FLOMEKO2019
18th International Flow Measurement Conference
Portugal | Lisbon | LNEC | 26-28 june 2019

Best Practices for Proving Coriolis Meters

by

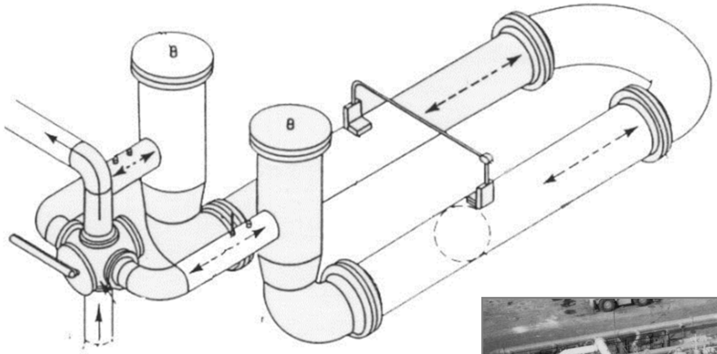
Marc Buttler, Emerson Automation Solutions

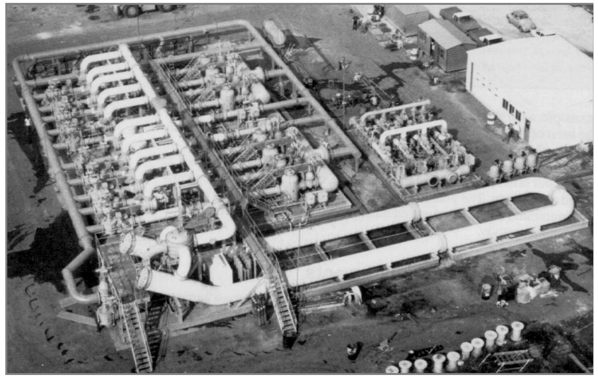
Pipe Provers

FLOMEKO2019
18th International Flow Measurement Conference
Lisbon | LNEC | 26-28 june 2019

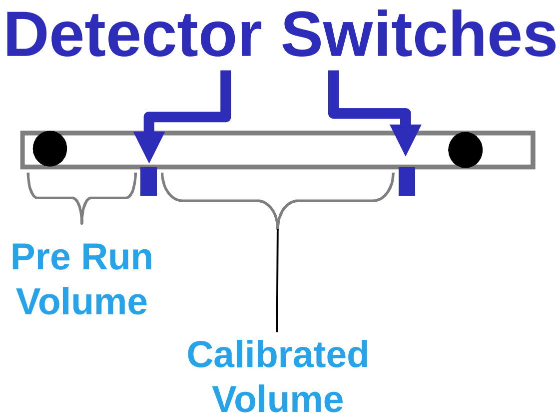
Also referred to as:

- Ball Provers
- Bi-Di Provers





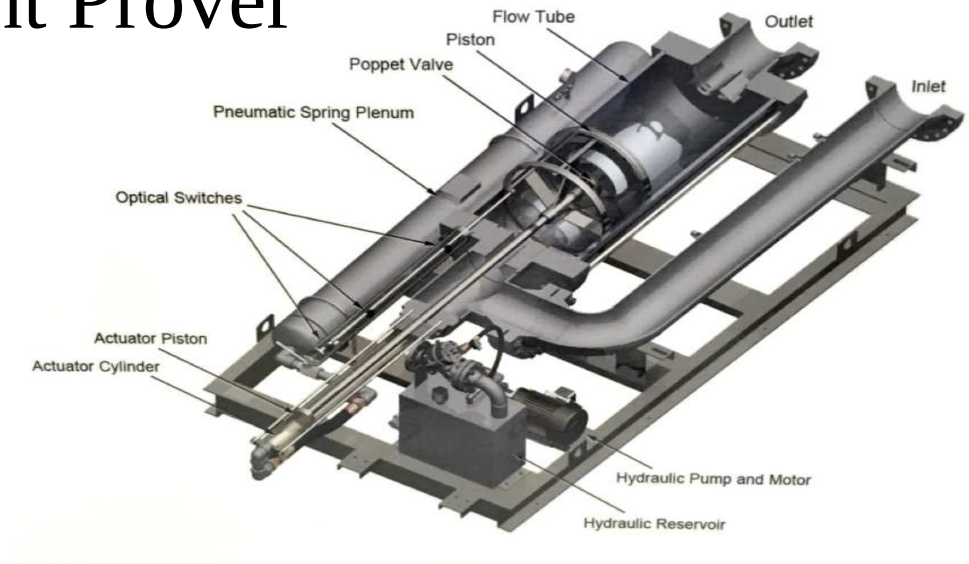
Can be Uni-directional
or Bi-directional

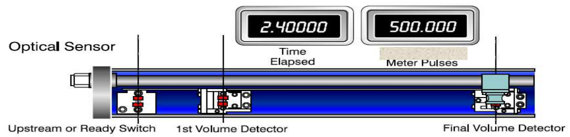


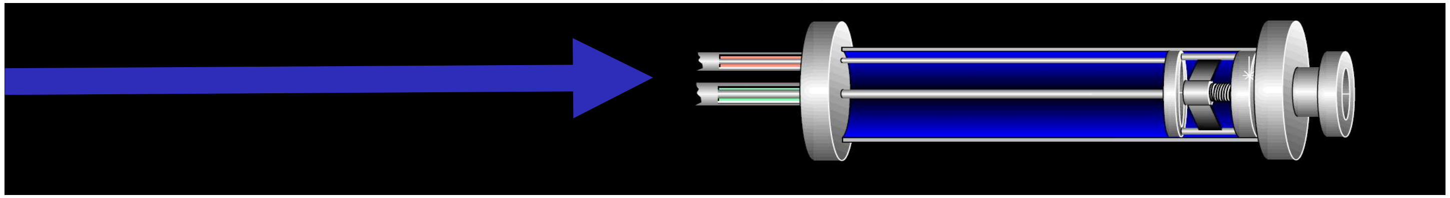
Small Volume Provers

Also referred to as:

- Captive-Displacement Prover
- Compact Prover

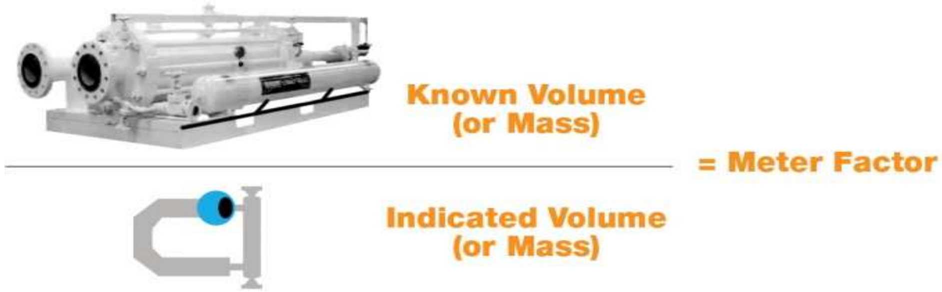






Measures of Proving Quality

Meter Factor (MF)

