Calibration, Fluid Property Effects Reproducibility and Long Term Stability. All in 20 minutes!

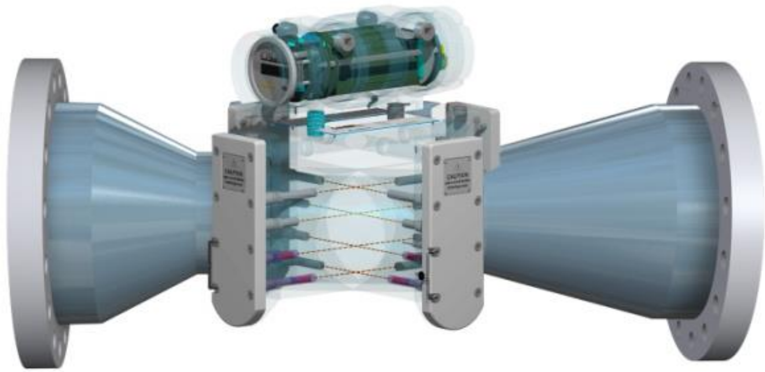



Dr Gregor Brown
Cameron

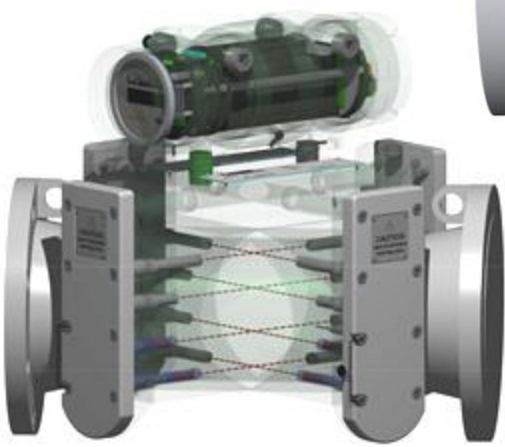
Agenda

- Calibration process
- Cameron calibration laboratory
- Reproducibility/calibration transfer to other fluids
- Meter design and impact on the influence of fluid properties
- Calibration transfer to the field
- Long term stability

4-path, 8-path and 8-path RN meters



Linearity +/- 0.1%



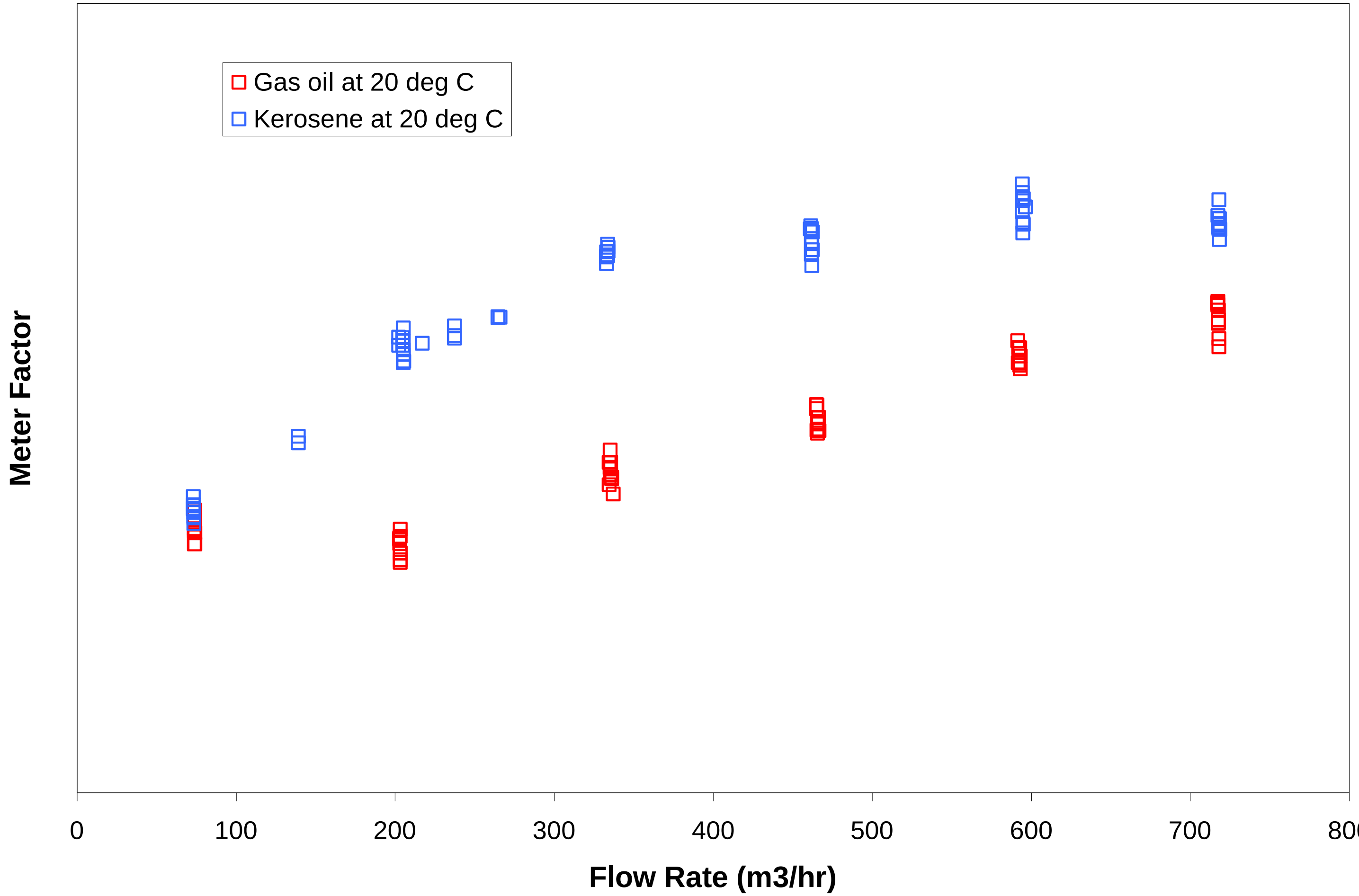
Linearity +/- 0.1 %

Linearity +/- 0.15 %

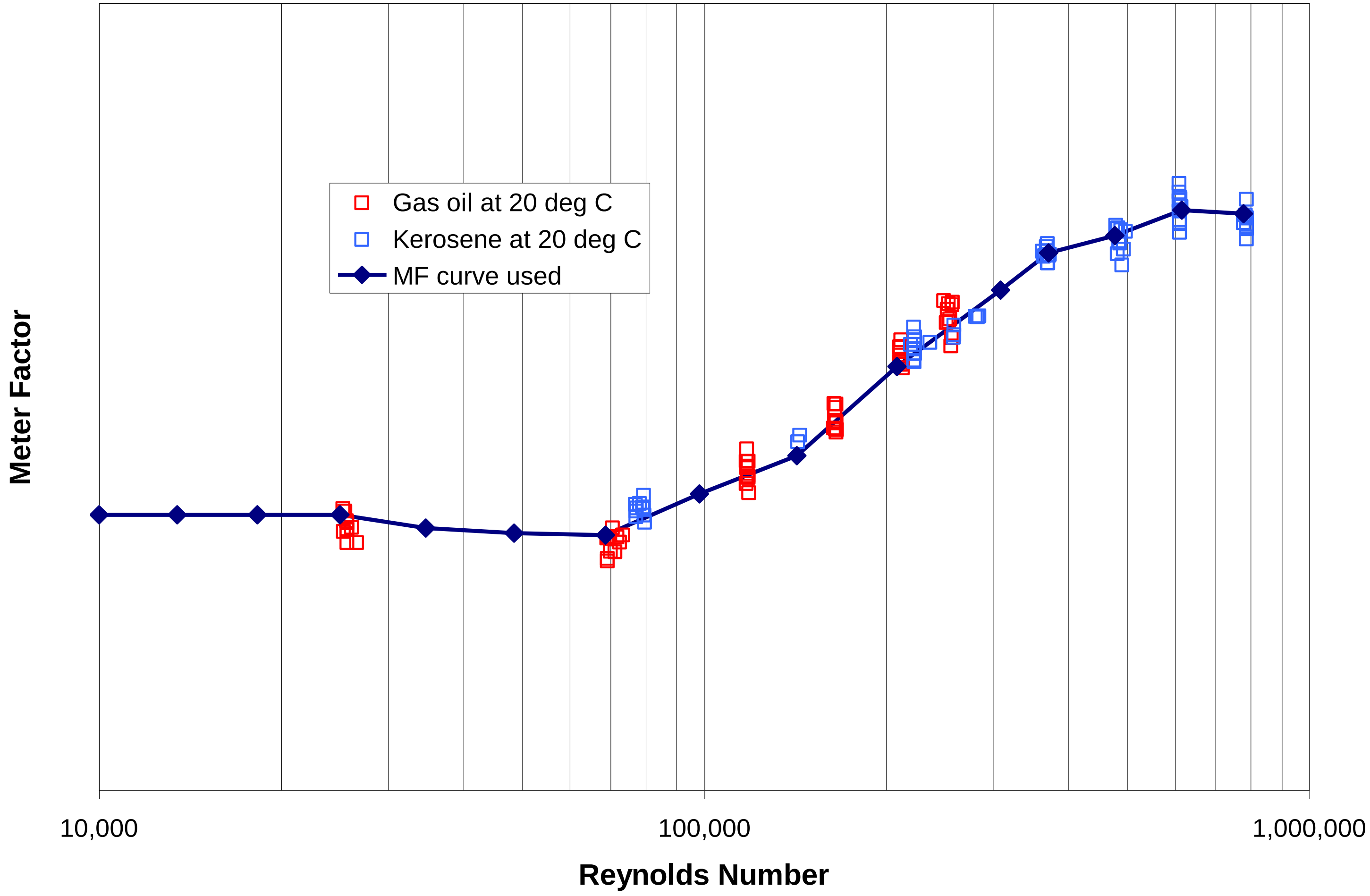
Calibration process for Caldon meters

- Characterise over the Reynolds range of the application, using one, two or three oils
- Enter calibration data into two tables in the meter as a function of measured profile flatness and/or Reynolds number
- Calibrate the linearized meter using each of the oils; default six flowrates per oil to API 5.8 repeatability requirements

