Calculation of Mismeasurement due to incorrect installation of orifice plate using CFD

ITE 1 – TUV SUD National Engineering Laboratory

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Summary of ITE 1 Results

- During the mis-measurement period the total measured flowrate was 14,426 GWh and 1,324.1 million Sm^3
- There was an undermeasurement of 867.09 GWh and 79.441 million Sm^3
- This mis measurement was calculated based on a change in discharge coefficient predicted through CFD.
- The CFD was validated using previous published data for similar orifice plates with good agreement

Case (Reynolds number)	Discharge Coefficient - CFD Ideal	Discharge Coefficient - CFD Reversed	Shift In Discharge Coefficient (%)
Low Flow (Re 7,095,465)	0.59706	0.63556	6.45
Medium Flow (Re 14,190,929)	0.59377	0.63465	6.88
Maximum Flow (Re 26,607,993)	0.59119	0.63475	7.37

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Case (Reynolds number)	Discharge Coefficient - CFD Ideal	Discharge Coefficient - CFD Reversed	Shift In Discharge Coefficient (%)
Low Flow (Re 7,095,465	0.59496	0.62663	5.32
Medium Flow (Re 14,190,929)	0.59386	0.62559	5.34
Maximum Flow (Re 26,607,993)	0.59133	0.62469	5.64

5036

Description of CFD

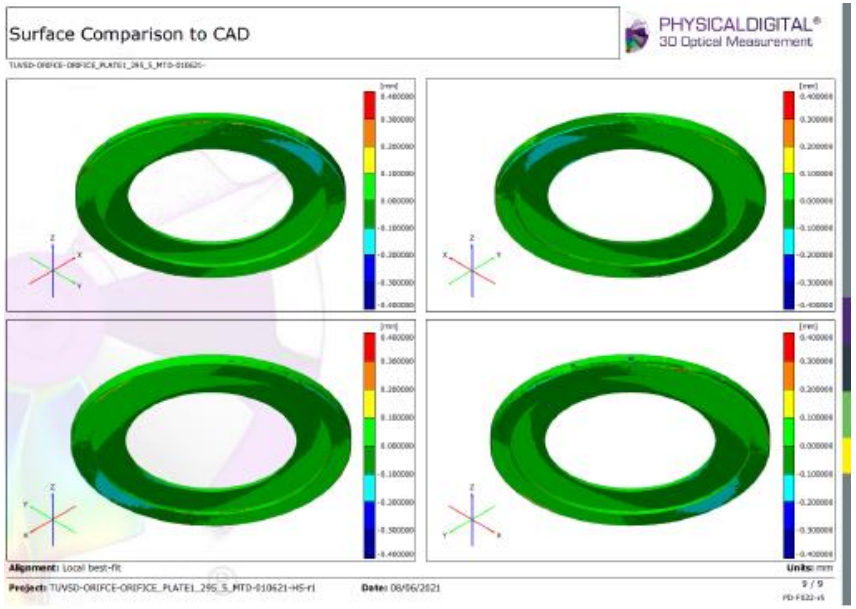
- ANSYS FLUENT 2021 R1 used for all simulations
- The simulations were run under ideal conditions, to confirm modelling accuracy, and then with plates installed backwards

