Density-based Watercut using a Speed-of-Sound Augmented Coriolis Meter on a Gas/Liquid Separator with Variable Gas Carry-Under

Daniel L. Gysling

Gabriel Dragnea

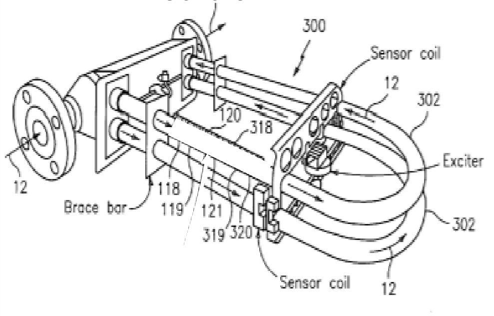
Agenda

- Speed-of-Sound Augmented Coriolis Flow Measurement Technology
- Impact of Gas Carry-under on Production Surveillance Using Gas / Liquid Separation
- Challenges of Coriolis Meters operating on Multiphase flows
- Multiphase Flow Loop Validation SOS-augmented Coriolis Meter
- Conclusions

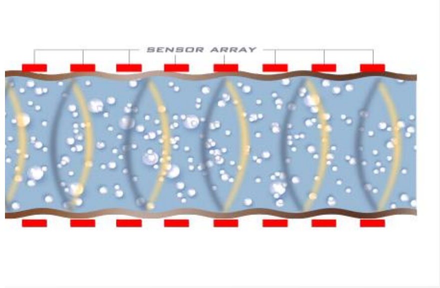
Background on SONAR and Coriolis Technology

- Coriolis meters were introduced in 1977 and have become the largest class of industrial flow meters
- Coriolis meters provide two fundamental measurements: mass flow and density
- Coriolis meters excel on single phase fluids but are often challenged by multiphase flows
- SONAR flow measurement technology was introduced in 2000 and has become a standard for clamp-on measurement of multiphase flows
- SONAR flow measurement technology utilizes an array of strain-based sensors to measure the speed at which low frequency sound propagates within process flow lines
- Process-fluid speed-of-sound enables quantification of several aspects of multiphase flows including gas void fraction and fluid compressibility
- Integrating SONAR-based Speed-of-Sound measurement within Coriolis meters enables improved accuracy and functionality on single and multiphase flows

