Wet Gas Performance of Coriolis Meters: Continuation of Laboratory and Field Evaluation

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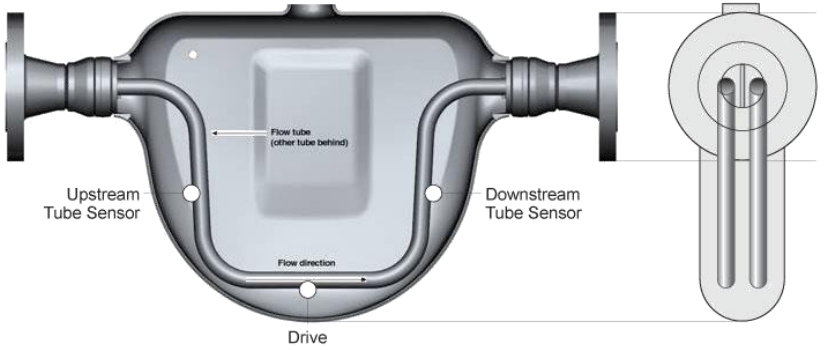
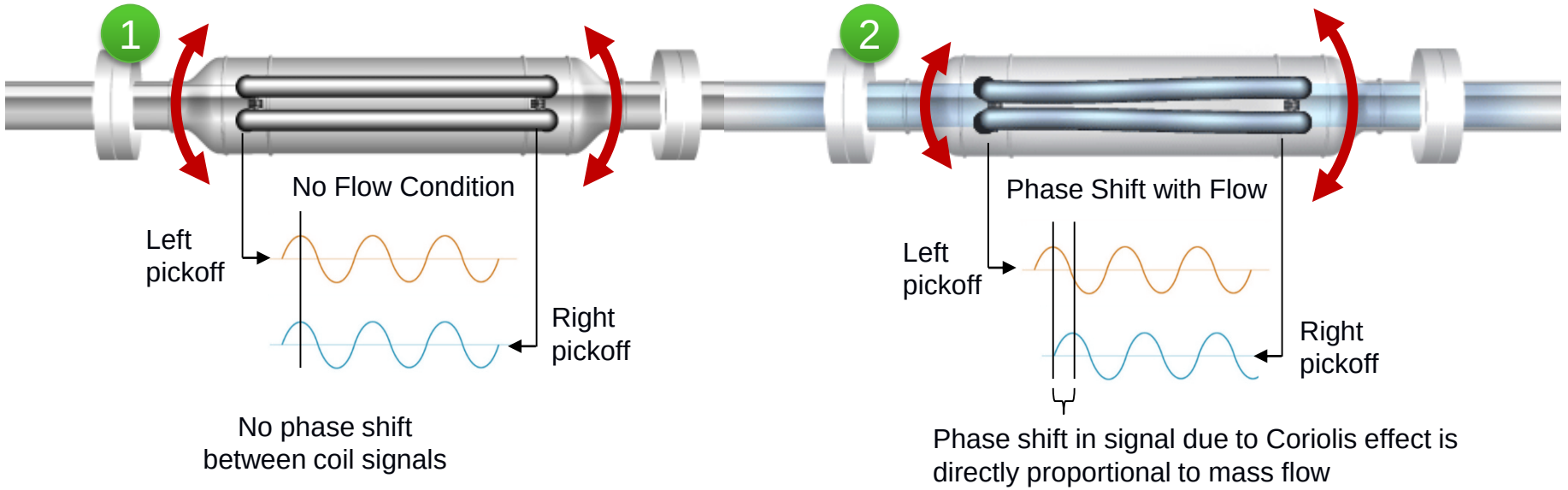
Content

Theory of Operation – The Coriolis Effect

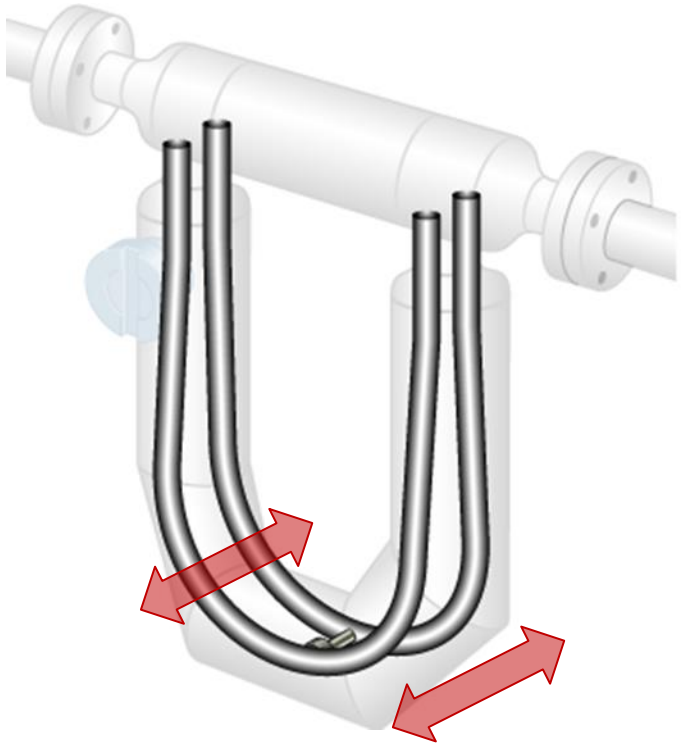
1. During a no flow condition, flow tubes vibrate in phase with each other.
2. With flow, Coriolis forces are induced causing the flow tubes to twist in opposition to each other.

