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Wet Gas Performance of Coriolis Meters: Lab and Field Results

by

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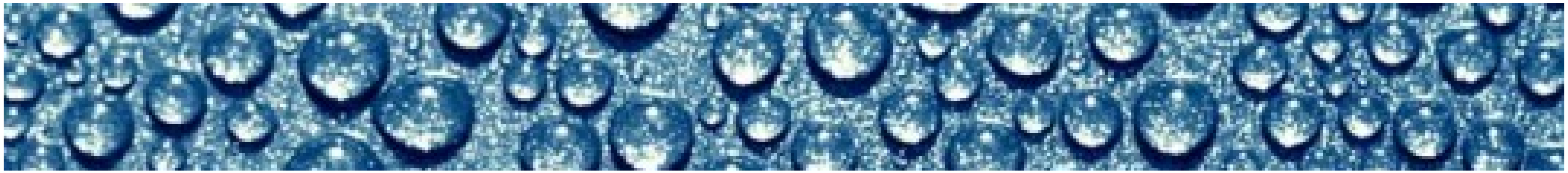
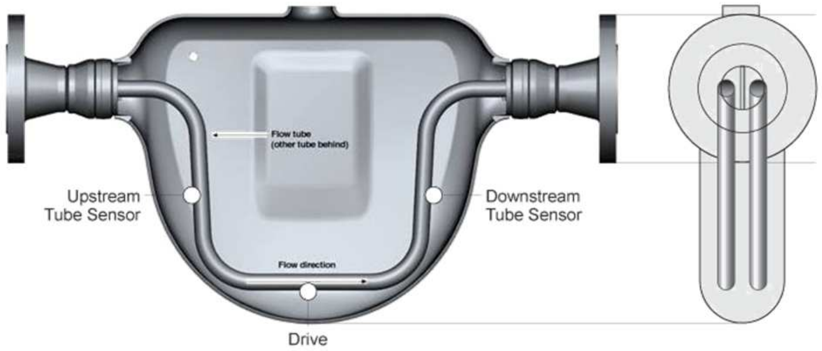


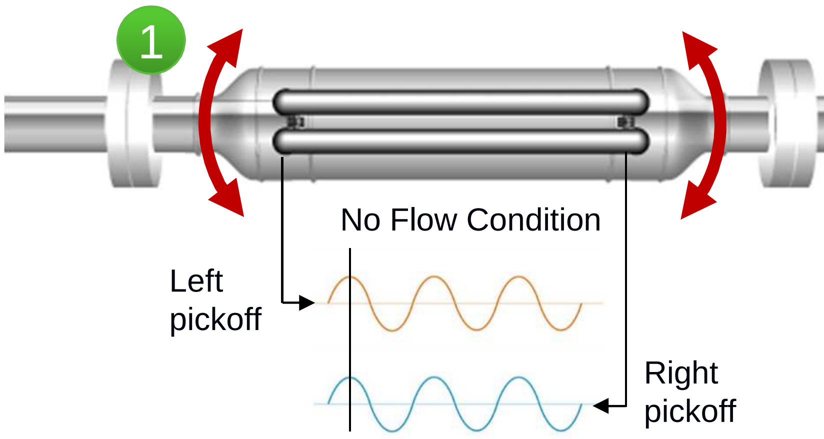
Agenda

- **Introduction**
- **Quick Coriolis Overview**
- **Design Elements to Consider for Multiphase Use**
- **Determination of Multiphase Conditions**
- **Algorithms for Different Flow Regimes**
- **Results from Testing in Lab and Field**
- **Conclusion**

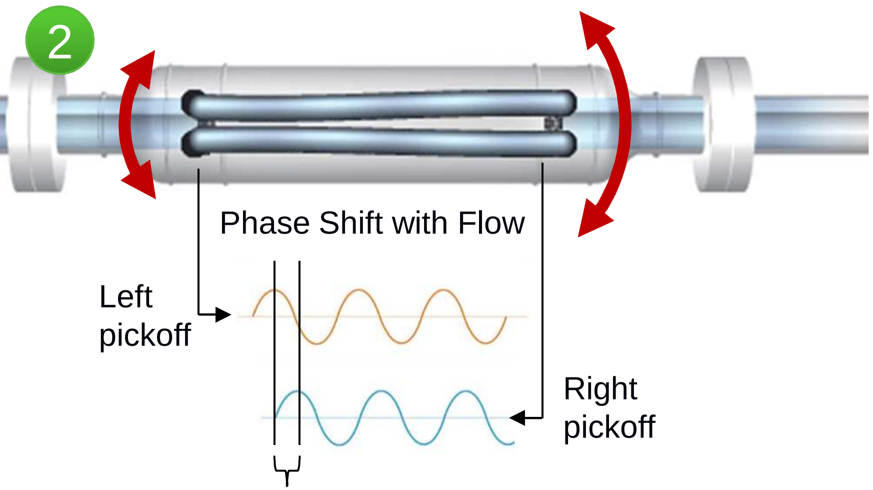
Theory of Operation – The Coriolis Effect

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.





