NEL's Views & Experience on Calibration

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Contents

Calibration at NEL

Areas of Interest

- Pressure effects
- Venturi expansibility equations
- Uncertainty
- Calibrations at service conditions
- Meter diagnostics
- Contribution to standards
- Research into DP meters
- Wet-gas flow measurement

UKAS Accredited

- Our Dry Gas Flow Facility is accredited by the United Kingdom Accreditation Service (UKAS).

Dry Gas Calibration Range

- 20 to 2200 m^3/hr
- 10 to 63 barg
- 15 to 25 ^oC
- Nitrogen

- Reference meters: USMs & turbine
- Dry gas and wet-gas testing

Experience with Various Meter Types

- Venturi Tubes
- Coriolis
- Ultrasonic
- Turbine

Standards

There are a number of standards which can provide guidance to end users on the correct practices for gas flow measurement.

Within the standards however, there are gaps which require further research. This is an area in which NEL look to be proactive in contributing knowledge and research to developing international standards.

Differential Pressure Meters	Ultrasonic & Coriolis Meters
• Until recently there was no calibration section within the standards. • Expansibility equation for Venturi Tubes • Venturi Tube performance in high pressure gas flow. • Venturi Tube installation effects • Standards will be updated in future	• Limited information on high temperature and pressure • Installation effects • Limited information on the practical use of meter diagnostics. • Lack of information on the effects of calibration fluids.

UK Regulator guidelines on re-calibration intervals

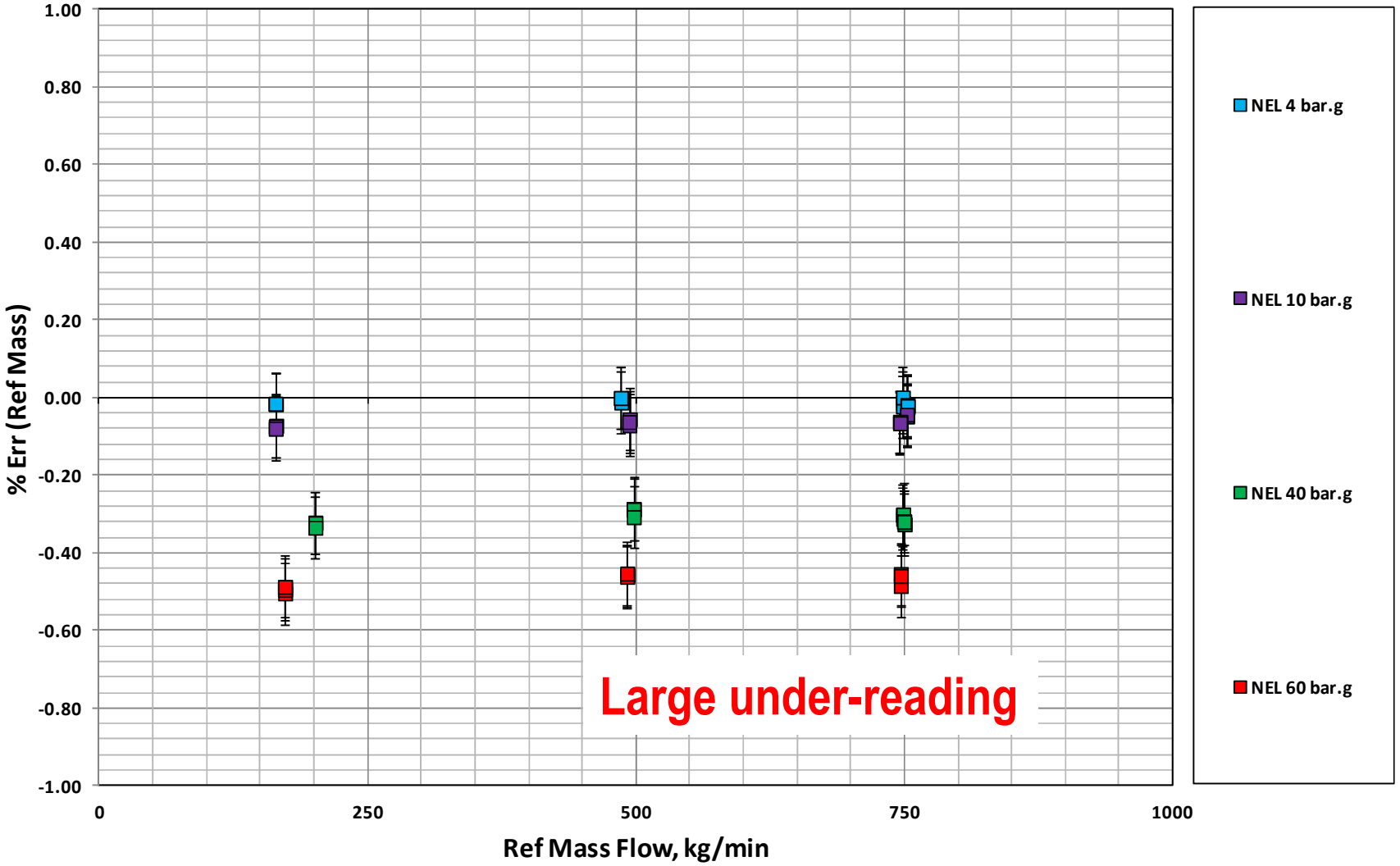
- Traditionally re-calibration intervals were time-based
- Time scales could be set by regulator
- UK regulator now ‘strongly encouraging’ operators to abandon time-based calibrations where possible in favour of a risk/condition based approach
- Risk-based
  - Combines historical knowledge of uncertainty and resultant financial exposure.
- Condition-based
  - Limit the duration of any measurement bias
  - Meter condition can be monitored through diagnostics or comparison of duplicate measurements.