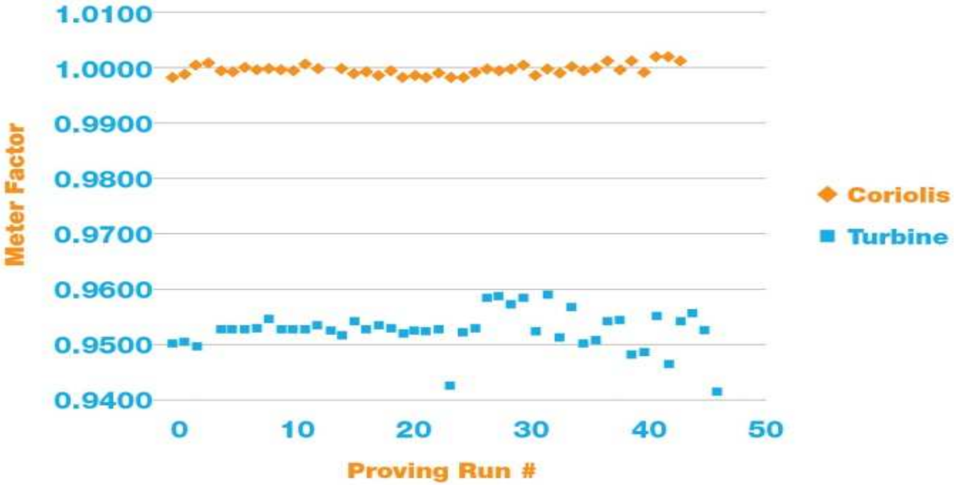


Repeatability

- Short-term stability of MF
- Verifies the uncertainty of the MF within 0.00027 (0.027%)

Reproducibility

- Long-term stability of MF



Repeatability Criteria for 0.027% Uncertainty (Preferred Uncertainty) for ±0.00027 Random Uncertainty in Average Meter FActor

Number of Proving Runs	Moving (Variable) Repeatability Limit
5	0.0005
10	0.0012
15	0.0017
20	0.0022

Purposes of Proving

- Establish Meter Factors (MF)
- Determine if meter factors change as operating conditions change
- Establish meter reliability and reproducibility over time
- Verify meter accuracy and repeatability
- Meet contractual and regulatory requirements
- Reduce uncertainty
- Anticipate meter failures

Early Proving

The Coriolis Meter Advantage in Proving Applications

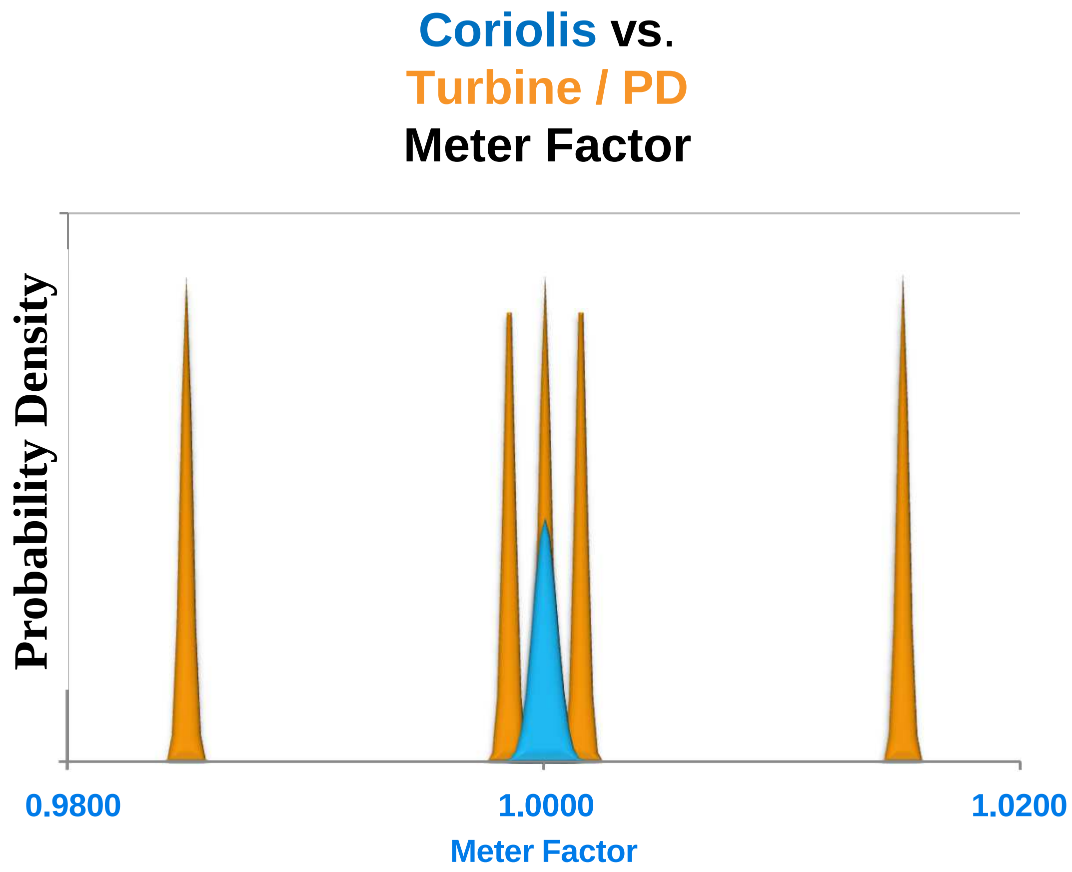
Reproducibility of Coriolis vs. Traditional Technologies