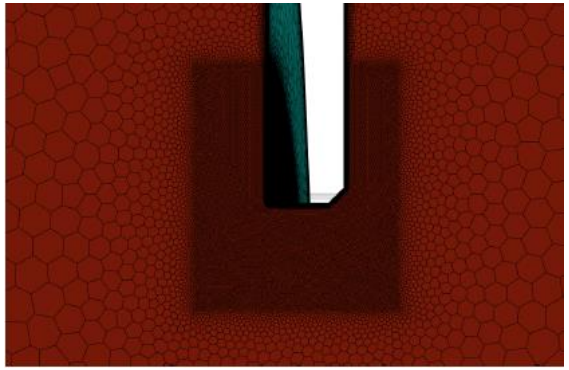
TABLE 1: SIMULATED CASES

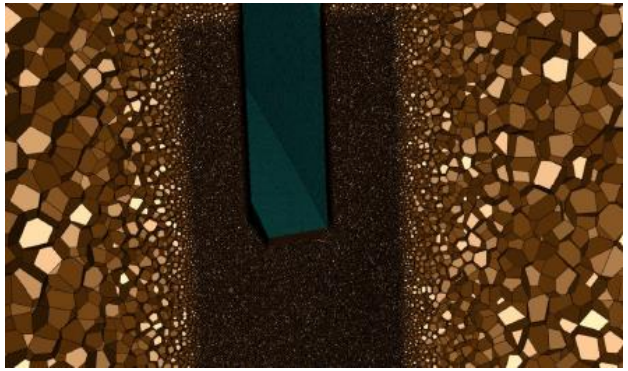
Case	Inlet Velocity (ms^{-1})	Density (kgm^{-3})	Viscosity ($kgm^{-1}s^{-1}$)	Reynolds Number	Mass Flowrate (kgs^{-1})
Low	4	49.38	1.20×10^{-5}	7,095,190	28.98
Medium	8	49.38	1.20×10^{-5}	14,190,381	57.96
High	15	49.38	1.20×10^{-5}	26,606,964	108.67

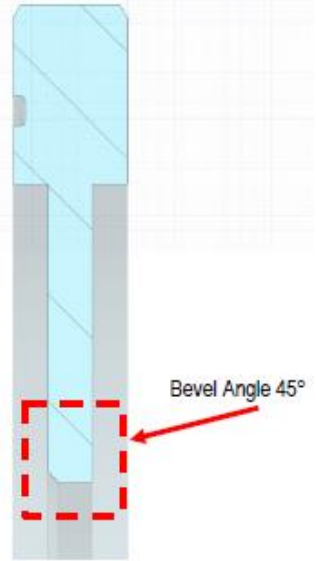
Description of CFD

- Plates were laser scanned for dimensions
- Models of scans were created and used for simulations
- Simulation were ran as quarter symmetry models to reduce computation time
- Pressure tapping dimensions were not available at time of modelling
- Very high quality unstructured polyhedral mesh used with refinement at plate





