A Mystery of the Difference between Duty Streams and Master Meter in Export Gas Metering System

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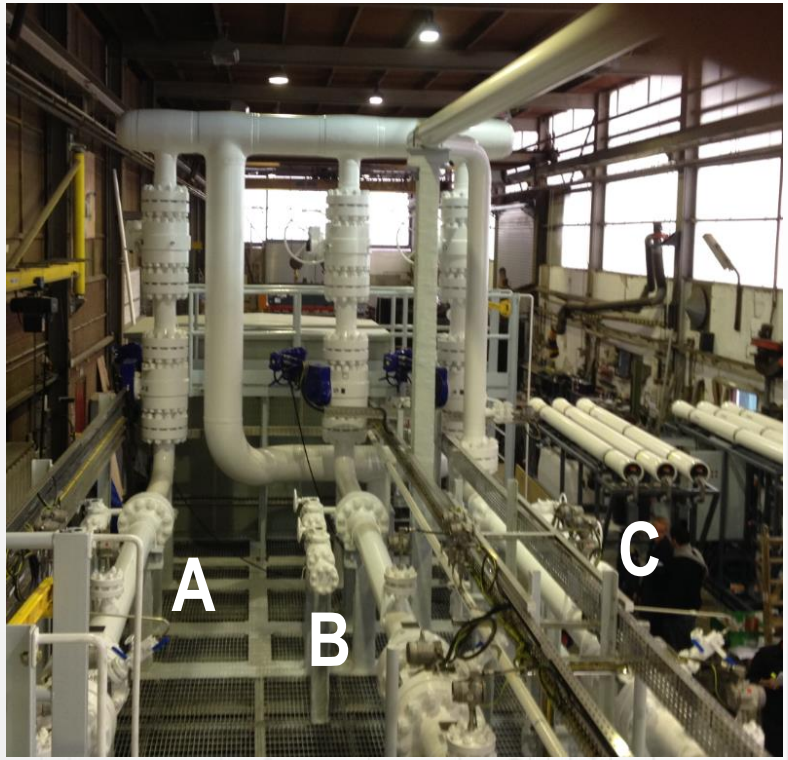
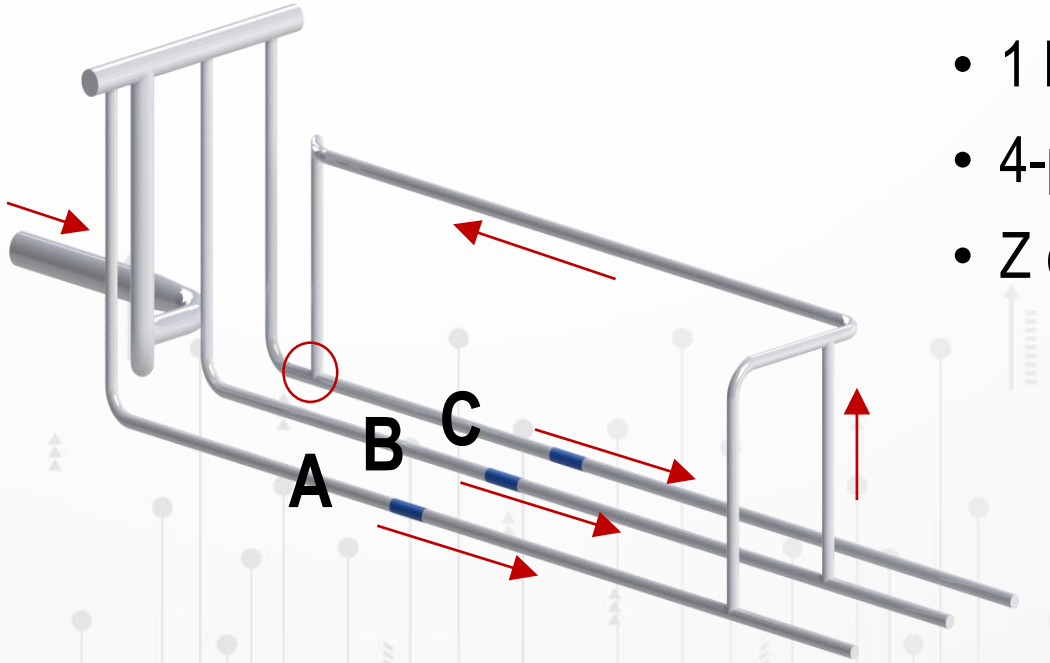
Content

