Measurement Error & Calculation Methodology

Alrewas EM MER EM009

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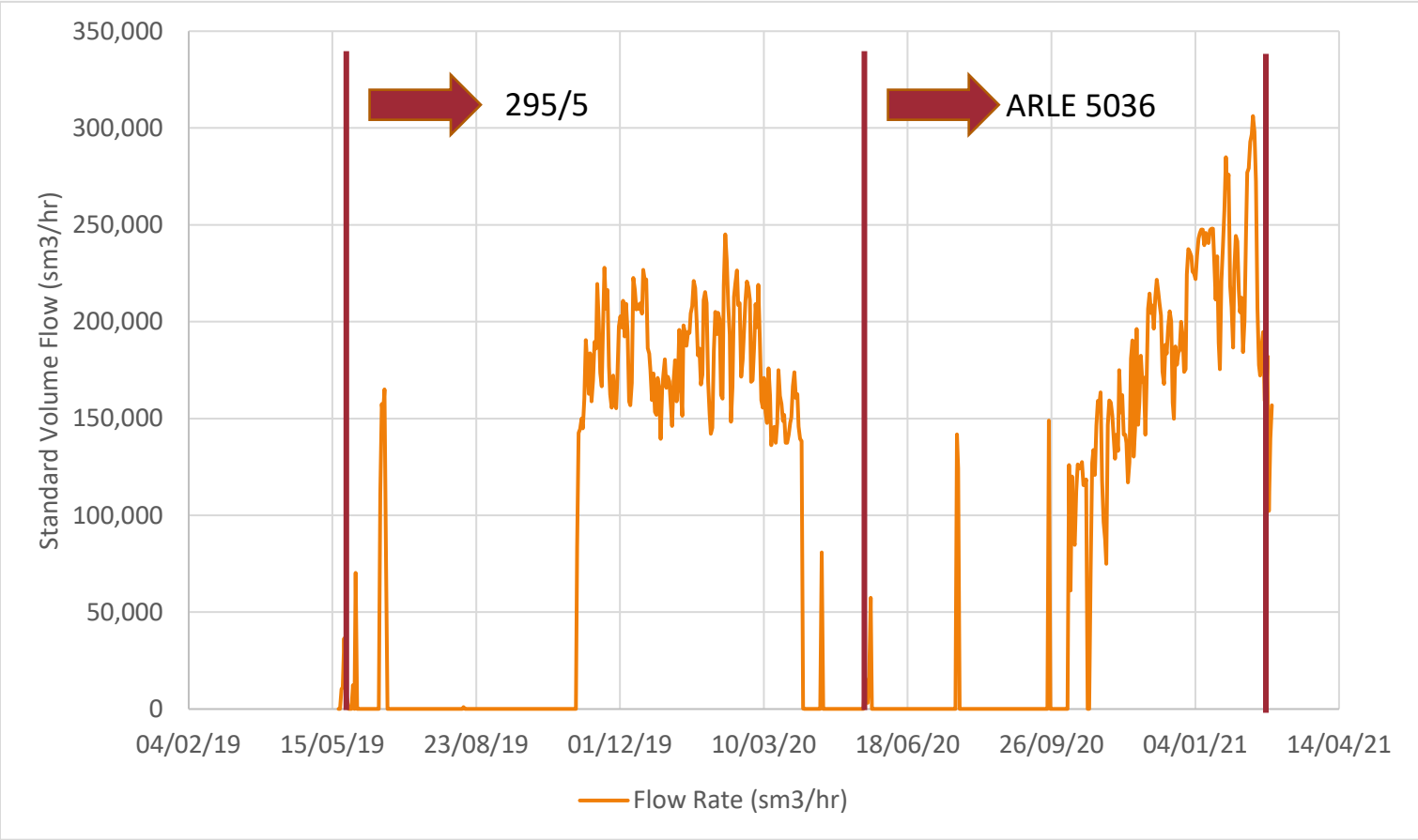
Alrewas Measurement Error Report



- Plate installed backwards
  - 23rd May 2019
- Plate swapped out and installed backwards
  - 20th May 2020
- Plate swapped out and installed correctly
  - 23rd Feb 2021

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

Determination of Measurement Error

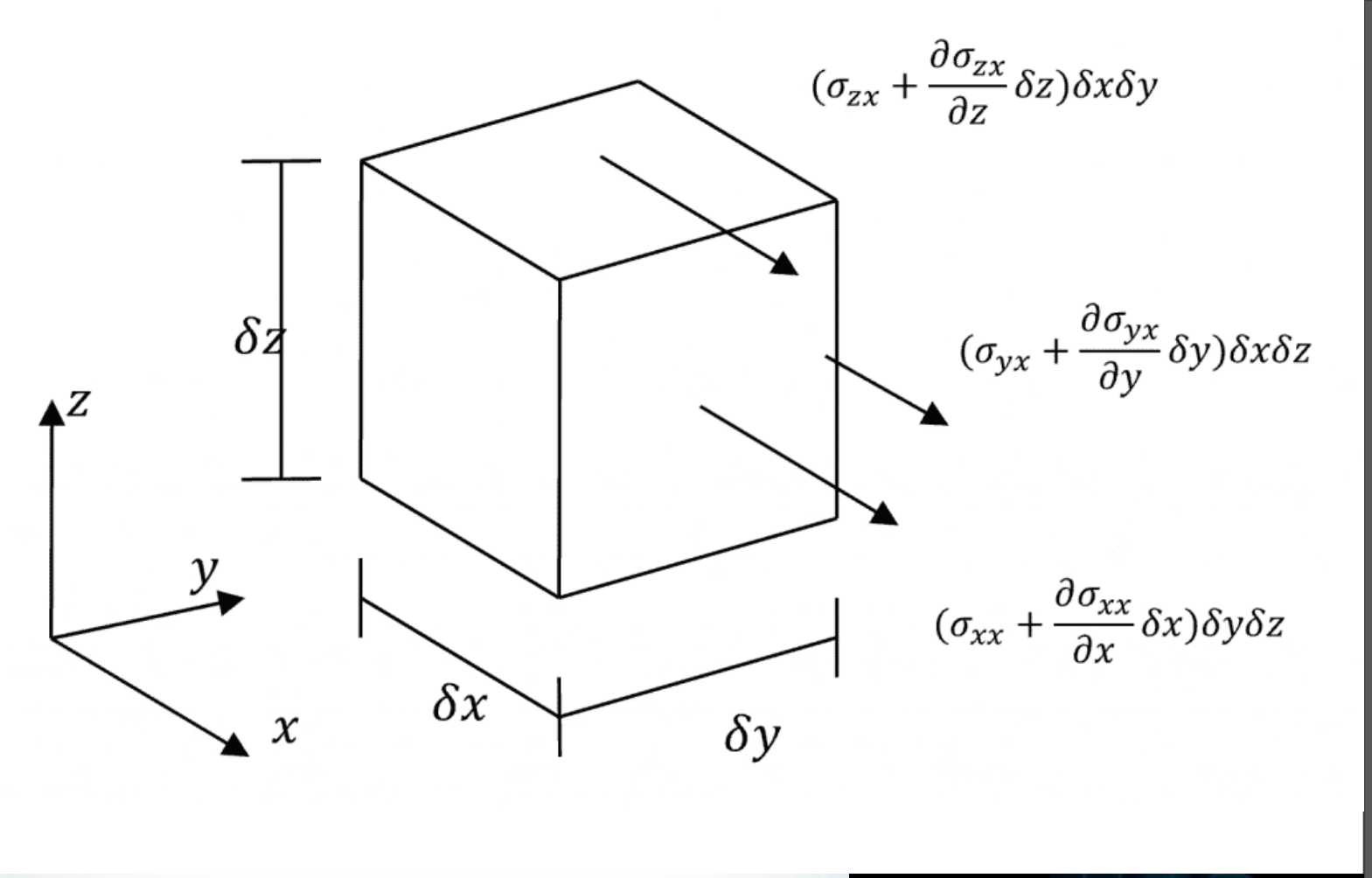
Computational Fluid Dynamics (CFD)