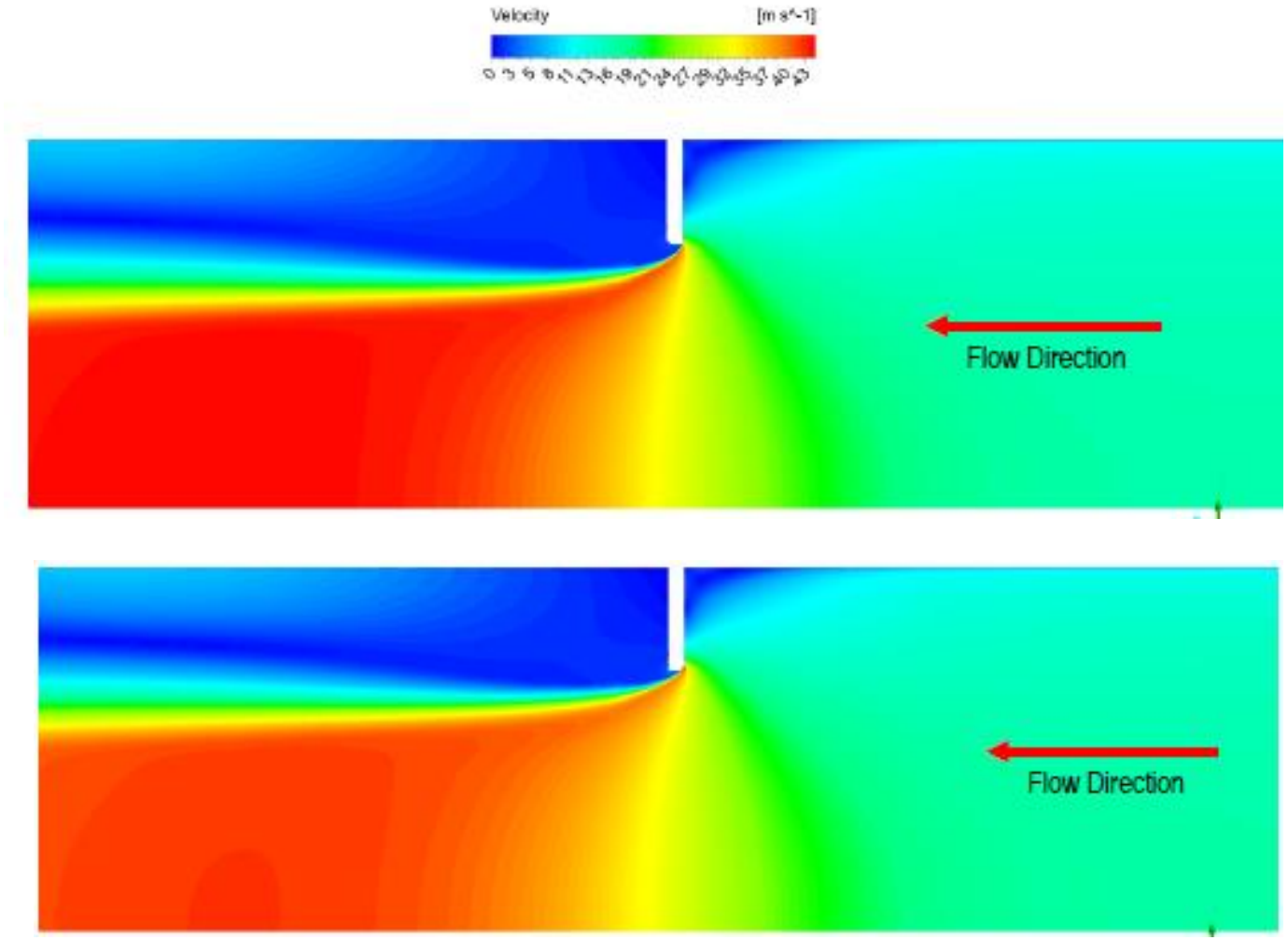




Mesh Independence

Case	BOI 1 Cell Size (mm)	BOI 2 Cell Size (mm)	Max Mesh Size (mm)	Discharge Coefficient (Ideal)	Difference (%)
Low Flow (Plate 5036)	0.2	4	12	0.59496	0.10
Low Flow (Plate 5036)	0.4	4	12	0.59553	
Medium Flow (Plate 5036)	0.2	4	12	0.59386	0.11
Medium Flow (Plate 5036)	0.4	4	12	0.59452	
Maximum Flow (Plate 5036)	0.2	4	12	0.59133	0.12
Maximum Flow (Plate 5036)	0.4	4	12	0.59203	