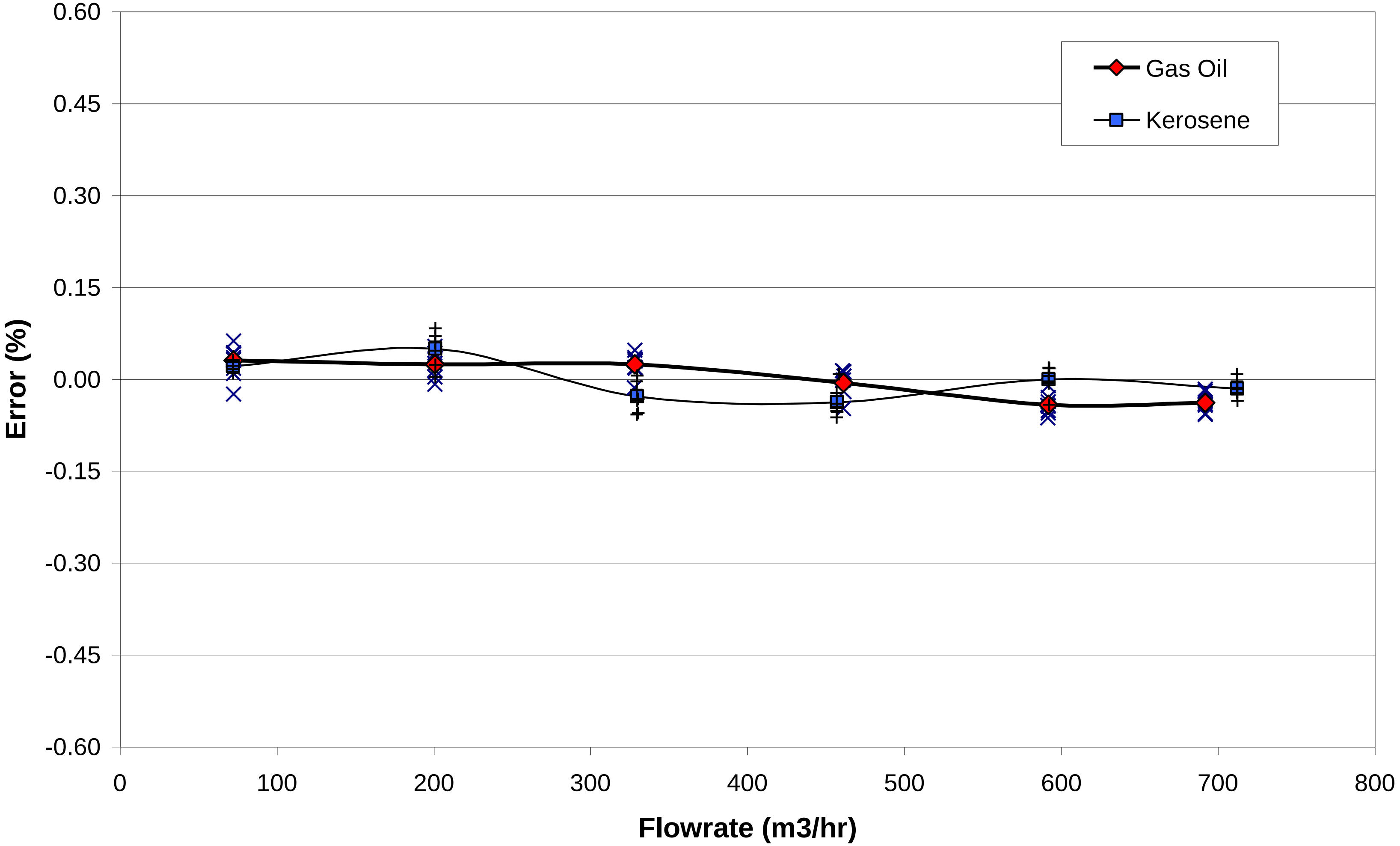
Raw Calibration vs Flow Rate



Reynolds Number Calibration Curve



Final Calibration Result

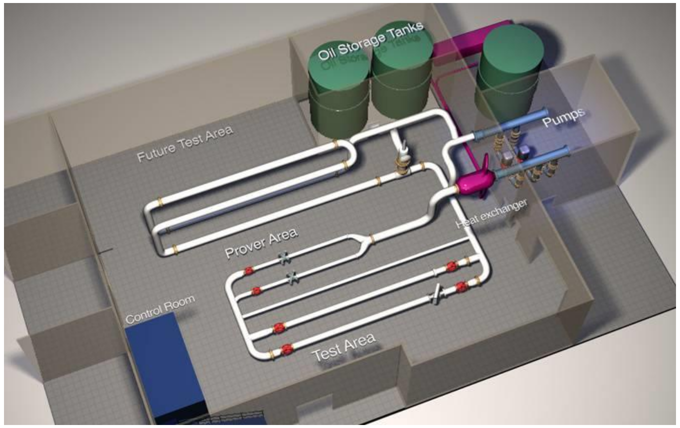


CALDON ULTRASONICS TECHNOLOGY CENTRE

CALIBRATION LABORATORY

PITTSBURGH, USA

Main laboratory area



- Prover
- Master meters
- Heat exchanger
- Test meter lines
- 7.5 ton bridge crane
- Main control room

Calibration fluids

- Refined hydrocarbon oils
- Oils chosen to give a good range of viscosity for Reynolds number span
  - EXXSOL D80, kerosene substitute, approx. 3 cSt
  - DRAKEOL 5, approx. 15 cSt
  - DRAKEOL 32, approx. 150 cSt

NVLAP Certified Uncertainties

- 10 to 750 m^3/hr
  - – Small volume prover 0.03%
  - – Turbine master meter 0.04%
- 150 to 2200 m^3/hr
  - – Ball prover 10 m^3 0.04%
  - – Ball prover 3.3 m^3 0.07%
  - – One master meter 0.09%
- 600 to 3900 m^3/hr
  - – Two master meters 0.08%

NVLAP® National Voluntary Laboratory Accreditation Program

DEPARTMENT OF COMMERCE * UNITED STATES OF AMERICA *

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005

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CALIBRATION LABORATORIES — **NVLAP LAB CODE 200813-0**
Scope Revised: 2011-08-19

MECHANICAL

NVLAP Code: 20/M05
Flow Rate (Hydrocarbon Fluids Only)[Note2,3]

Range in m^3/h	*Best Uncertainty (±) in %* [note 1]	*Remarks*
10 to 750	0.03	Brooks Small Volume Prover
10 to 750	0.04	One Master Meter
150 to 2200	0.04	10 Cubic Meter Prover Volume
50 to 200	0.07	3.3 Cubic Meter Prover Volume
300 to 2000	0.09	One Master Meter
600 to 3900	0.08	Two Master Meters

1. Represents an expanded uncertainty using a coverage factor, $k = 2$, at an approximate level of confidence of 95 %.
2. The laboratory performs calibrations of pulse generating flow meters.
3. The laboratory performs volumetric flow calibrations only (not mass flow).