Flow Rate

- Lower Flow Rate
- Higher Flow Rate

Viscosity

- Lower Viscosity
- Higher Viscosity



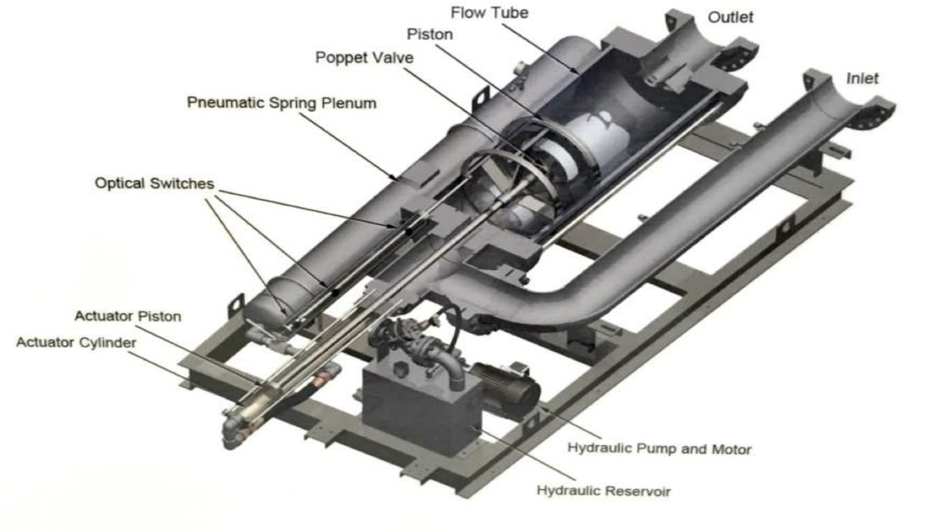
Proving Challenges

Proving Costs

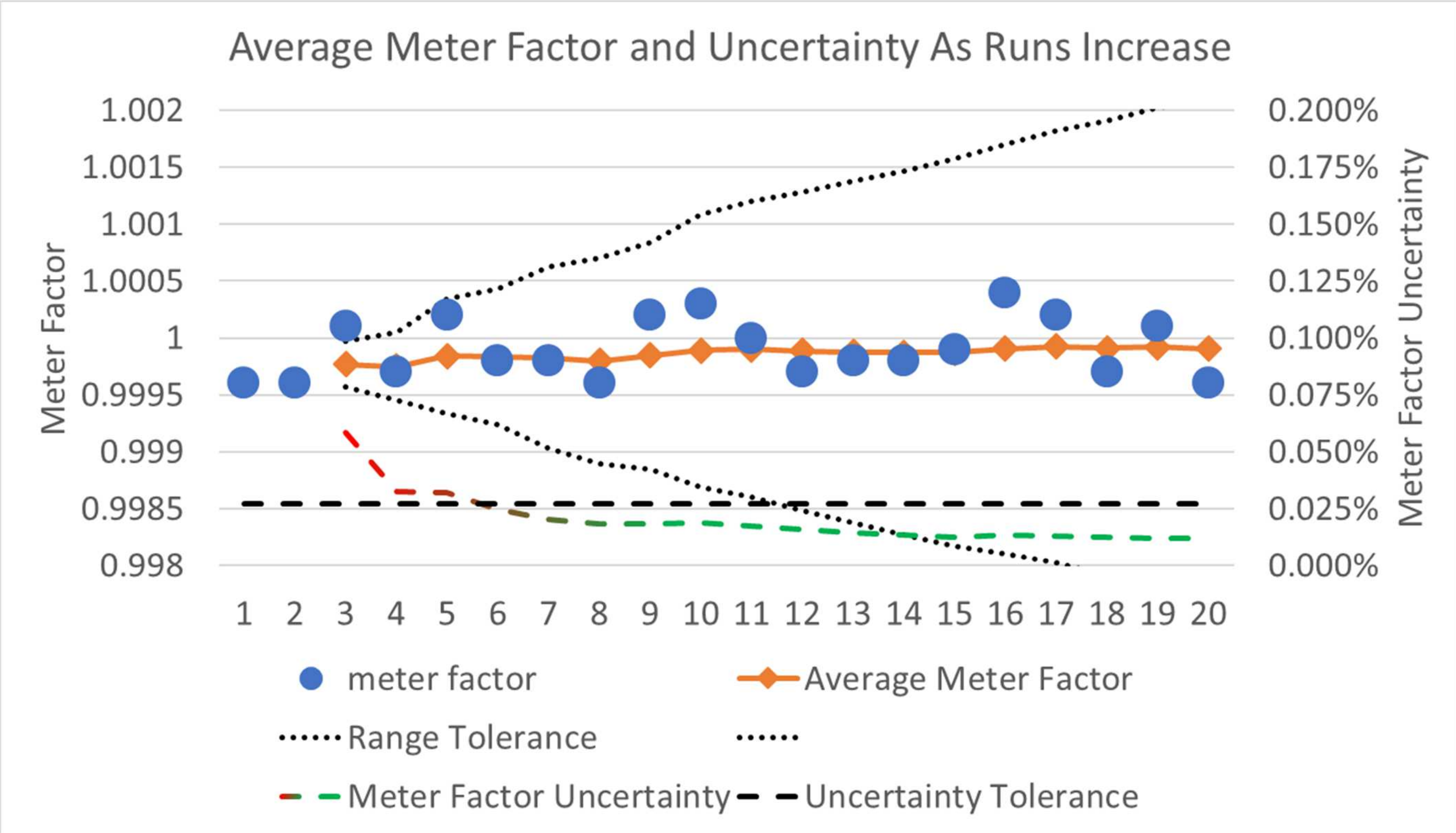
- Prover size
- Prover Maintenance
- Proving Efficiency and First Pass Yield

Proving Performance

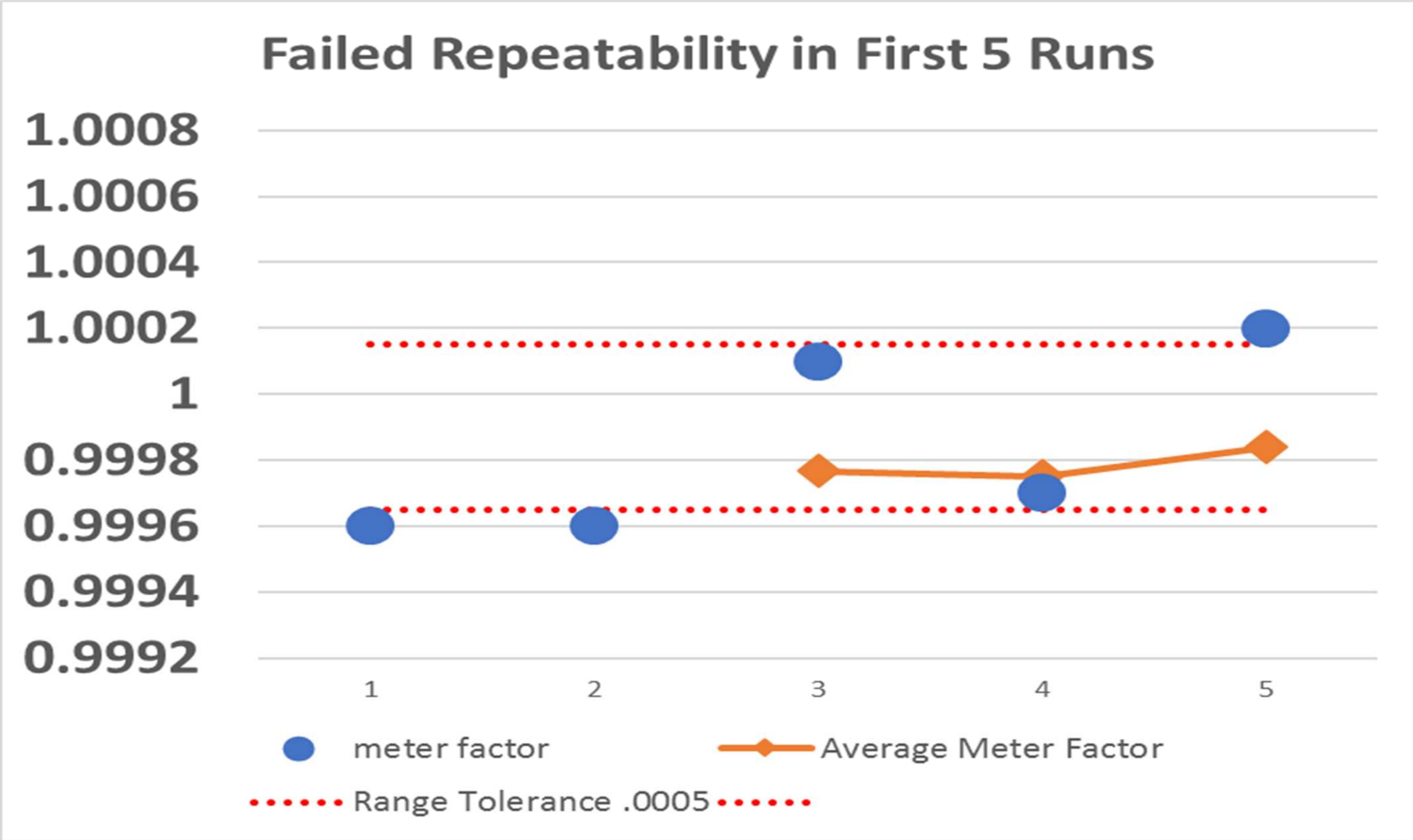
- Pulse Stability
- Condition Stability
- Meter Response Time
- Statistical Data and Uncertainty