Export Gas Metering System Initial Setup

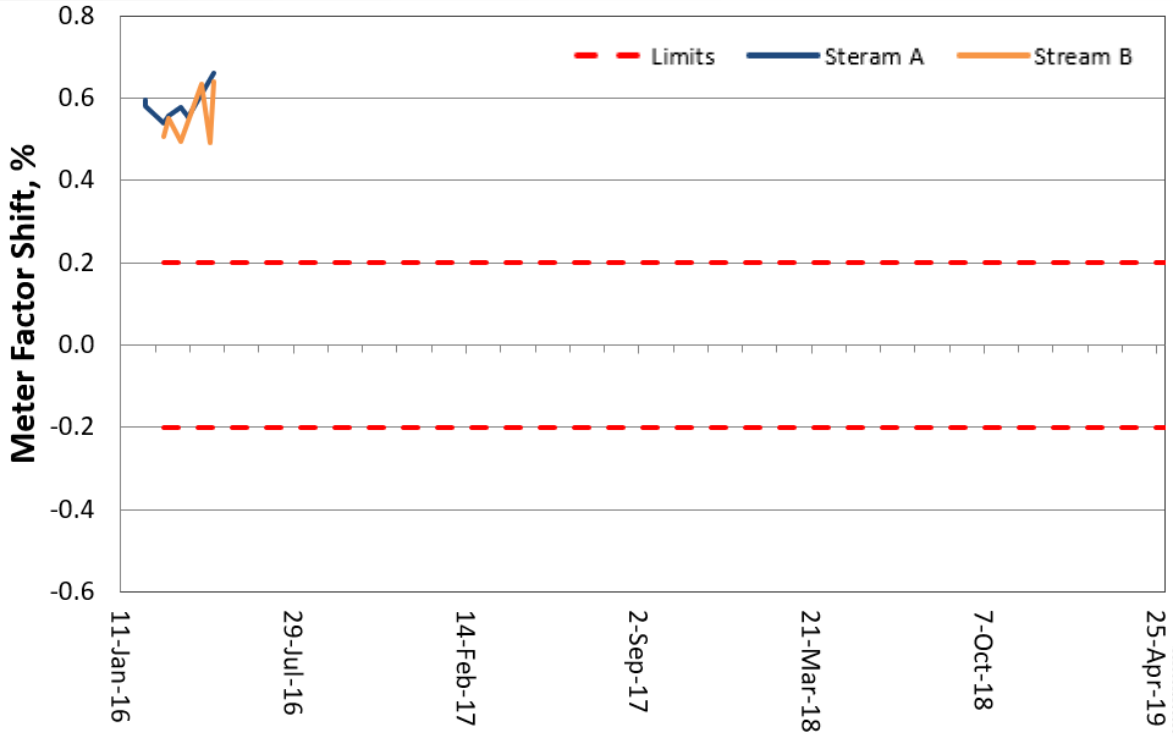




- 2 Duty streams (A and B)
- 1 Master meter stream (C)
- 4-path 8 inch USMs
- Z configuration with T-entry

Hypothesis No 1

A and B Streams Proving Results



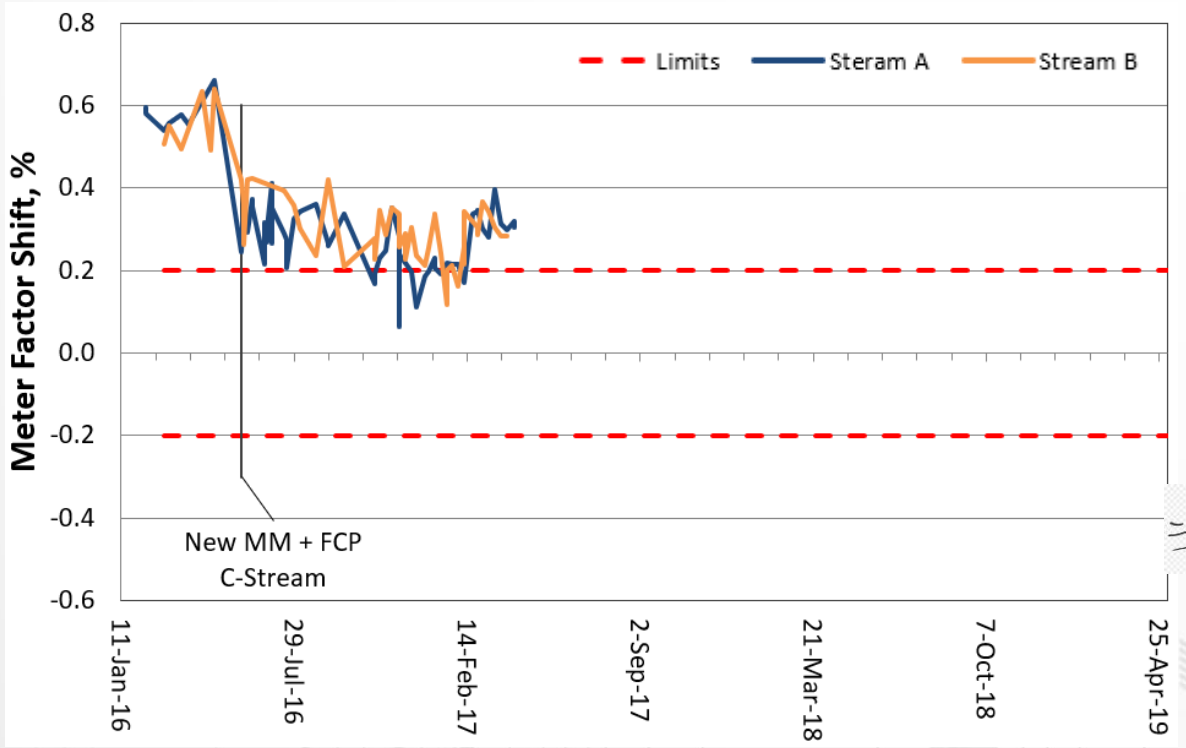
At Start-Up

- First Prove showed **0.6 % Difference** between Master and Duty Meters
- Brand-new Flow Meters
- Same Laboratory Calibration
- USM Diagnostics showed skewed profile and higher turbulence in C-Stream
- On inspection the FCP on C-Stream that was there at the FAT had been removed when the meter had been recalibrated prior to start-up