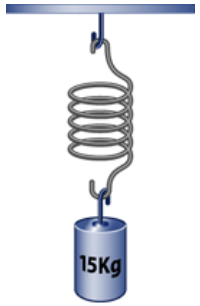




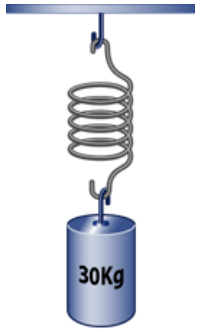
Phase shift between pickoff coils is directly proportional to mass flow

Theory of Operation - Density

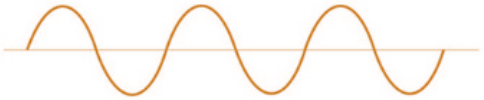




Low Fluid Density *decreases* system mass and *increases* frequency of tube oscillation



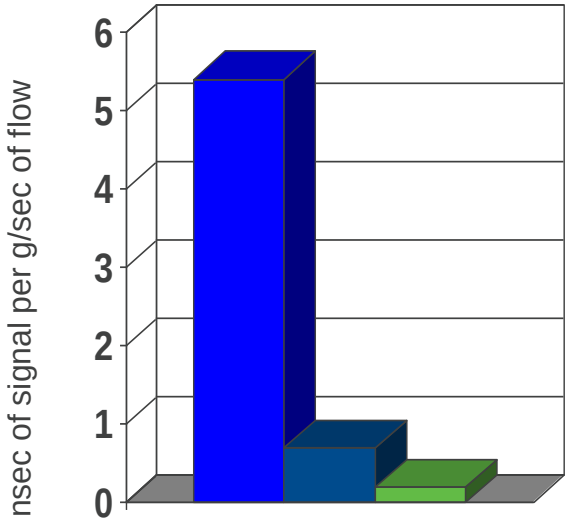
High Fluid Density *increases* system mass and *decreases* frequency of tube oscillation



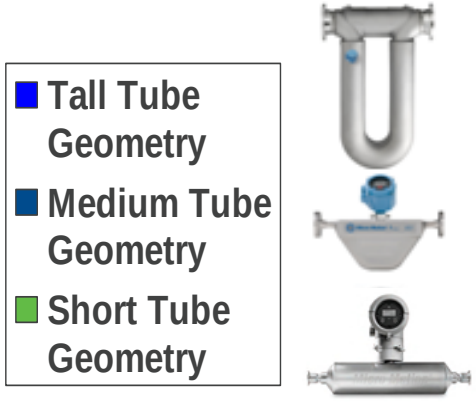
Density measurement is based on the natural frequency of the system, including the flow tubes and the process fluid.

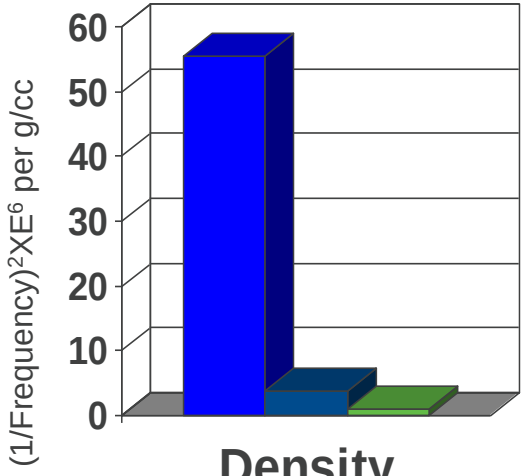
Coriolis Meter Raw Sensitivity Varies with Design

- **Raw Sensitivity Depends on Tube Geometry**
- **Signal to Noise Ratio Depends on Raw Sensitivity and Stability**
- **Accuracy, Stability, Calibration Flexibility, Immunity to Secondary Effects, and Diagnostic Capabilities Depend on Signal to Noise Ratio**