2011-07-01 through 2012-06-30
Effective dates

Sally S. Bruce
For the National Institute of Standards and Technology

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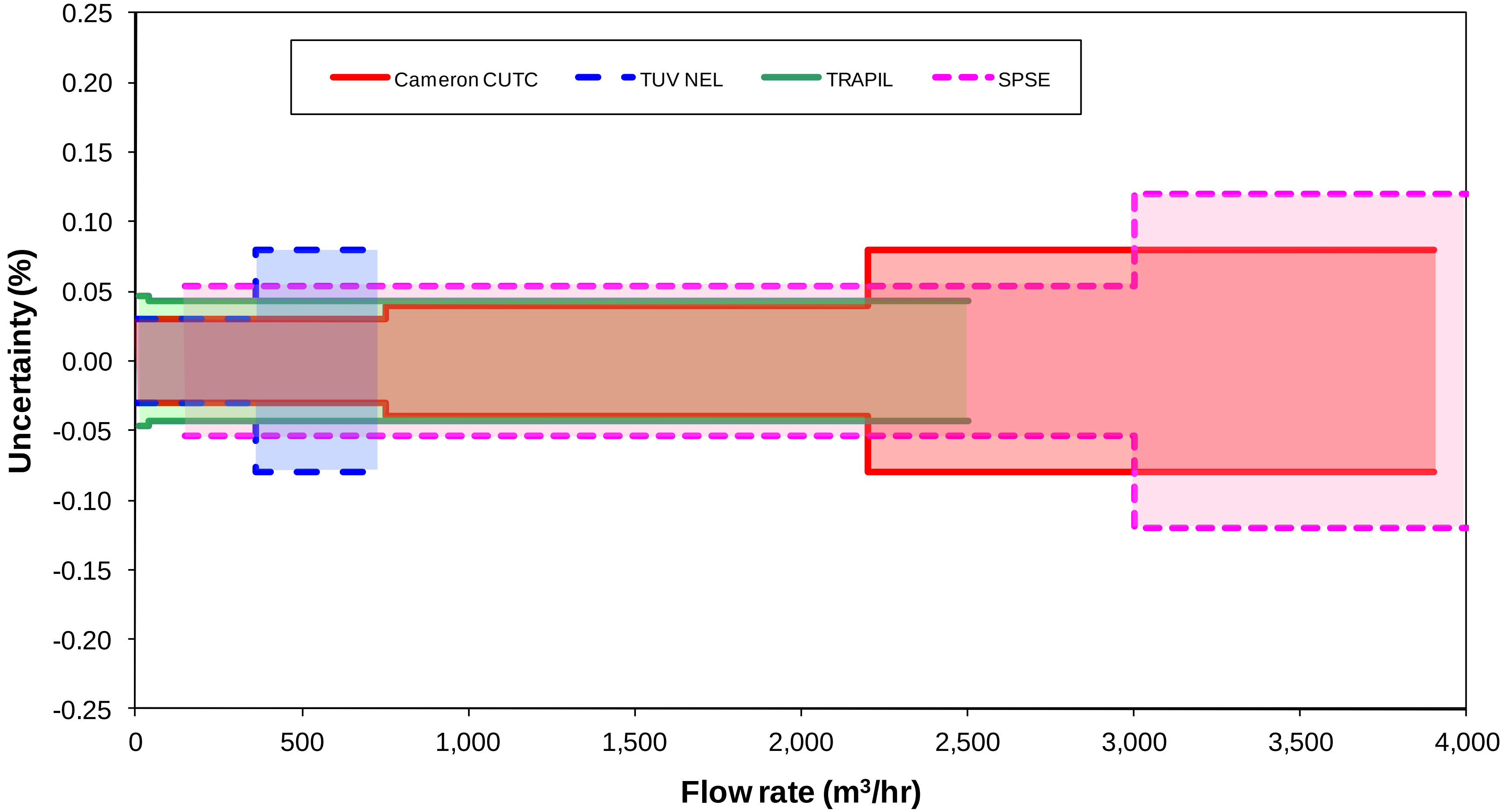
Comparison of ISO17025 capabilities



Mutual recognition arrangements

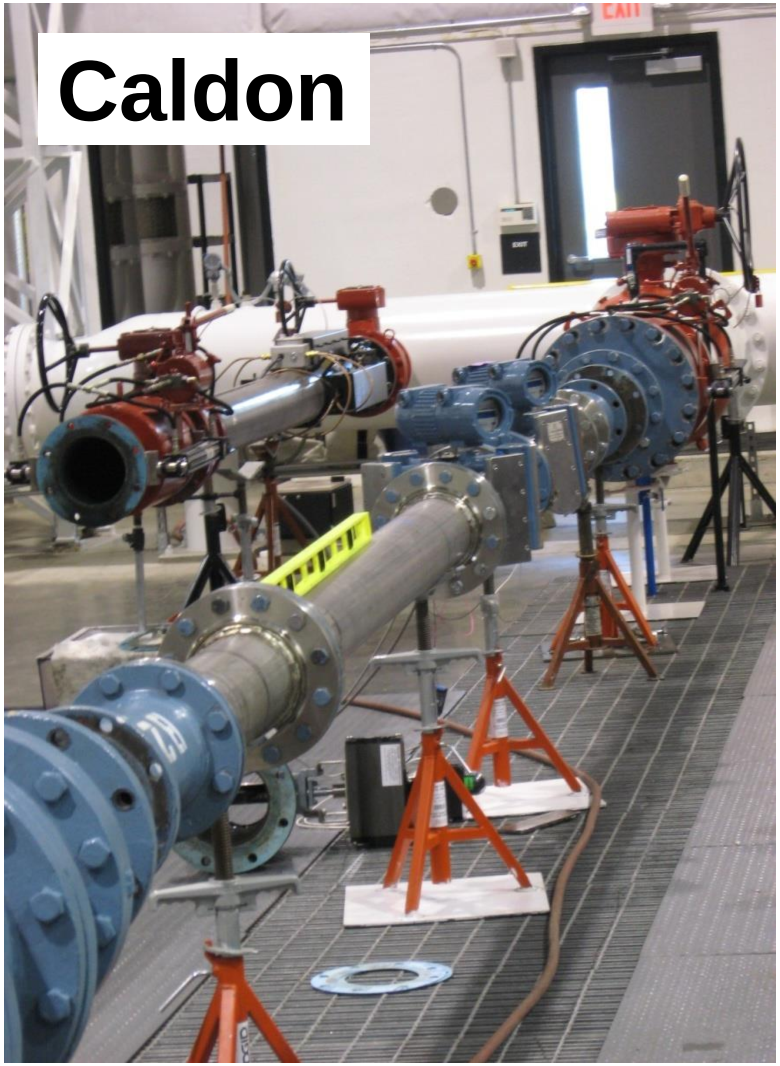
- NVLAP is a signatory to the following MRA's:
  - ILAC - International Laboratory Accreditation Cooperation
  - APLAC - Asia Pacific Laboratory Accreditation Cooperation
  - IAAC - Inter American Accreditation Cooperation

VSL CMC Certification

- The National Measurement Institute of the Netherlands, VSL, provide Cameron with an additional Calibration Measurement Capabilities (CMC) certification
- This certification focuses on the uncertainty of the calibration method
- This is a voluntary certification that adds a further layer of quality assurance to the Caldon laboratory operations