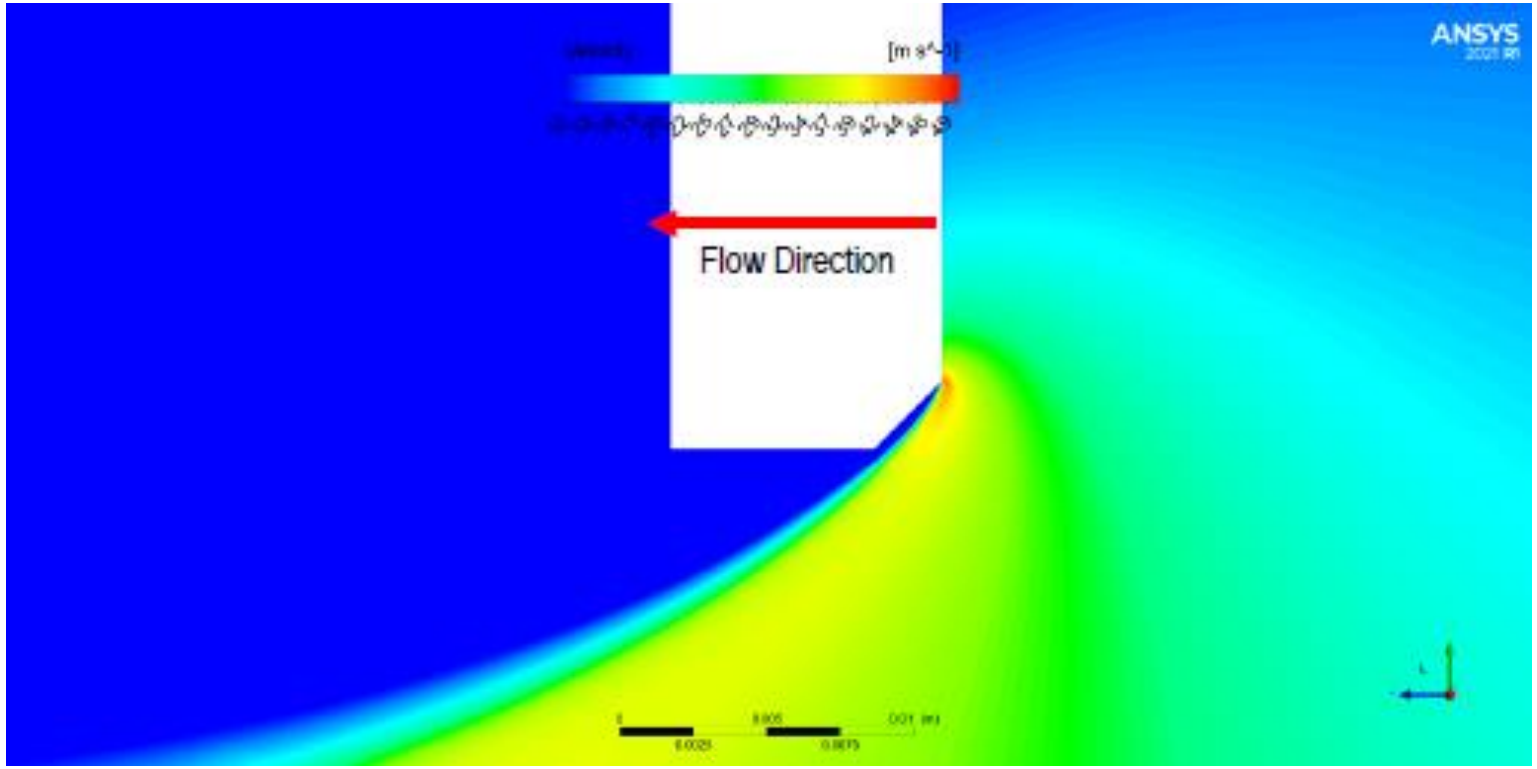
Simulation Results/Observations



Correct Installation

Incorrect Installation

Simulation Results/Observations



Incorrect Installation

Simulation Results/Observations

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Case	Discharge Coefficient - Standard [1]	Discharge Coefficient - CFD Ideal	CFD Ideal Case Deviation From Standard (%)
Low Flow	0.59767	0.59706	-0.10266
Medium Flow	0.59701	0.59377	-0.54306
Maximum Flow	0.59653	0.59119	-0.89592

Case	Discharge Coefficient - CFD Ideal	Discharge Coefficient - CFD Reversed	Shift In Discharge Coefficient (%)
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Case	Discharge Coefficient - Standard [1]	Discharge Coefficient - CFD Ideal	CFD Ideal Case Deviation From Standard (%)
Low Flow	0.59768	0.59496	-0.4543
Medium Flow	0.59702	0.59386	-0.52933
Maximum Flow	0.59654	0.59133	-0.87361