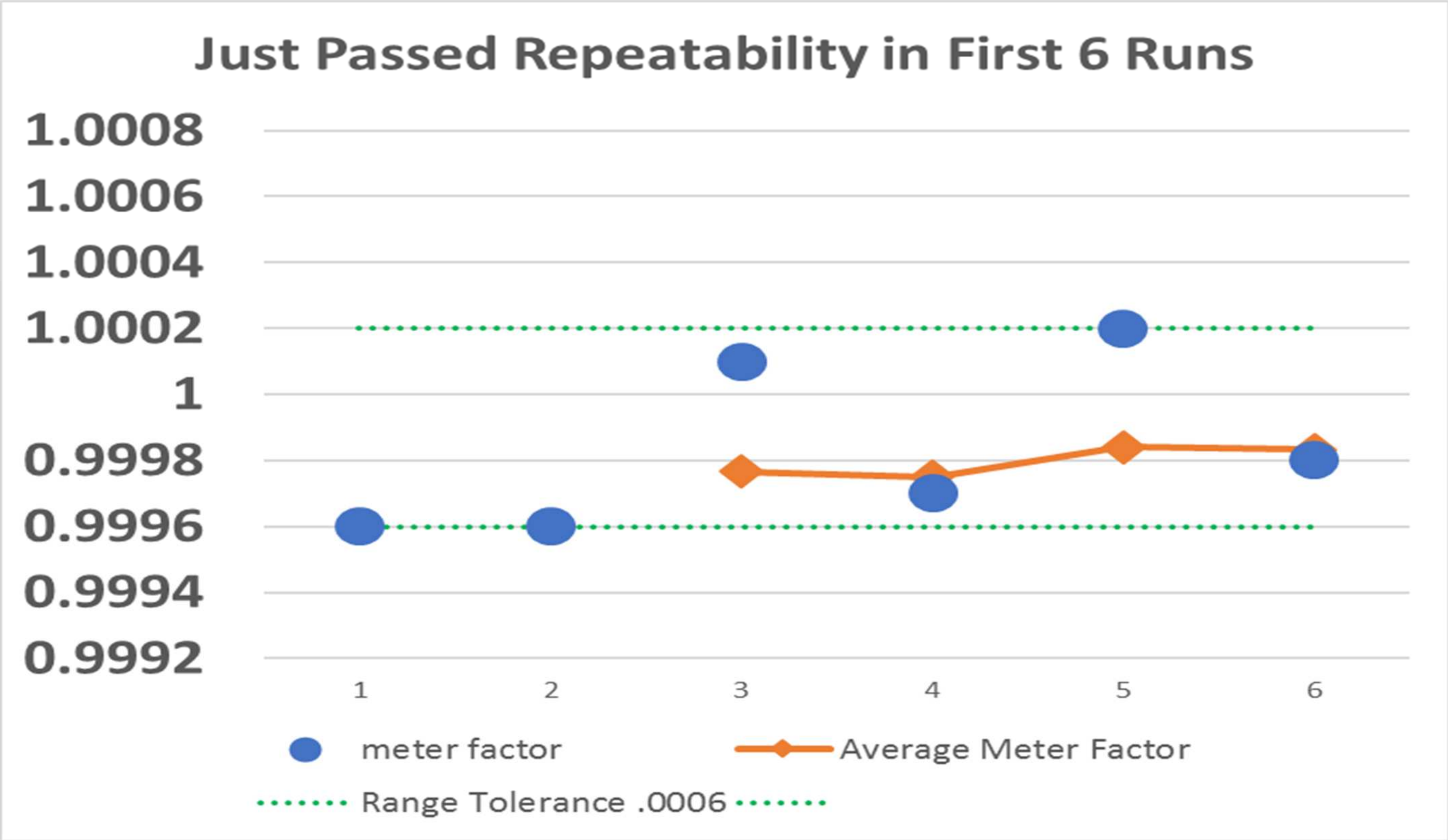
Repeatability and Number of Runs



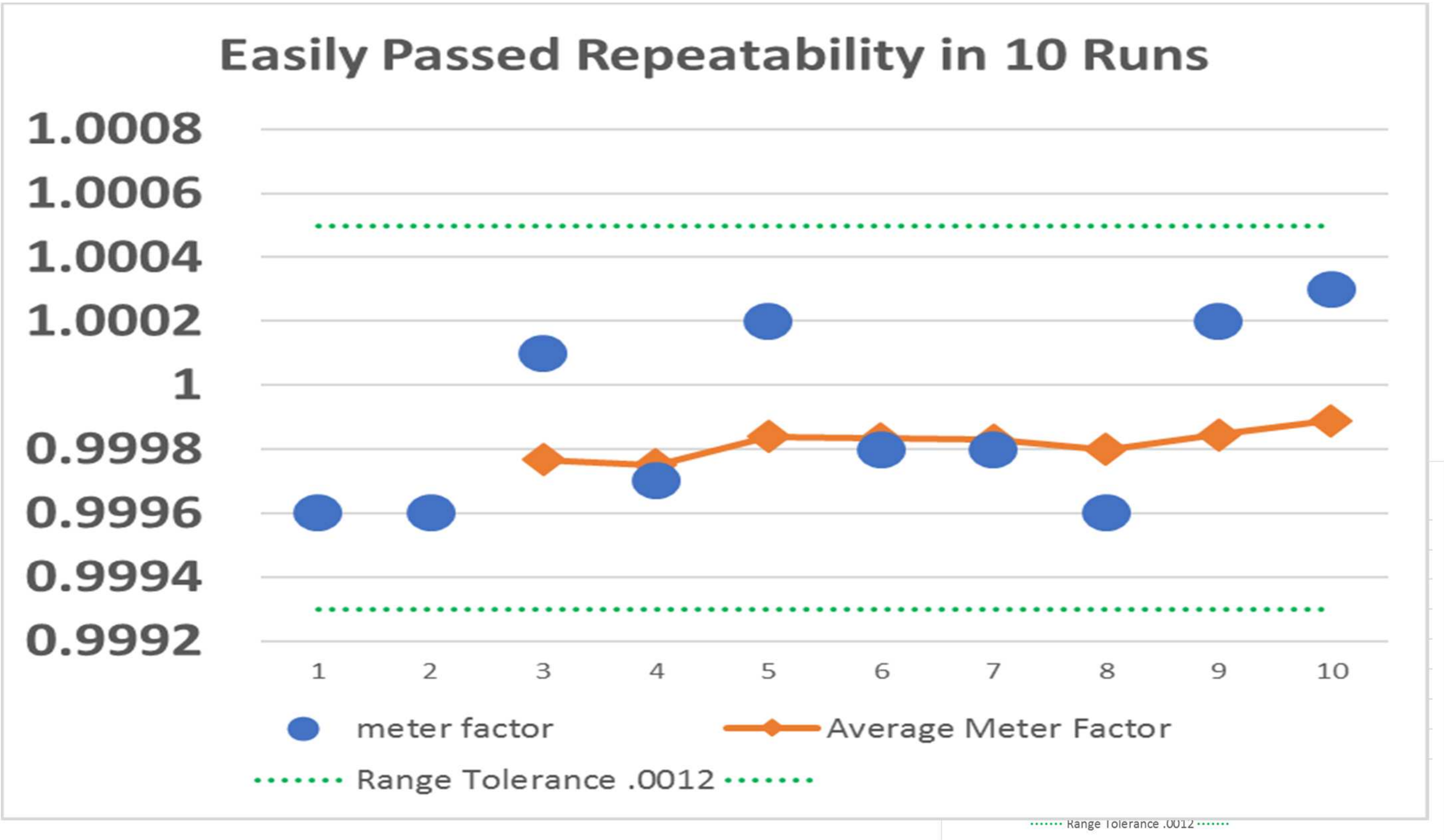
Progressive Uncertainty and Repeatability



Progressive Uncertainty and Repeatability

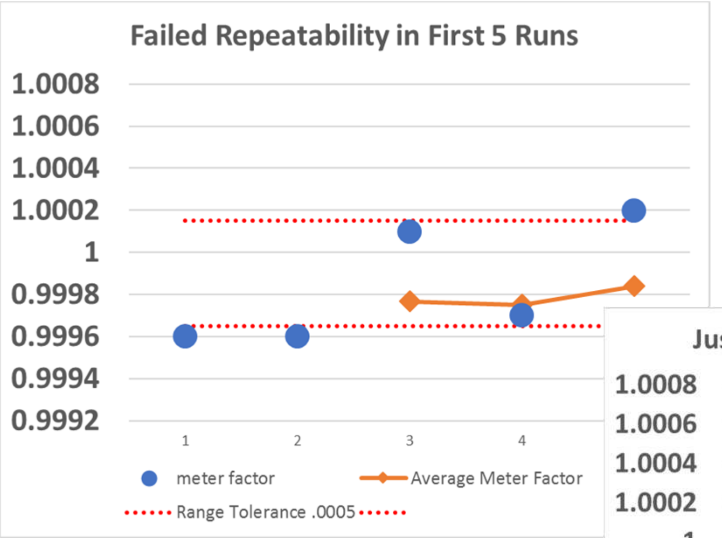