Hypothesis No 1: FCP absence is a cause of difference

Hypothesis No 2

A and B Streams Proving Results



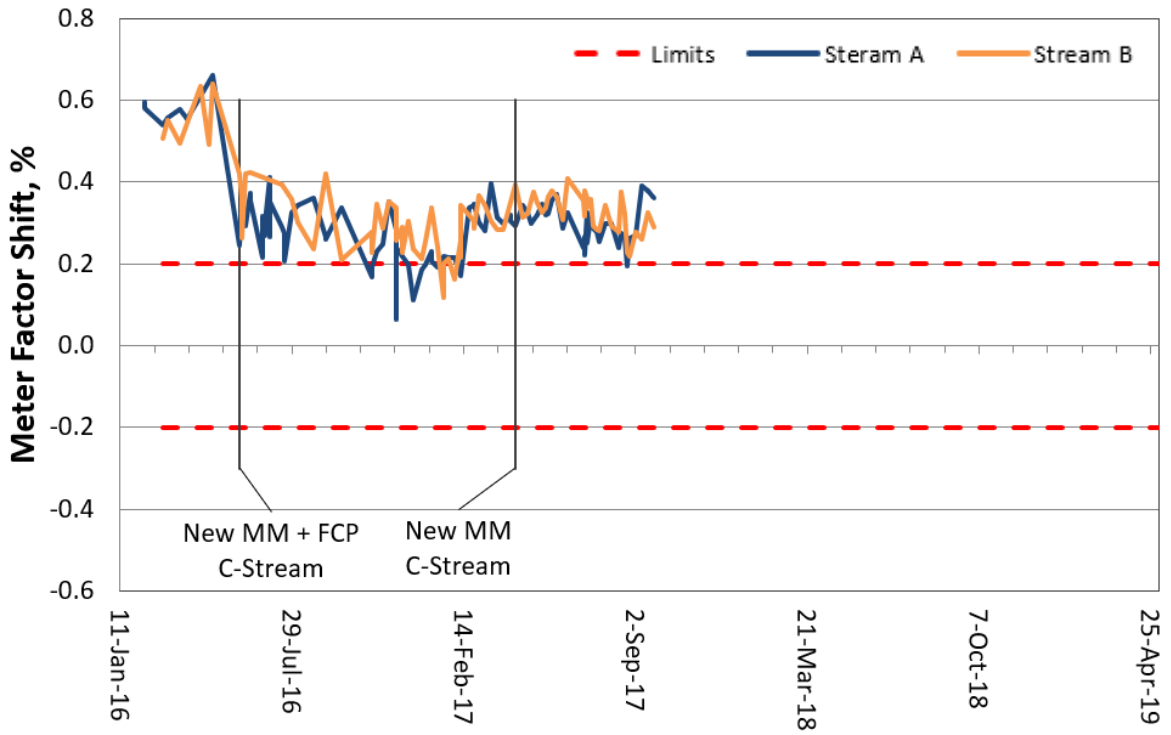
FCP in C-Stream

- New Master Meter, FCP and Correct Upstream Straight Length were found and installed in C-Stream in May 2016
- Drop of **0.3 % in Difference** between Master and both Duty Meters but still not satisfactory
- Both Duty Meters show Identical Shift

Hypothesis No 2: Master Meter is still wrong

Hypothesis No 3

A and B Streams Proving Results



New Meter in C-Stream

- Master Meter was changed out again in April 2017
- Change-over had no visible effect on Meter Factor Shift

Hypothesis No 3:

- Flow distortion in Stream A and B because of lack of FCP
- C-Stream design, Out-of-Plane 90-Degree Bends, blind T-entry
- C-Stream Velocity Profile might not be fully developed
- FCP might be not in Optimal Position

- CFD Modelling was requested in April 2017

CFD Modelling Scope and Methods

Scope:

- Investigate installation effects in all streams of the Export Gas Metering System
- Recommend optimum position of Flow Conditioning Plate (FCP) in Master C-Stream

Methods of Investigation:

- CFD for prediction of velocity profiles in turbulent pipe flows
- South Ural State University (SUSU) to carry out CFD modelling
- CFD model validation using Performance Indicators of 4-path USM flow meter: Profile Factor, Asymmetry Factor and Cross Flow
- CFD model utilisation for prediction of FCP optimum position

CFD Model Setup

Equations

Stationary Reynolds-Averaged Navier–Stokes (RANS) equations with k–ω SST turbulence model

Boundary Conditions

Inflow: Uniform or Transferred velocity profiles

Outflow: Zero-gradient

Mesh

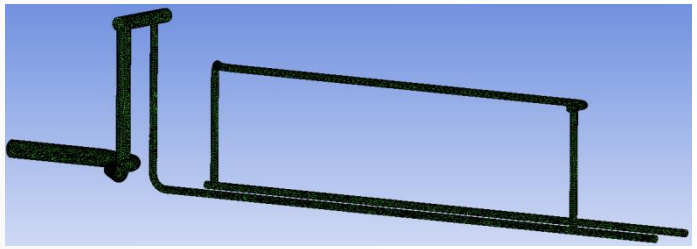
Hexahedral and Tetrahedral mesh with size of wall-adjacent cells specified by non-dimensional wall distance parameter y^+ from 1 to 200

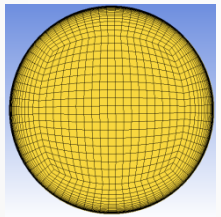
CFD Tools

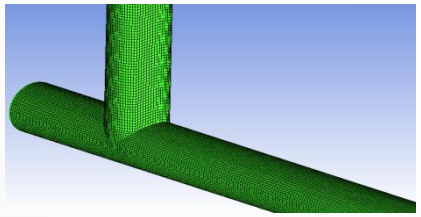
ANSYS ICEM – module for mesh generation

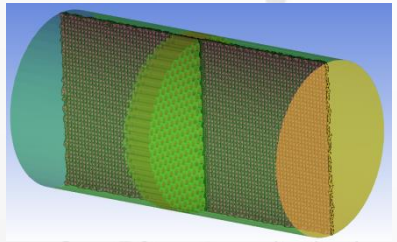
ANSYS CFX – module for calculation of fluid dynamics