Coriolis Meters in High-Pressure Conditions

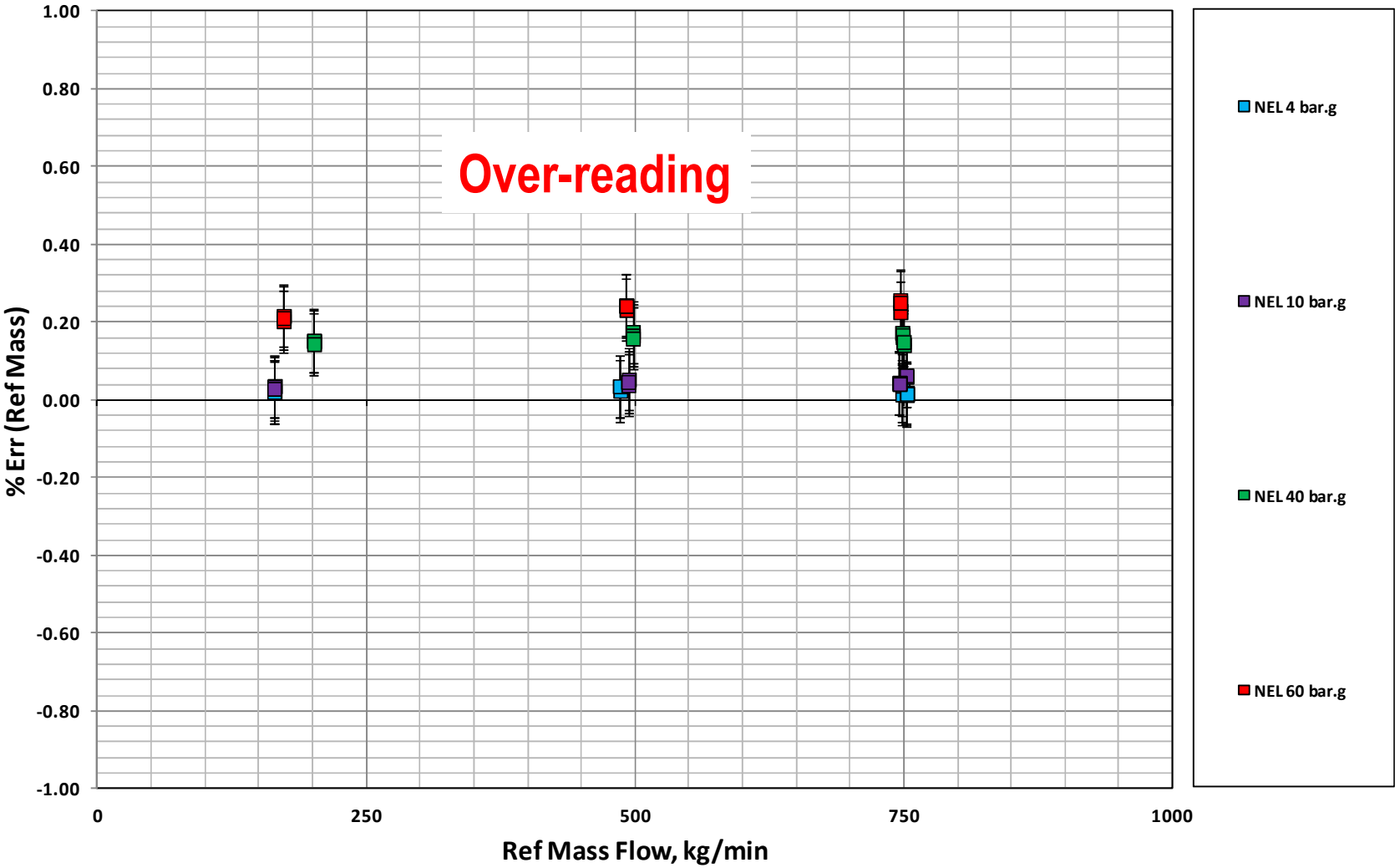
Experience with calibration of Coriolis meters

- Increase in calibration of Coriolis meters for higher pressure gas applications.
  - Size 1-inch to 4-inch
- Increased awareness of pressure affects on Coriolis meters for flow measurement and density measurement.
- NEL completed Joint Industry Project on pressure effects on Coriolis meters
  - Tested in NEL's high-pressure gas facility
  - Results can be released in Oct 2017
- UK regulator has pushed for Coriolis meters to be calibrated at service conditions if used at elevated temperatures and pressures.
- Lack of confidence in manufacturers corrections – more traceable evidence required.
  - Currently manufacturers corrections can cause over-readings and under-readings.