Progressive Uncertainty and Repeatability

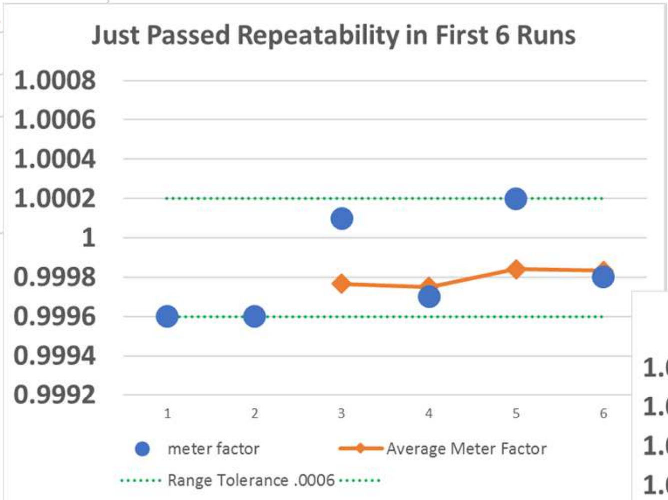


Progressive Uncertainty and Repeatability

FLOMEKO2019
18th International Flow Measurement Conference
Portugal | Lisbon | LNEC | 26-28 june 2019