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

Flow Testing Using a Clamp-on Ultrasonic

- How well 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 repeatable/reproducible is the flow meter?
- Can constant flow be maintained for the testing?
- What is the uncertainty of the measurement?

Both CFD and Flow Testing was Performed



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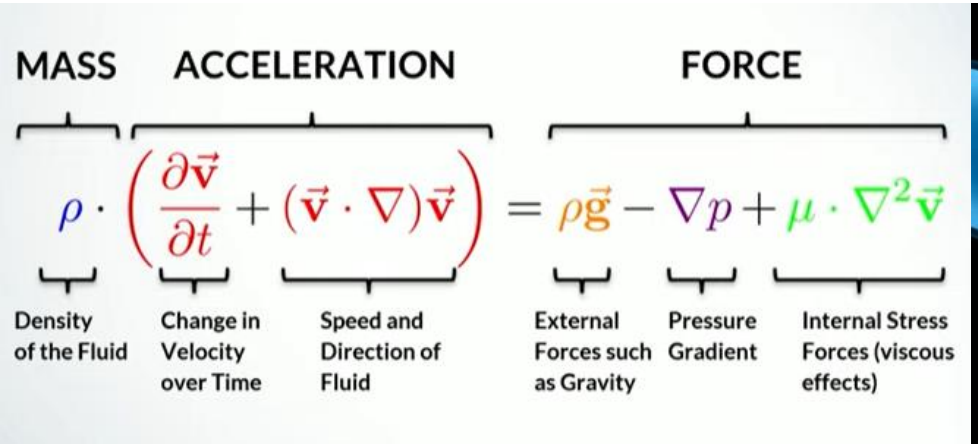
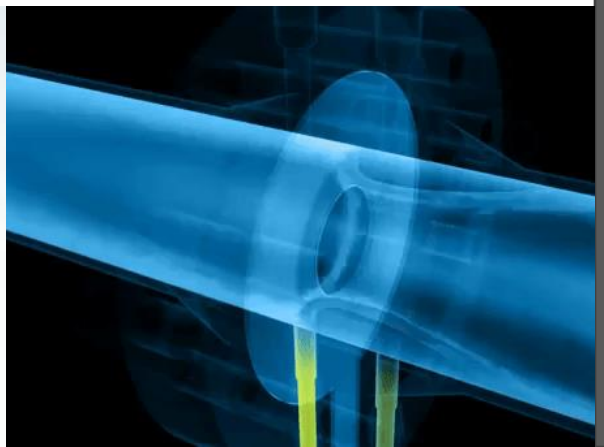
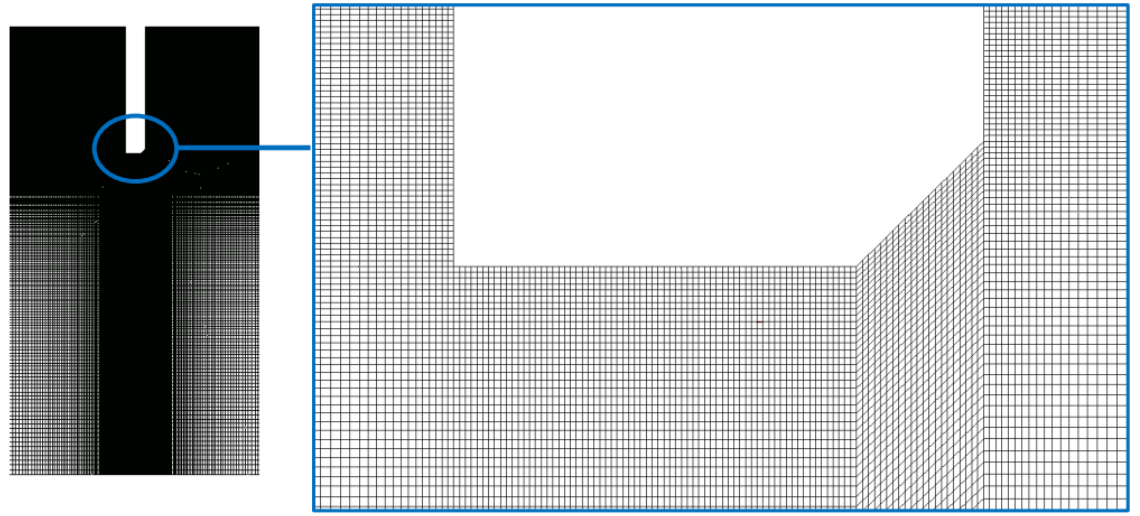
Computational Fluid Dynamics