Pressure effect on Coriolis – **without** manufacturer correction



Pressure effect on Coriolis – **with** manufacturer correction



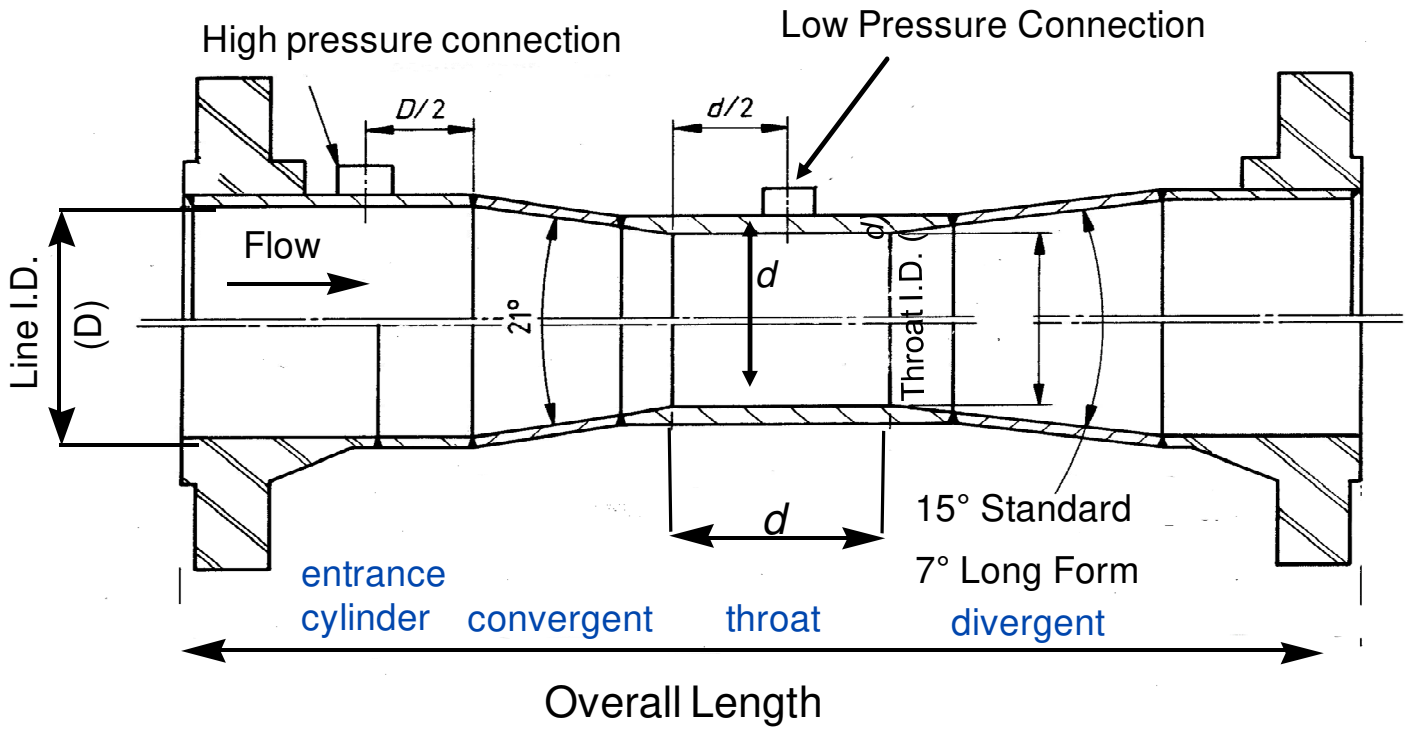
Coriolis Meters in High-Pressure Conditions

- Would not recommend using water calibration
  - Unless use manufacturer correction and increase measurement uncertainty
- Recommend calibration at service conditions
- Must also consider viscosity & temperature affects