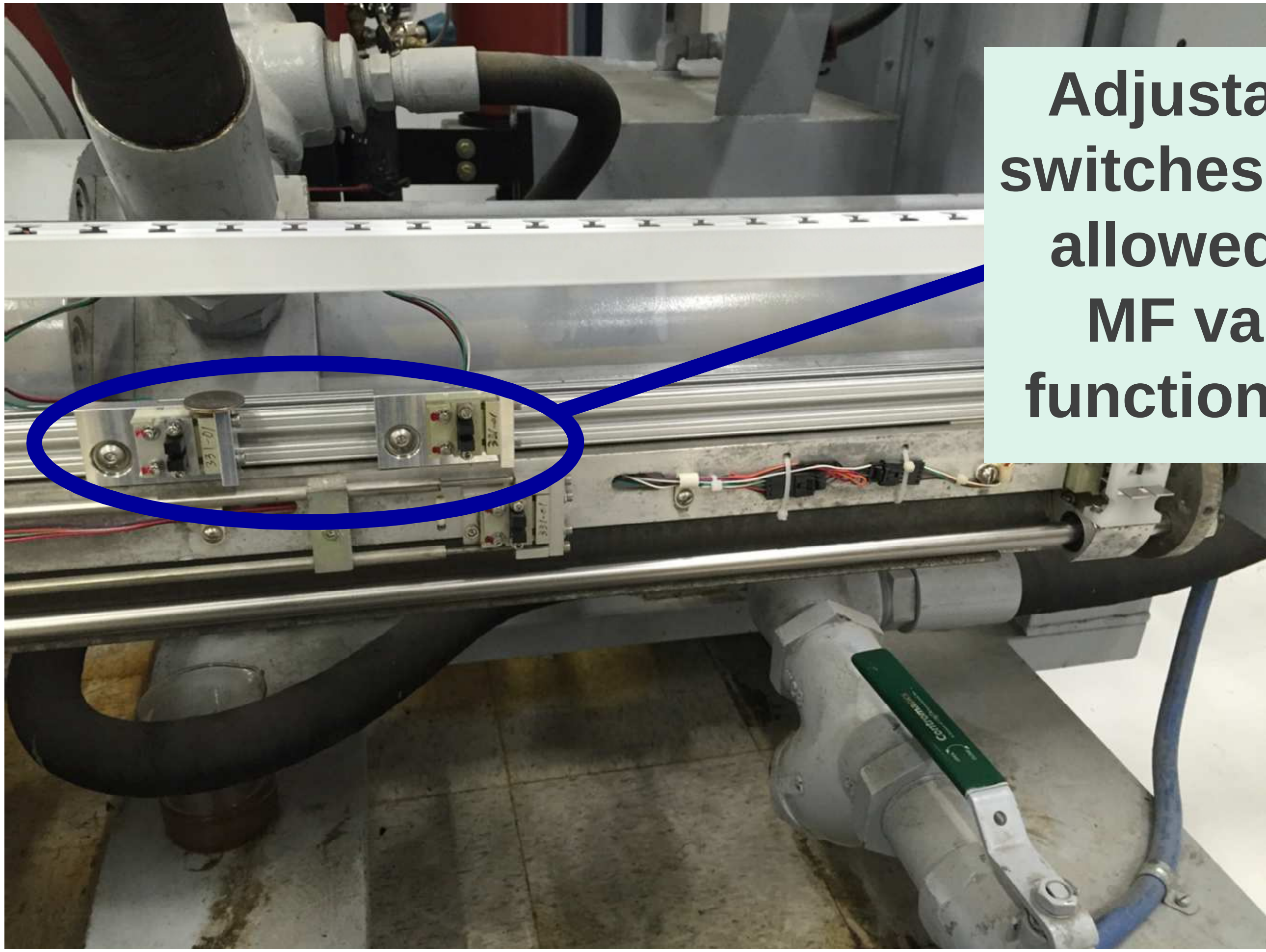
Meter Factor
Uncertainty = 0.032%



Meter Factor
Uncertainty = 0.025%

Meter Factor
Uncertainty = 0.019%

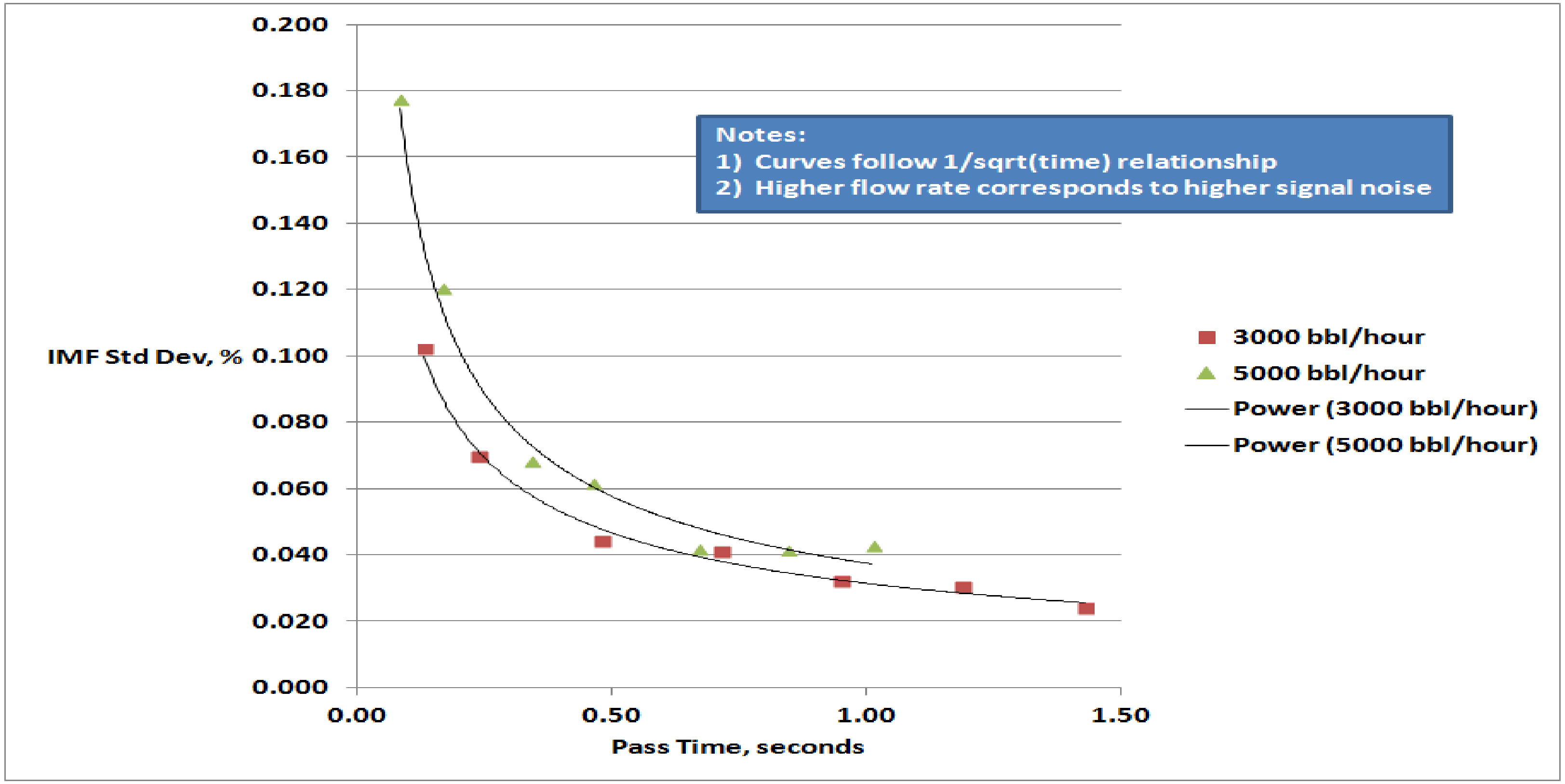
Testing with Adjustable Prover Detector Switches



Adjustable detector switches on the prover allowed us to study MF variation as a function of pass time