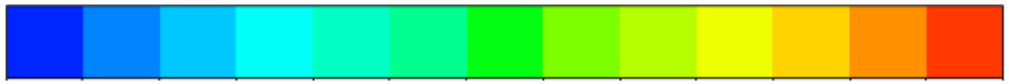
Determination Of Measurement Error Using CFD

- Simulated 2 orifice plates, forward and reverse at 3 Reynolds No.
  - 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 solvers used
    - ANSYS CFX
    - ANSYS Fluent

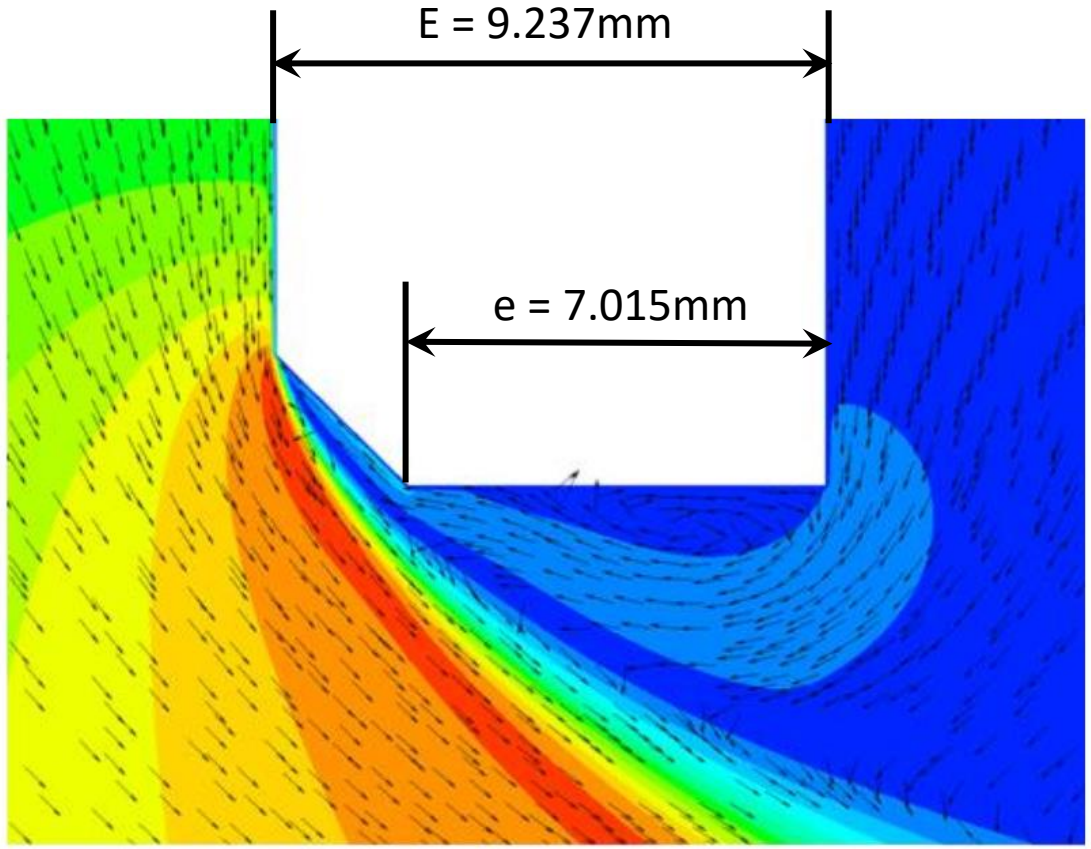


Configuration of The CFD Model

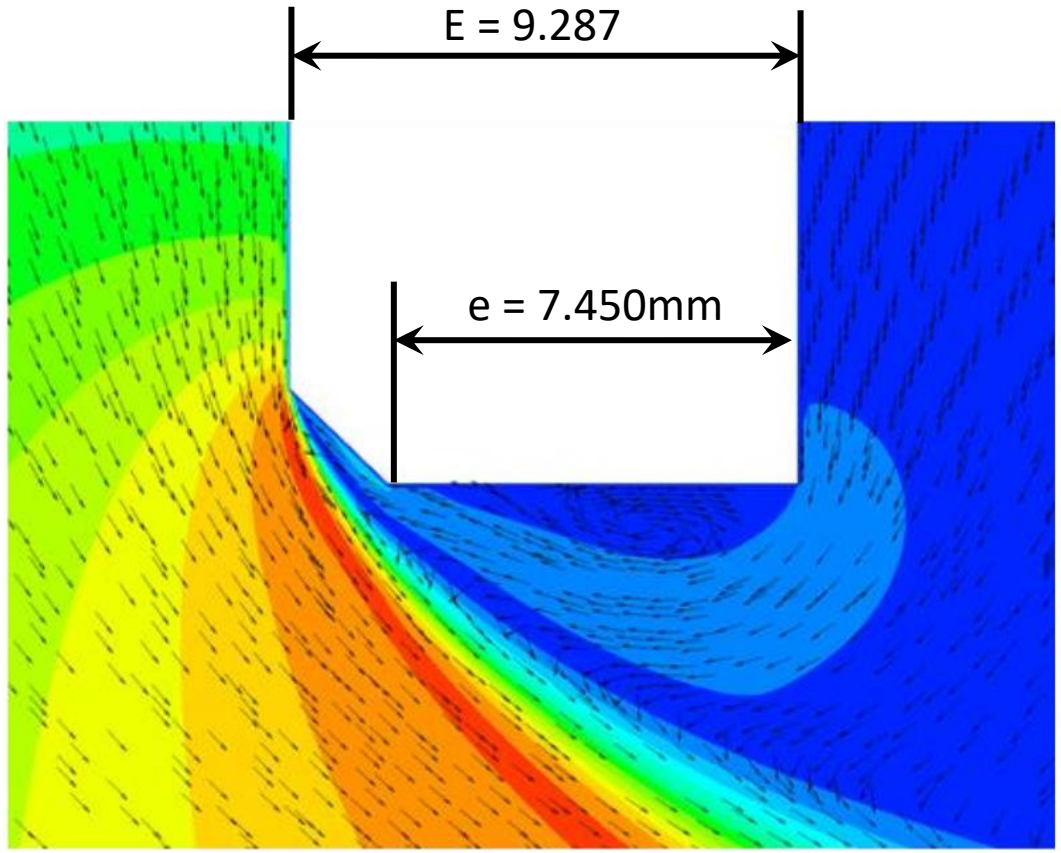
Low Pressure



High Pressure



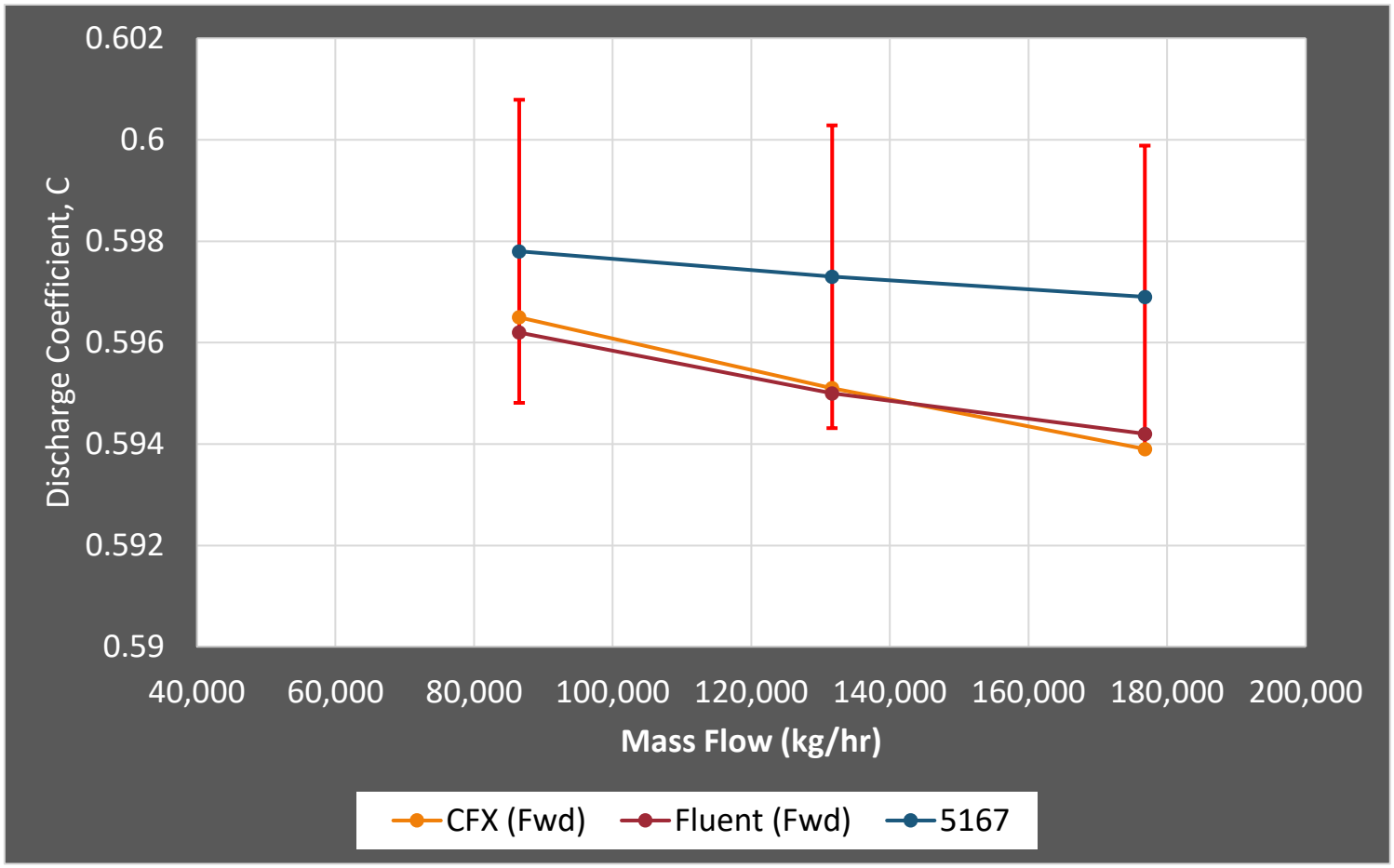
295/5, d=309.997