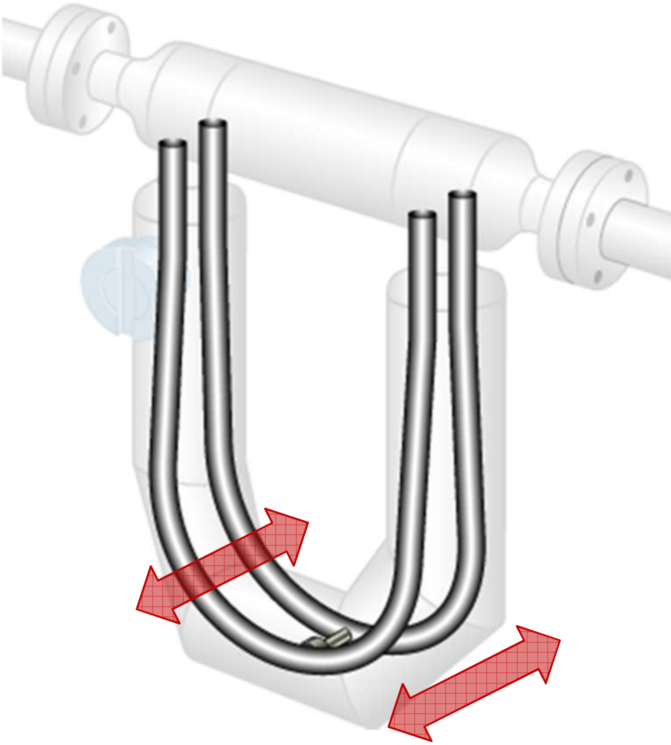
No phase shift
between coil signals

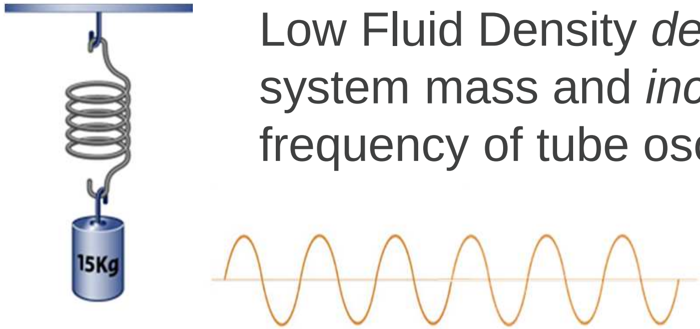


Phase shift in signal due to Coriolis effect is
directly proportional to mass flow

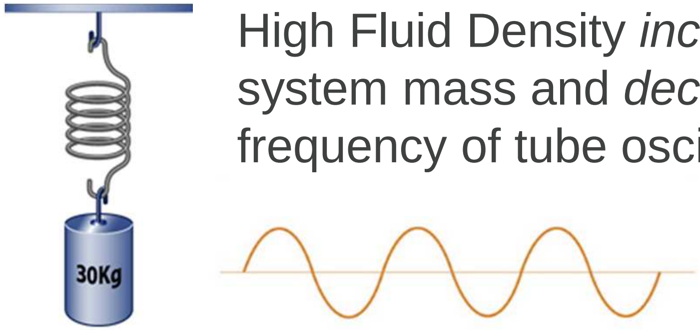
Phase shift between pickoff coils is directly proportional to <u>mass</u> flow

Theory of Operation - Density





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

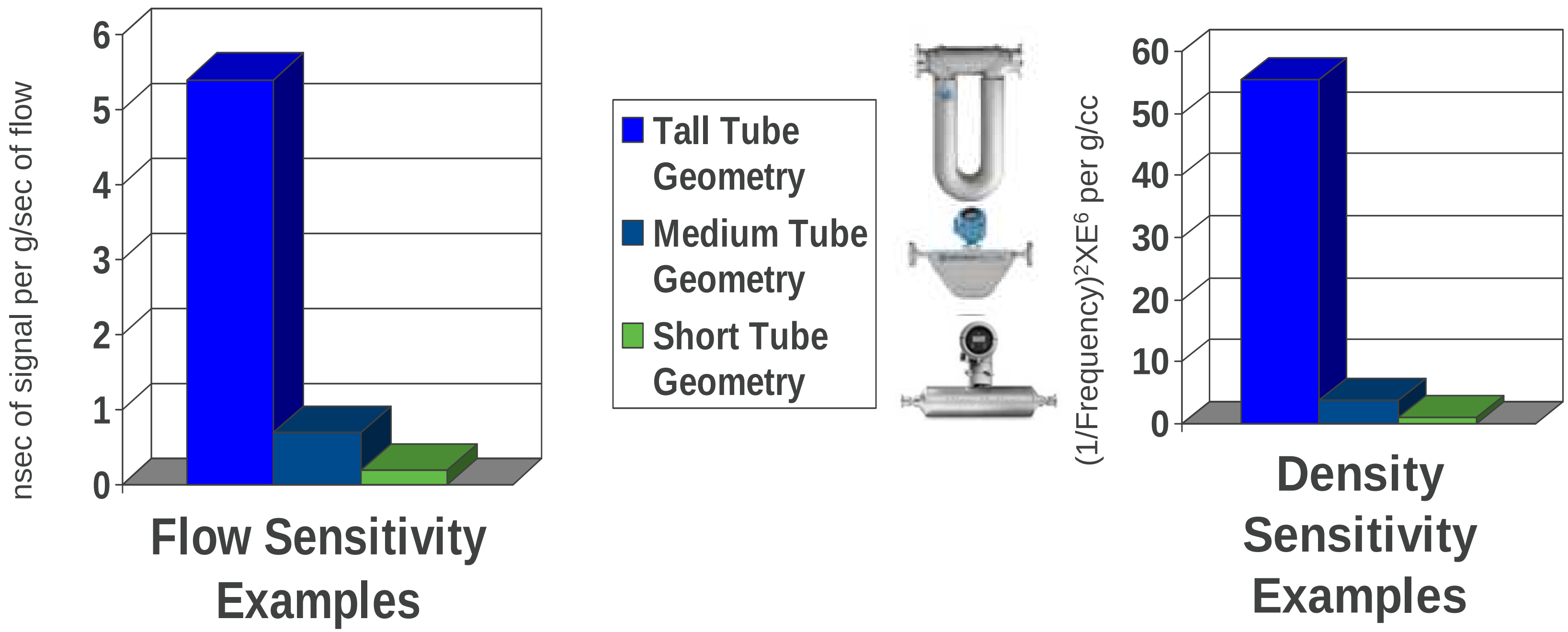


High Fluid Density *increases* system mass and *decreases* frequency of tube oscillation

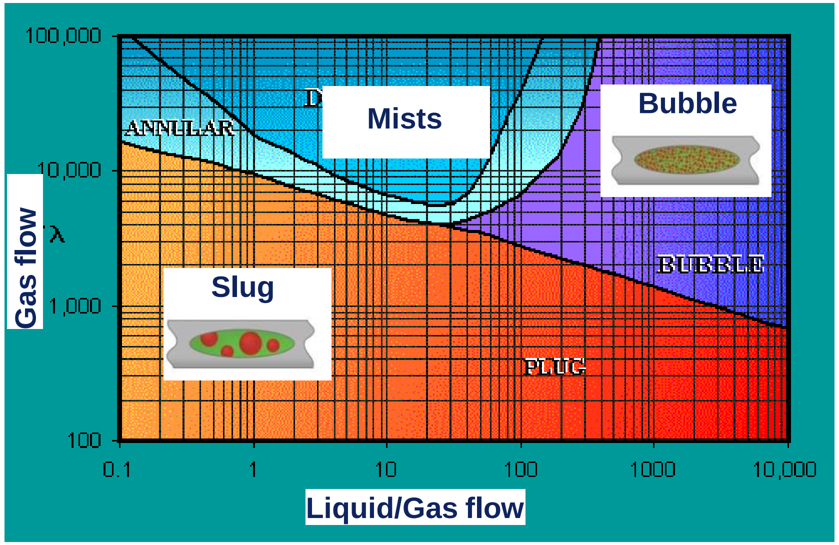
Density measurement is based on the natural frequency of the system, including the flow tubes and the process fluid.