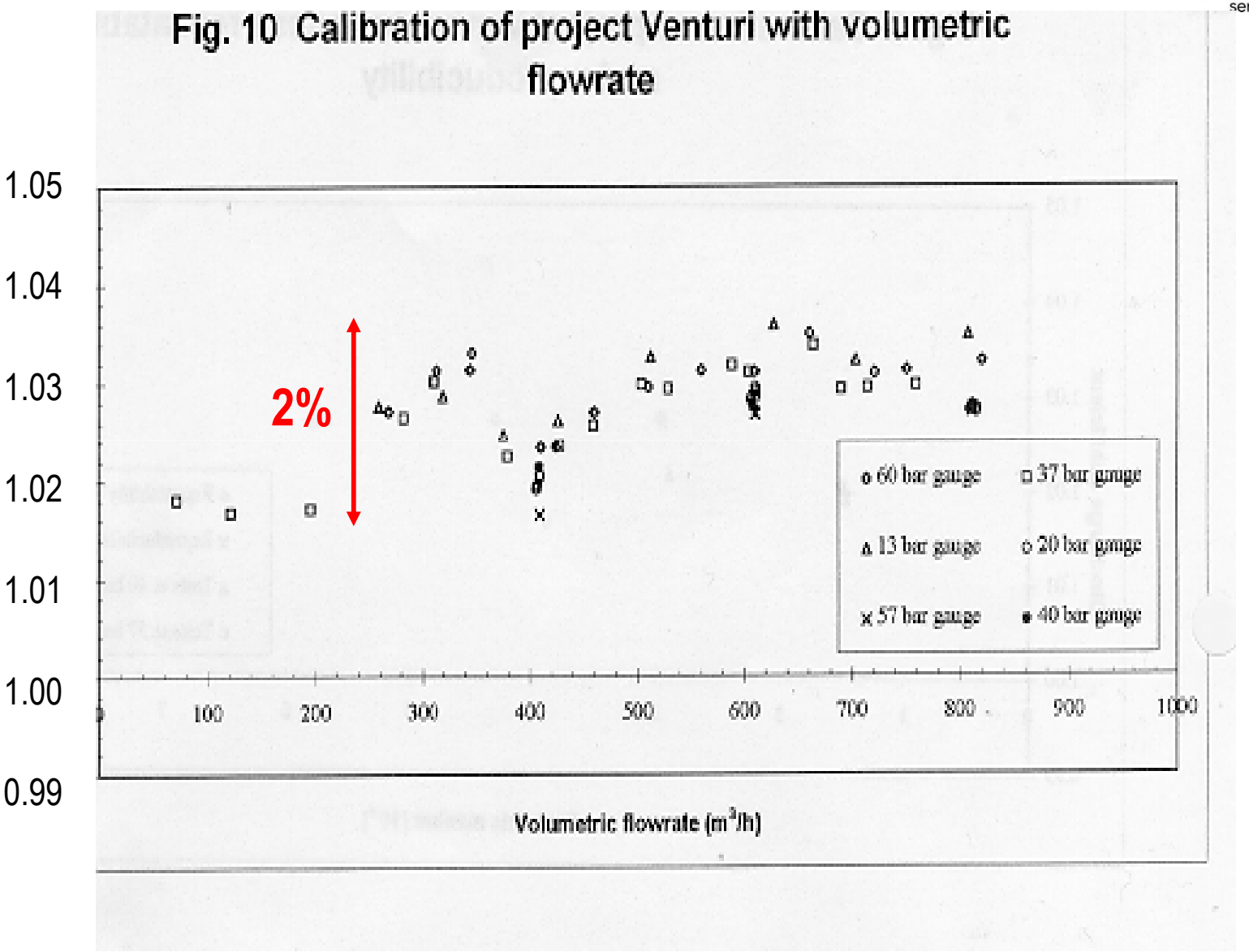
Venturi Tubes in High-Pressure Gas

Experience with calibration of Venturi tubes

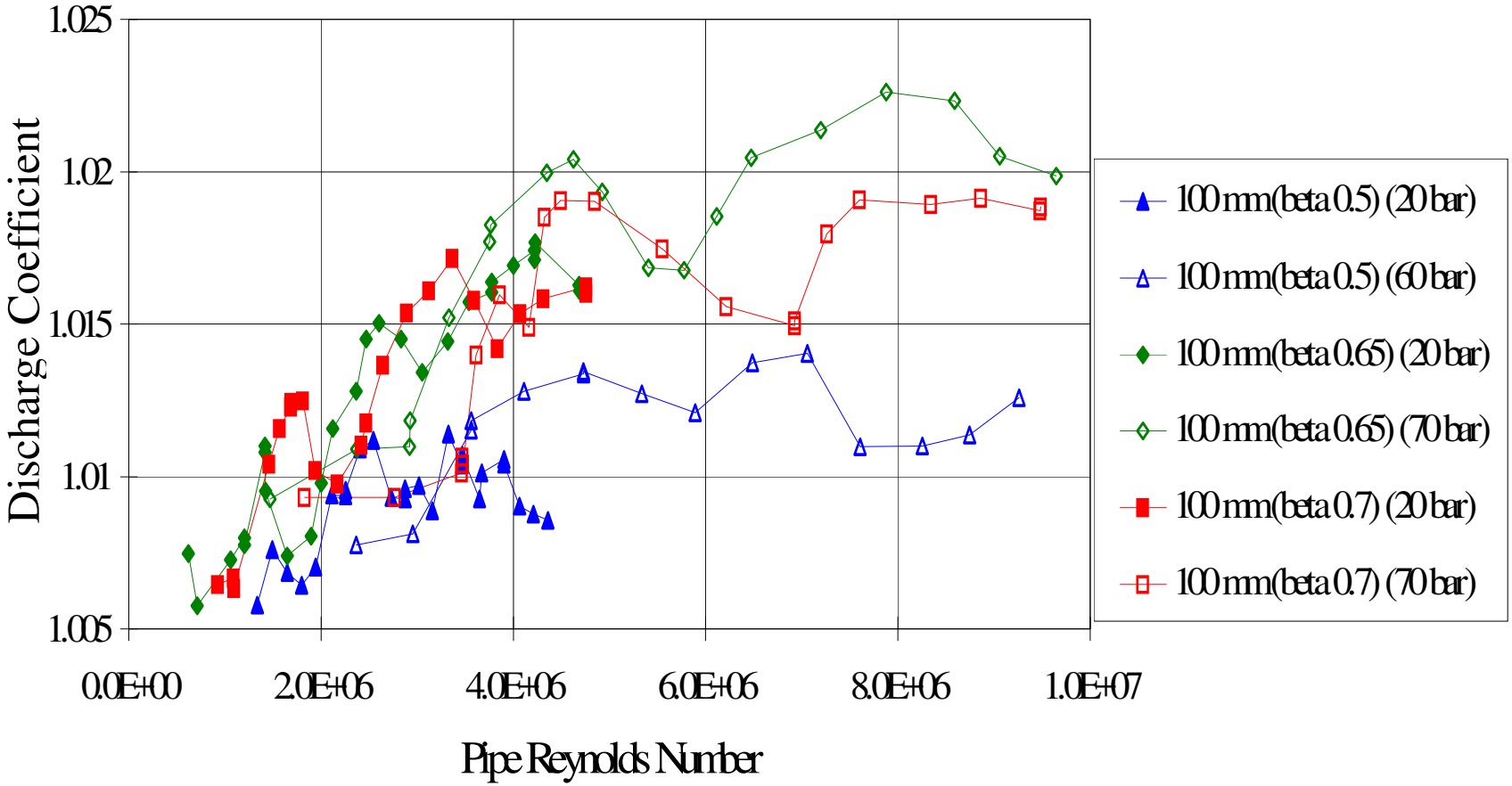
- Extensive experience of calibrating Venturi tubes
- Used for dry and wet-gas applications
- If uncalibrated uncertainty in discharge coefficient ~3%
- Calibration can reduce uncertainty to below 0.5%



Data from Jamieson et al (1996)