ARLE 5036, d=310.002

VERY SIMILAR ORIFICE PLATES. DIFFERENCE IN d=0.005mm

CFD Validation

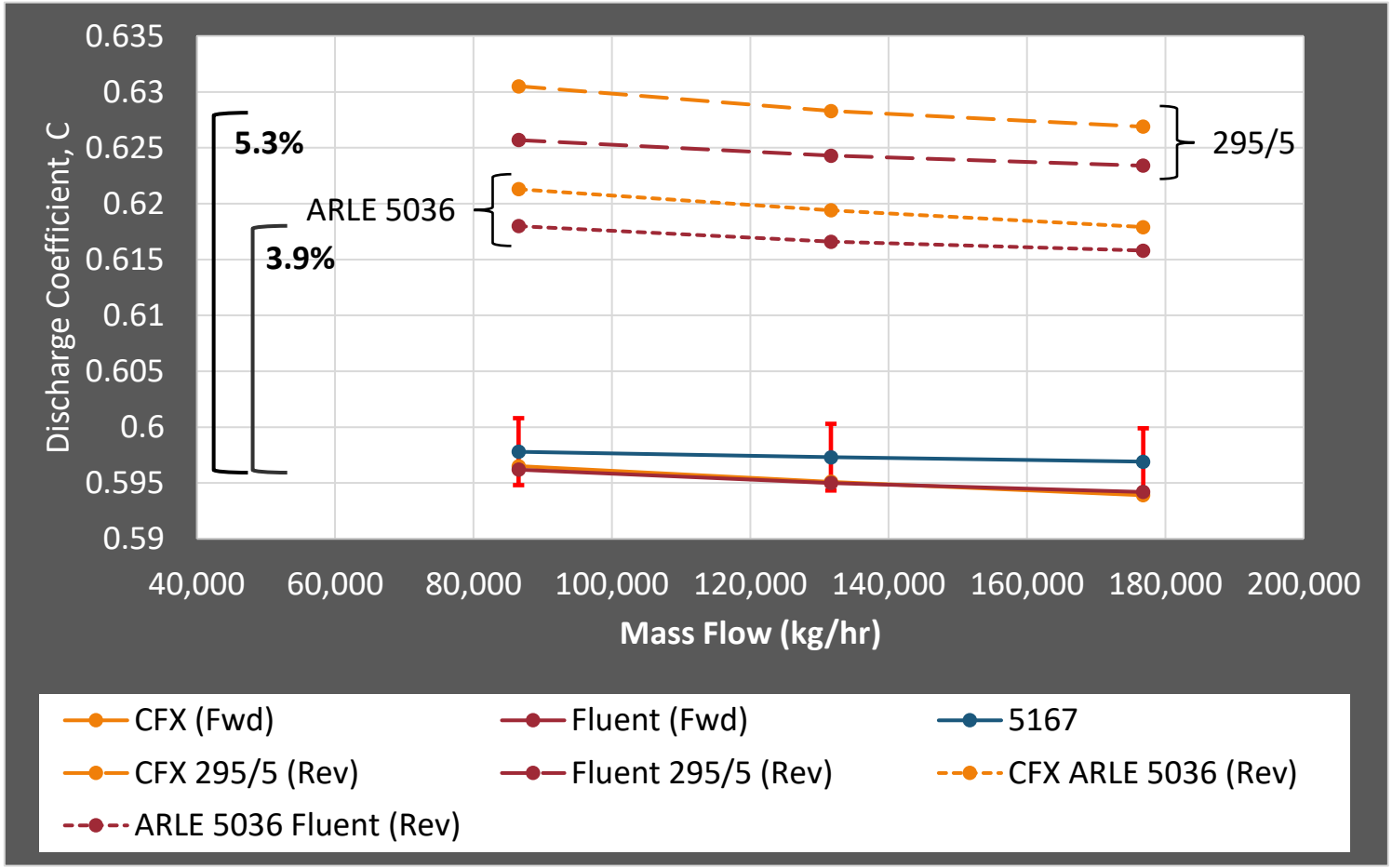


Flow (kg/hr)	CFX (Fwd)	Fluent (Fwd)	ISO 5167	Error (%)
86,519	0.5965	0.5962	0.5978	-0.27%
131,659	0.5951	0.595	0.5973	-0.39%
176,799	0.5939	0.5942	0.5969	-0.45%

- 5167 Error Bands – 0.5%
- CFD conducted at 3 points
- Simulated in correct orientation
- All CFD results with 0.5% of ISO5167
- Results for plate 295/5