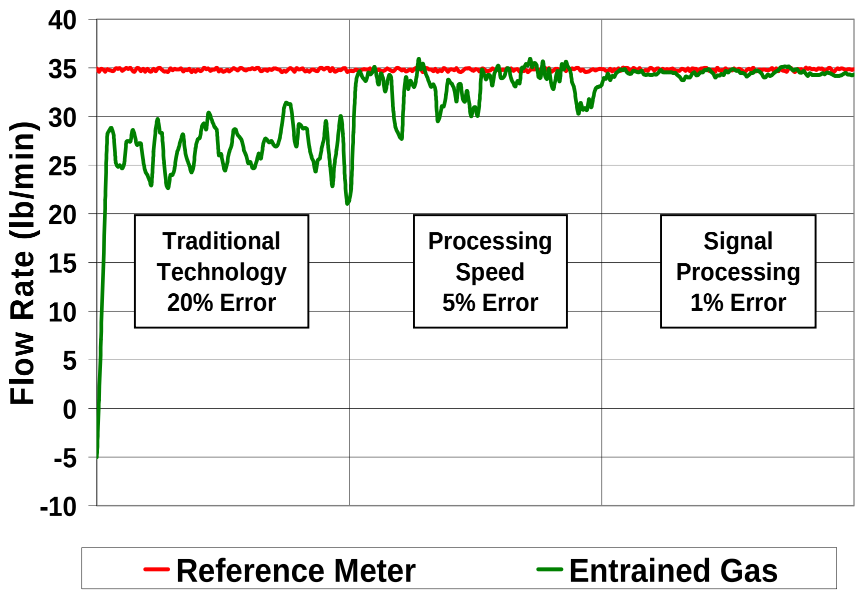
Coriolis Meter Raw Sensitivity Varies with Design