Venturi tubes in high-pressure gas: C vs Re_D



Venturi tubes in high-pressure gas: *C* vs throat velocity

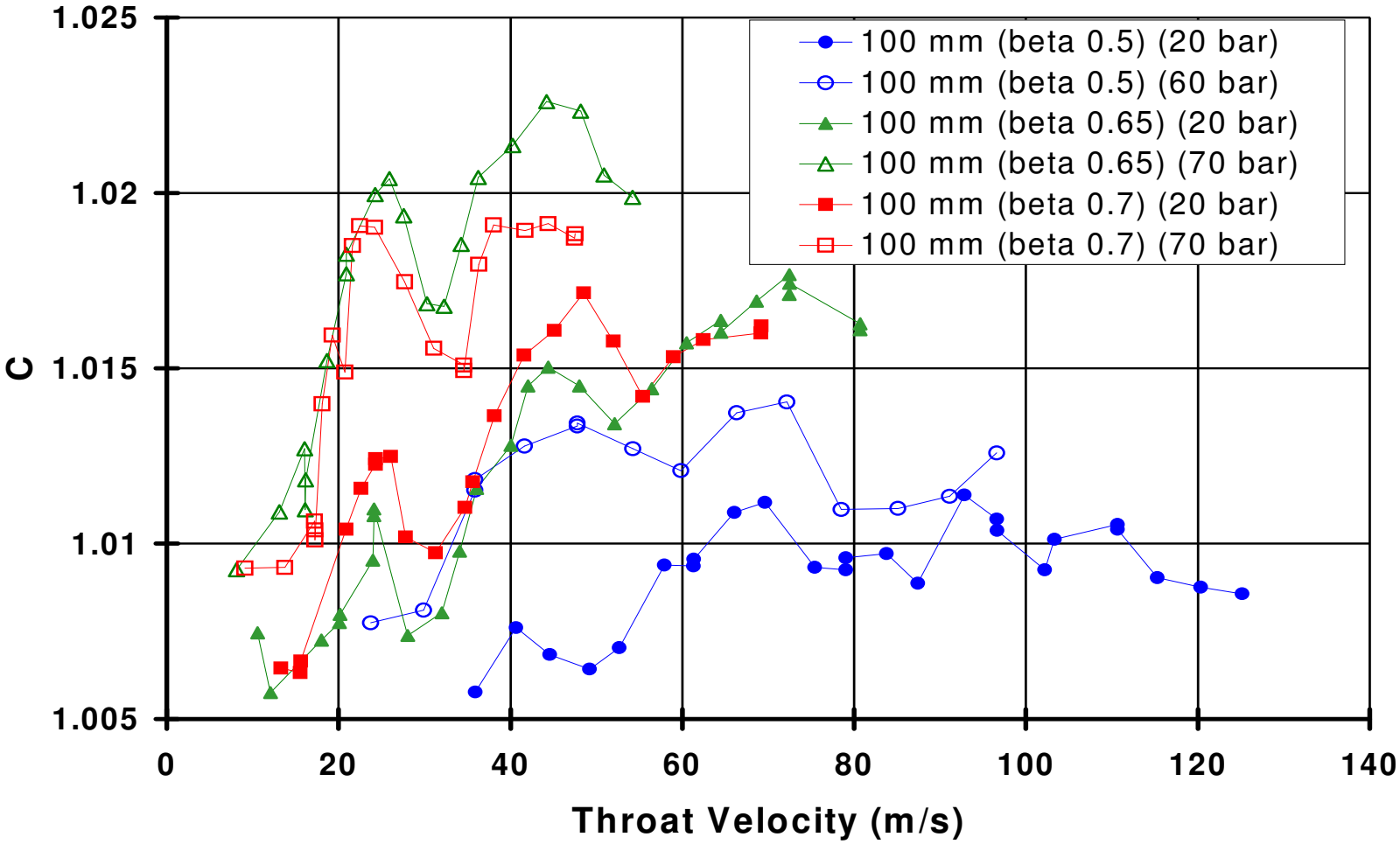
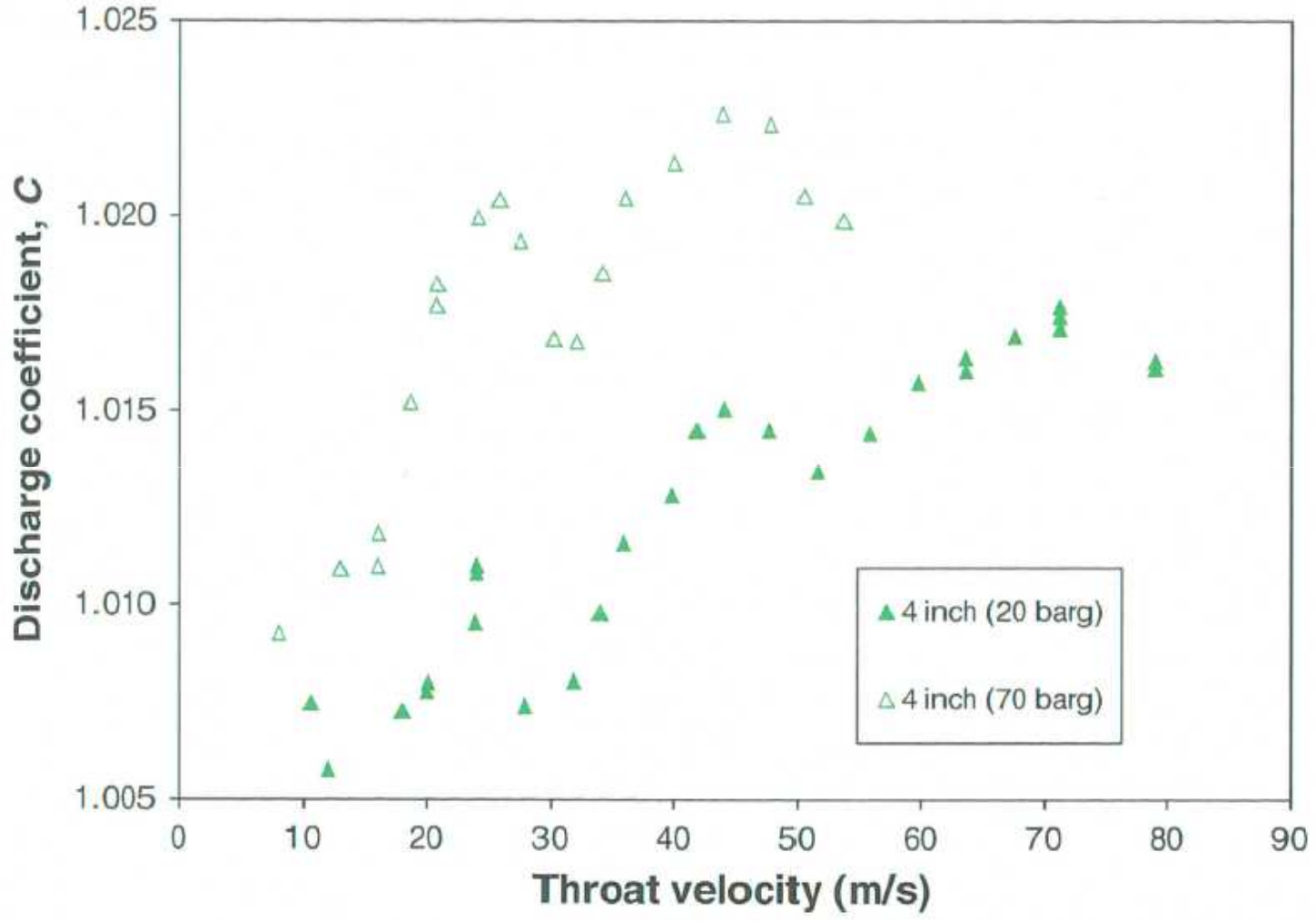


