Method Used to Determine Measurement Error

Alrewas EM MER EM009

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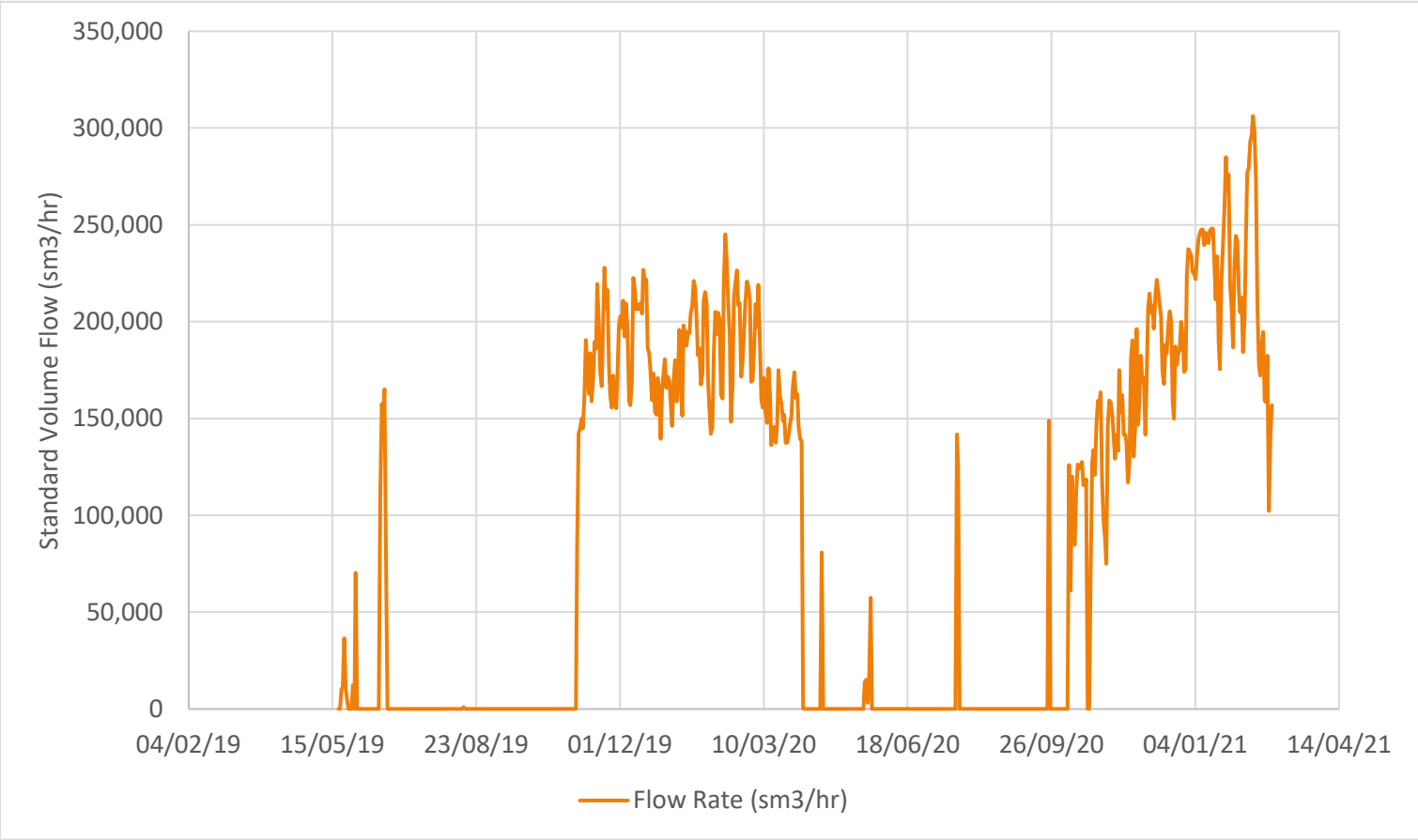
Alrewas Measurement Error Report



- Plate installed backwards
  - 23rd May 2019
- Plate swapped out and installed backwards
  - 20th May 2020
- Plate swapped out and installed correctly
  - 23rd Feb 2021
- How to evaluate the error?

Measurement Error Occurred from 23rd May 2019 to 23rd Feb 2021

Determination of Measurement Error

Computational Fluid Dynamics?