- Both plates provided very similar results

CFD Discharge Coefficient Close to ISO 5167

CFD Reverse Orientation



Flow (kg/hr)	CFX 295/5	Fluent 295/5	CFX ARLE 5036	Fluent ARLE 5036
86,519	0.6305	0.6257	0.6213	0.618
131,659	0.6283	0.6243	0.6194	0.6166
176,799	0.6269	0.6234	0.6179	0.6158

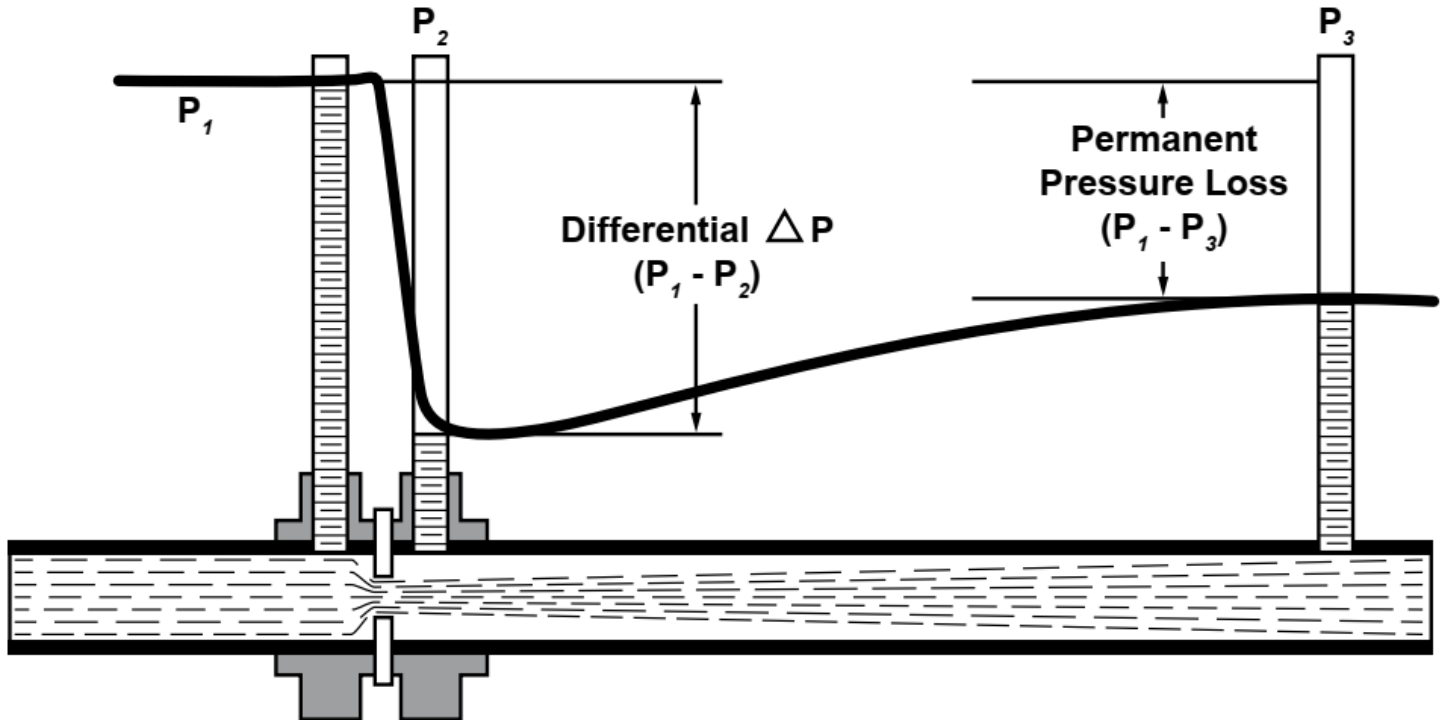
- Both plates had an increased C
- Under measurement predicted
- 295/5 has larger under measurement
- CFX predicts slightly larger error