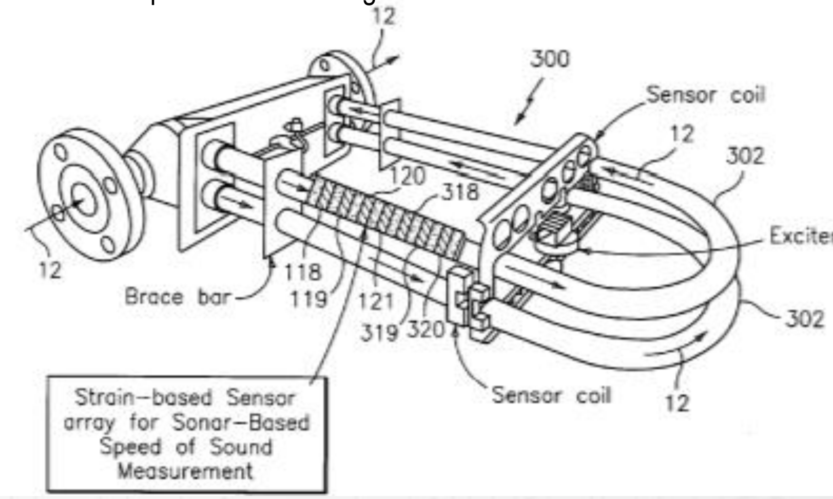
Coriolis



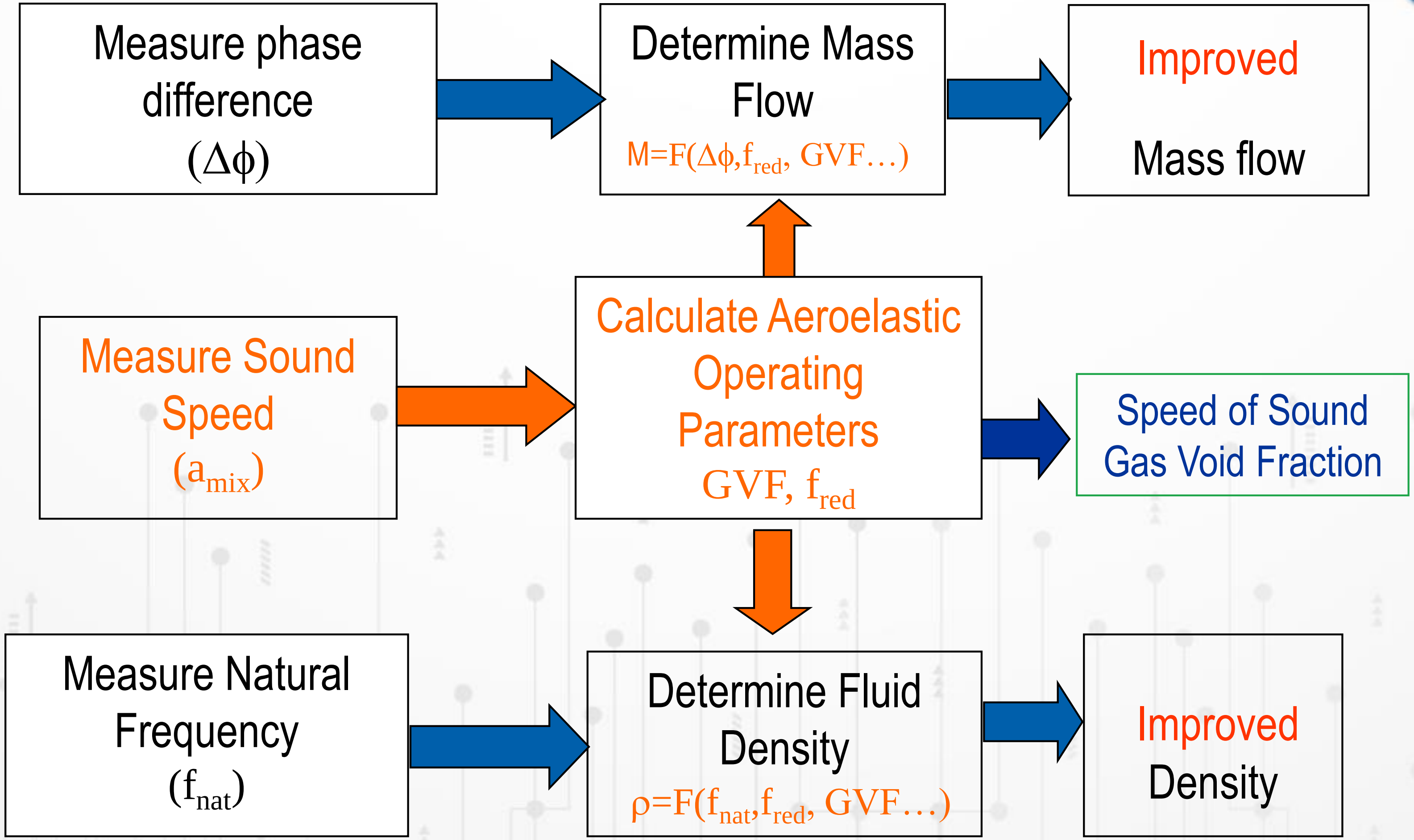
SONAR



Speed-of-Sound Augmented Coriolis



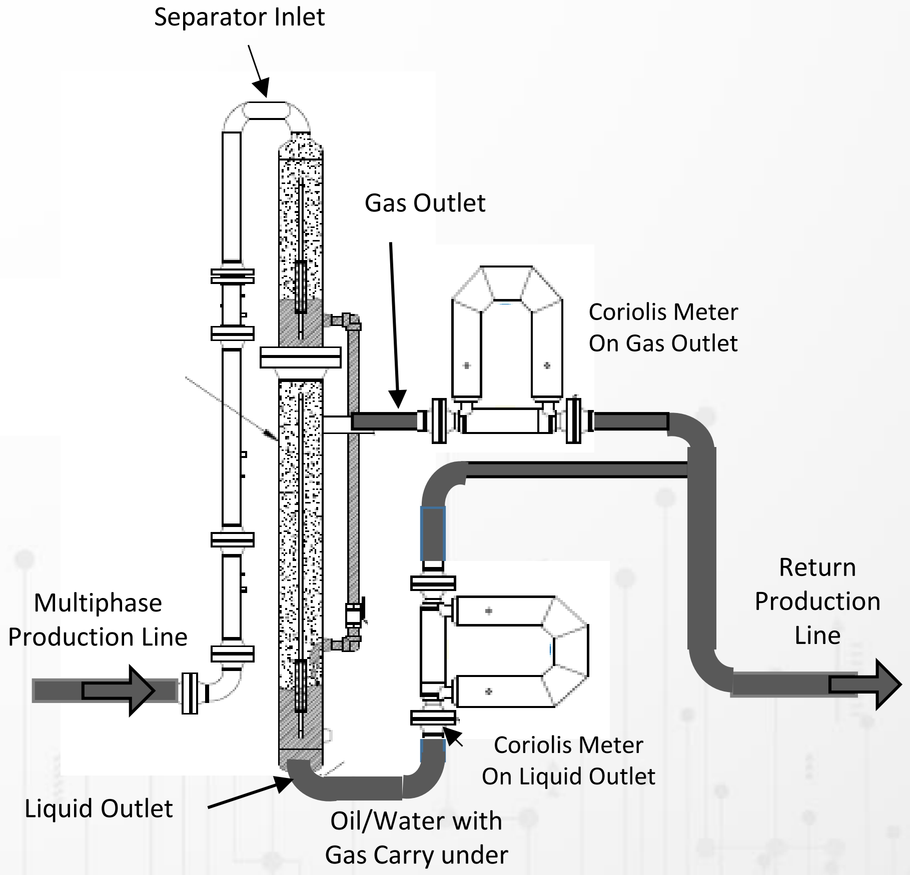
Speed-of-Sound Augmented Coriolis Meters



Production Surveillance Using Compact Gas/Liquid Separation

- Conventional Production Surveillance often utilize large 3ϕ separators to measure the gas, oil and water phases individually, using single phase meters
- While often effective, 3ϕ separators can be expensive and/or impractical for many applications
- Due to the compact size and the accuracy and reliability of Coriolis meters, the industry is increasingly utilizing compact, gas/liquid separation combined with Coriolis meters for measuring liquid and gas outlets
- Production Surveillance utilizing gas/liquid separation requires accurate measurement of watercut for accurate net oil measurement
- Small amounts of Gas Carry-under in the liquid outlet can result in significant net-oil measurement errors

Compact Gas / Liquid Separator with Coriolis meters for 3ϕ Surveillance



Quantifying the Effects of Decoupling and Compressibility on Coriolis meters

Hemp (2006) published a model for the effects of Decoupling and Compressibility on Coriolis meter

Hemp's model relates the mass flow and density reported by a Coriolis, calibrated on a single phase flow, but operating on an bubbly flow, to the actual mass flow and density of the liquid phase

$$\dot{m}_{liquid} = \frac{\dot{m}_{measured}}{\left(1 - \underbrace{\frac{(K_M - 1)}{1-\alpha}\alpha}_{\text{Decoupling}} + \underbrace{\frac{1}{2} f_{red}^2}_{\text{Compressibility}}\right)} \quad \text{and} \quad \rho_{liquid} = \frac{\rho_{measured}}{\left(1 - \underbrace{K_D \alpha}_{\text{Decoupling}} + \underbrace{\frac{1}{4} f_{red}^2}_{\text{Compressibility}}\right)}$$

where α is the gas void fraction, f_{red} is the reduced frequency and K_M (1>K_M>3) and K_D (1>K_D>3) are decoupling constants for mass flow and density, respectively