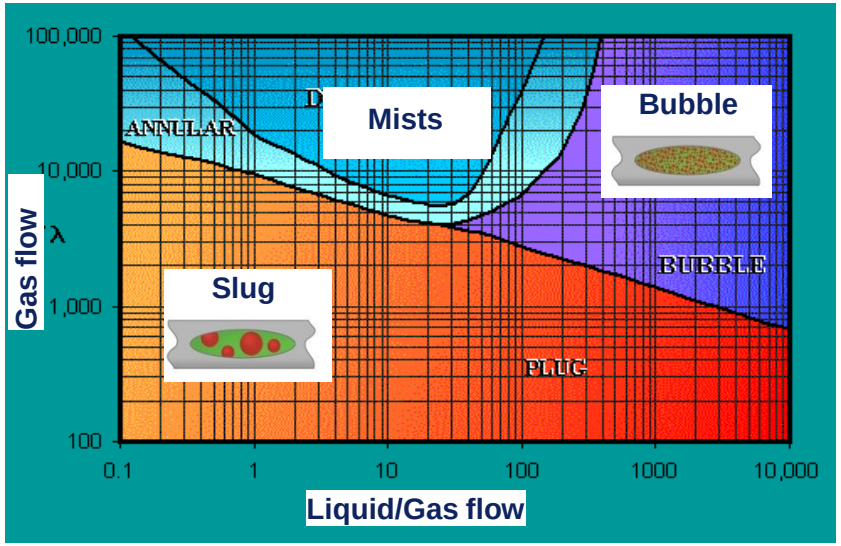
Flow Sensitivity Examples





Density Sensitivity Examples

Improvements to Handle Multiphase Regimes

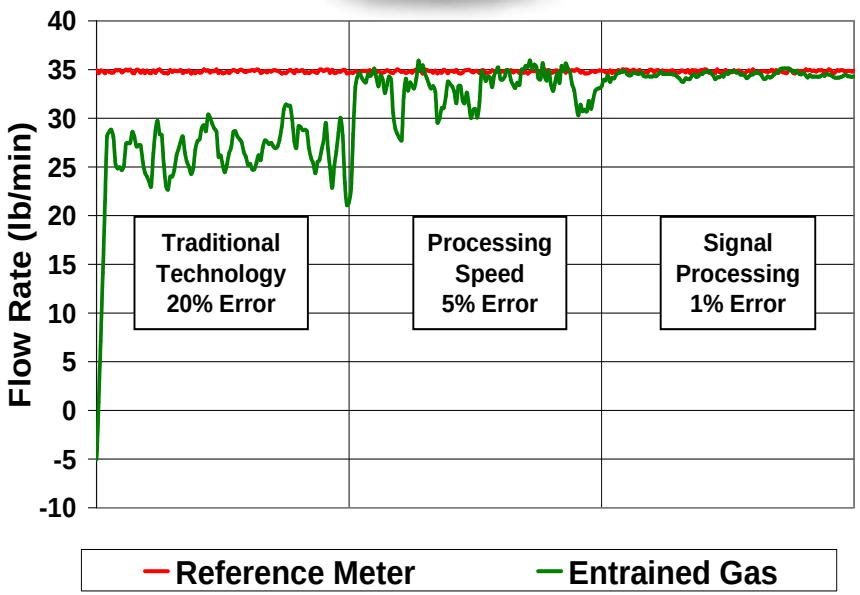


Electronics Improvements

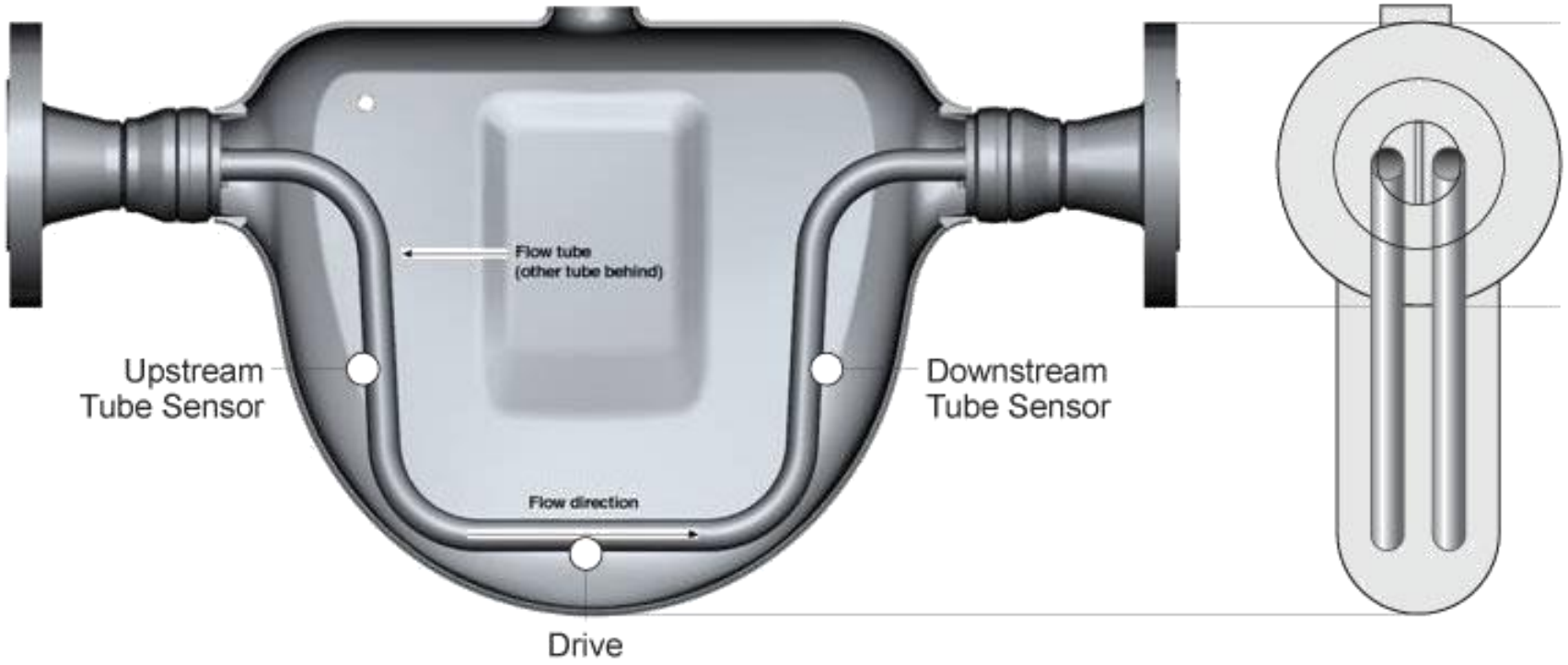
- Processing speed
- Signal processing algorithms
- Function with noisy signals