- **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**



Improvements to Handle Entrained Gas





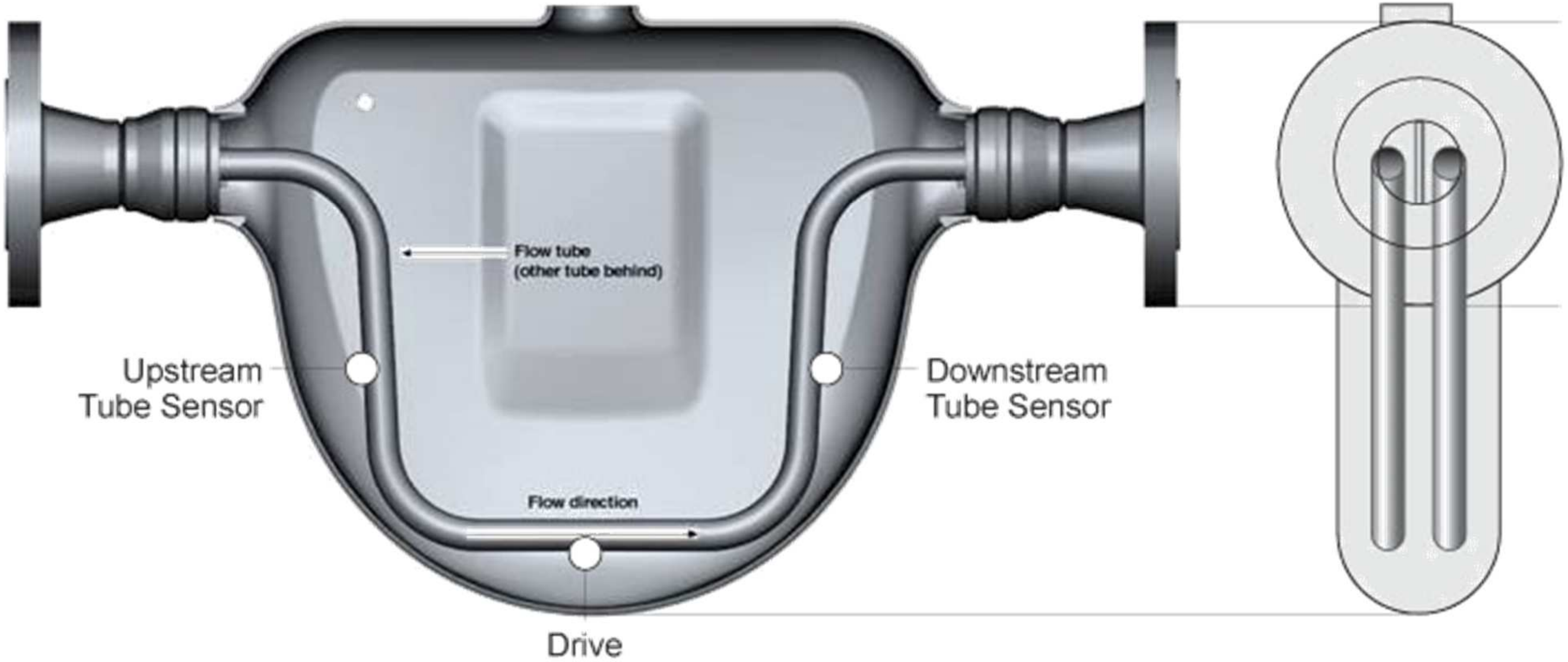
Electronics Improvements

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

Structure Improvements

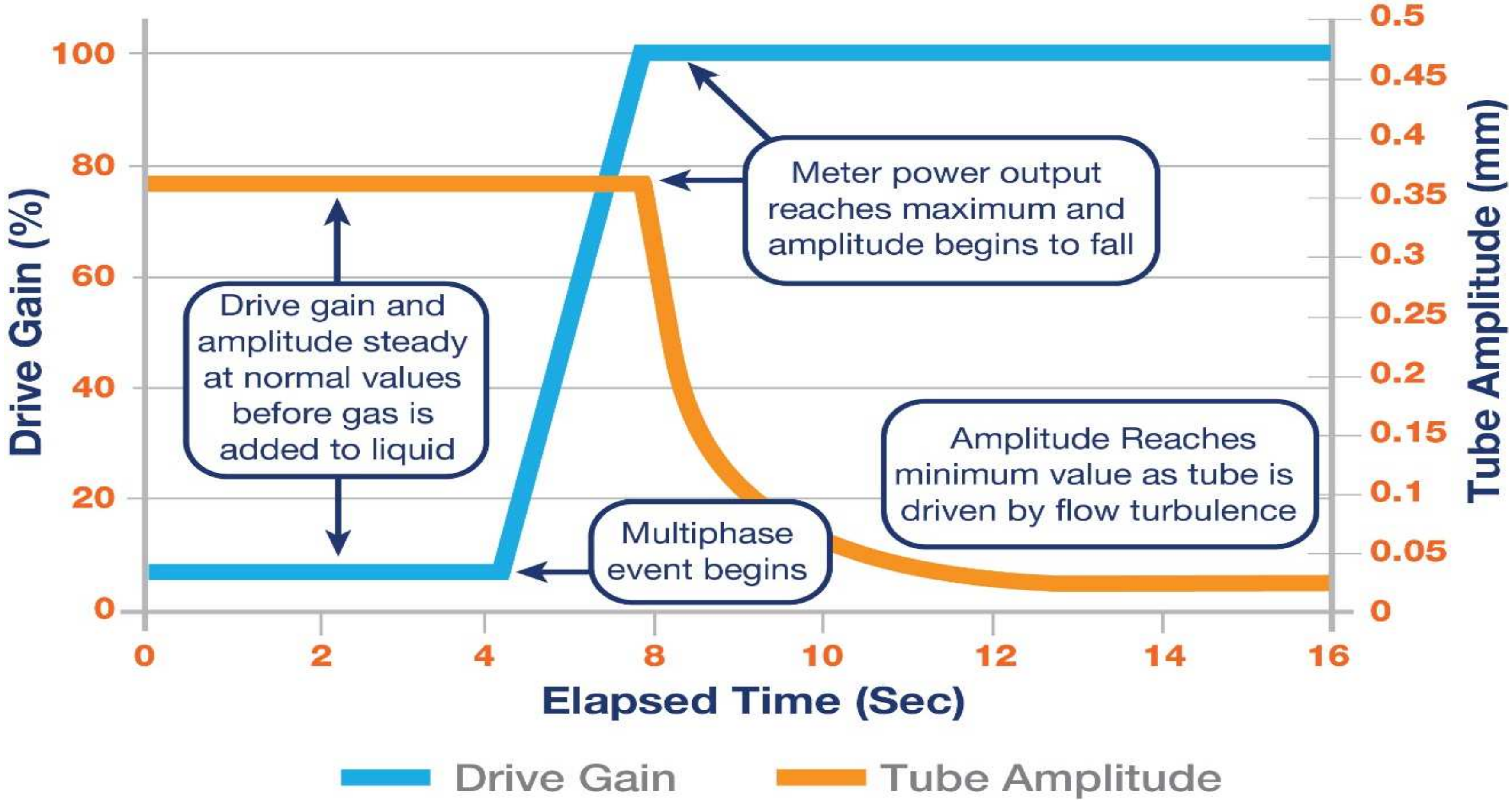
- Better balance and vibration isolation
- Modal separation

Vibration Drive and Amplitude



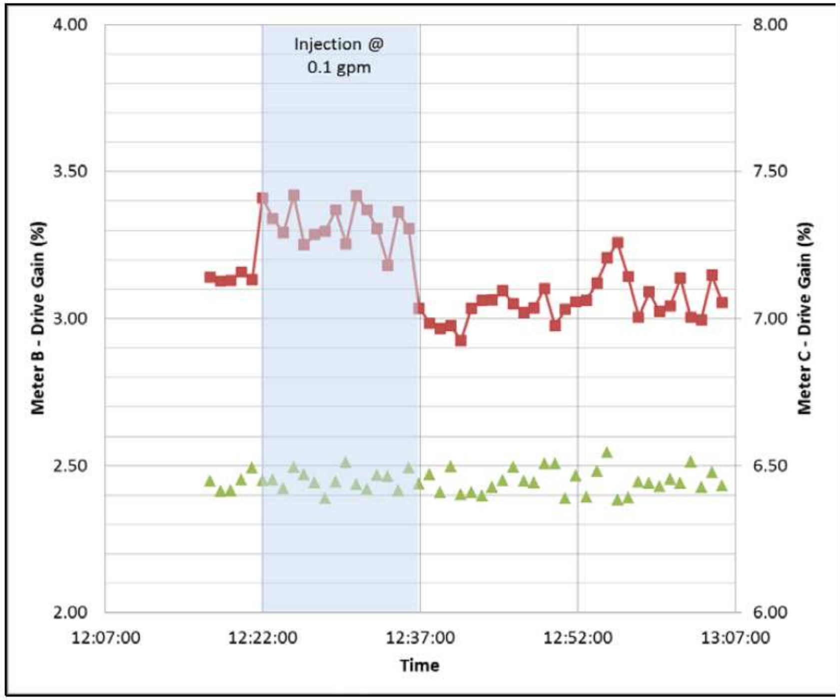
Drive and pickoff coils provide damping data