Figure 3(b) Calibration in gas against throat velocity: beta = 0.5, 0.65 and 0.7, standard convergent angle

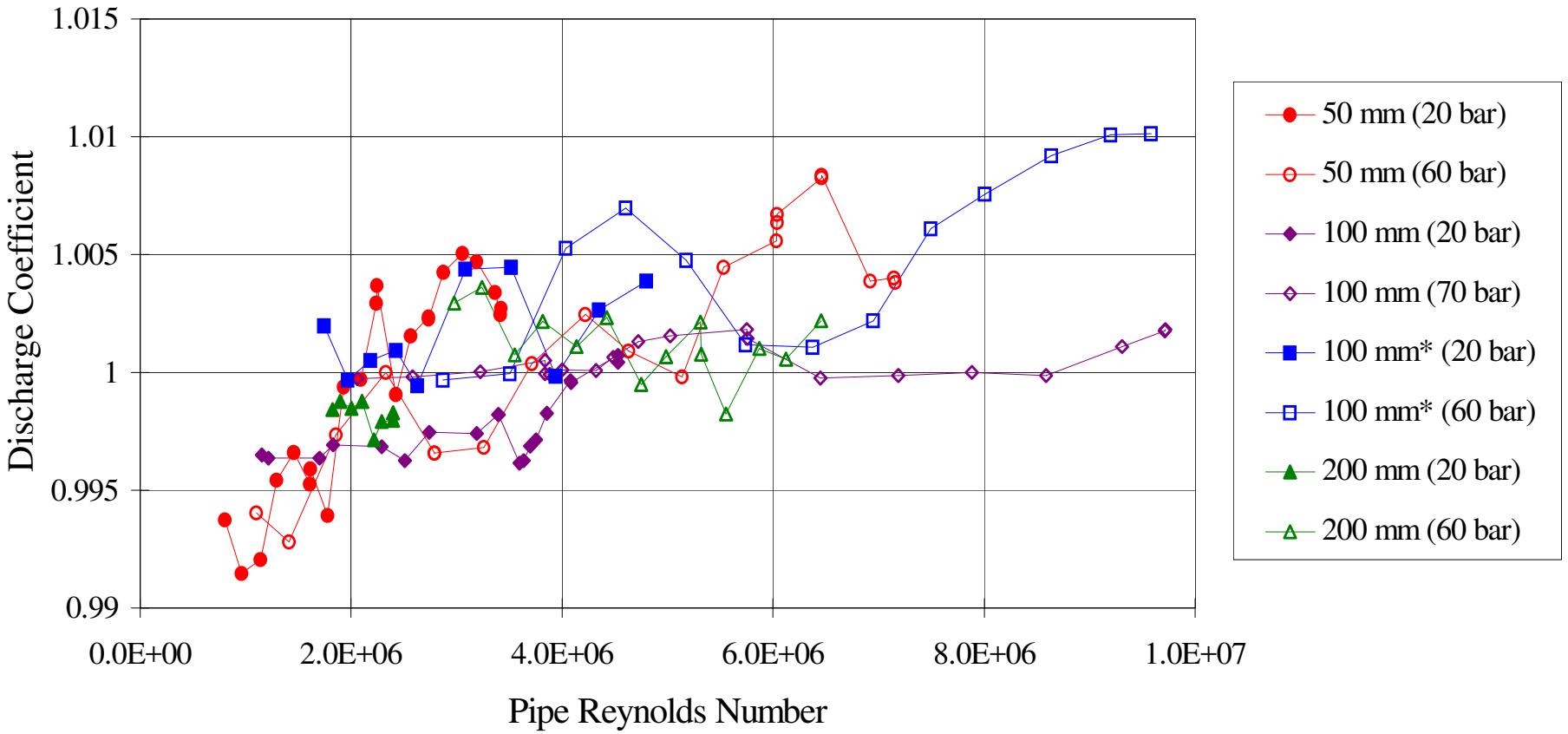
Venturi tubes in high-pressure gas: *C* vs throat velocity



4-inch, β=0.65 Venturi

Venturi tubes in high-pressure gas: β = 0.75

Figure 5 Discharge coefficients in air for diameter ratio 0.75



Non-standard design of Venturi

- Standard design of Venturi tubes is outlined in ISO 5167
- Some manufacturers are modifying the design especially the pressure tappings, e.g. for subsea applications
    - can have a large effect on the discharge coefficient & “humps”
- Any changes will require the Venturi tube to be calibrated.