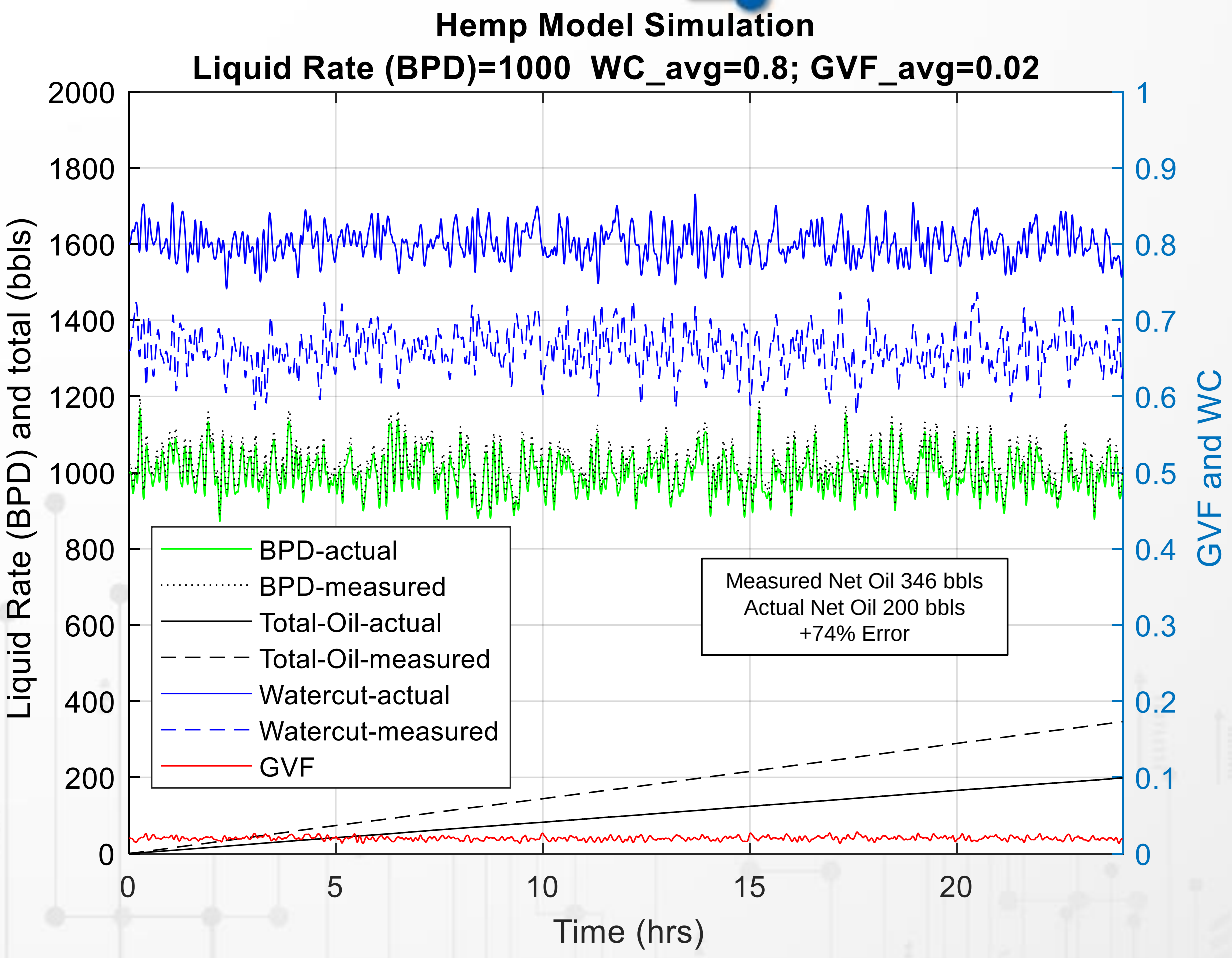
Process fluid sound speed, a_{mix}, provides real-time gas void fraction, α, measurement and $f_{red} \equiv \frac{2\pi f_{tube} R_{tube}}{a_{mix}}$

Using Hemps' formulation, process fluid sound speed enables quantification of both decoupling and compressibility effects, particularly well-suited for determining watercut in the presence of gas carry-under

Simulated Errors Due to Gas Carry-Under With Compact Two Phase Separation and Conventional Coriolis Meters

- Hemp's Model used to simulate Coriolis errors during a well test with nominally 1000 bpd liquid at 80% watercut and 2% gas carry-under at 100 psia
- Parameters representative of 3-inch dual bent tube Coriolis meter with K_D=K_M=1.5
- Volumetric flow measured by Coriolis is Majority of Error in net oil due to error in measured watercut
- For this simulation, a 2% Gas Carry-Under results in 74% Error in Net Oil

$$relError_{NetOil} = \frac{1}{1 - Wc_{actual}} \frac{\rho_{liquid}}{\rho_{water} - \rho_{oil}} \left(K_D \alpha - \frac{1}{4} f_{red}^2 \right)$$