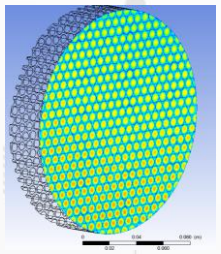
CFD Model Setup: 4-Step Solution

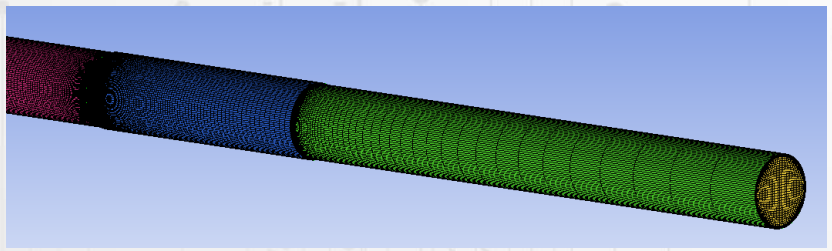












Step 1: Entire Metering System
Tetrahedral Mesh
0.4 million elements

Velocity Profile

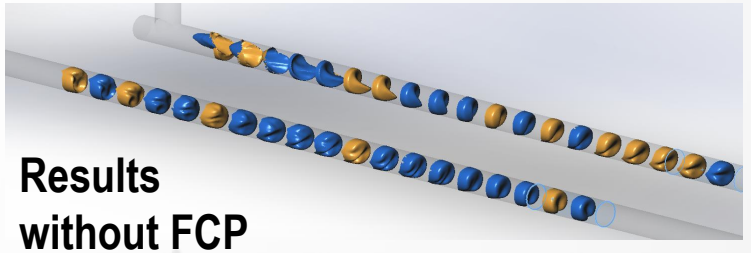
Step 2: B and C without FCP
Hexahedral Mesh
2.3 million elements

Velocity Profile

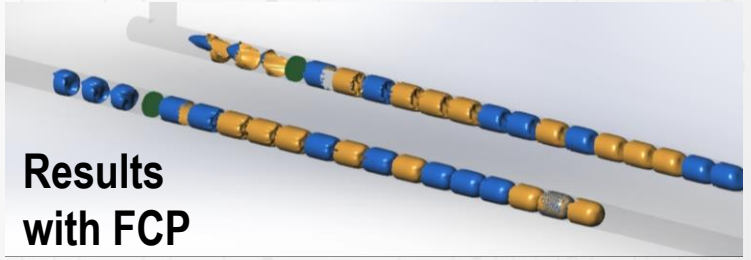
Step 3: FCP in B and C
Tetrahedral Mesh
7.5 million elements

Velocity Profile

Step 4: B and C with FCP Effect
Hexahedral Mesh
4.7 million elements



Results without FCP



Results with FCP

CFD Model Conclusion

Mesh

- Hexahedral mesh gives better results
- Tetrahedral mesh saves time

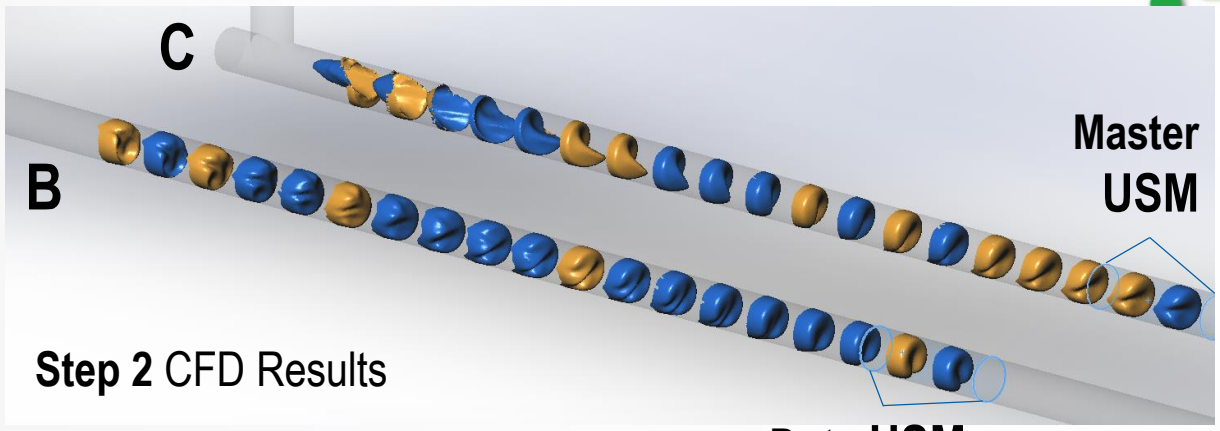
Model

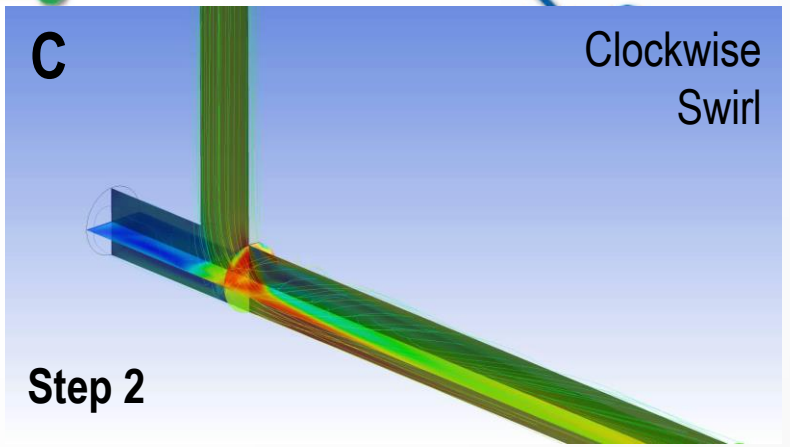
- k-ω SST model is optimal for engineering calculations
- Large eddy flow requires more complicated turbulence model with 6 differential equations, DES or LES methods