Calibration of Venturi tubes

- Calibrations usually 10 points with 3 repeats
  - More important to collect more data at different conditions than repeats

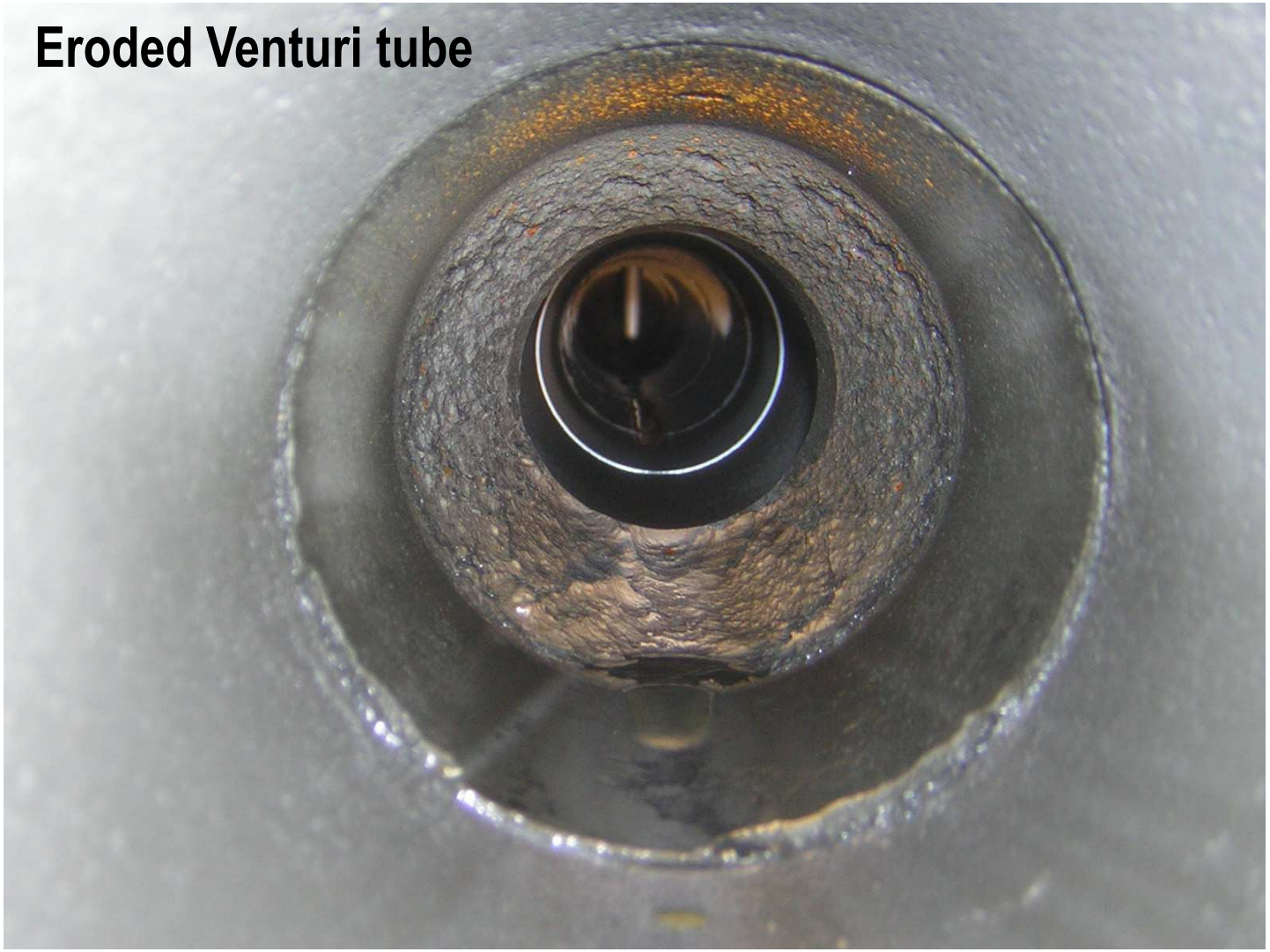
- Must consider what to do with calibration data
  - Fitting an equation for use....how?
  - Many end-users confused by the data and “humps”
  - Advise not to fit an equation for the “humps” but to fit equation to the general shape and increase uncertainty on the equation fit to include the “humps”

Calibration of Venturi tubes....*continued*...

Must consider what to do with calibration data.....