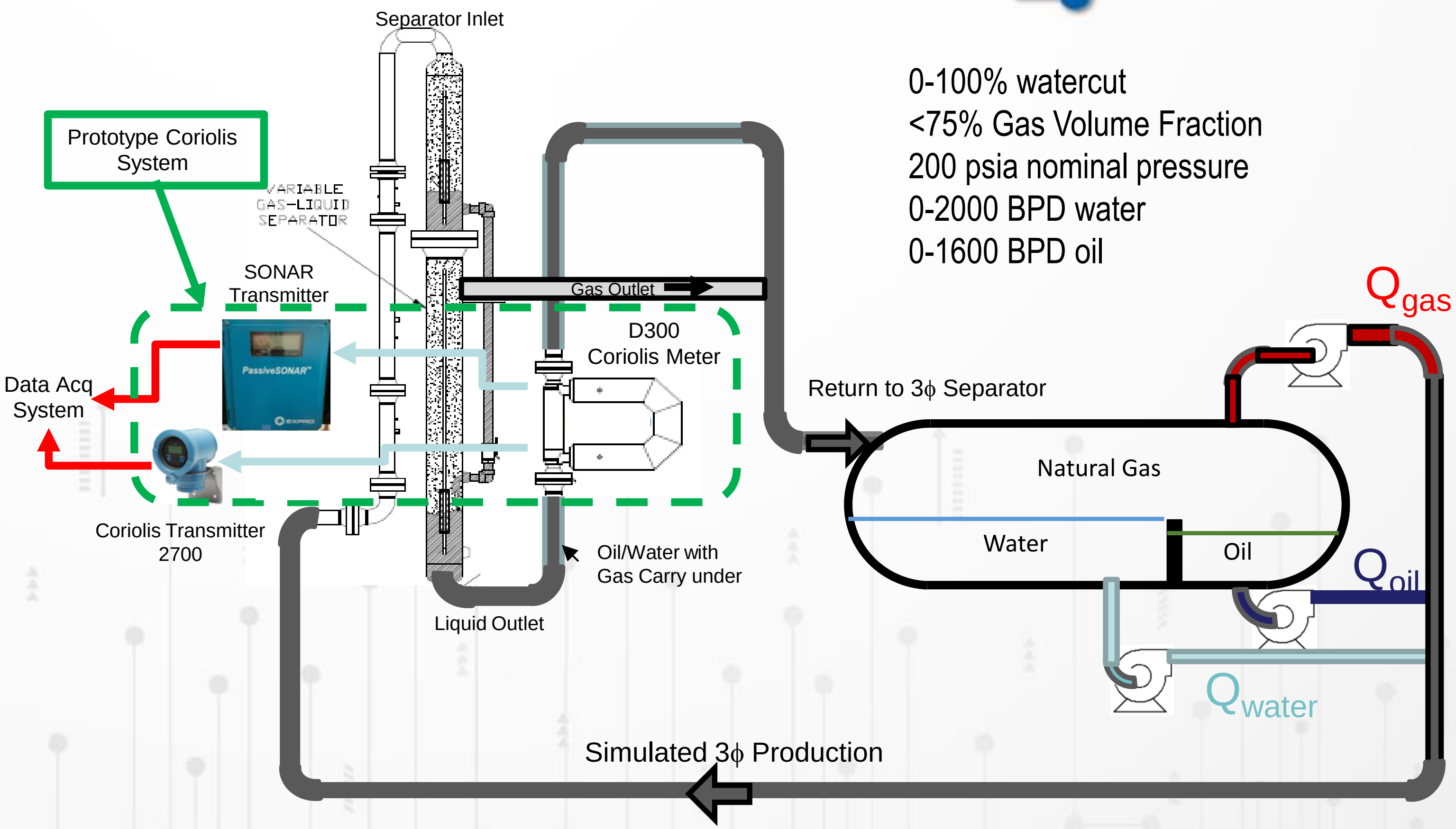
Prototype Coriolis Meter Installed on Compact Separator at Multiphase Flow Loop Facility

- Prototype Speed-of-Sound Augmented Coriolis meter built by incorporating SONAR instrumentation within a MicroMotion D300 Coriolis meter
- Coriolis meter utilizes a MicroMotion 2700 series transmitter
- Coriolis meter installed on Liquid outlet of Compact Two Phase Separator in Flag Orientation with flow upwards