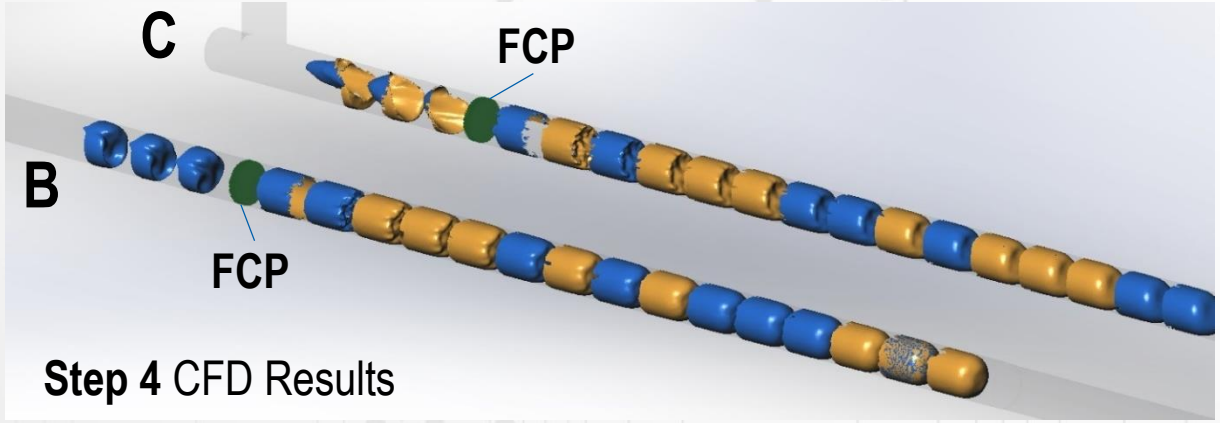
CFD Tools

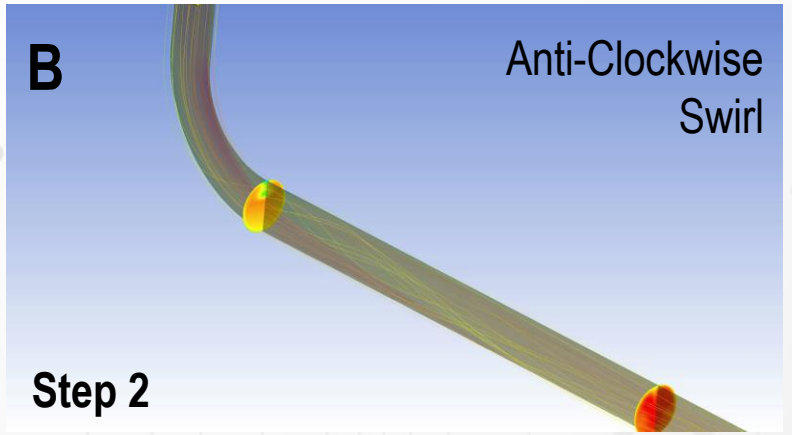
- CFD helps visualise and understand physical process