Structural Improvements

- Better balance and vibration isolation
- Modal separation

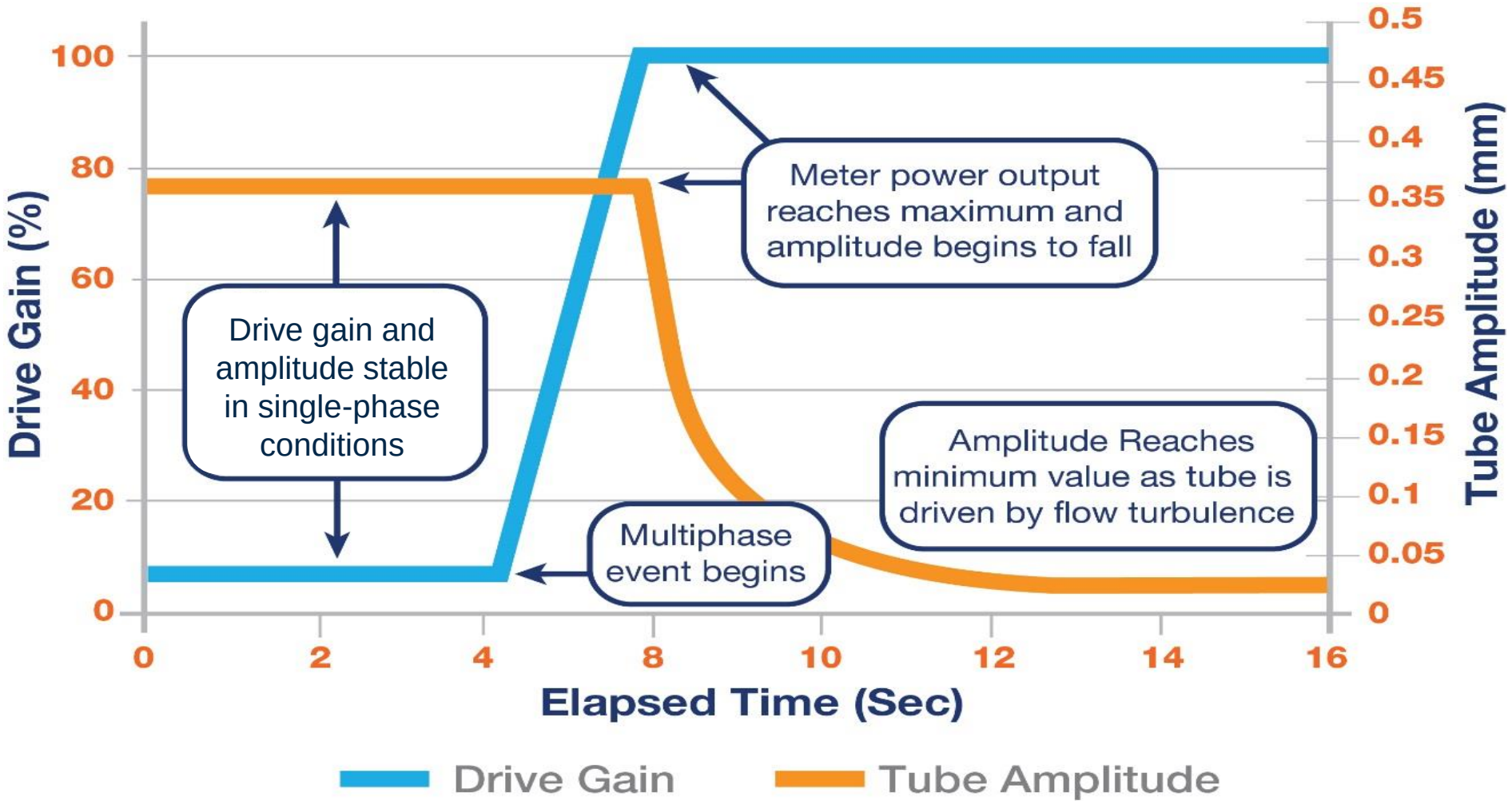


Vibration Drive and Amplitude



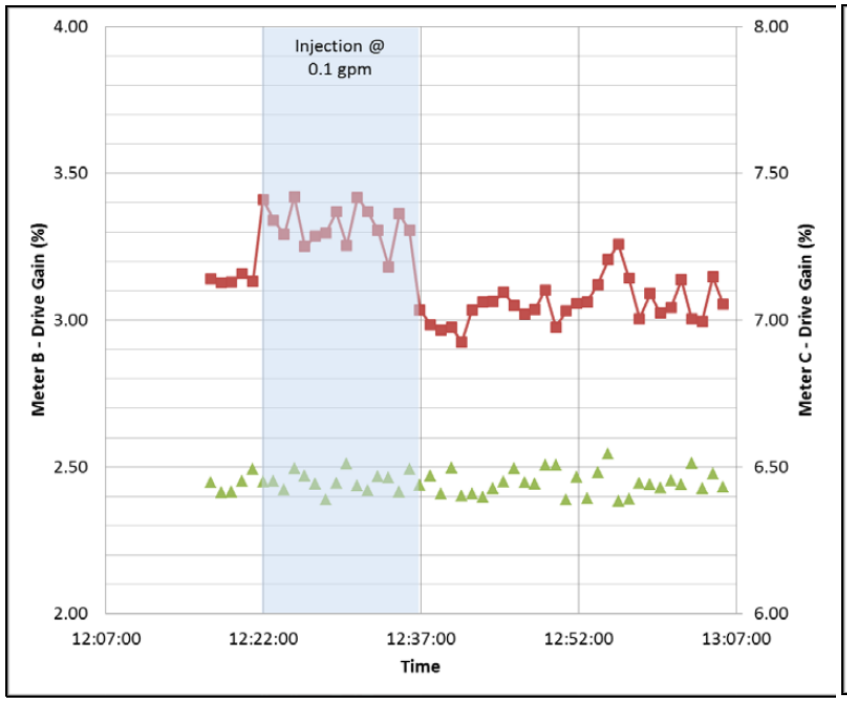
Drive and pickoff coils provide damping data