VSL
Dutch Metrology Institute

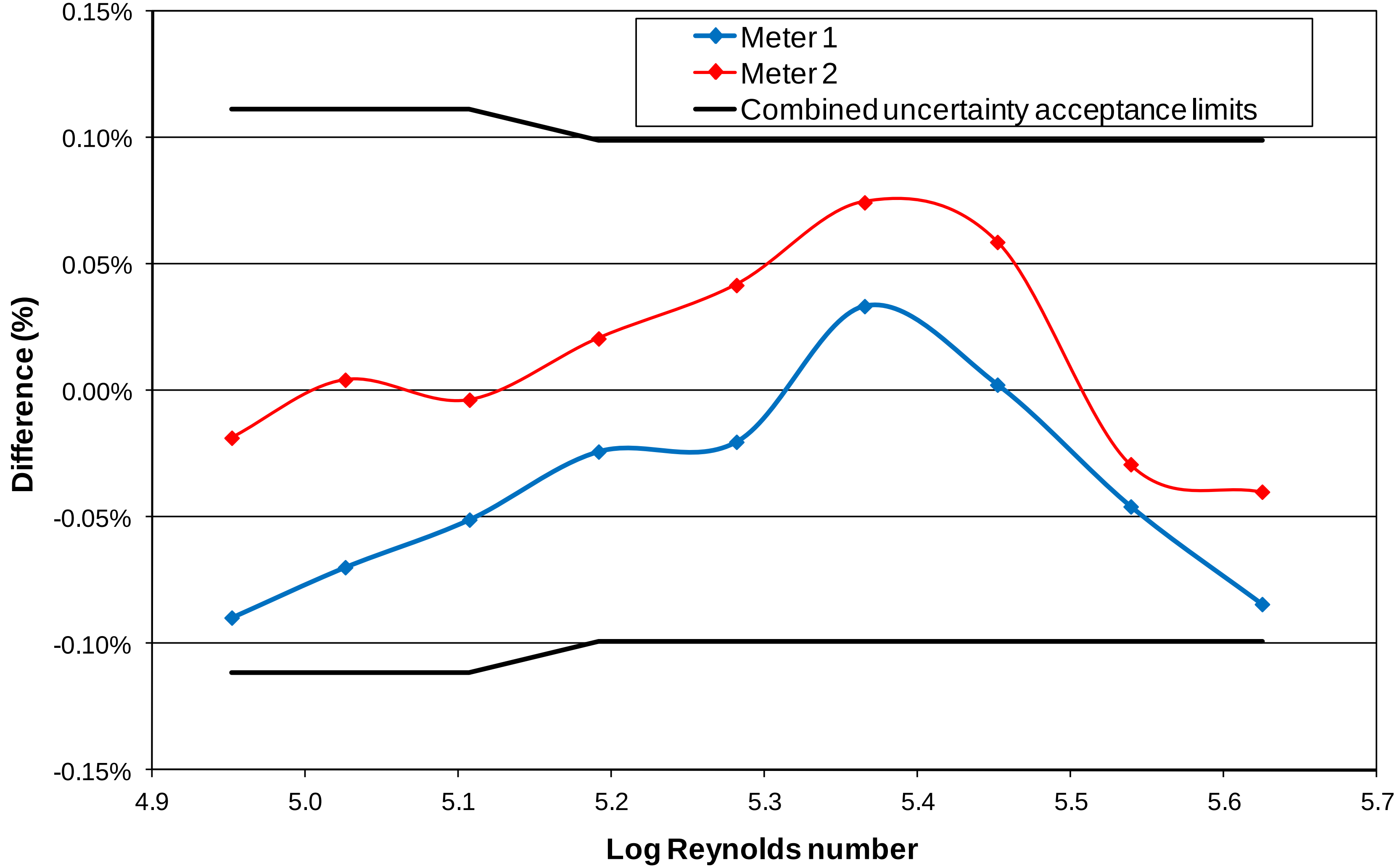
Intercomparision using 8-path USMs



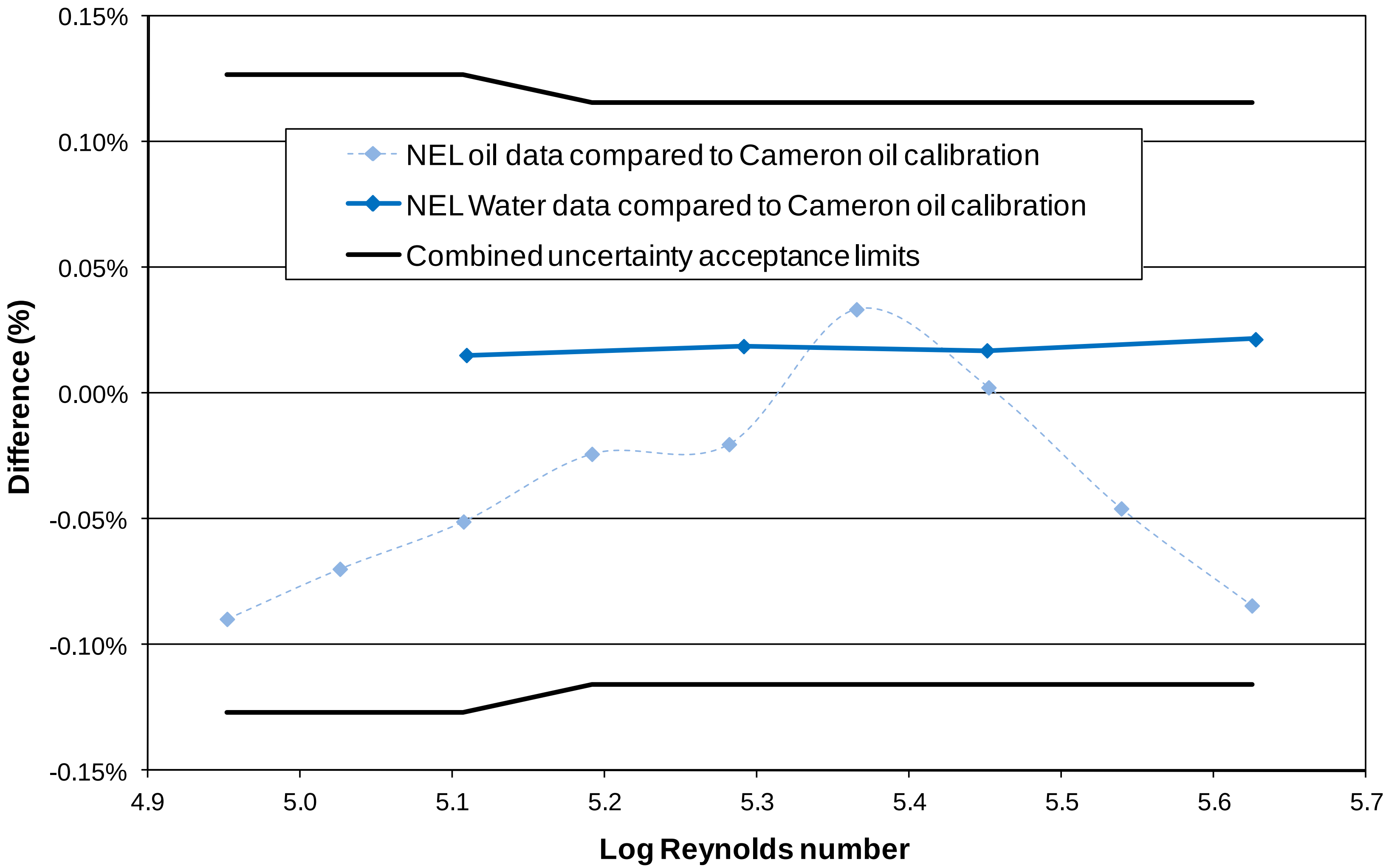
Intercomparision package

- Primary comparison was carried out using kerosene substitute (Exxsol D80) over a flow range of 100 to 600 m^3/hr in both facilities
  - Caldon lab tests vs ball prover
  - NEL tests versus turbine secondary standards
- A secondary comparison was also carried out using the NEL water flow facility gravimetric standard
- Comparisons were made at overlapping Reynolds numbers

Intercomparision results on kerosene



Intercomparision results vs water



Intercomparision results

- The results from both meters and both NEL facilities (oil and water) demonstrated metrological equivalence with the Caldon laboratory
- The closest and most linear agreement was actually found in the case of the water comparison, suggesting that the difference in the oil calibration were in part due to the curve fitting to the NEL secondary standard turbines

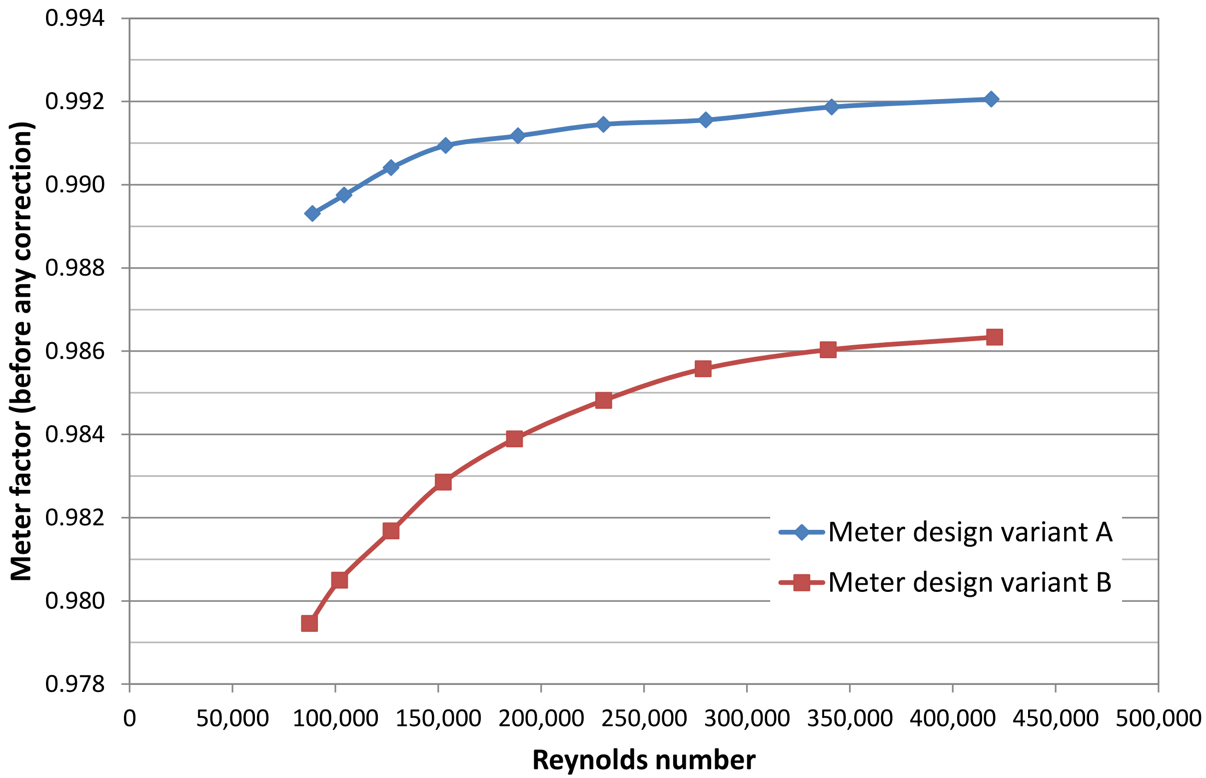
Influence of inputs and design on fluid property effects