Detection of Multiple Phases

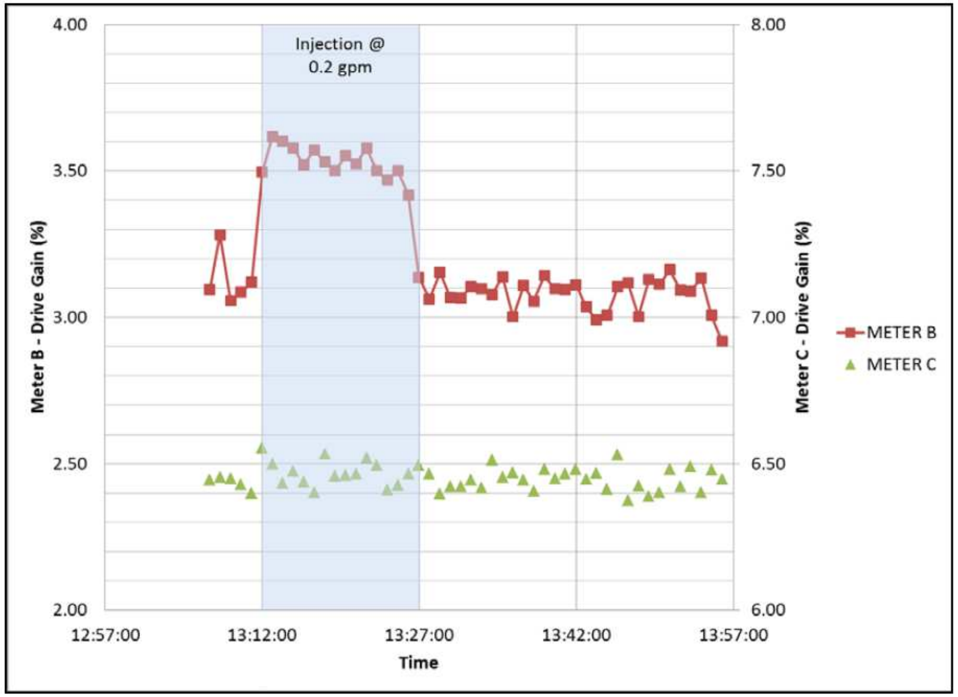


Damping of flow tubes indicates multiple phases

Identification of Mist: 99.9+% GVF



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



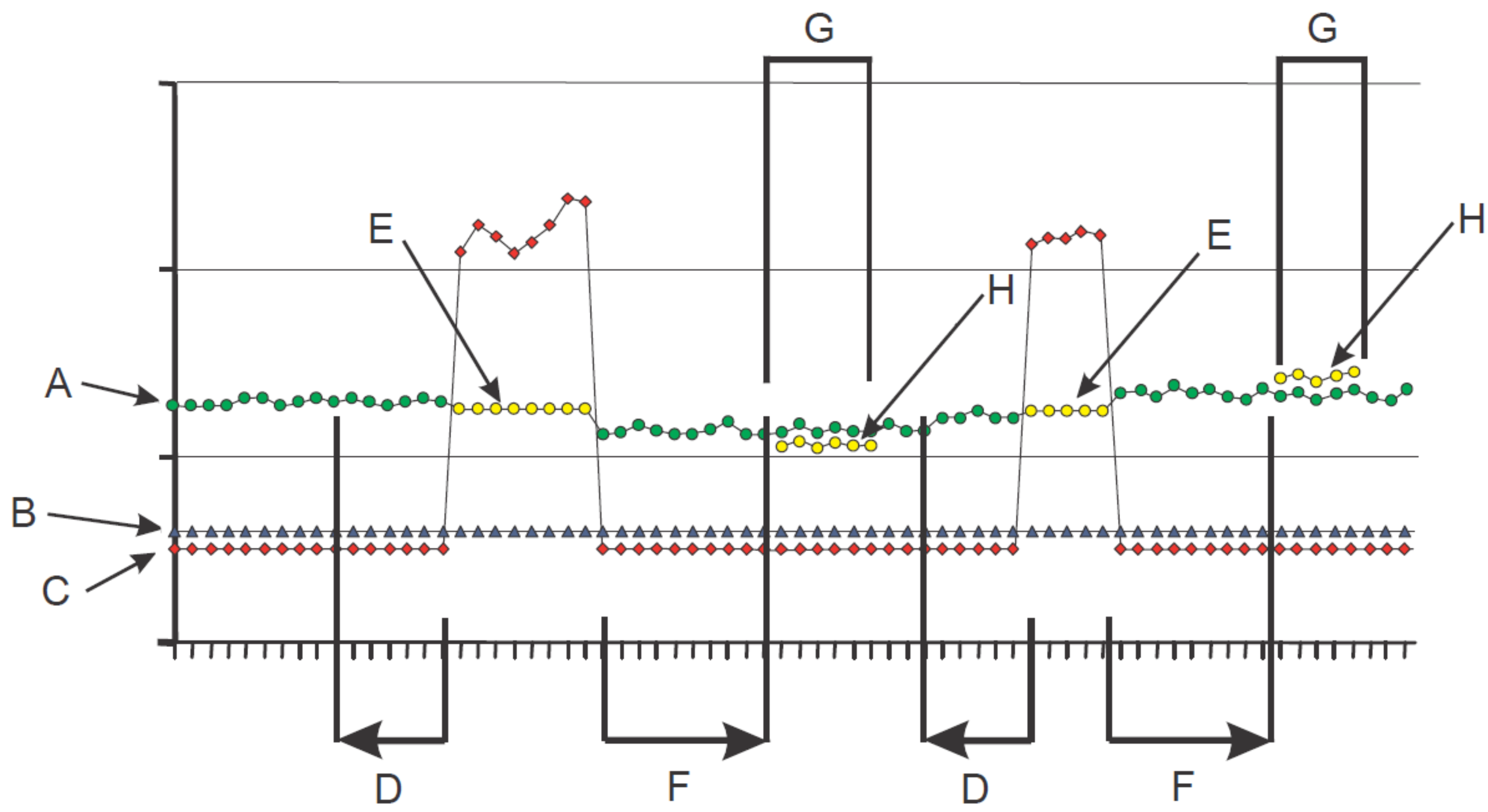
Drive Gain Results for Meter B at 100 acfm and 0.2 gpm

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

Algorithm for Slugging Regime & Intermittent Multiphase

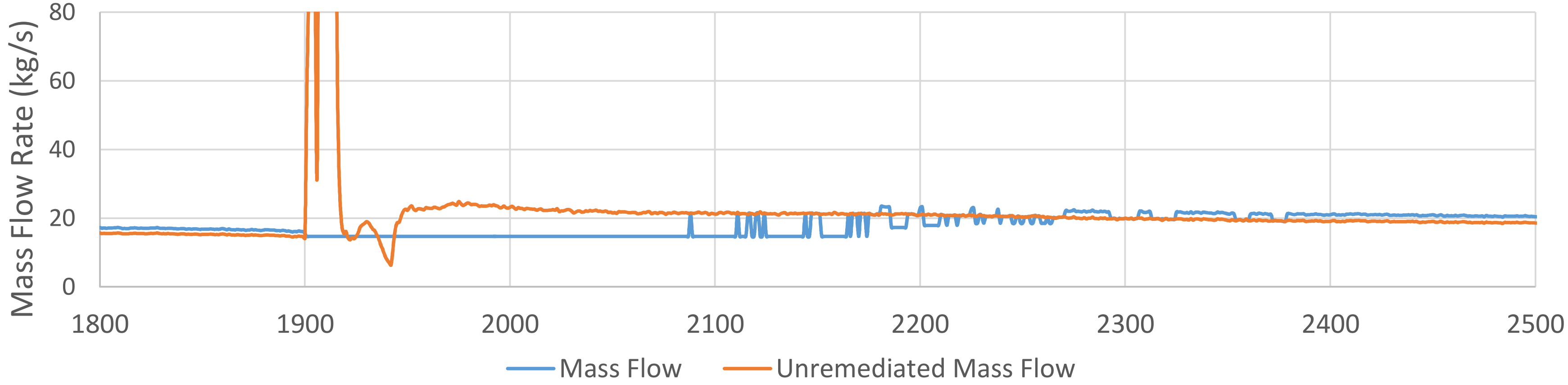
- Tube damping provides very sensitive detection, but it is not a measurement of phase fraction
  - With this diagnostic, we can break up the wet gas problem into
    - Unstable or intermittent wet gas – the process is normally dry, but there are slugs or occasional phase contamination
      - This has several real world applications: separators, plunger lift, etc.
    - Stable or continuous wet gas.