Case	Discharge Coefficient - CFD Ideal	Discharge Coefficient - CFD Reversed	Shift In Discharge Coefficient (%)
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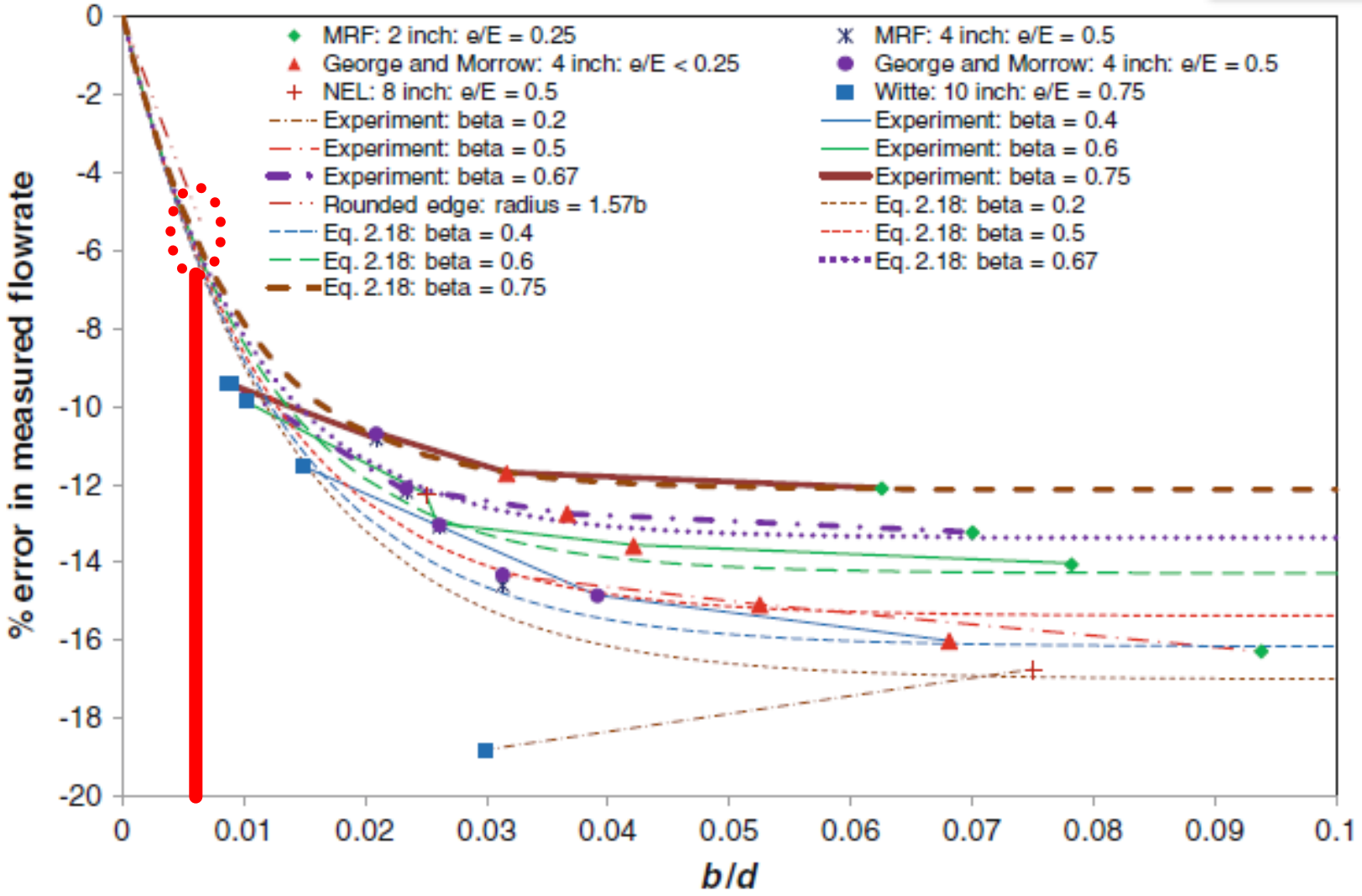
Validation

- The same process was completed based on a published paper by George and Morrow (SWRI)
- The NEL Modelling process was within 0.25% of the published results which were based on physical tests

Correctly Installed Point	Incorrectly Installed Point	CFD Discharge Coefficient for Correct Installation	CFD Discharge Coefficient for Reverse Installation	SwRI Shift In Discharge Coefficient (%)	CFD Shift In Discharge Coefficient (%)
F082600.010	F082600.030	0.60969	0.69509	13.78	14.01
F082600.015	F082600.035	0.61108	0.69597	13.69	13.89