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

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

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

Under Measurement of 4-5% Predicted



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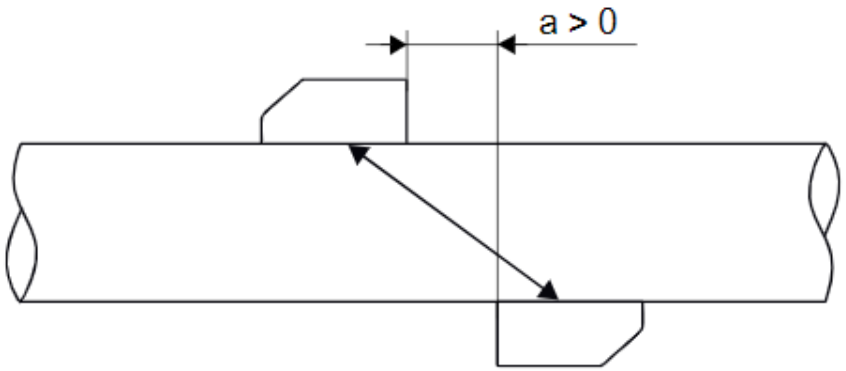
Flow Tests

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

Flow Test 1

295/5 Forward

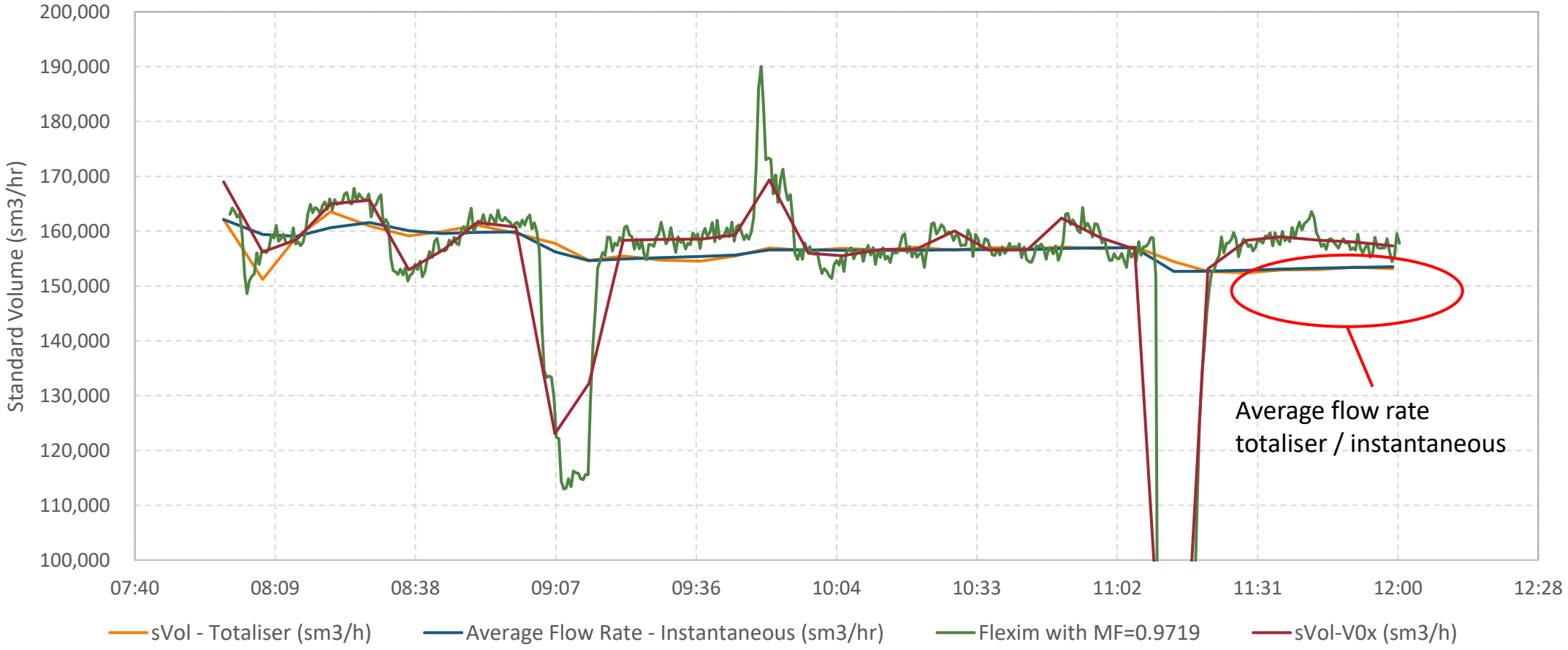


Plate 295/5 in the correct orientation

Meter Factor for USM = 0.9719

Flow Test 2
295/5 Reverse

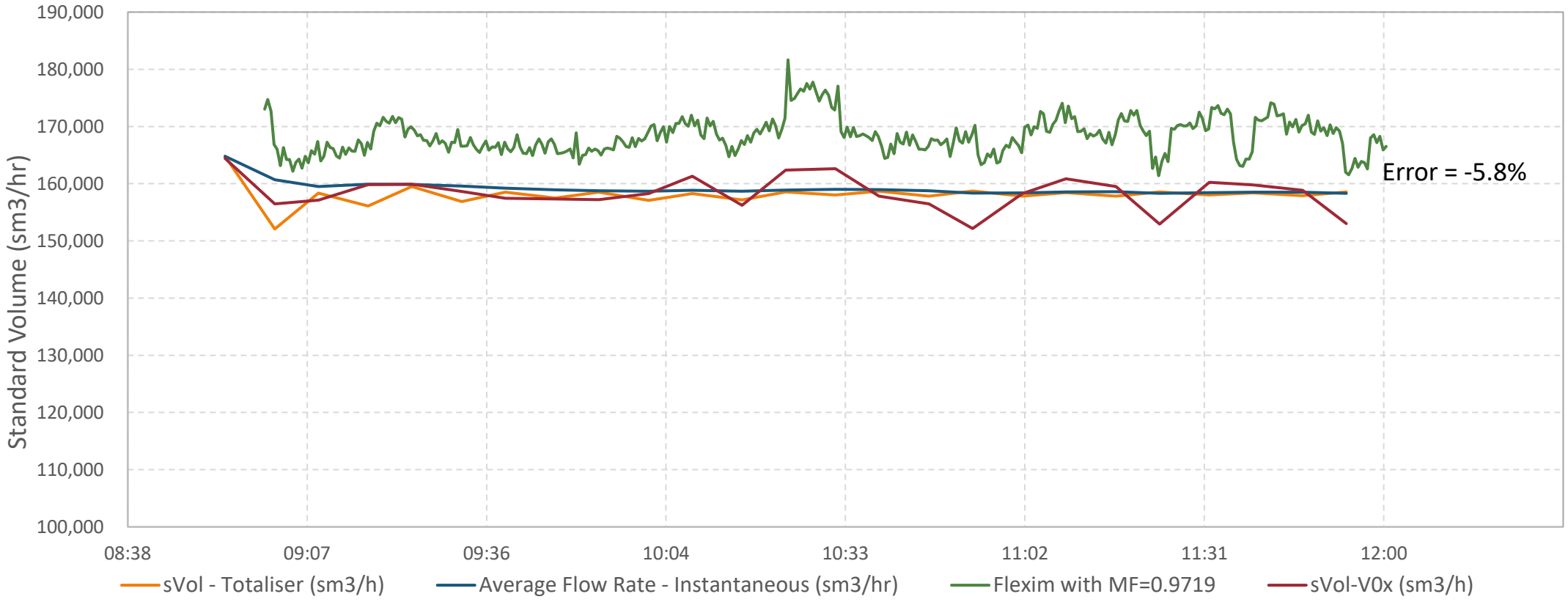


Plate 295/5 in the reverse orientation