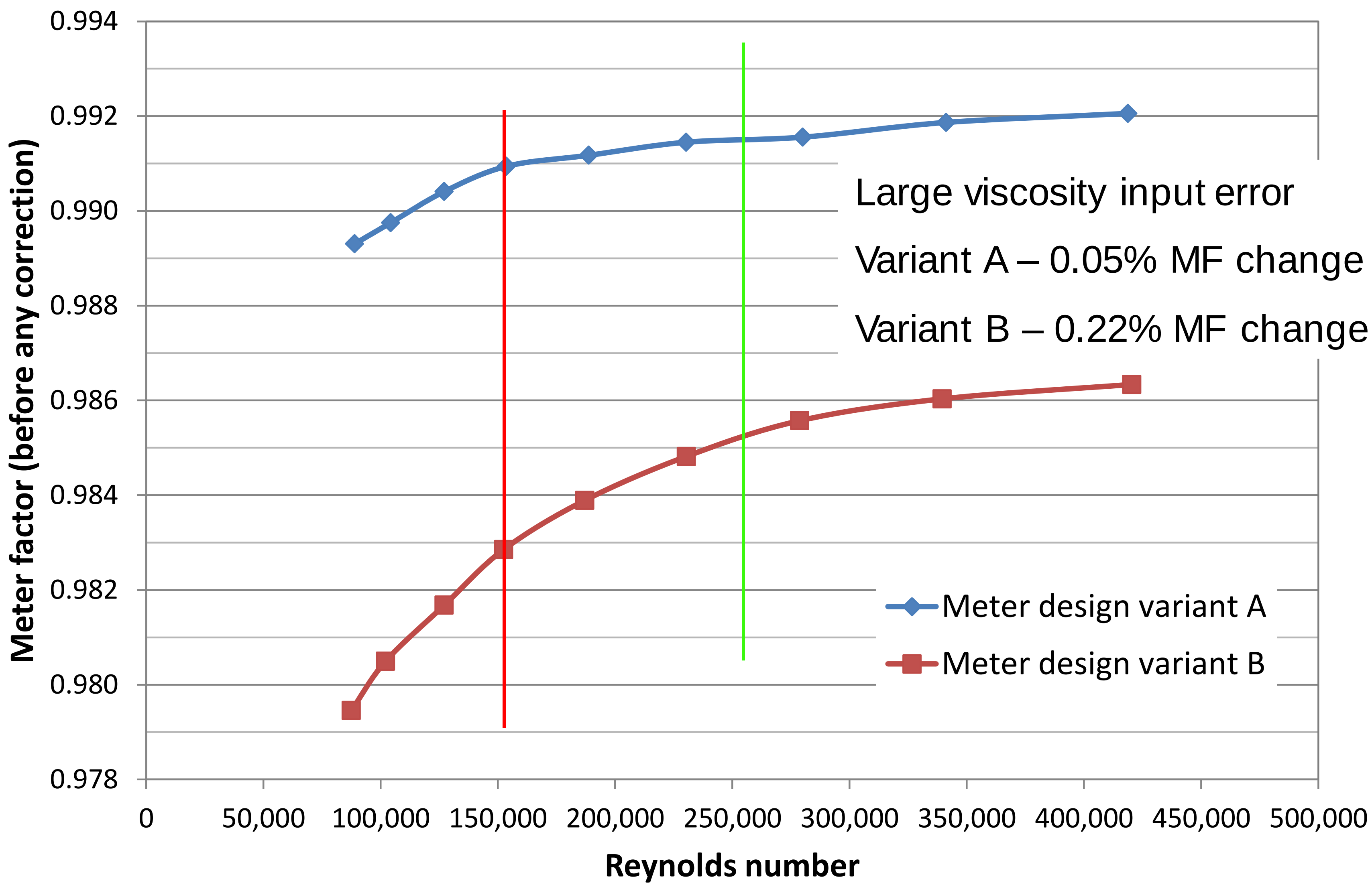
Internal linearization

- The more linear the meter is to start with the less correction is required
- Correction using velocity profile may be prone to installation effects, which can have a Reynolds dependence
- Correction using an inferred Reynolds number requires a reliable viscosity input
- Good design can minimize residual fluid property effects

Linearity before adjustment of two 6-inch meters

- Both 8-path meters, same electronics, same transducers
- Intentional meter body design differences



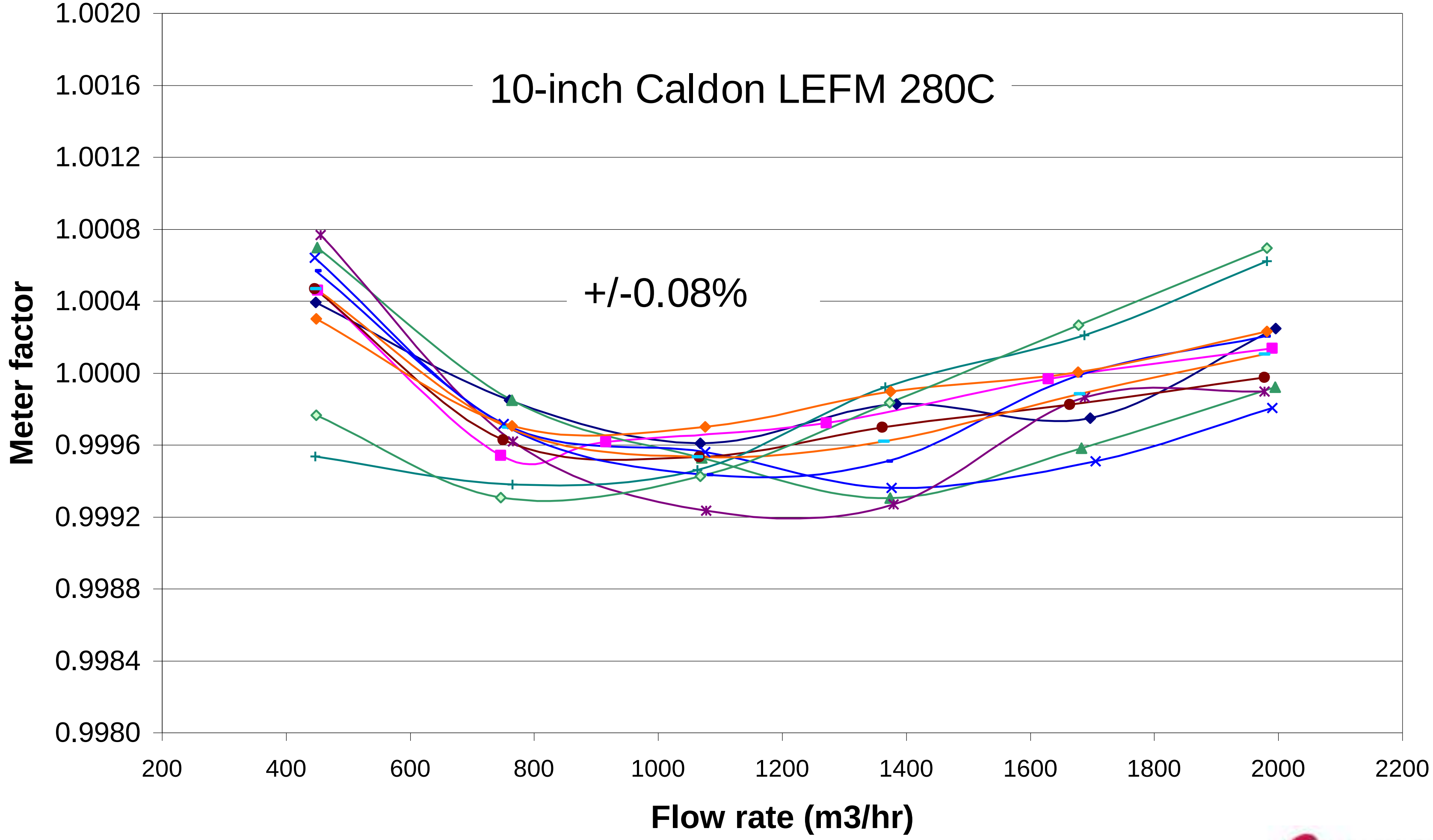

0.994
0.992
0.990
0.988
0.986
0.984
0.982
0.980
0.978
Meter factor (before any correction)
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
500,000
Reynolds number
Large viscosity input error
Variant A – 0.05% MF change
Variant B – 0.22% MF change
Meter design variant A
Meter design variant B

Design variants can minimise non-linearity *and* installation effects

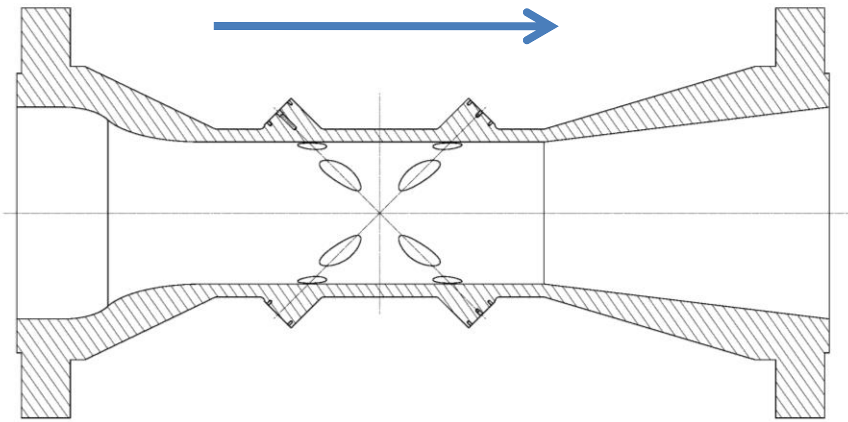
This can involve some differences in design/model selection and configuration for different applications