CFD Results in 3D

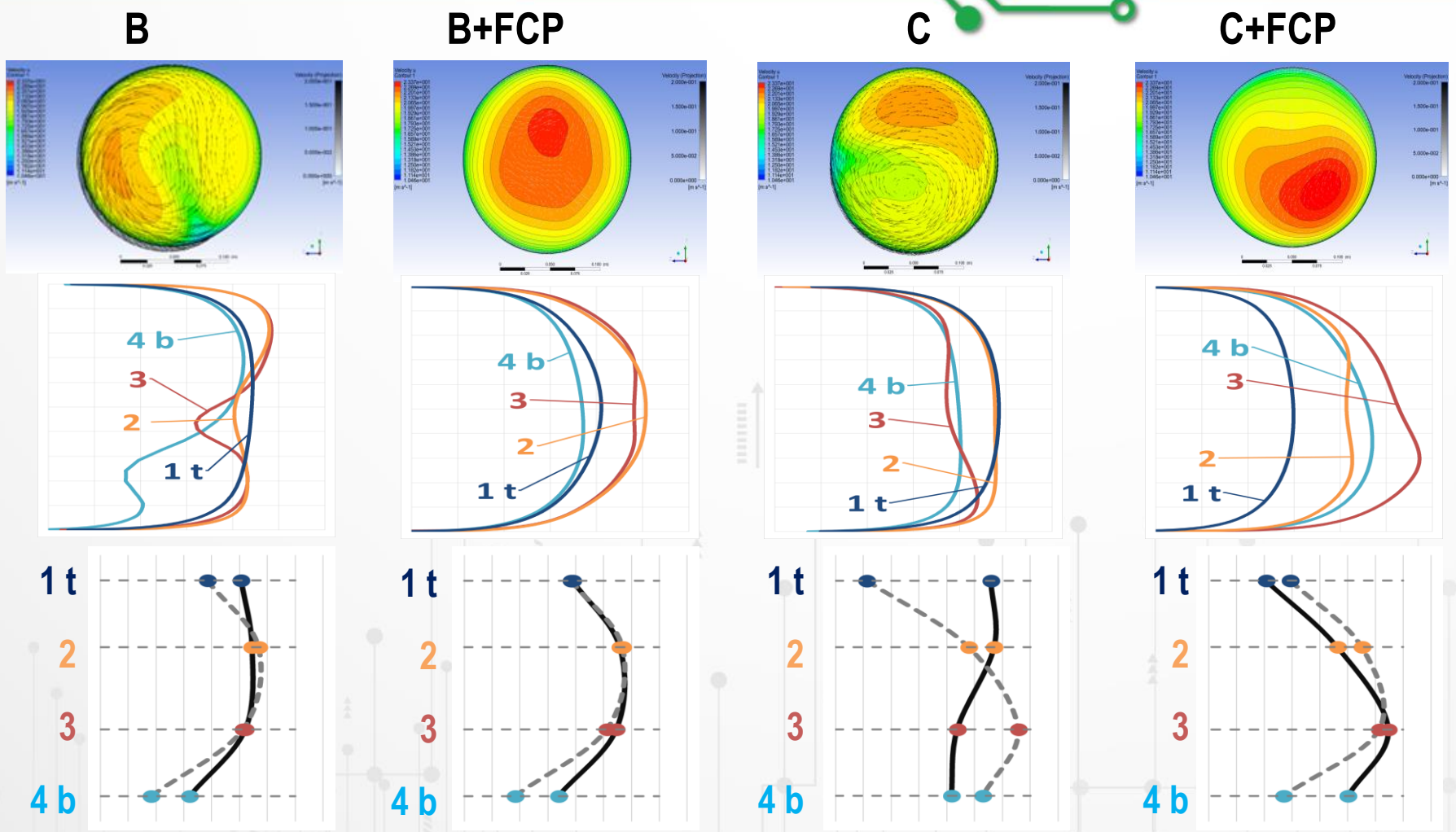








CFD Results and Model Validation



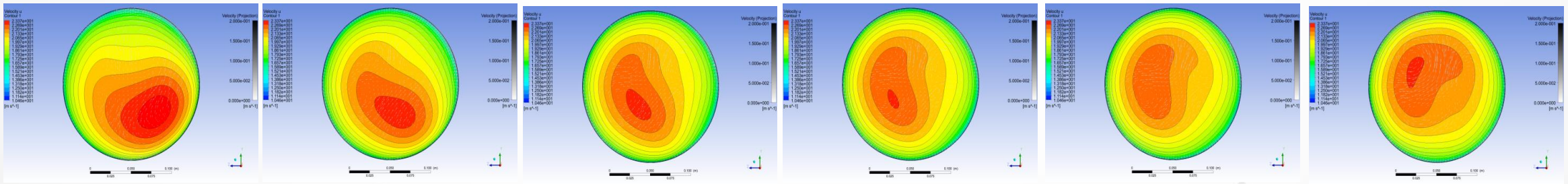
Iso-surface of Velocity Profile at USM Inlet Section

Velocity Distribution along USM paths
t – top
b – bottom

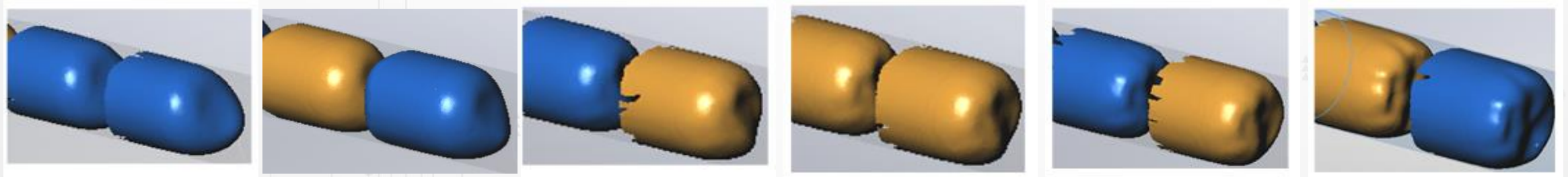
USM vs CFD Path Velocities

CFD Results and FCP Position in C-Stream

21.9 D As-Built	18.9 D +0.5 m	16 D +1.0 m	14.5 D +1.25 m	13 D +1.5 m	10 D + 2 m



Iso-surface of Velocity Profile at USM Inlet Section

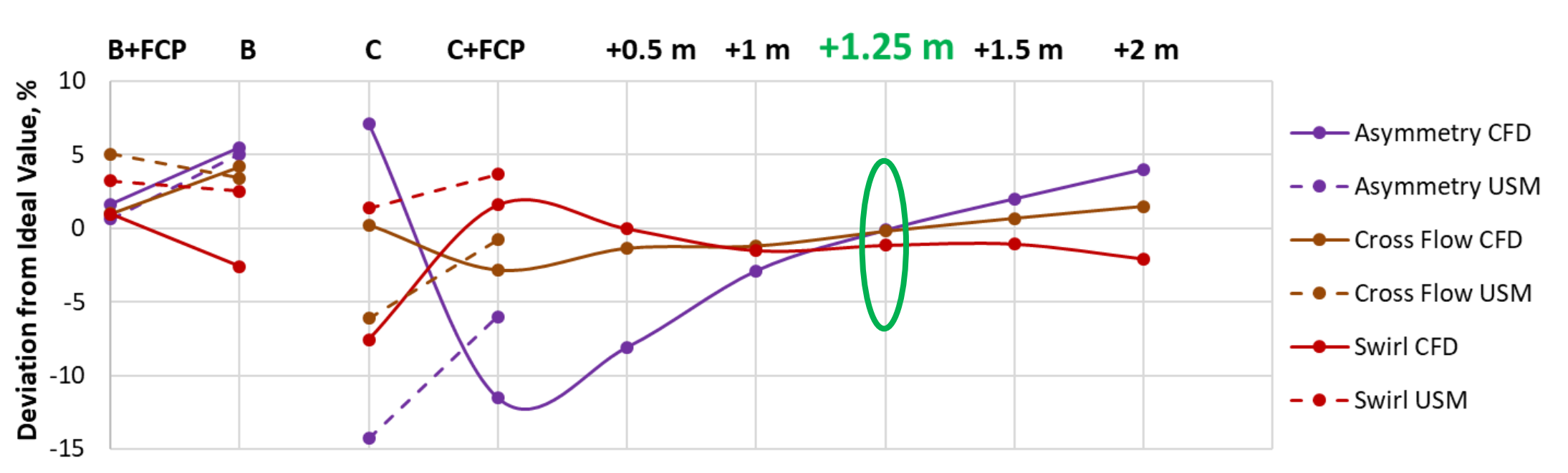


3D Velocity Profile at USM Inlet Section

Optimal FCP Position in C-Stream

Ideal Value of Performance Indicators for 4-path USM:

Asymmetry	(V1+V2)/(V3+V4) = **1**
Cross Flow	(V1+V3)/(V2+V4) = **1**
Swirl (Profile Factor)	(V2+V3)/(V1+V4) = **1.12**



CFD Modelling Results and Recommendations

Stream C (Master Meter)

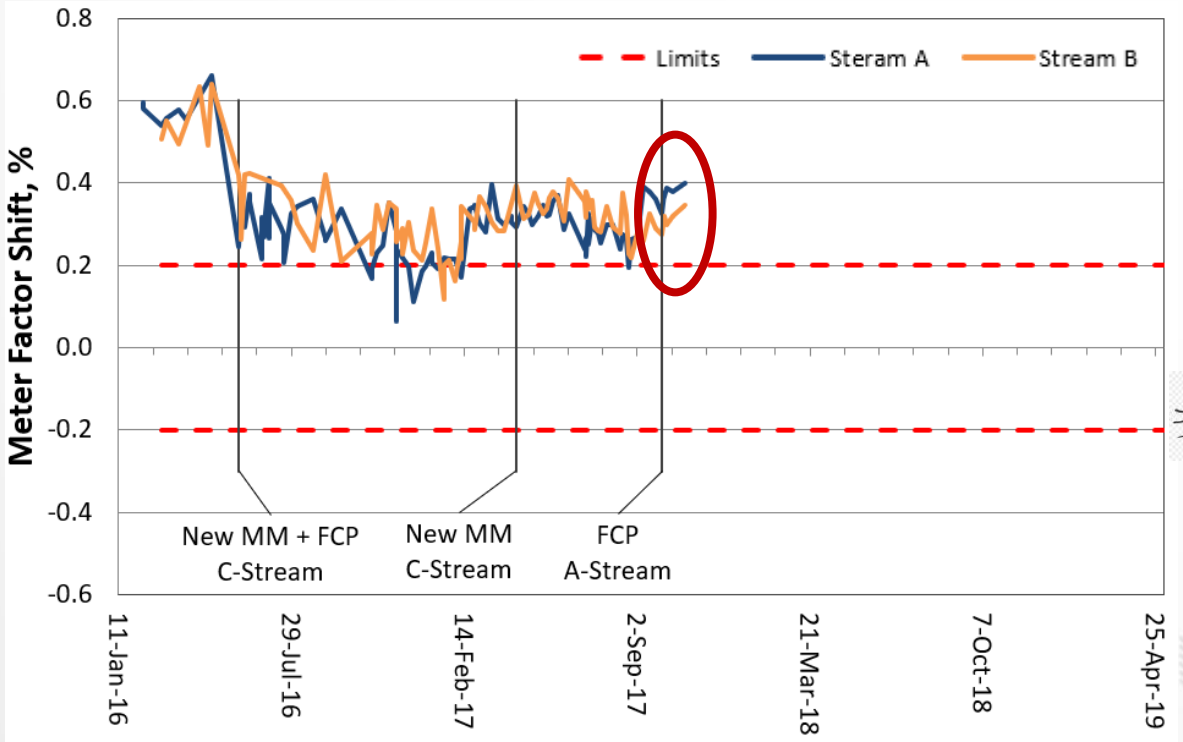
- Move FCP plate downstream by 1.25 meter from the current location towards the Flow Meter
- Redesign C-Stream T-shape blind entry and consider curved entry

Streams A and B (Duty Meters)