Detection of Multiple Phases

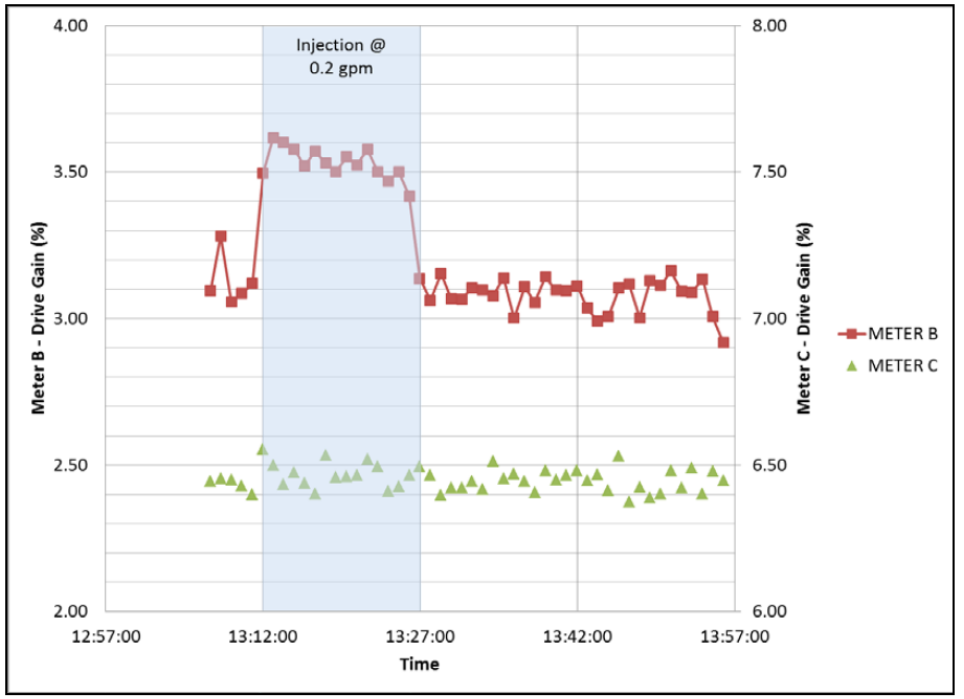


Damping of flow tubes indicates multiple phases

Lab Testing: Sensitivity to Liquid Phase



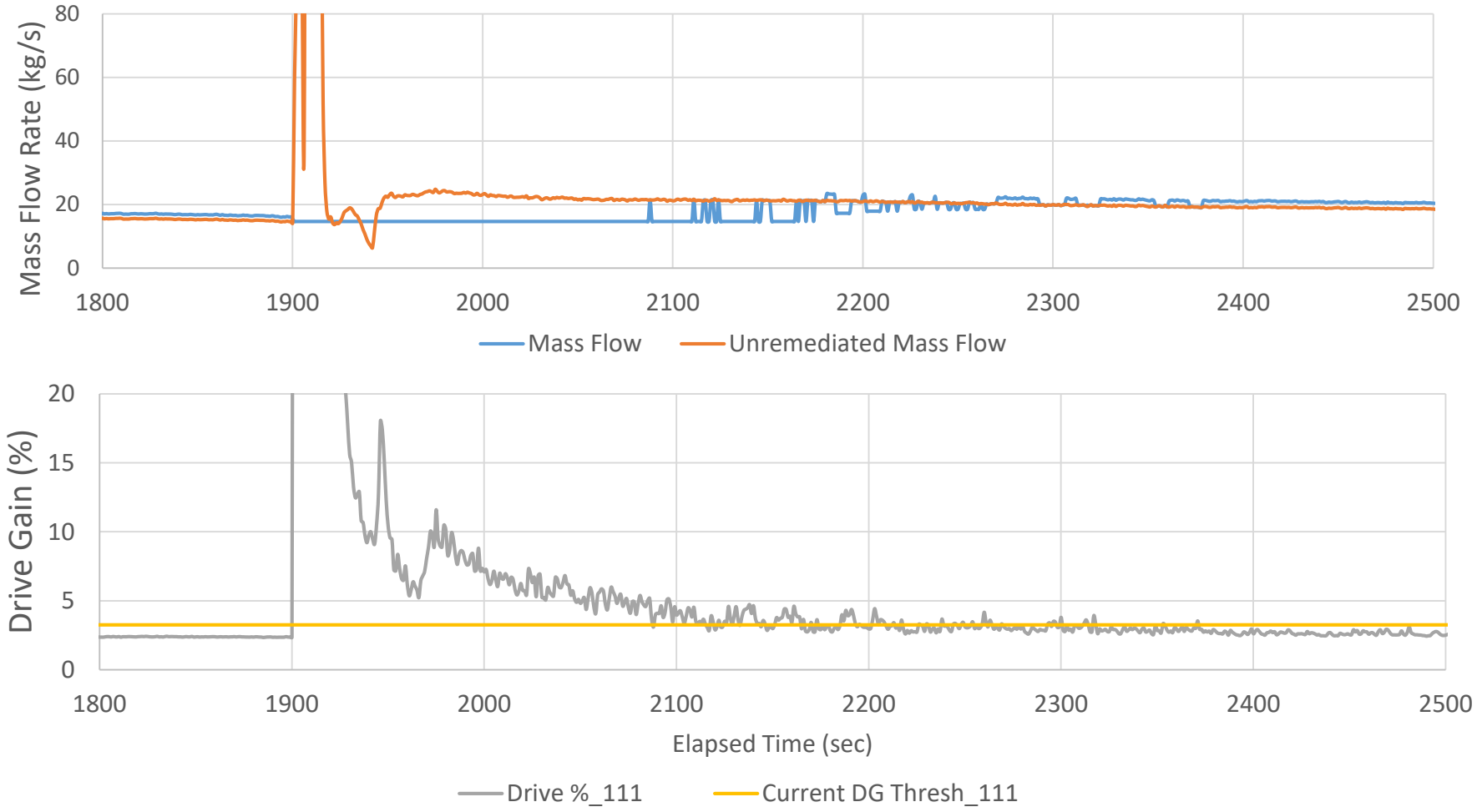
Drive Gain Results for Meter B at 100 acfm and 0.1 gpm



Drive Gain Results for Meter B at 100 acfm and 0.2 gpm

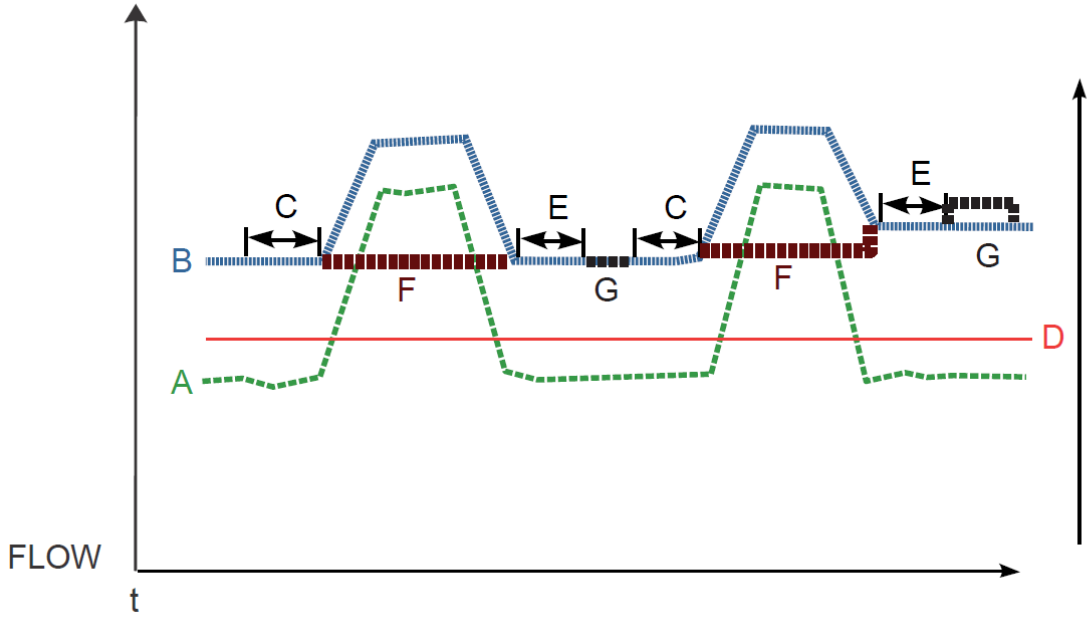
Sensor element design, signal processing and control of vibration has effect on ability to detect phase contamination