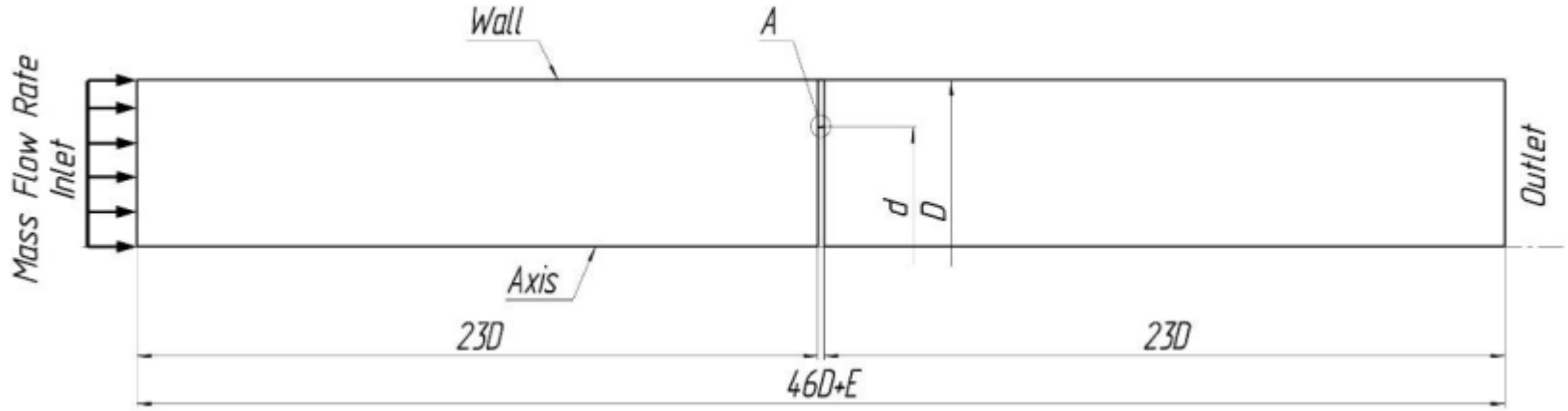
- A high level of expertise is required to set the problem up properly
- Configuration of the geometry
- Configuration of the mesh
- Configuration of the physical models
- Selection of boundary conditions
- Solver constraints and convergence criteria
- What is the uncertainty associated with the result?

Flow Testing Using a Clamp-on Ultrasonic?

- Do clamp-on meters work ok in gas?
- How accurately can the pipe diameter be determined?
- How accurately can the pipe wall thickness be determined?
- How to determine the path length?
- How repeatable/reproducible is the flow meter?
- Can constant flow be maintained for the testing?
- What is the uncertainty of the measurement?

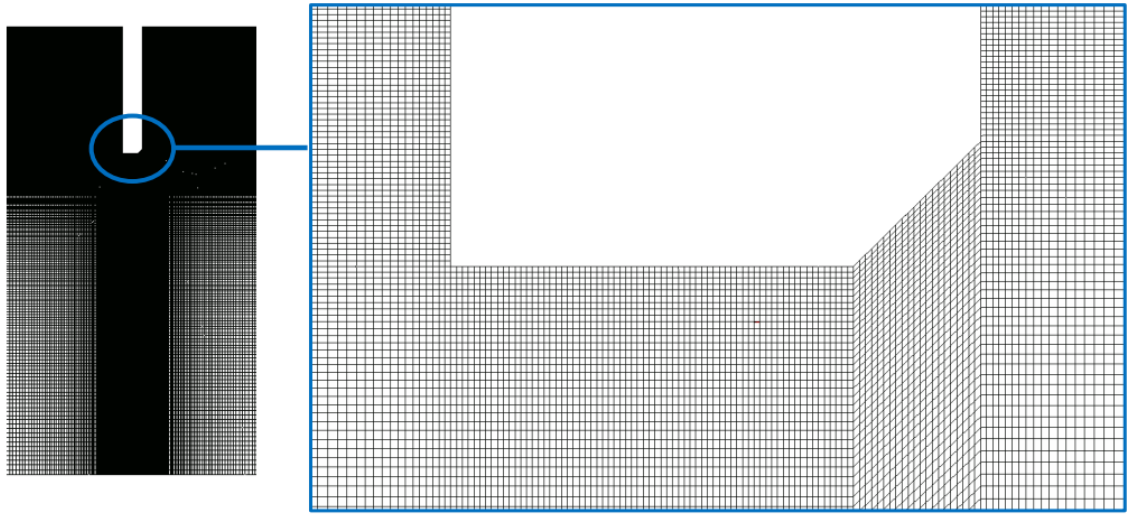
Determination Of Measurement Error Using CFD

