/