Field Data: Liquid Slugs in Gas



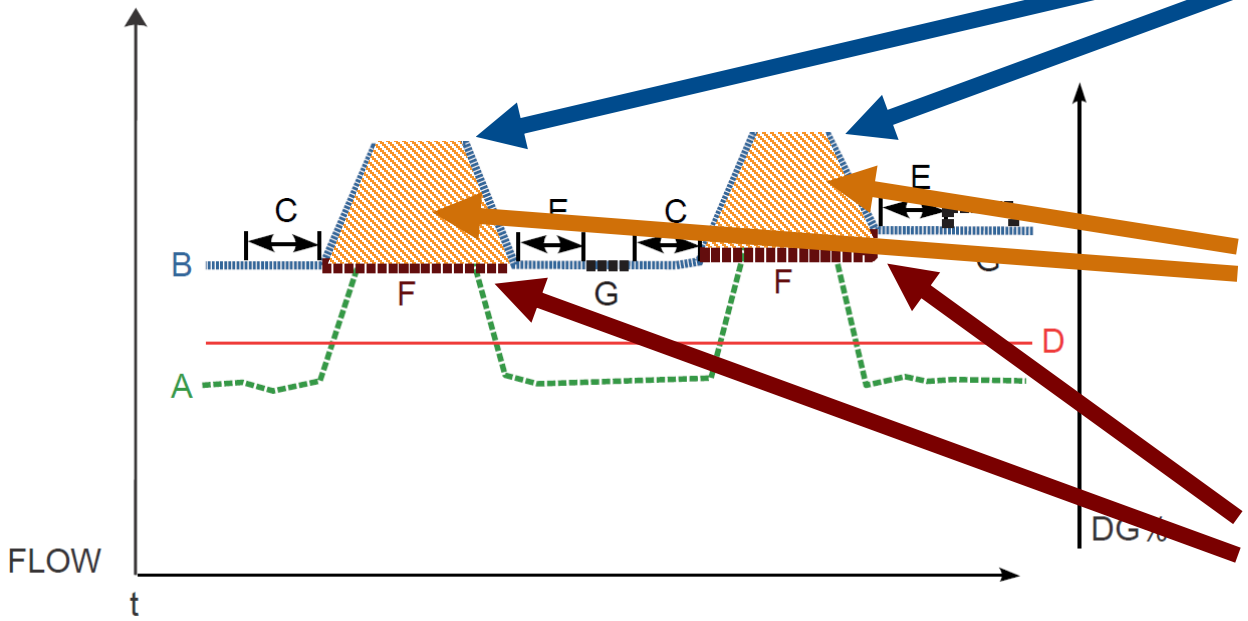
Immediate detection of liquid slugs allows them to be excluded from gas measurement

Simple Wet Gas Algorithm



A. Flow Rate
B. Drive Gain Threshold
C. Drive Gain (actual)
D. Pre-Mist Averaging Period and Source of M1
E. Averaged flow rate values
F. Post-Mist Adjustment Delay and source of M2
G. Adjustment Period
H. Adjusted flow rate values

Simple Wet Gas Algorithm

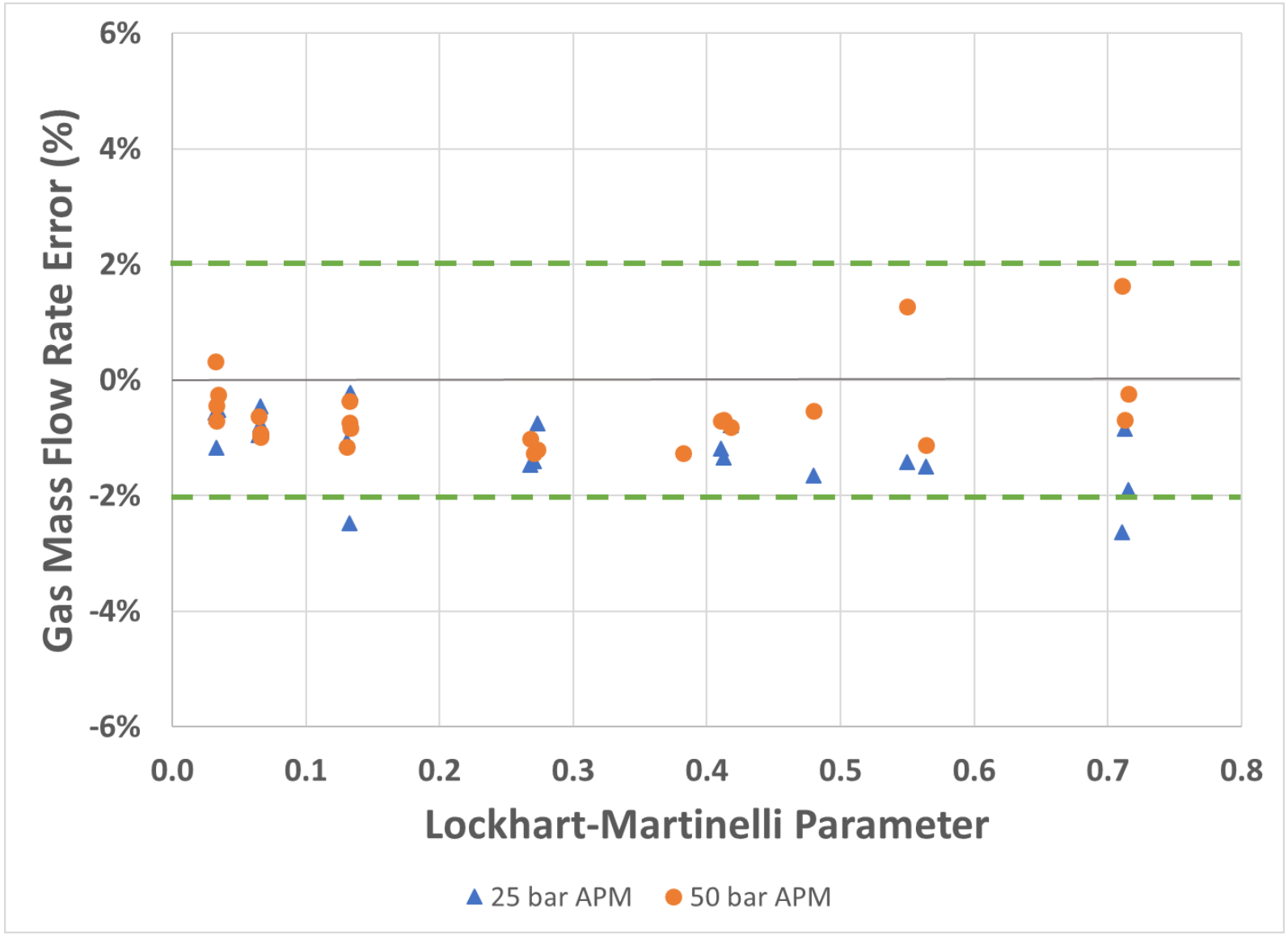


Total Mixture Flow
(Liquid & Gas)