- Geometry
  - 49D upstream straight lengths following 45º bend (from audit report – no site visit)
  - In accordance with ISO 5167
  - Plate dimensions from UKAS calibration certificate
  - Computation domain assumed 23D upstream and downstream (flow swapped direction for reverse orientation)



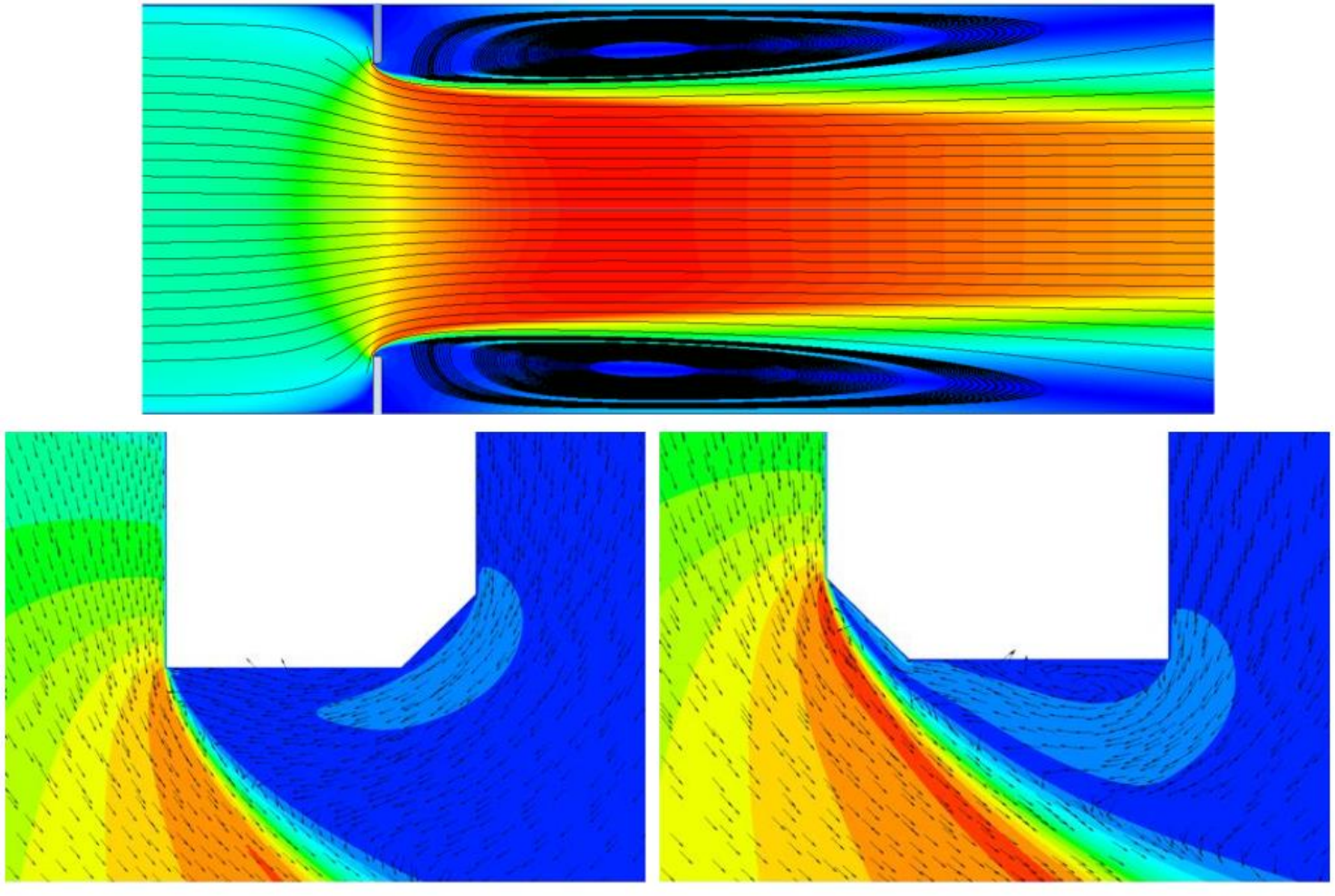
Determination Of Measurement Error Using CFD

- Mesh
  - Non-structural hexahedral mesh
  - Mesh of 994,900 nodes - 500,000 elements
  - Reynolds-Averaged Navier-Stokes (RANS) based model
  - k-ω Shear Stress Transport (SST)
    - Turbulent flows
    - Accurately predicts flow separation
  - Two packages Used
    - ANSYS CFX
    - ANSYS Fluent