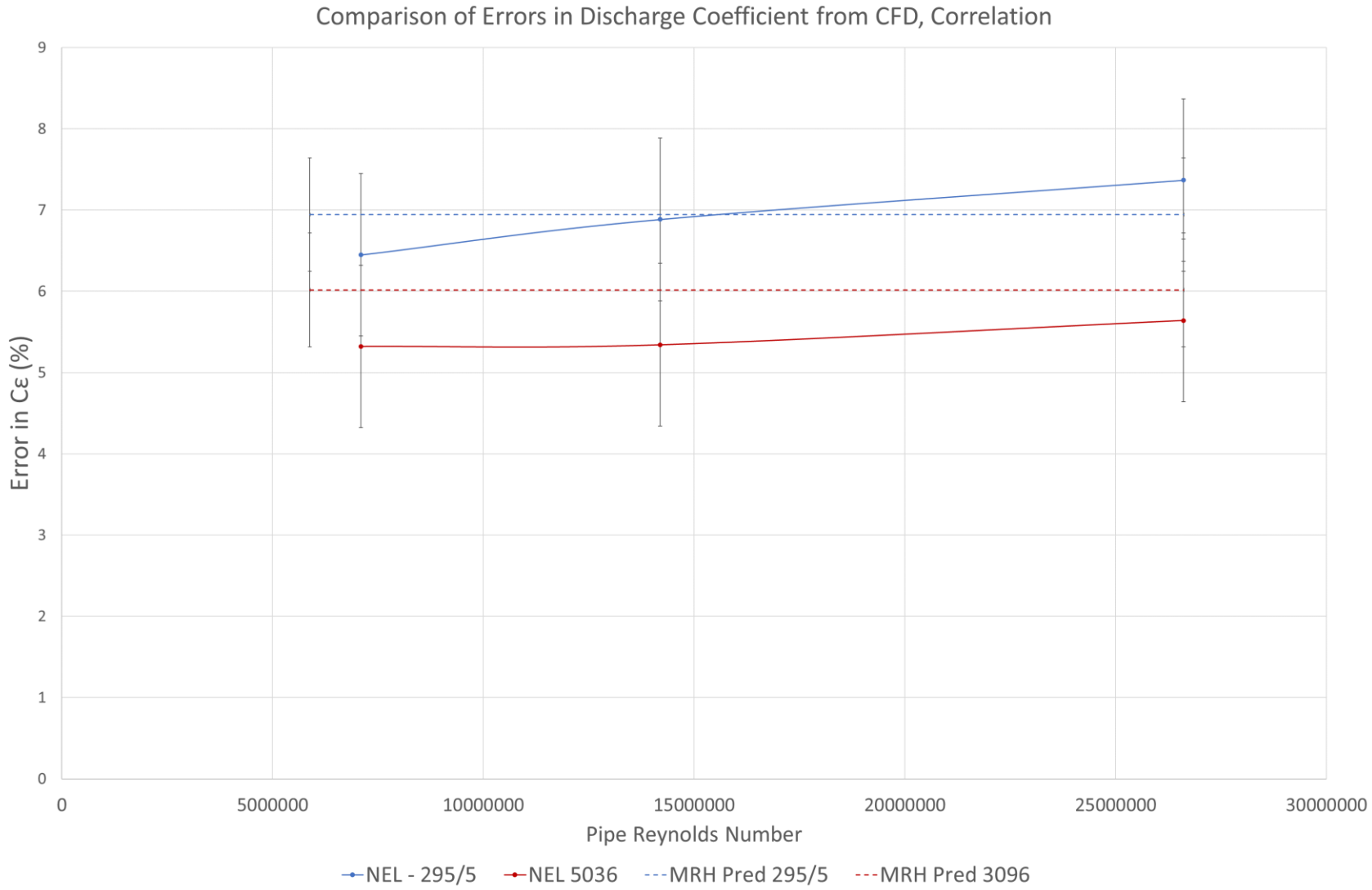
- Additionally, a further prediction was considered based on a correlation from a textbook. The text book uses the SWRI and other sources for the data. The assessment of these plates are within 0.7% of the prediction:

Validation



b/d of 0.007 and 0.006

All Results


Comparison of Errors in Discharge Coefficient from CFD, Correlation
Error in Cε (%)
0
1
2
3
4
5
6
7
8
9
0
5000000
10000000
15000000
20000000
25000000
30000000
Pipe Reynolds Number
NEL - 295/5
NEL 5036
MRH Pred 295/5
MRH Pred 3096

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Questions?