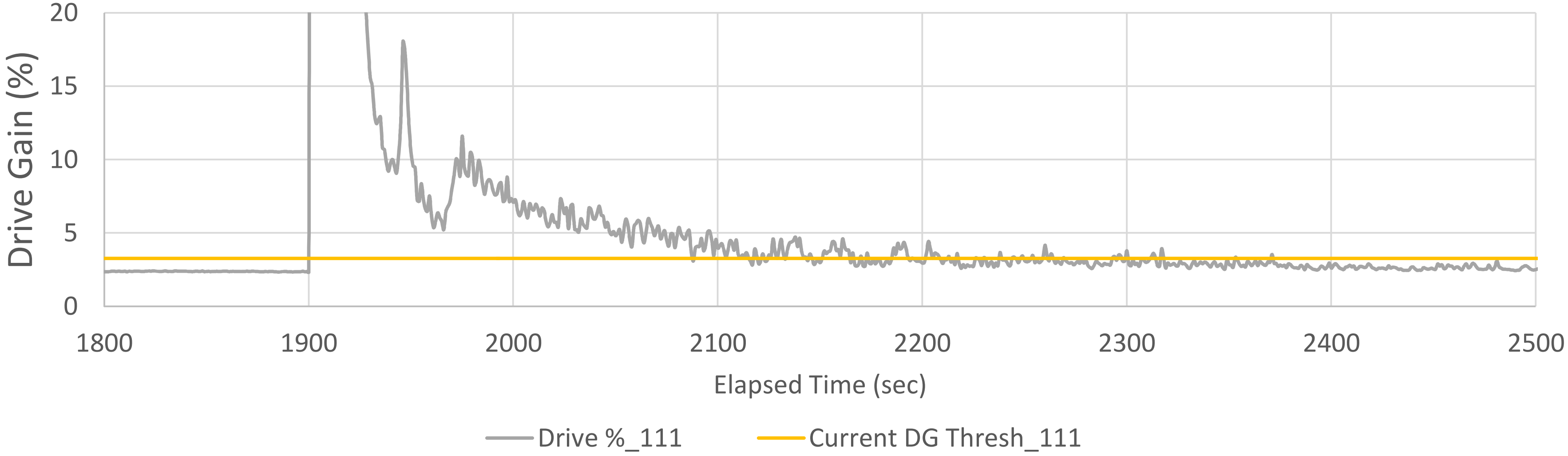
Simple Wet Gas Algorithm



A.	*Flow rate*
B.	*TMR 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*

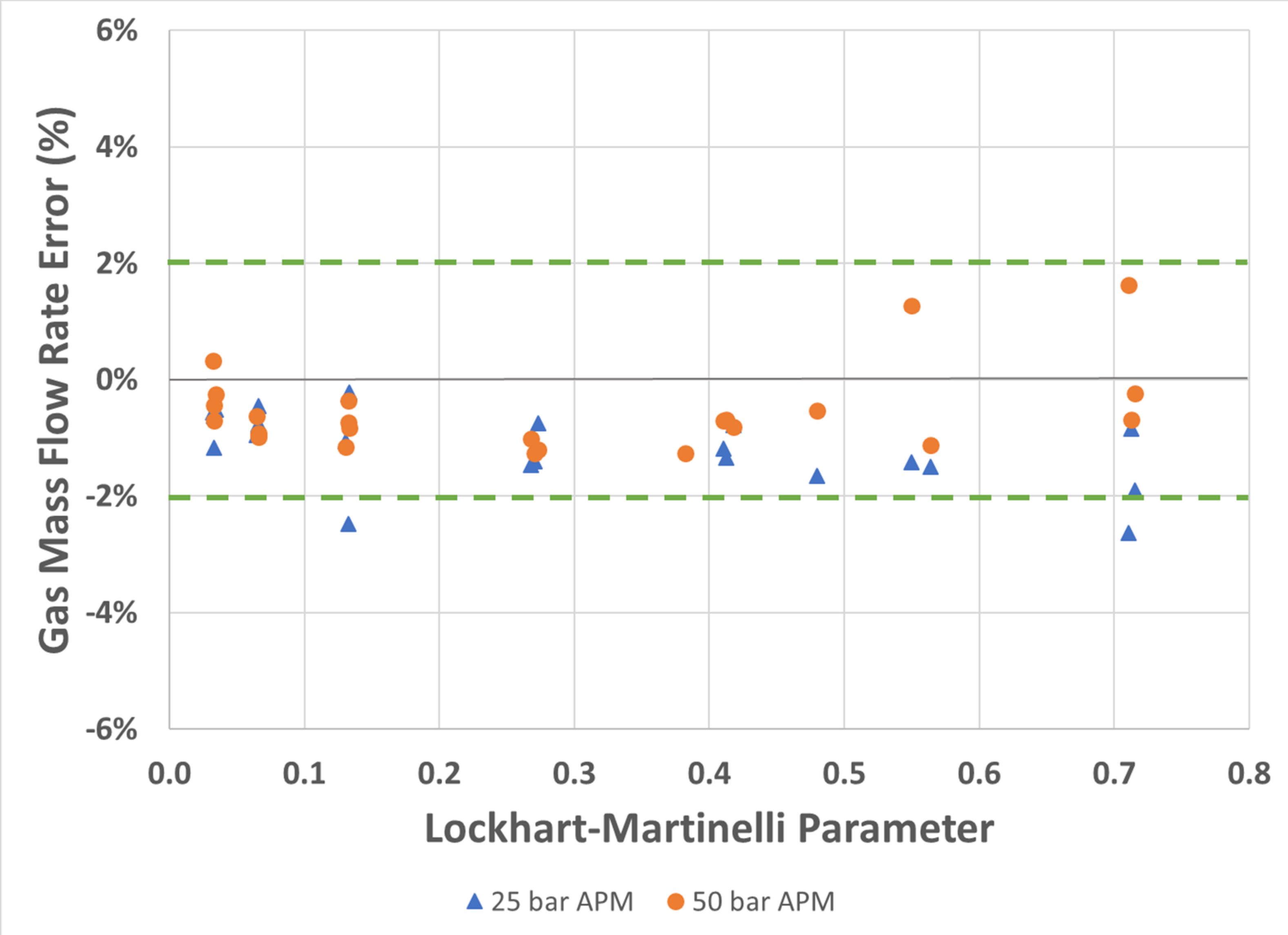
Algorithm for liquid slugs in gas