10-inch full-bore LNG meters for high Re

11 LNG meters after single point MF adjustment



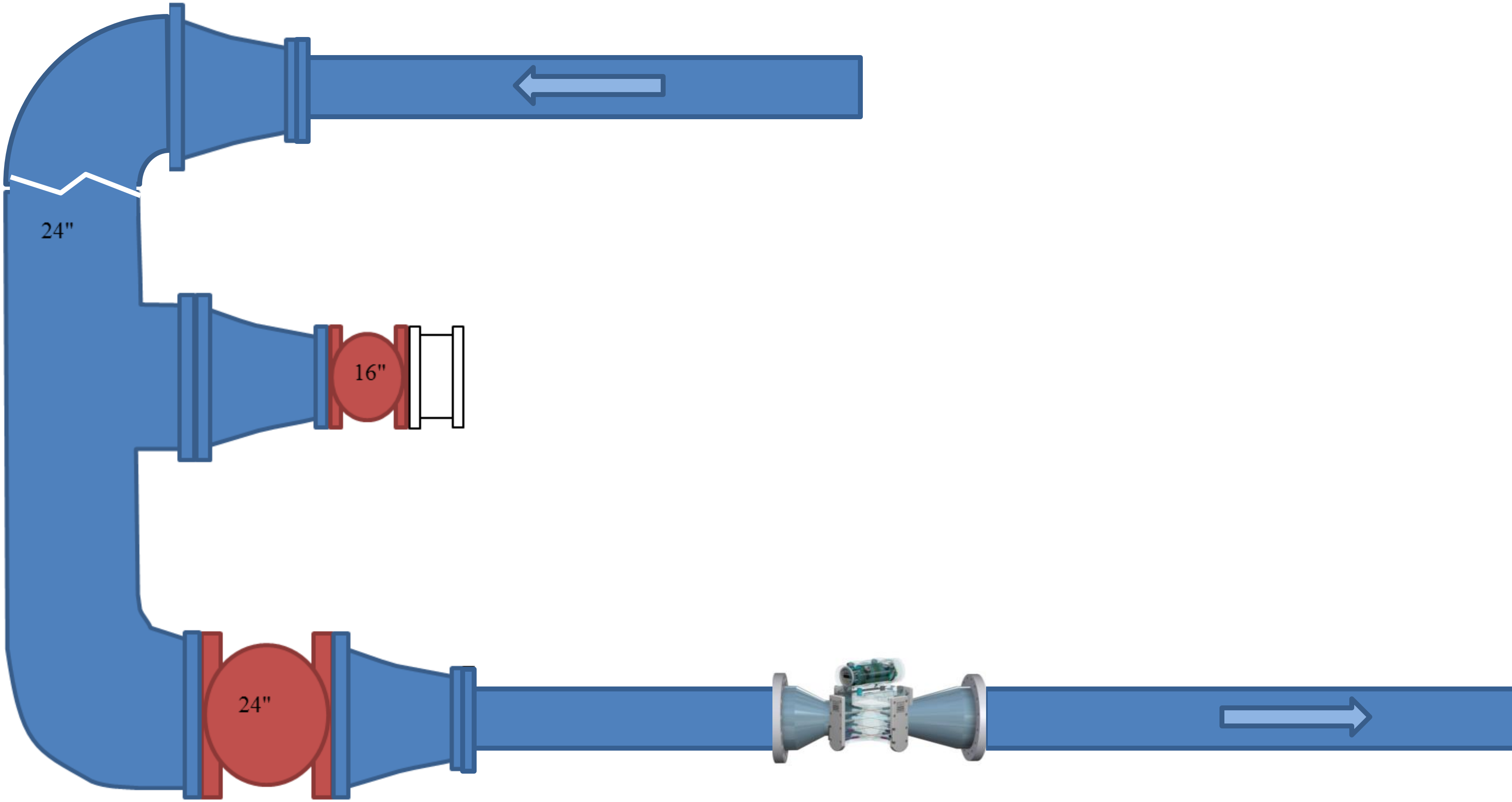
Reducing Nozzle Meter for Low Reynolds Numbers



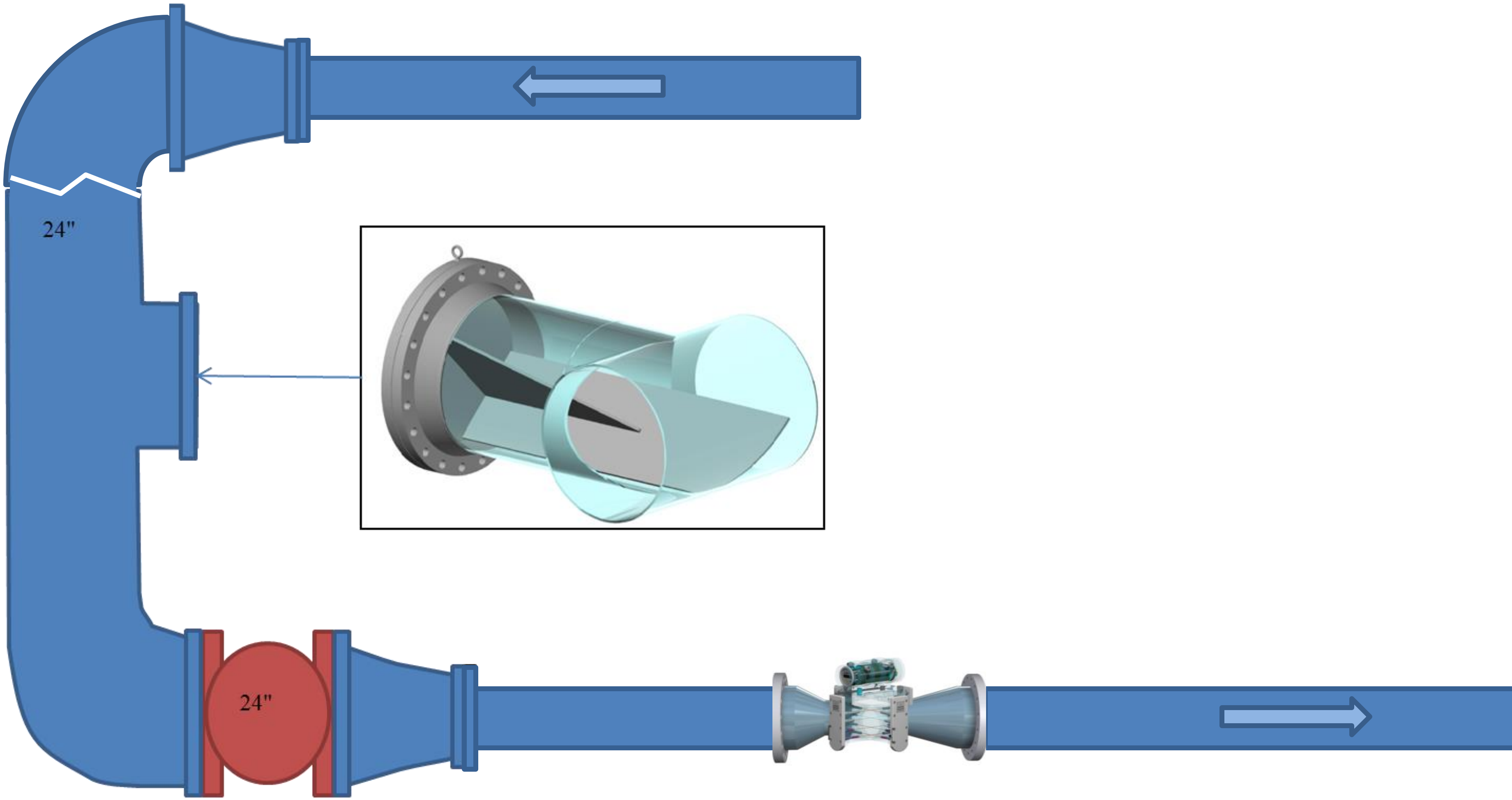
10-inch LEFM 280CiRN test

- Three installation configurations tested without adjustment of the meter between tests
- 10-inch meter vs 10 m^3 unidirectional prover
- Two fluids/viscosities (12 and 100 cSt)
- 6 flow rates for each condition, mean value at each flow determined to better than +/- 0.027%