Prover Pass Uncertainty is a Strong Function of Pass Time

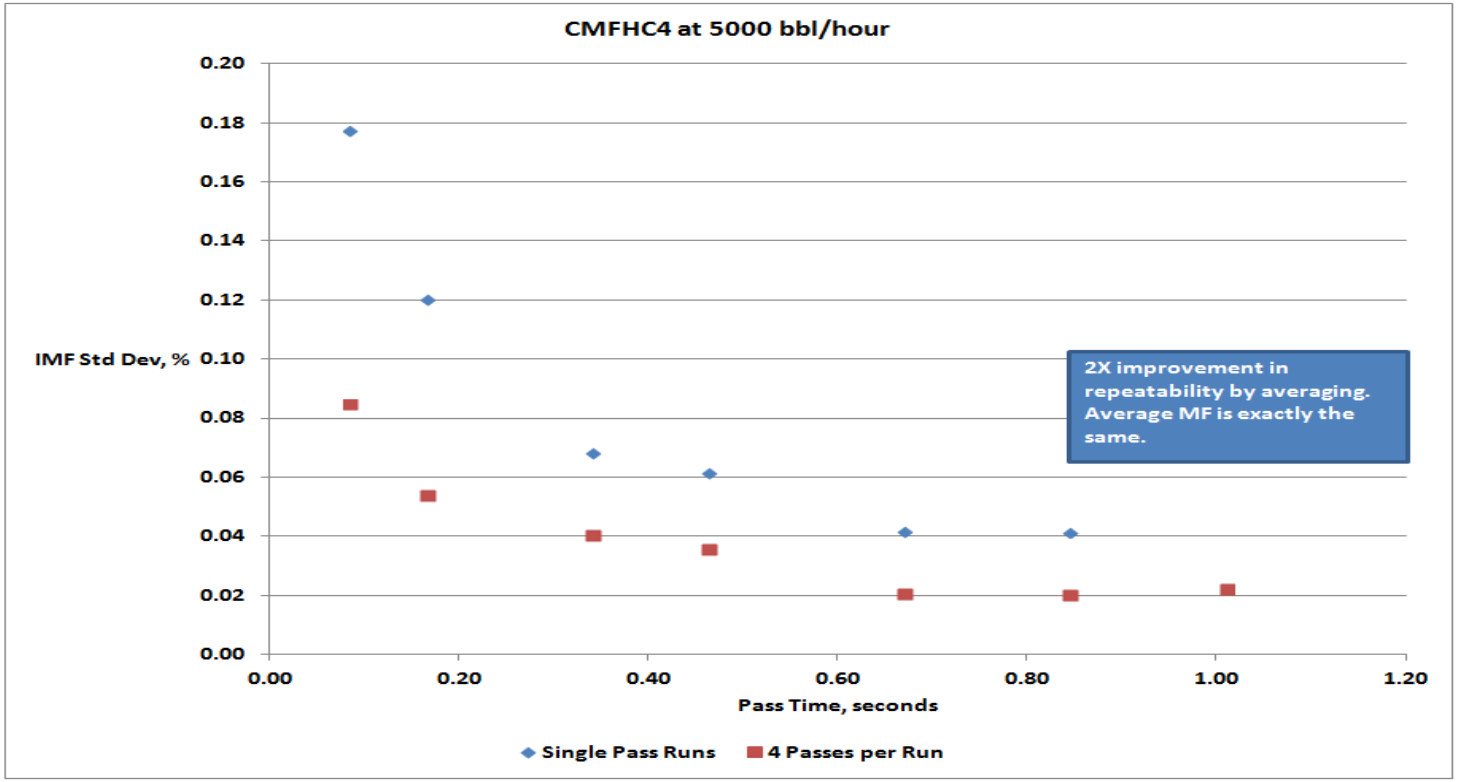
- **Uncertainty of each prover pass = uncertainty of the Indicated Meter Flowrate (IMF) integrated over the time period of the pass**
- **Shorter passes = higher uncertainty for each individual pass**



Improving Run Repeatability by Averaging Passes

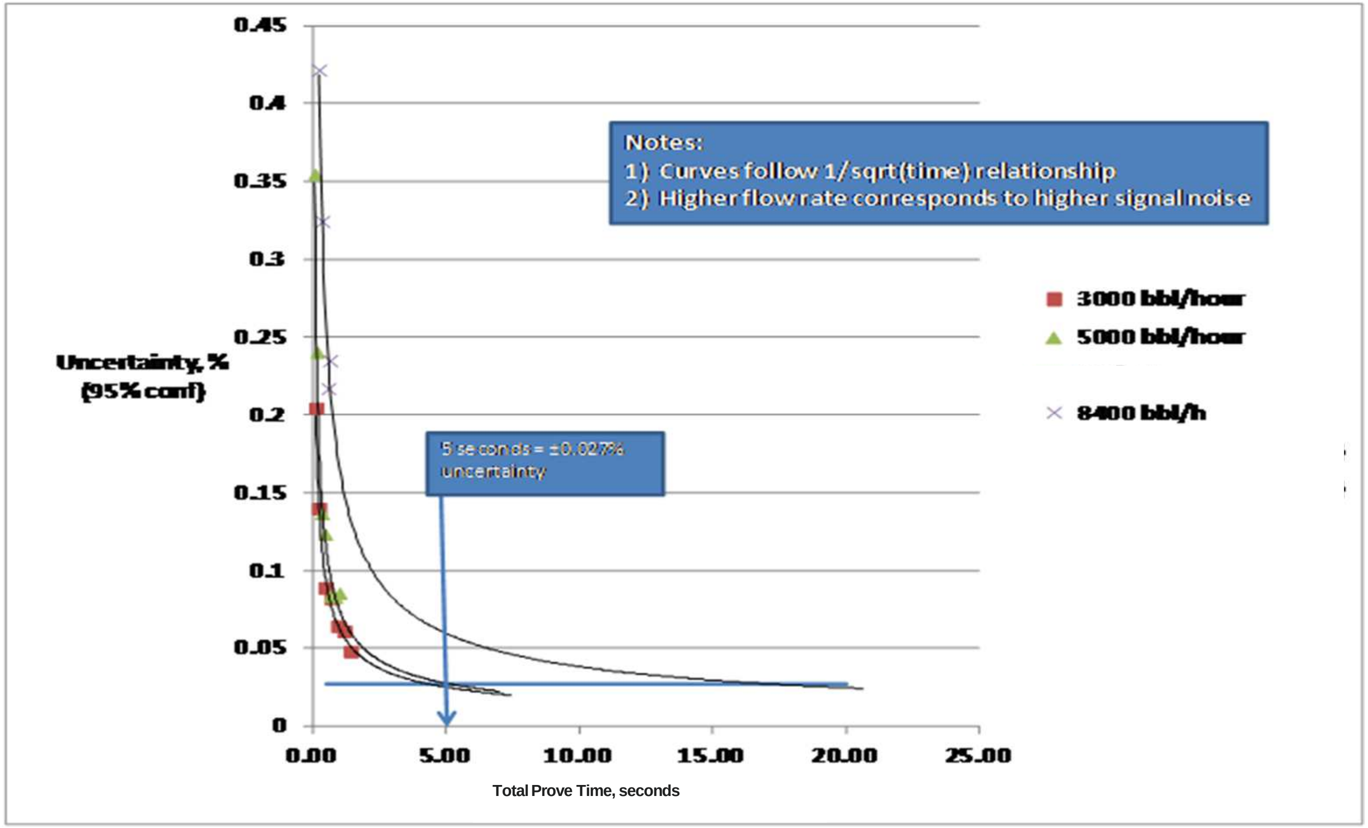
- **Run repeatability is a function of total run time**
  - **Repeatability improves as 1/sqrt(n)**

  Example: Averaging 4 passes together results in a 2X improvement
- **Multiple passes per run = lower uncertainty per run**