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

CEESI Testing – Slugging Regime



Method for Stable Wet Gas

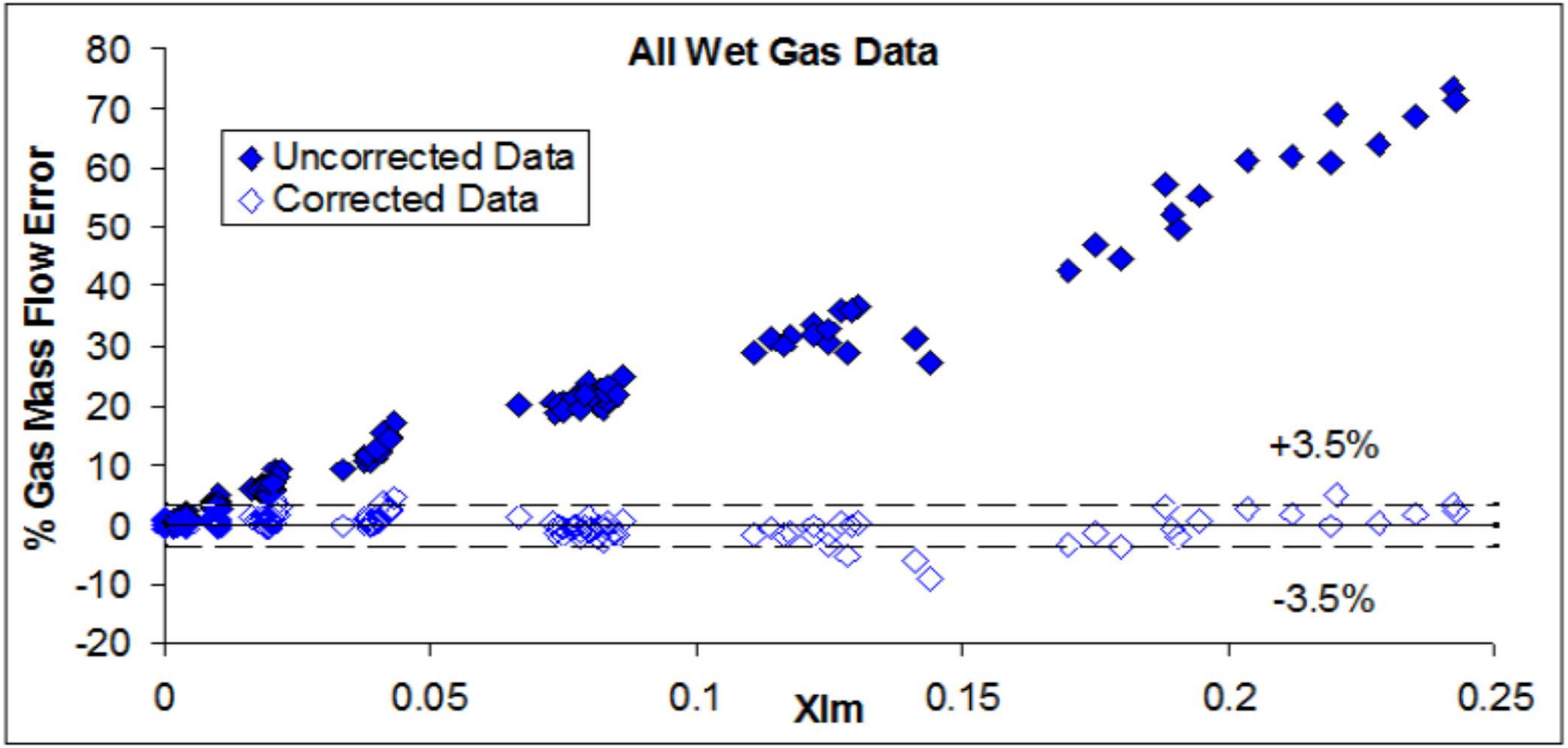
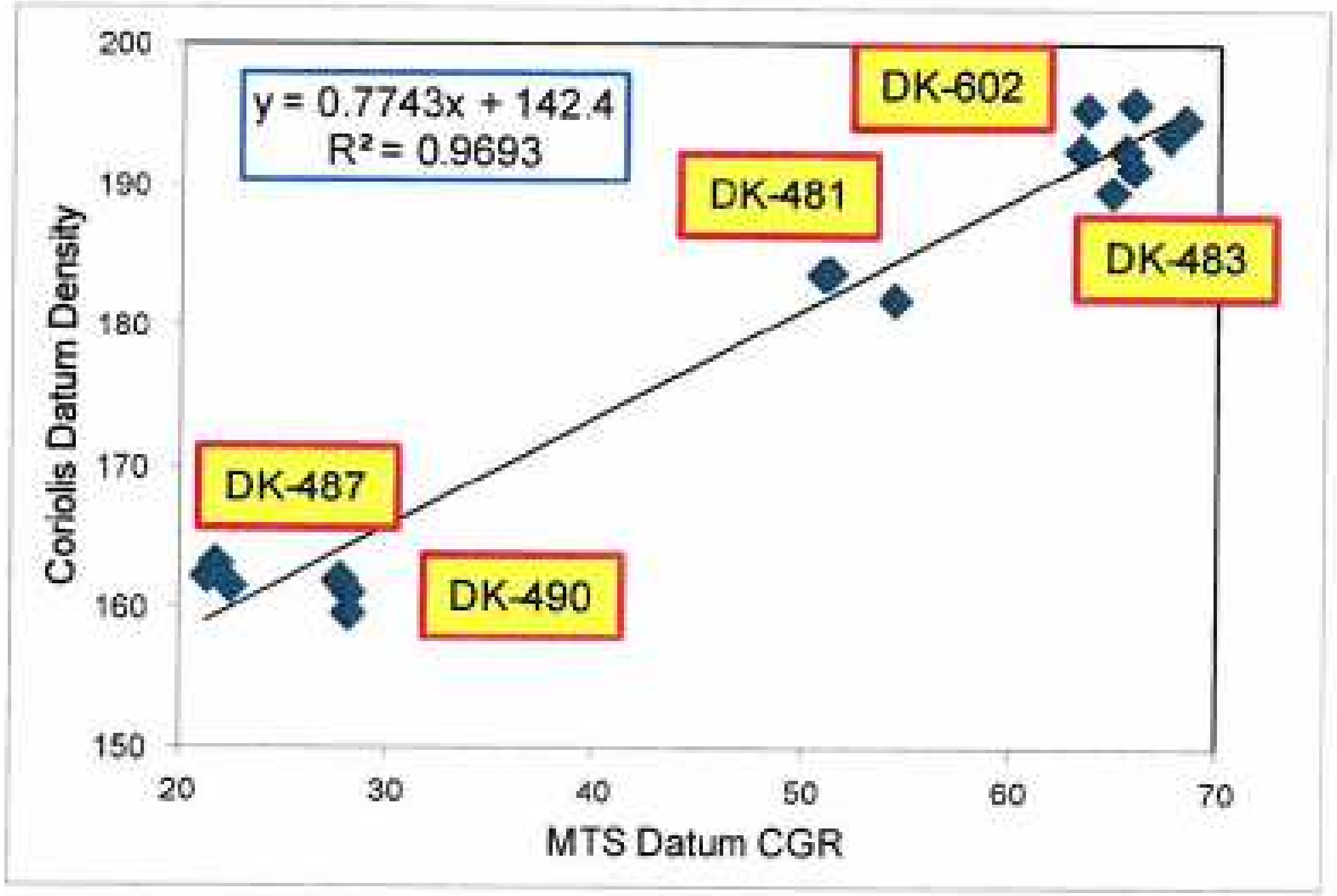