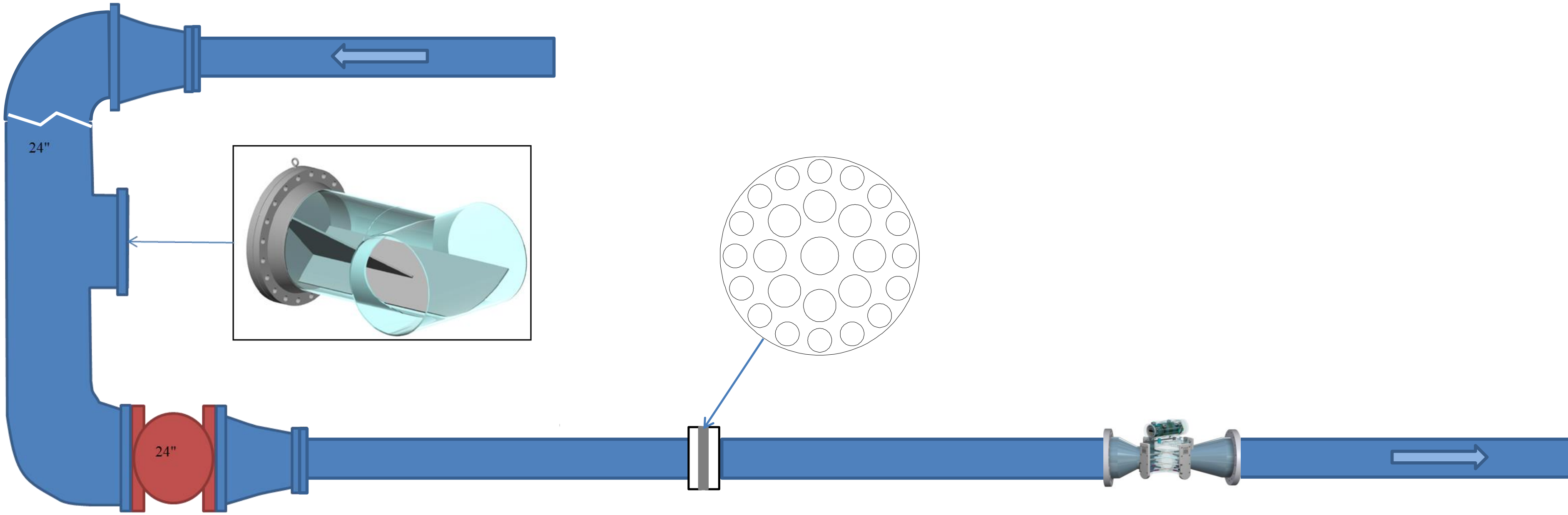
Installation at 5D



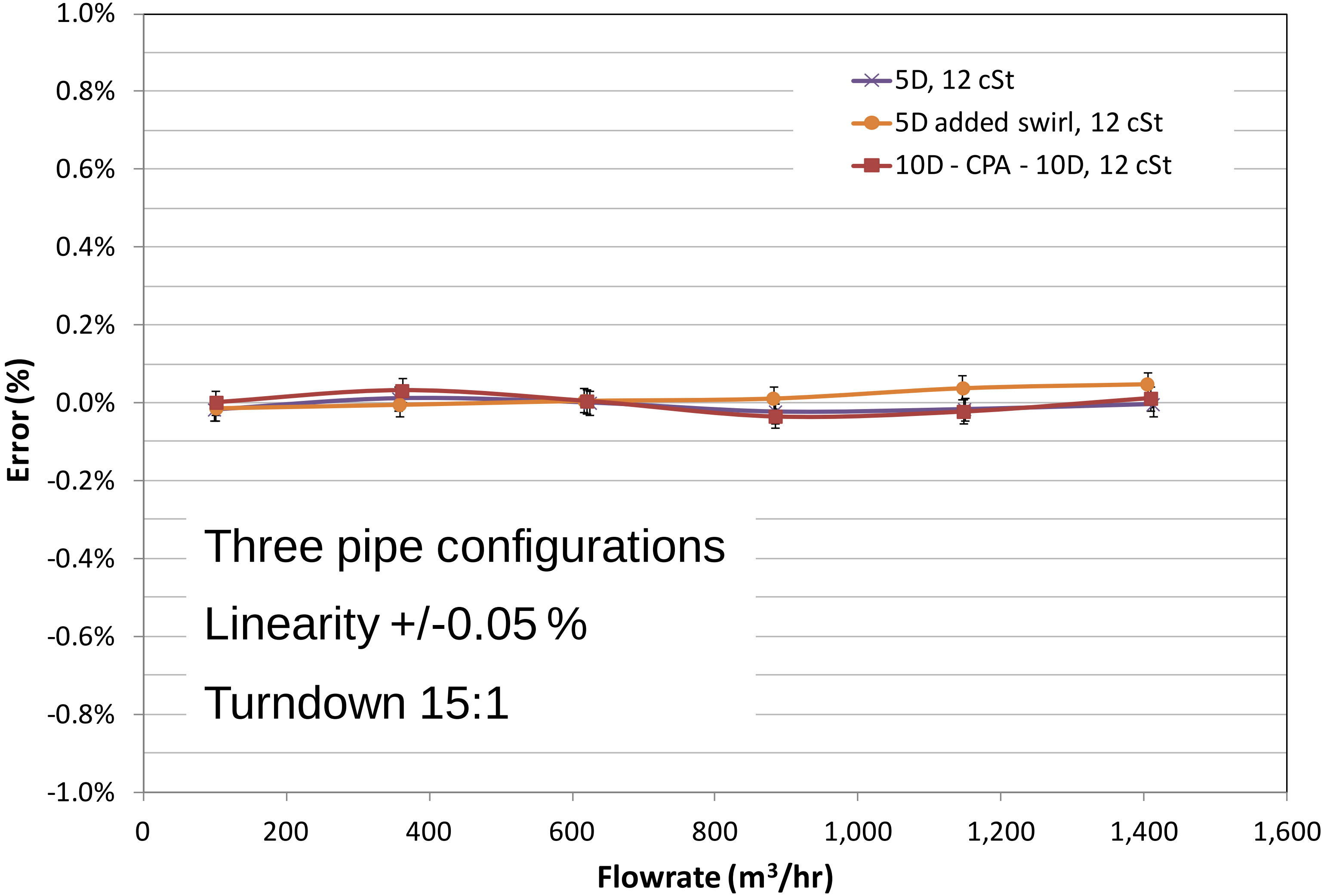
Installation at 5D with added swirl



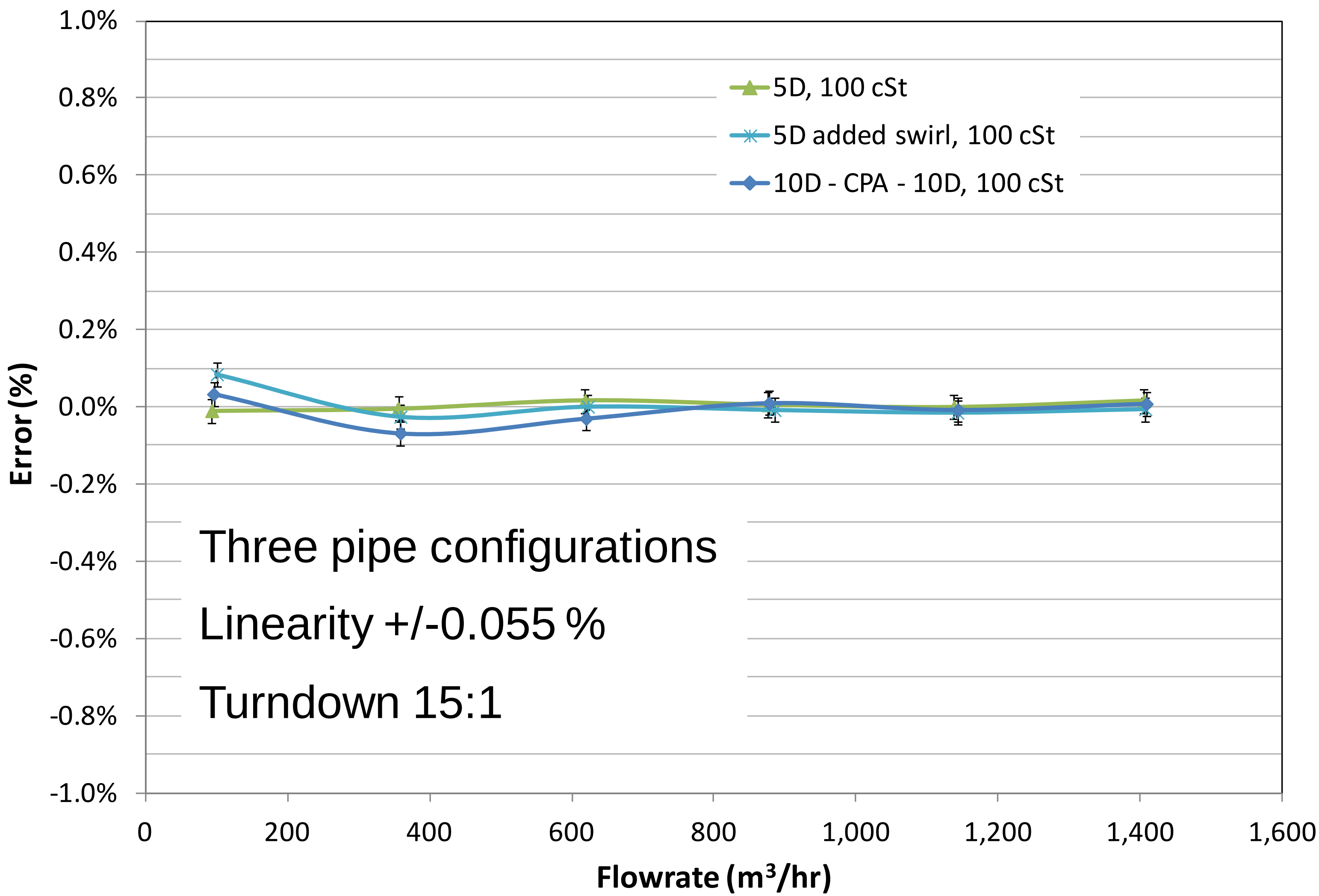
Installation with 10D – CPA – 10D



Linearity/error data vs flowrate – 12 cSt oil



Linearity/error data vs flowrate – 100 cSt oil

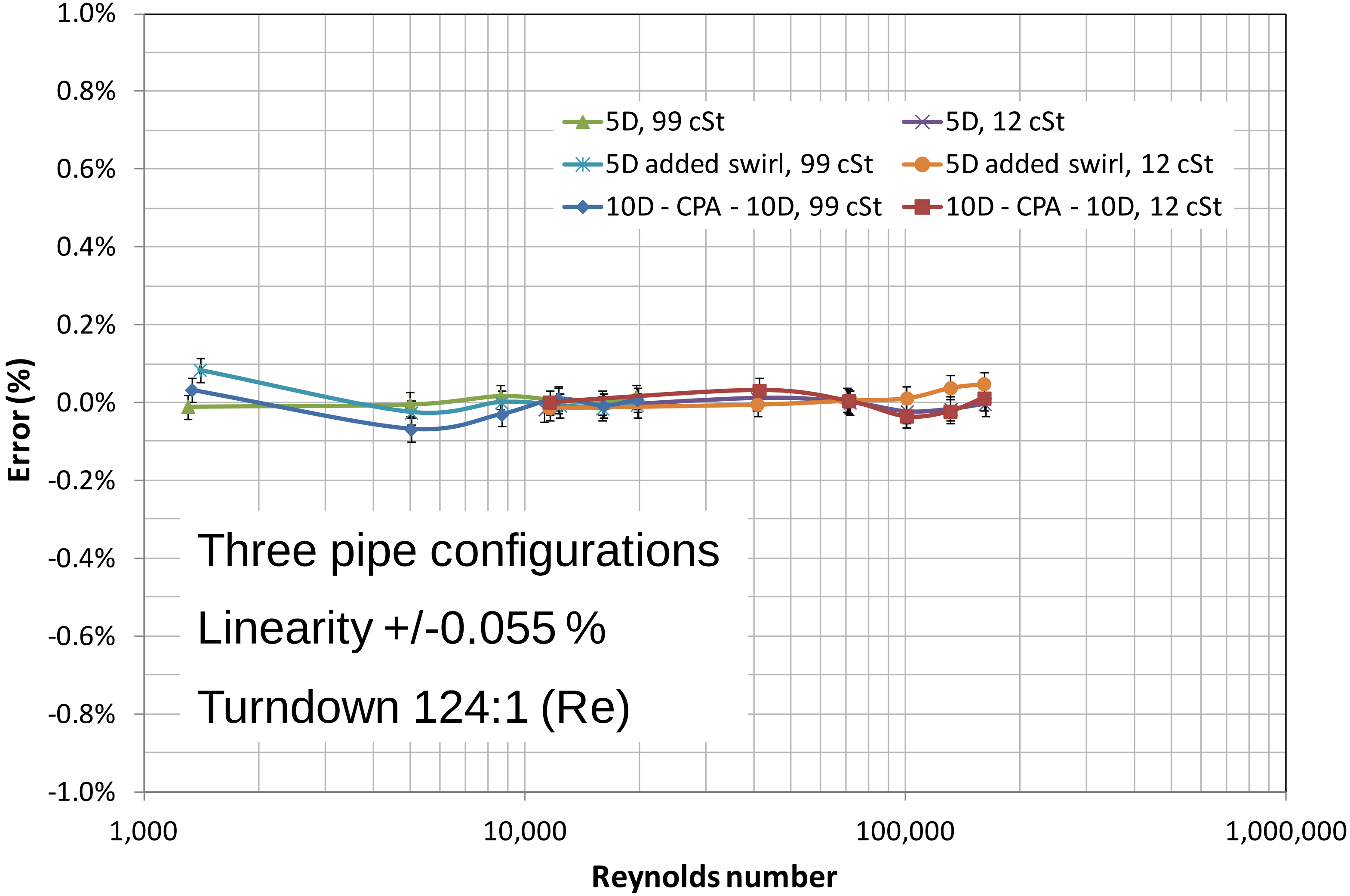


Three pipe configurations

Linearity +/-0.055 %

Turndown 15:1

Linearity data vs Reynolds number



8-Path Full-Bore Configuration
No flow conditioner and 5D

Toledo refinery, full bore 8-path meter


BOOMER

Toledo refinery proving reports

API 64

Flowrate	3203.8
Totalizer	0
Throughput	0
API @ 60 F	64.0
R.D. @ 60 F	0.72380
Viscosity	0
Avg Prvr Temp	63.4
Avg Prvr Press	172.0
Repeatability	0.036%
MF	1.0012
MF Variation	0.0000

Liquid Properties at Metering Conditions for CMF

Normal Op. Pressure	0	psig
Eq. Vapor Pressure	0	psig
CPL	1.00000	

	RUN	Accepted?	IMF
54	1	Yes	1.00114
36	2	Yes	1.00125
71	3	Yes	1.00146
17	4	Yes	1.00110
39	5	Yes	1.00112
5074			1.00121

MF 1.00121

API 42.5

Flowrate	3044.2
Totalizer	0
Throughput	0
API @ 60 F	42.5
R.D. @ 60 F	0.81320
Viscosity	0
Avg Prvr Temp	66.0
Avg Prvr Press	168.0
Repeatability	0.043%
MF	1.0011
MF Variation	1.0011

Liquid Properties at Metering Conditions for CMF

Normal Op. Pressure	0	psig
Eq. Vapor Pressure	0	psig
CPL	1.00000	

	RUN	Accepted?	IMF
2	1	Yes	1.00114
2	2	Yes	1.00096
6	3	Yes	1.00139
1	4	Yes	1.00104
5	5	Yes	1.00098
0512			1.00110

MF 1.00110

API 35.5

Flowrate	2138.4
Totalizer	0
Throughput	0
API @ 60 F	35.5
R.D. @ 60 F	0.84730
Viscosity	0
Avg Prvr Temp	75.3
Avg Prvr Press	247.0
Repeatability	0.022%
MF	1.0010
MF Variation	1.0010

Liquid Properties at Metering Conditions for CMF

Normal Op. Pressure	0	psig
Eq. Vapor Pressure	0	psig
CPL	1.00000	

	RUN	Accepted?	IMF
607	1	Yes	1.00095
940	2	Yes	1.00107
029	3	Yes	1.00085
617	4	Yes	1.00105
867	5	Yes	1.00098
9.4120			1.00098

MF 1.00098

UK Chevron Alba FSU Export Metering