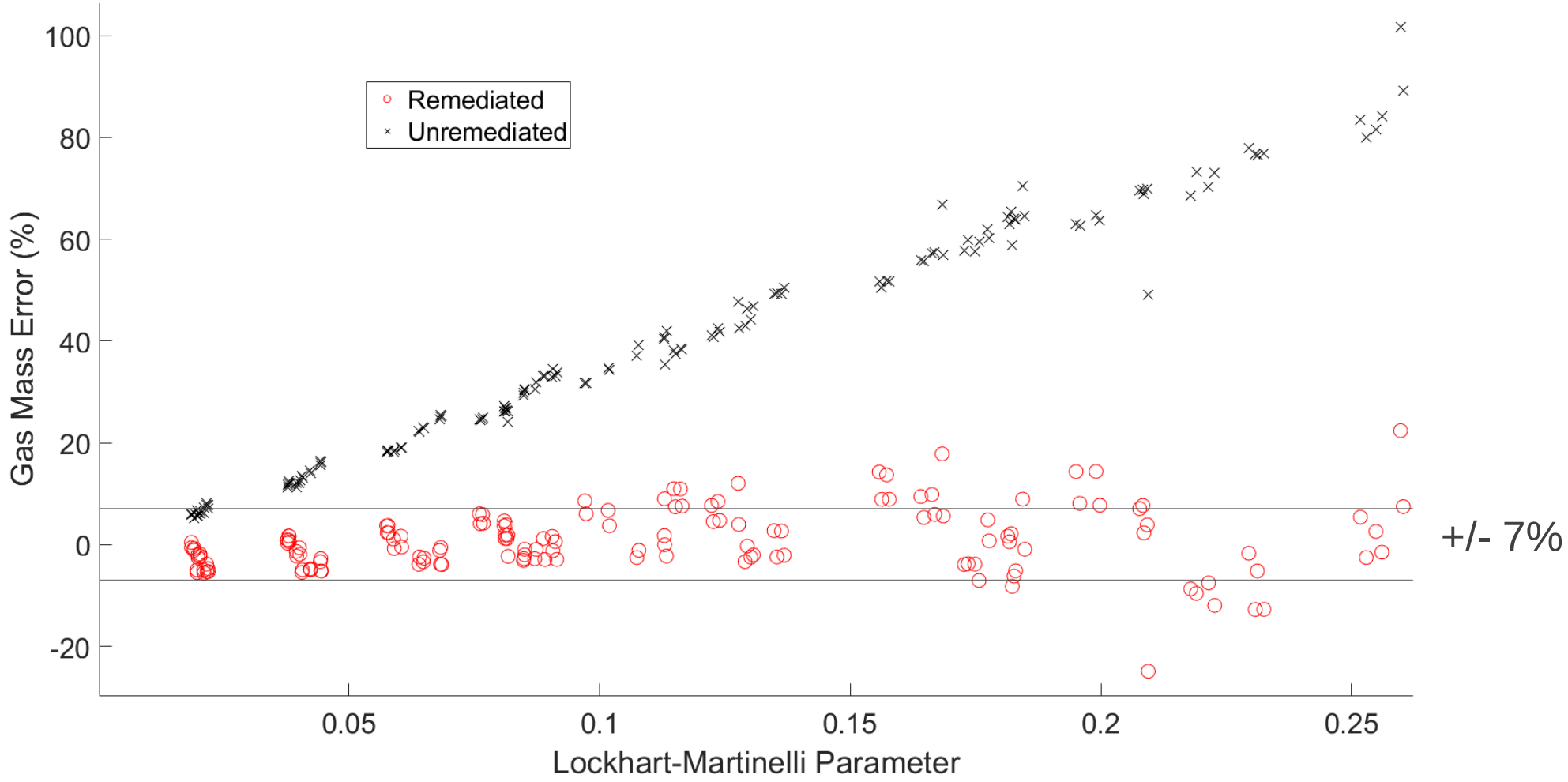
Liquid Flow Output
= Total – Dry Gas

Remediated Dry Gas
Flow Output

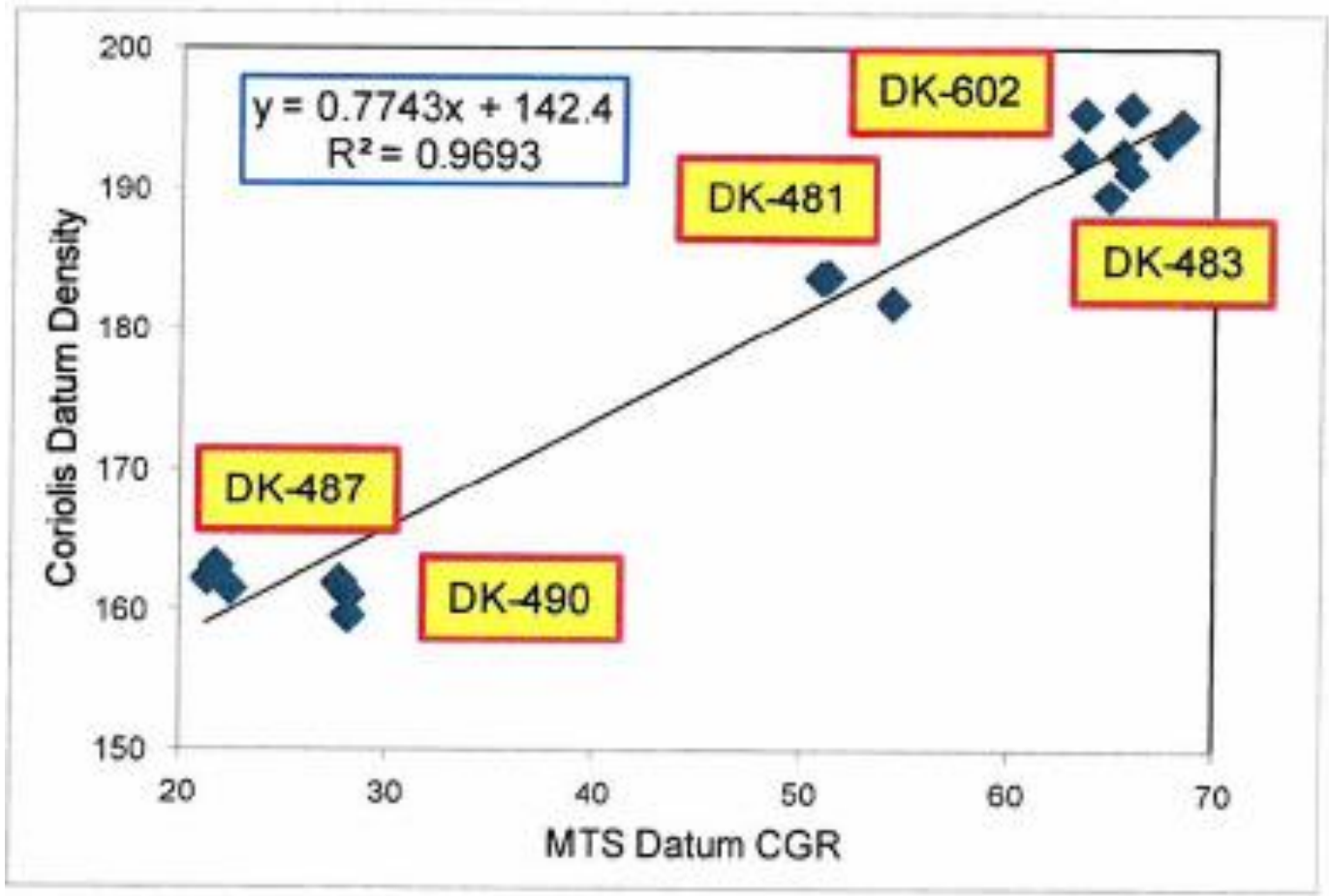
CEESI Testing – Slugging Regime



Lab Testing: Continuous Wet Gas

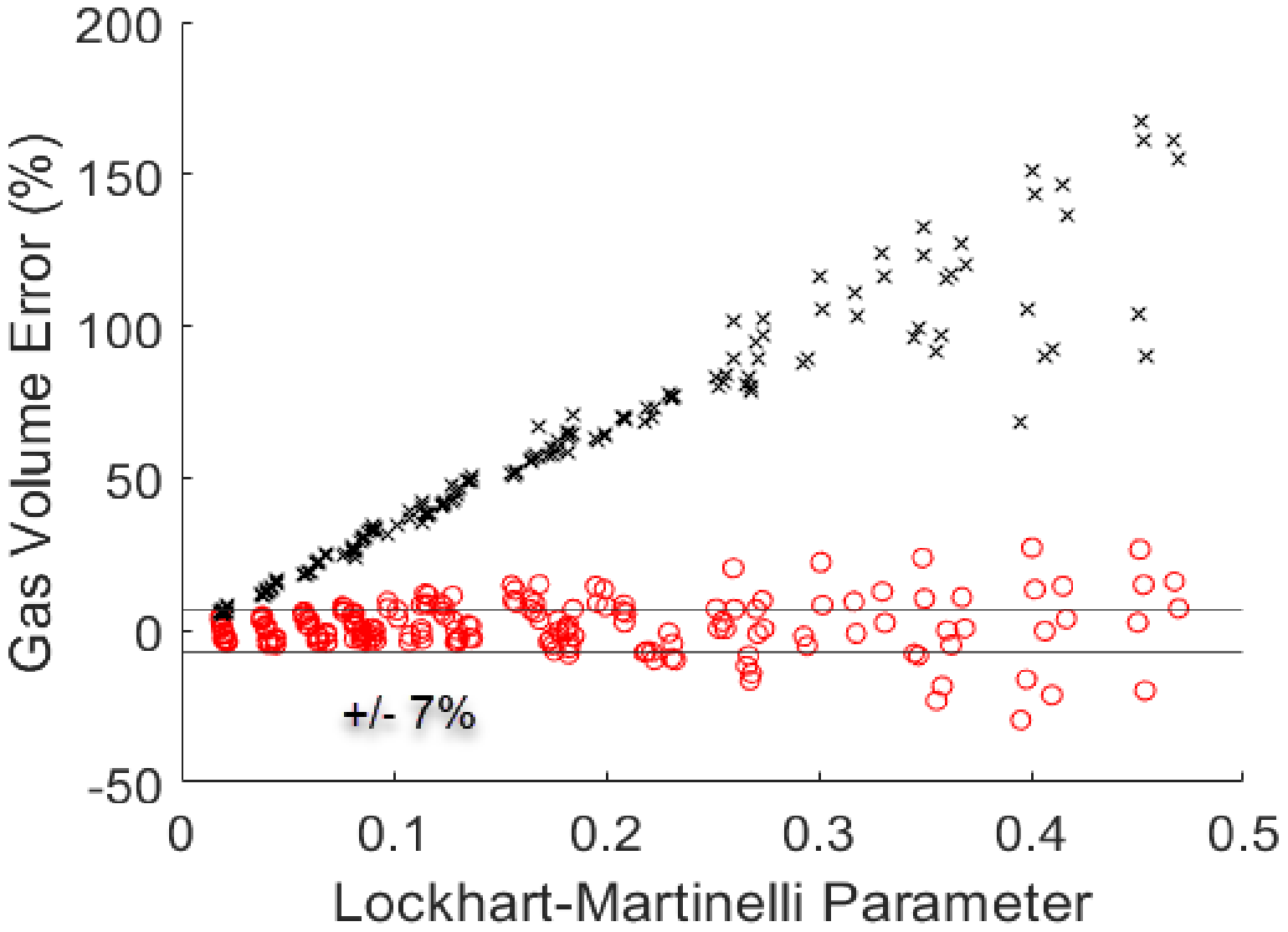


Field Data: Determining Liquid Content



A useable approach in the field is to use well tests to reference measured density to phase fractions

Extending Corrections for More Liquid



Experience in the Field

- **Field conditions always more challenging than lab**
  - Different process conditions, fluid properties, hydrates, solids
  - Questionable references
- **Thousands of meters in the field using intermittent multiphase algorithm**
  - Separator outlets, plunger lift wells, naturally slugging regimes
  - Generally accepted to be within ± 3% GSV over broad range of pressure, temperature, flow rate and liquid loading conditions
- **Field trials underway on continuous / changing regime wet gas**
  - Initial results within uncertainty of field reference: ± 7% GSV
  - Primary challenge is hydrate formation
  - Tracking field operational changes that could affect trial also a challenge

Summary

- Coriolis technology has improved in the past ~10 years
  - Time to revisit guidelines for wet gas use
- Not all Coriolis designs are expected to have the same behavior in multiphase or wet gas
- It appears that viable methods exist to correct flow outputs
  - Coriolis meters can provide regime data, depending on design
  - May be less reliant on external inputs than existing approaches
    - Meter can measure liquid content and detect hydrates
- Additional research needed, revisit guidance on coriolis suitability for wet gas applications
  - Need to address field implementation challenges

NORTH SEA FLOW MEASUREMENT WORKSHOP

measuring for the energy transition

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