Fig. 16 - 3″ Coriolis Meter Over-Reading vs. XLM Uncorrected & Corrected Data.

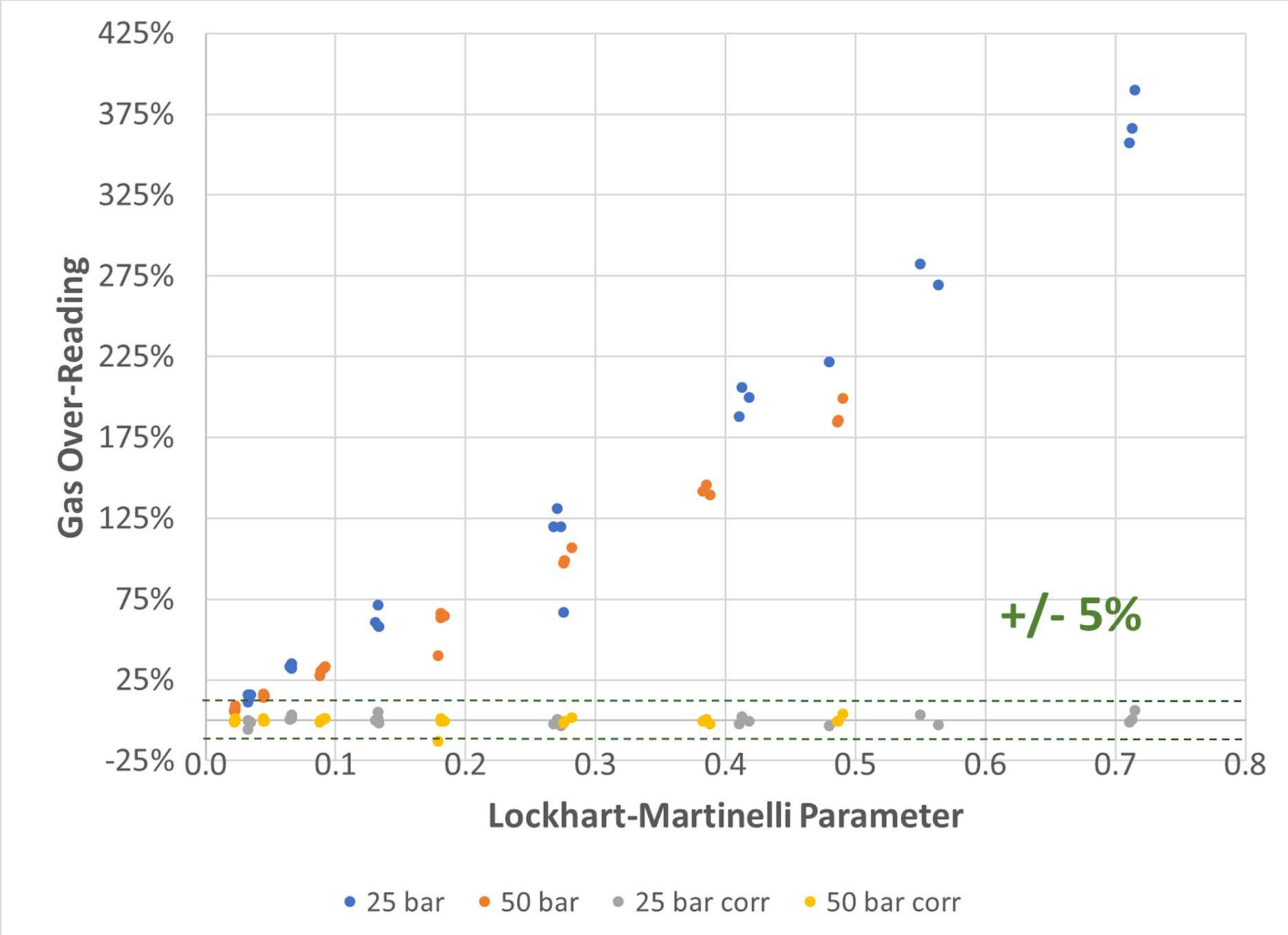
Richard Steven and Josh Kinney (CEESI), **“**Coriolis Meters & Wet Gas Service,” In Proc. *South East Asia Flow Measurement Conference 2017*

Simple Approach to Density Reference



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
  - Installation issues
  - 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
- Multiple 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 trail also a challenge

Summary

- Coriolis technology has improved in the past 10 - 20 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, with knowledge of flow regime
  - May be less reliant on external inputs than existing approaches
  - Coriolis meters can provide regime data, depends on design
- Additional research needed, revisit guidance on coriolis suitability for wet gas applications
  - Need to address field implementation challenges