Configuration of The mesh

Determination Of Measurement Error Using CFD



Some Pretty Pictures – Velocity, Pressure forward and Reverse

Determining The Correction

$$q_m = \frac{C}{\sqrt{1-\beta^4}} \frac{\pi d^2}{4} \varepsilon \sqrt{2\Delta P \rho}$$

$$q_r = \frac{C}{\sqrt{1-\beta^4}} \frac{\pi d^2}{4} \varepsilon \sqrt{2\Delta P_r \rho}$$

$$C_r \varepsilon_r = \frac{4 q_m \sqrt{1-\beta^4}}{\pi d^2 \sqrt{2\Delta P_r \rho}}$$

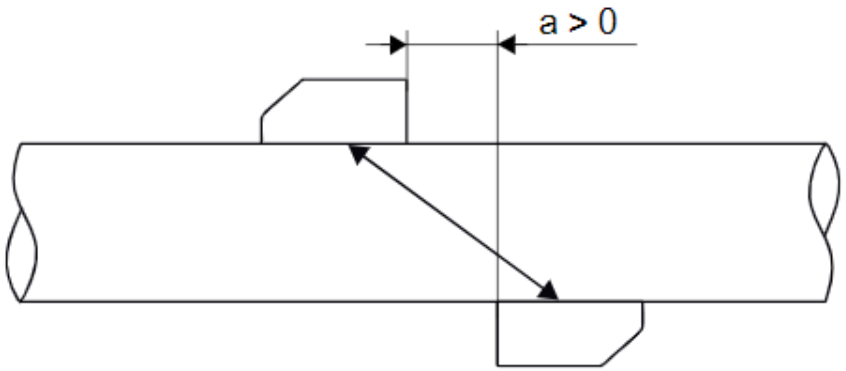
$$q_c = q_r \frac{C_r \varepsilon_r}{C\varepsilon}$$

- Determine $C\varepsilon$ in the forward orientation
- Determine $C\varepsilon$ in the reverse orientation
- Determine Correction at Multiple Flows / Reynolds Number
- Apply Correction

Correction Determined For 3 flow Rates forward and Reverse For Both Models

Determination Of Measurement Error Using Flow Tests

- Clamp-on Ultrasonic Flowmeter
  - Installed >5D upstream of Orifice
  - Pipe wall thickness measured by ultrasonic thickness gauge
  - Pipe circumference measured by tape
  - USM recommends separation of transducers
  - Run with Plate in correct orientation – determine ‘meter factor’
  - Run with both plates in reverse orientation to determine meter error in reverse orientation
  - Run second plate in correct orientation to determine reproducibility of USM



Fluxus G608 Mounted Upstream of Flow – Single Diametric Path

Determination Of Measurement Error Using Flow Tests

- Clamp-on Ultrasonic Flowmeter
  - Data logged locally in transmitter (30secs)
  - Exported ad .CSV file at end of test
- Orifice Flowmeter
  - DANINT
  - Stores .csv every 7 minutes (GC driven)
  - .V0x file – DP, P, T, standard volume flow rate
  - .Z0x file – composition, standard volume, standard volume totaliser
  - 7 minutes? Can we get a statistically meaningful set of results?

$$s(x) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$s(\bar{x}) = \frac{s(x)}{\sqrt{n}} \qquad U(\bar{x}) = T(\%, n)s(\bar{x})$$

$$SV_{av} = \frac{SV_{Tc} - SV_{To}}{T}$$

Determination Of Measurement Error Using Flow Tests

- Clamp-on Ultrasonic Flowmeter
  - Measures fluid velocity
  - Actual volume determined from velocity and diameter
- How to determine the standard volume for comparison with the orifice
- Assumption
  - Pressure is as measured at orifice
  - Temperature is as measured at orifice
  - Composition / density is as measured at orifice

$$Q_{su,usm} = Q_{lu,usm}\frac{\rho_l}{\rho_s}$$

$$MF = \frac{Q_{s,o}}{Q_{su,usm}}$$

$$Q_{s,usm} = MF \times Q_{su,usm}$$

So What Time is It?

Everybody should carry two watches. But a person with one watch knows what time it is, whilst someone with two watches can never be sure??

- A person with one watch can't be sure they know the correct time – they just have no means to identify the uncertainty…

- How far apart are the results?
- How stable was the flow for the flow tests
- How reproduceable was the USM?
- Is there any Reynolds Number dependency?

Thank You

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