- Install FCP into both streams

Hypothesis No 4

A and B Streams Proving Results

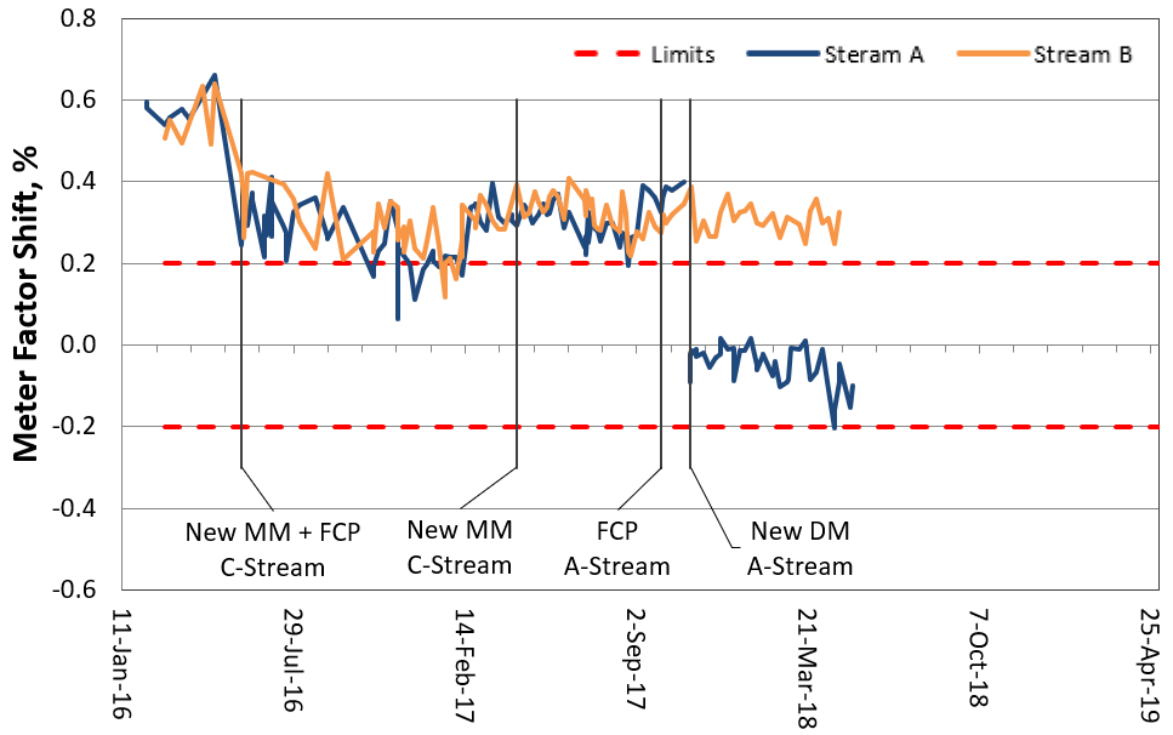


FCP in A-Stream

- FCP in A-Stream was installed in October 2017
- Turbulence in A-Stream improved as predicted by CFD
- 0.3 % difference between Master and both Duty Meters
- Flow Meters cope with swirl and profile disturbances quite well
- **Hypothesis No 4:** Duty Meters might be an Issue
- Only Calibration Certificates were provided showing no issues
- Inspection of minute-by-minute calibration data showed the same P and T for each meter
- Both Duty Meters were calibrated in series at the same time

Mystery Revealed for A-Stream

A and B Streams Proving Results

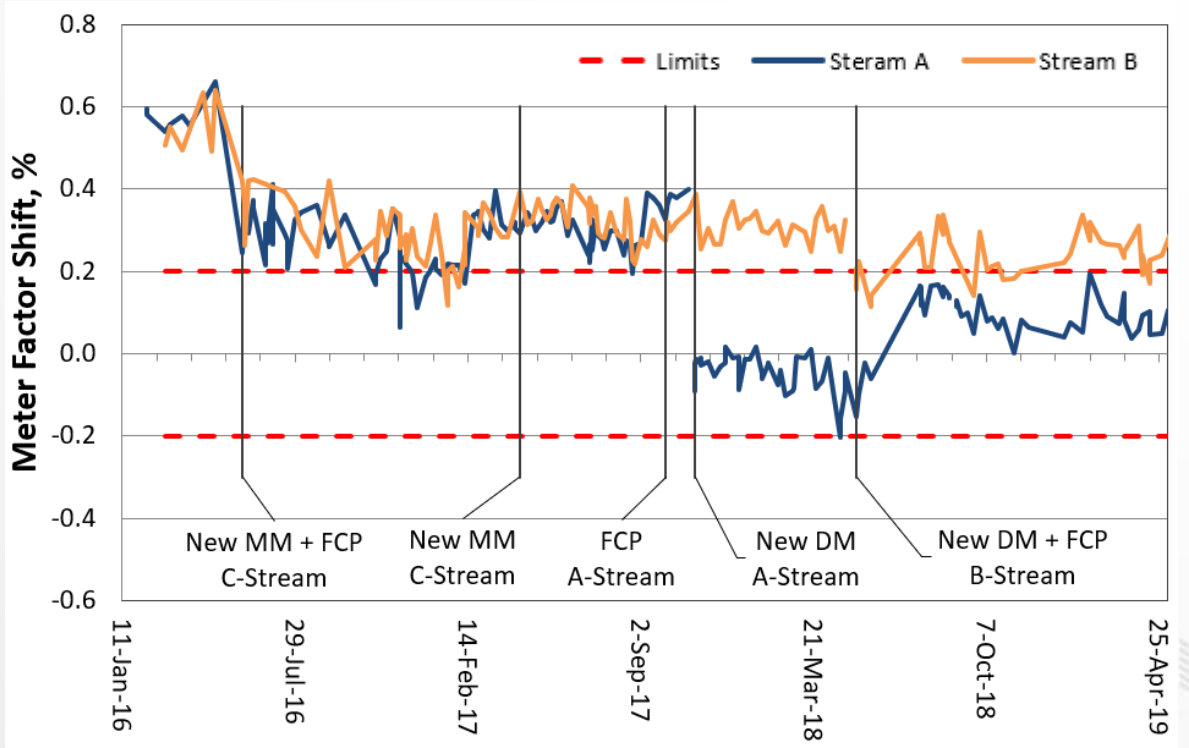


New Meter in A-Stream

- A-Stream Duty Meter change-over was in November 2017 after being calibrated in another laboratory
- Difference between Master and A-Stream Duty Meter is within 0.2 %
- Concluding that the calibration of Duty Meters was an issue

Mystery Revealed for B-Stream

A and B Streams Proving Results



New Meter in B-Stream

- B-Stream Duty Meter change-over together with FCP in May 2018
- Delay in change-over due to lifting problems over pressurised pipework
- Difference between Master and B-Stream Duty Meter is at the level of 0.2 %

Conclusion: How to avoid Mysteries in Metering?

Cost-Driven design of Metering System does not deliver the best Metering Solution:

- a blind T-entry in a Z-configuration introduces significant flow disturbance, where a curve bend would be better and use of CFD would highlight the best position of FCP
- FCP Installation should be mandatory for Gas USM Metering Systems irrespective to the upstream straight pipe length
- Flow Control Valves would remove preferential flow during proving
- Correction of Metering System Design afterwards is expensive and time-consuming

CFD Modelling:

- CFD modelling helps visualise process, understand weak points and improve design
- CFD models should be validated using real data where possible

Challenge all Assumptions: even if they appear obvious

Insist on witnessing calibration of all Metering Instrumentation

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