Orifice Meter Reads 5.8% lower than the MF Corected USM

Flow Test 3

ARLE 5036 Forward

Orifice Meter Reads 0.025% lower than the MF Corrected USM

USM Demonstrated to be reproducable

Flow Test 4

ARLE 5036 Reverse

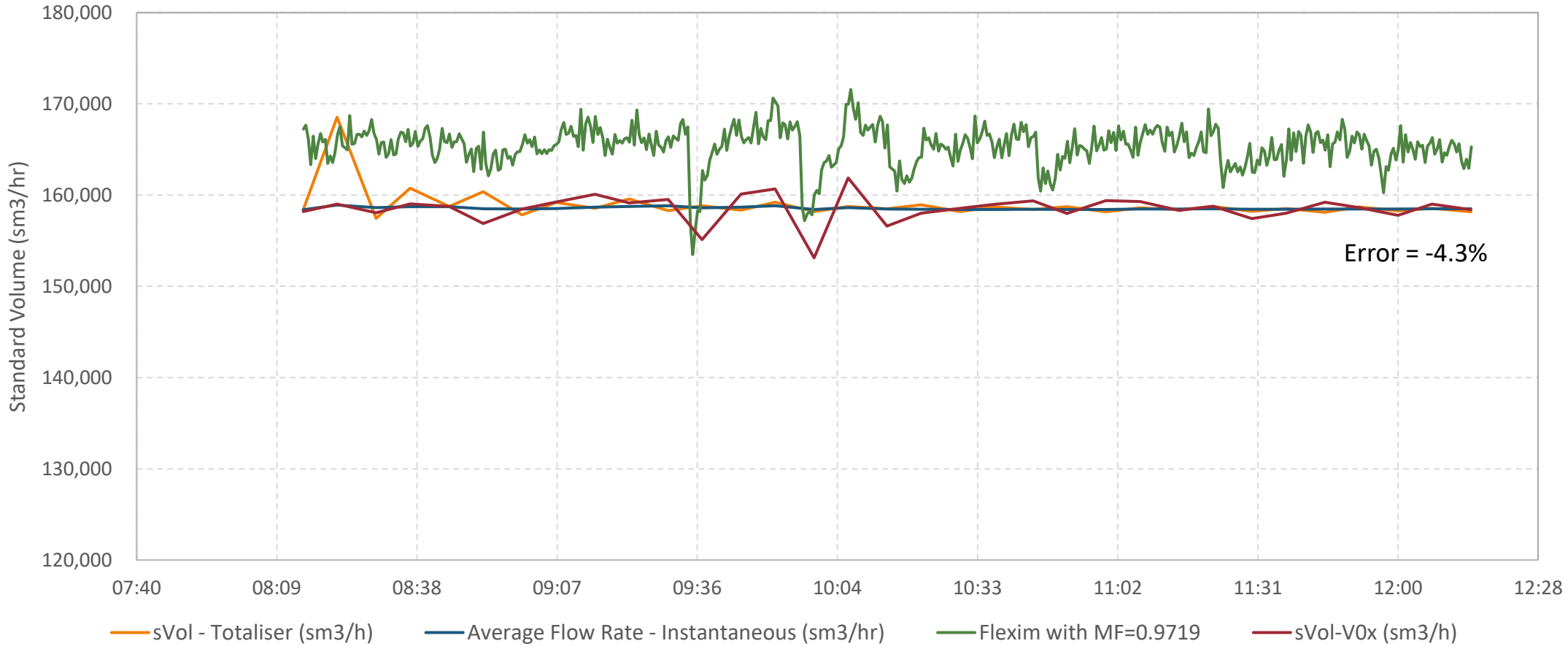
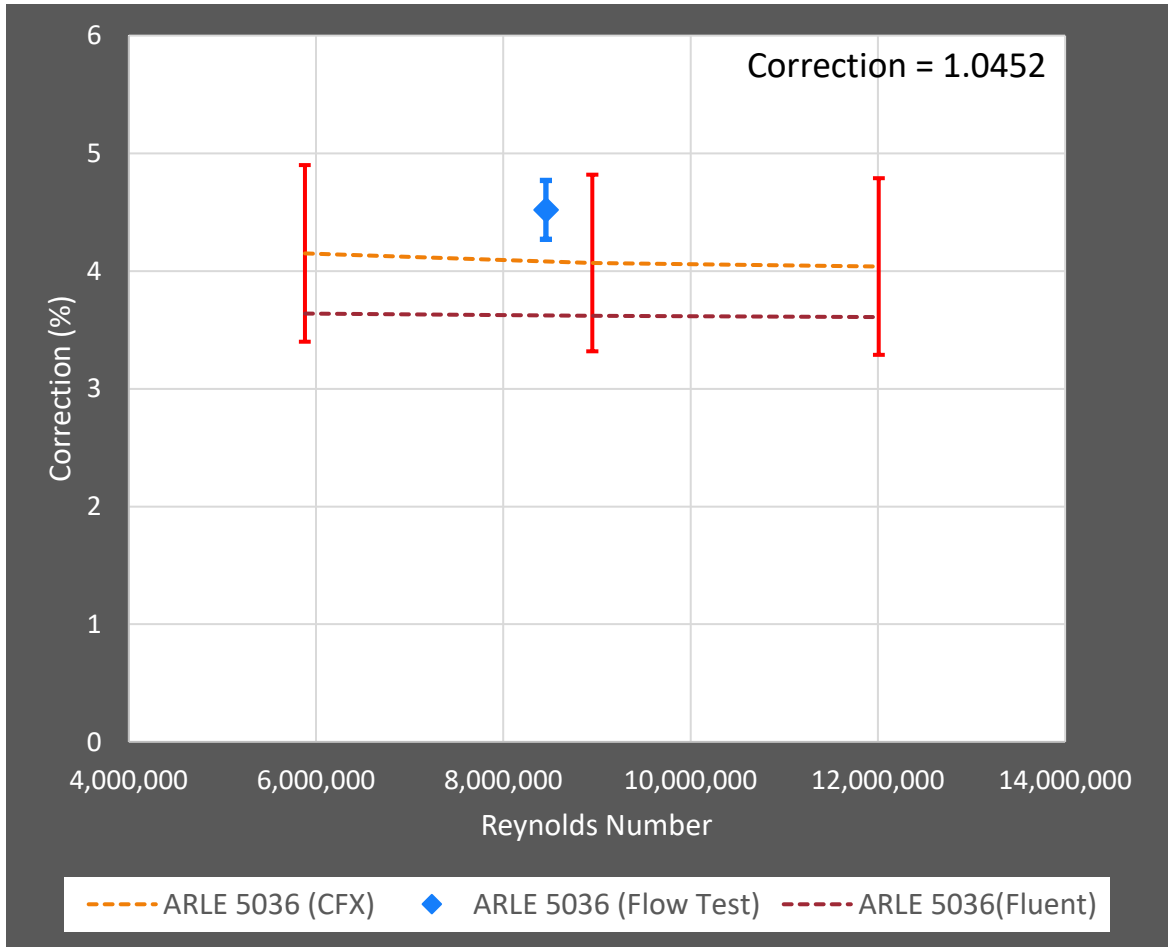
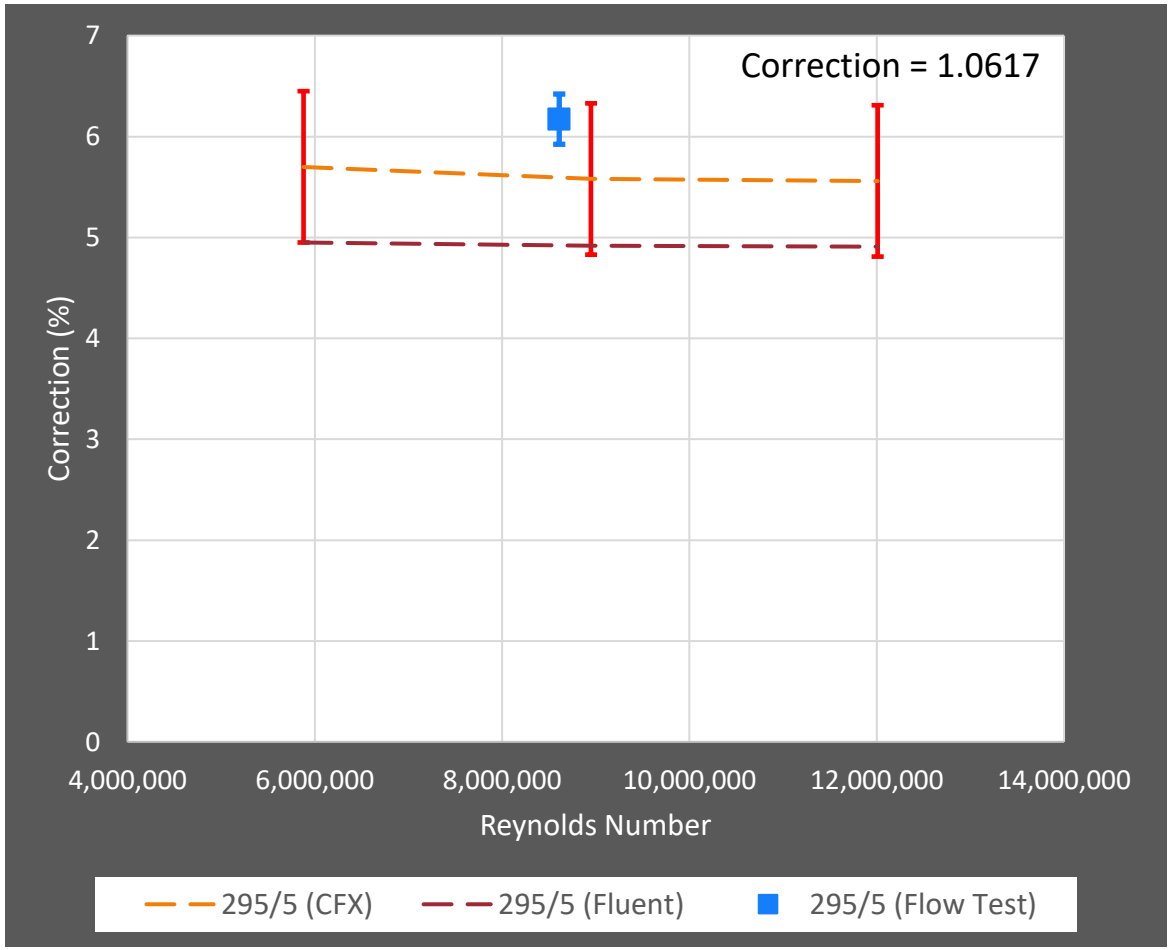


Plate ARLE 5036 in the Reverse orientation

Orifice Meter Reads 4.3% lower than the MF Corected USM

Result Summary





Error Bars 0.75% from CFX, 0.25% from Flow Test

If Your Experiment Needs Statistics, you should have done a better Experiment....

Mis-Measurement Summary

Site Name:	**Alrewas EM MTD**
DN Reference:	MER/CAD/204/21
Measurement Error Notification:	EM009
Meter Type:	Orifice Meter
LDZ:	EM
Start Date of Measurement Error:	23/05/2019
End Date of Measurement Error:	23/02/2021
Throughput during Period – Standard Volume (sm3):	1,319,252,002
Throughput during Period – Energy (kWh):	14,395,996,944
Over or Under Measurement:	Under measurement
Correction – Standard Volume, sm3 / (%):	71,113,997 (5.4%)
Correction – Energy, kWh (%):	776,099,094 (5.4%)

5.4% Measurement Error Over Full Period

Thank You

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