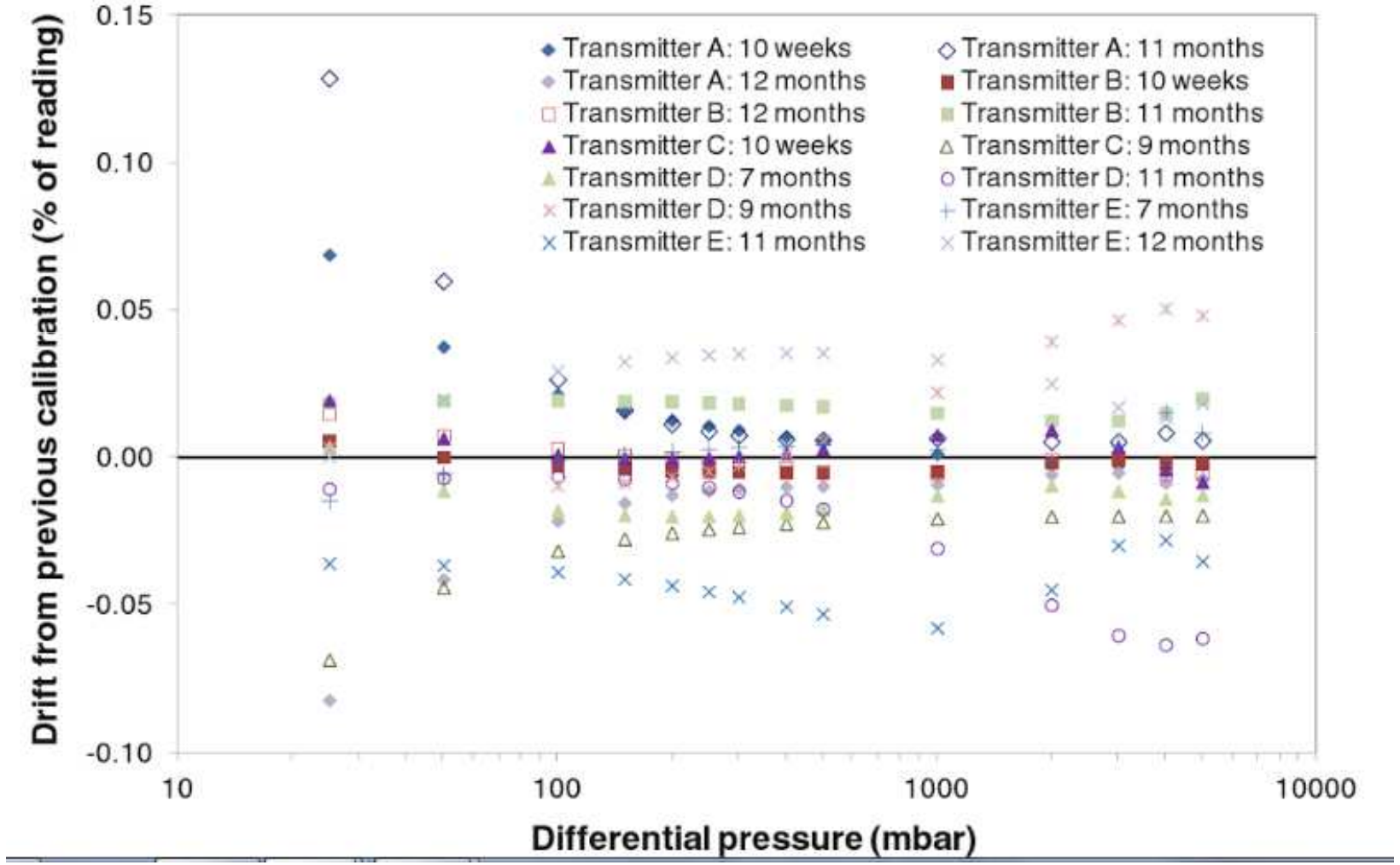
- For cost reduction end-users & manufacturers only want calibration at one pressure
  - NEL would recommend calibration at two pressures to account for “humps”
- Lack of guidance in ISO 5167-4 on how to deal with data from high-pressure gas calibrations
  - Hopeful that standard will be modified in future revisions

Calibrate Venturi tube once……



DP Sensors – Advancements

Biggest advancement in DP meters is from new smart DP sensors
NEL data: 50 mbar to 5 bar the largest drift is 0.06%



Calibrating at service conditions.....

Or matching on Reynolds number.....

Calibrating at Service Conditions

Why should we calibrate at service conditions?

- Operating conditions can vary dramatically from calibration conditions.
- An offset in the meter reading can occur where there is a variation in temperature or pressure from the calibration conditions.

What's the problem with calibrating at service conditions?

- It's not always possible!
  - Calibration facilities may not have capabilities to match service conditions, especially high pressures.

Calibrations based on Reynolds number and using at different conditions

Commonly done instead of extrapolating meter performance

What about pressure effects....

New high-pressure multiphase facility at NEL

Very challenging to build a facility to this specification

Parameter	Operation range
Pressure	15 – 140 bar(g)
Temperature	20 – 50 Deg C
Gas flowrate	10 – 3000 m^3/hr
Oil flowrate	125 – 550 m^3/hr
Water flowrate	125 – 550 m^3/hr

- Potential gas reference meters are combination of USMs & Venturi tubes
- One concern is the gas reference traceability (using nitrogen)
- Using other facilities (e.g. FORCE) can only calibrate up to 65 bar
- Could base calibration on Reynolds number
    - e.g. calibrate at lower pressure and higher flow rate to match Re
    - but what about pressure effect on the meters
    - currently investigating options.....

Future Trends

What the future holds for calibration...

- Continuing shift away from time-based re-calibrations with an emphasis on a combination approach.
- Development of end user understanding of diagnostic data, as it is currently believed there is difficulty in using diagnostics in real world applications.
- Updating of standards with further sections on calibrations of various meter types and the use of diagnostics.
- New high pressure calibration facilities, such as NEL's New Era Multiphase facility, to allow for a wider range of calibrations at service conditions.

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