Meter Factor Uncertainty is a Function of Total Prove Time (TPT)

- **Sum of Total Prove Time (TPT) is constant:**
  Pass Time X Number of Passes per Run X Runs
- **Meter Factor (MF) Uncertainty = uncertainty of <u>mean</u> of all proving runs**
- **Meter Factor uncertainty approaches zero as TPT increases to infinity**



Prover Sizing and Selection

- **Total Prove Time (TPT)** = total data collection time (prover displacer moving between the detector switches):

$$TPT = \frac{Base\ Prover\ Volume\ (BPV)}{Flow\ Rate} \text{ x (\#of runs) x (\# of passes per run)}$$

- Minimum TPT can be estimated by meter manufactures
  - Estimated minimum TPT can help predict prover size
  - TPT increases with increasing flow rate and flow noise

- The estimated minimum TPT predicts what prover size is needed to achieve the target MF uncertainty

Note: **Pass time must always be > 0.5 seconds and pre-run time must always be > 0.25 seconds**

Prover Sizing Examples
Method 1: BPV (for 5 passes)

Determine the Base Prover Volume (BPV):

$$BPV = \frac{TPT\ x\ Flow\ Rate}{(\#of\ Runs)x(Passes\ per\ Run)}$$

If:

- Flow rate = 1000 m^3/hr = 0,28 m^3/s
- Est. min. TPT = 20 seconds
- 5 single-pass runs (5 passes total)

Then:

- BPV = (20 X 0,28) ÷ (5 X 1) = 1,1 m^3

Prover Sizing Examples
Method 2: Total Passes

Determine the total number of passes needed:

$$\text{Total Passes} = TPT\ x\ \frac{Flow\ Rate}{Base\ Prover\ Volume\ (BPV)}$$

If:

- Flow rate = 360 m^3/hr = 0,1 m^3/s
- Est. min. TPT = 30 seconds
- BPV = 0,6 m^3

Then:

- Total Passes = (30 X 0,1) ÷ (0,6) = 5 passes

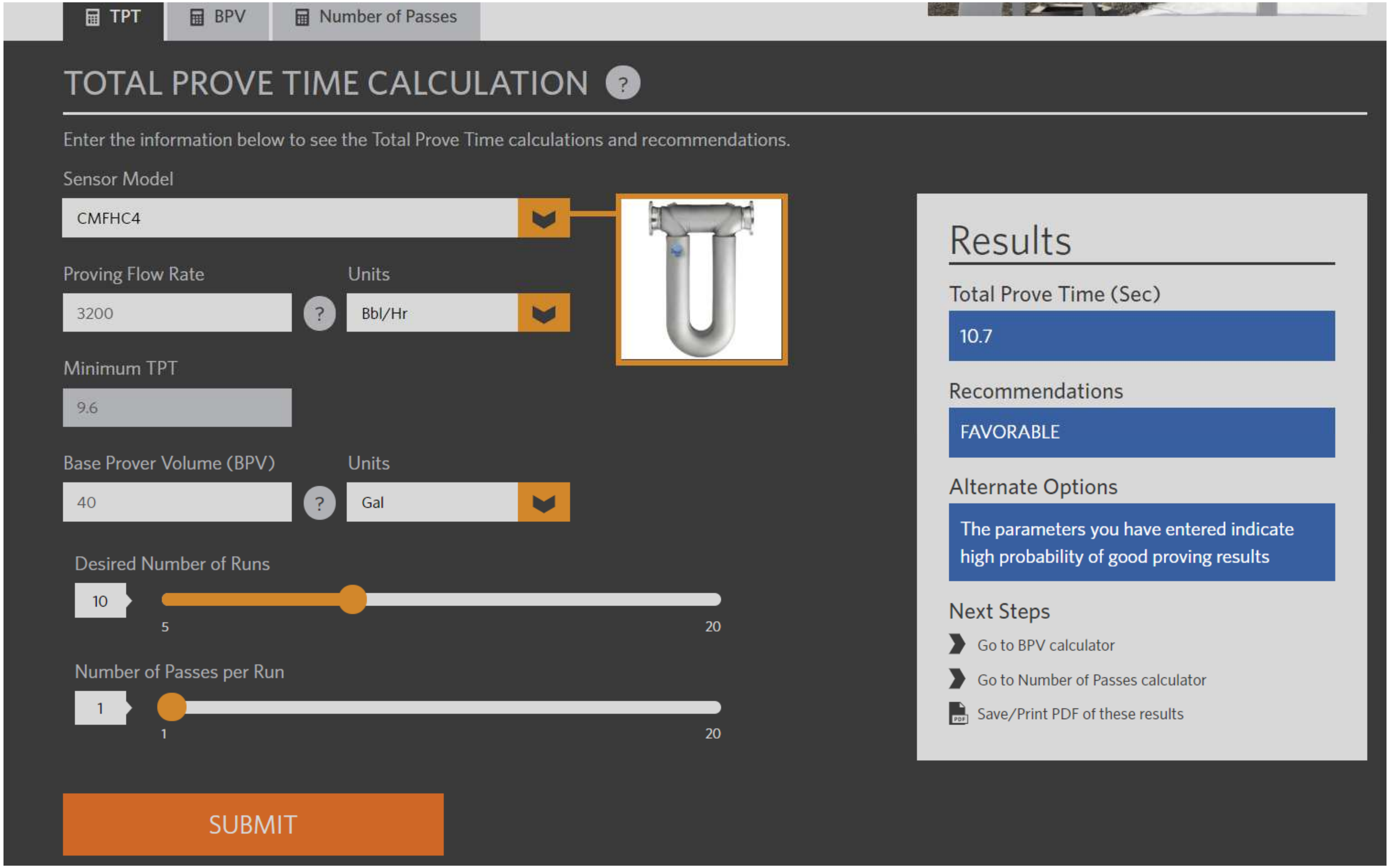
Prover Sizing Considerations

- Increasing BPV will allow for fewer passes
  - Can reach est. min. TPT with fewer passes
  - Reduced runs (less long-term wear and tear)
  - Shorter overall prove time

- Increasing passes will allow for a smaller prover
  - Can reach est. min. TPT with a smaller prover
  - Smaller BPV (lower capital investment)
  - Longer overall proving time

Example
Online Prover Sizing Tool

FLOMEKO2019
18th International Flow Measurement Conference
Portugal | Lisbon | LNEC | 26-28 june 2019



Coriolis Meters are Ideal as Master Meters

Unlimited Pass Time per Run

Mass and/or Volume Proving

Conclusion

FLOMEKO2019
18th International Flow Measurement Conference
Portugal | Lisbon | LNEC | 26-28 june 2019

Proving best practices are the path to:

- More efficient proving
- Lower costs
- Superior measurement confidence

A Stable Meter Factor is Always Better!

Thank You!

FLOMEKO2019
18th International Flow Measurement Conference
Portugal | Lisbon | LNEC | 26-28 june 2019