- Original system based on positive displacement (PD) meters and a ball prover was first replaced by a clamp-on meter based system on the export line
- Due to poor performance an upgrade was required
- Aim was to install with minimum changes to the original installation
- High viscosity (100 cSt) and limited space for installation as PD meters are not sensitive to installation effects
- Two 16-inch Caldon 8-path 280Ci flowmeters installed
- Traceable to Cameron's ISO17025 calibration lab
- Commissioned in 2011

Original system with PD meters

Just how important are the offshore meters ?

(Chevron Presentation at NEL/DECC oil and gas focus group meeting 2014)

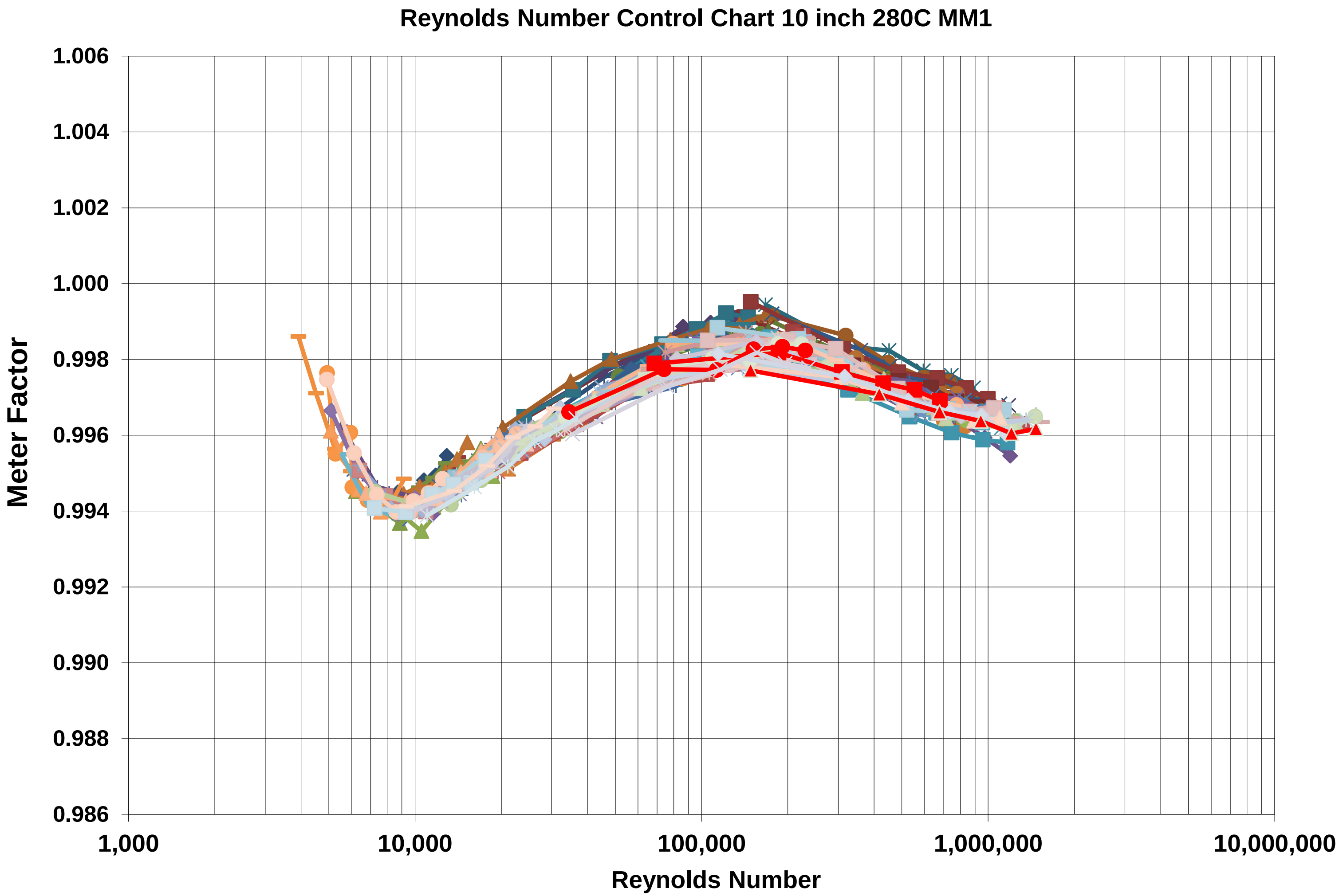
- For Alba FSU (nett) Prior to upgrading measurement system
  - CQQO versus Outturn Nett (2010-2011)
  - $-6.1 million – a very big number
  - Equates to 0.4 % 'loss' – that is, received 0.4 % less from outturn as against the offshore measured figure
- For Alba FSU (nett) Post upgrading measurement system
  - CQQO versus Outturn Nett (2011-)
  - $0.5 million
  - Equates to 0.06 % 'gain' – that is, received 0.06 % more from outturn as against the offshore measured figure
- Conclusion
  - Continue to maintain the FSU Measurement System to custody transfer standards

Long Term Stability

Calibration laboratory 10-inch Master Meters

- 8-path master meters are calibrated before use
- Control charts used to ensure everything is working as it should be

Unlinearised MF vs Re: 7 years of data



Summary

- Good quality ultrasonic meters are essentially stable and affected mainly by fluid hydraulics
  - Due to time limitations today I have not covered viscous attenuation and turndown effects
- Achieving and maintaining good linearity and reproducibility of meter factor is not straight forward but can be achieved with due care and attention at each stage of design and selection, calibration and implementation