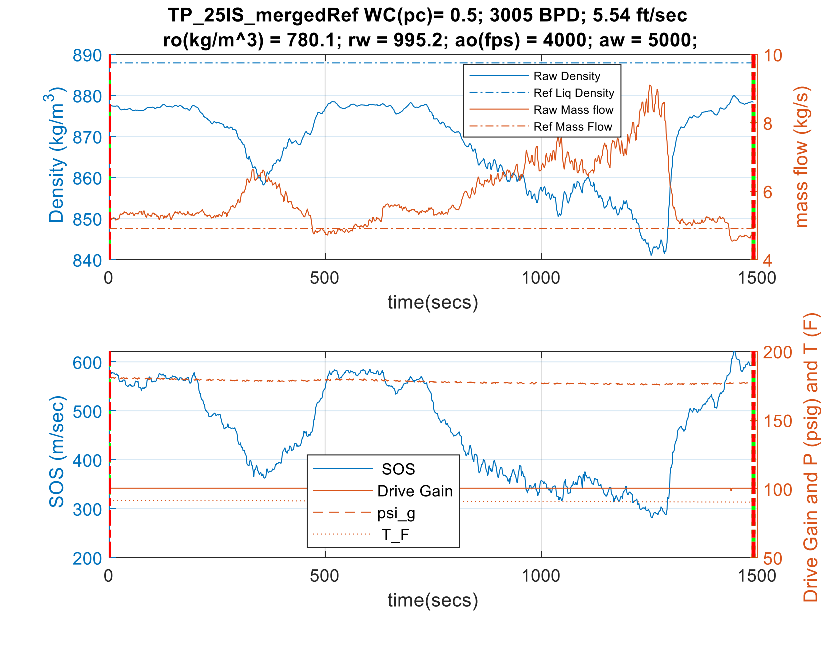
Prototype Speed-of-Sound Augmented Coriolis Meter

Schematic of Test Set up in Multiphase Flow Facility

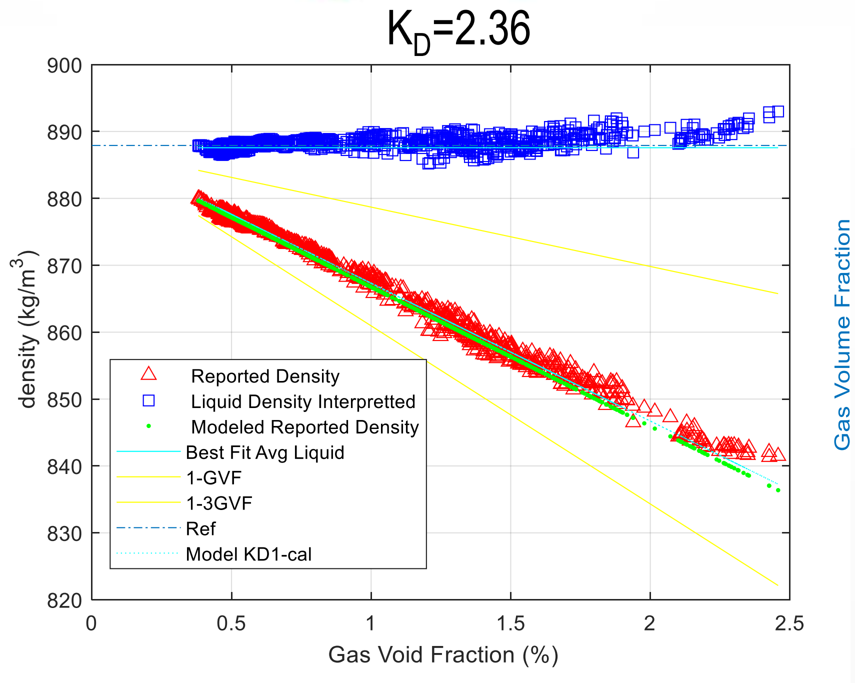
- Test Designed to Simulate Production Surveillance of High Gas Volume Fraction, 3ϕ Oil and Gas Wells
- Test was executed by setting and maintaining 3ϕ flow conditions at each test point while slowly varying liquid level within separator to vary gas carry-under levels
- Liquid rates through liquid outlet assumed constant during slow variation in separator liquid level



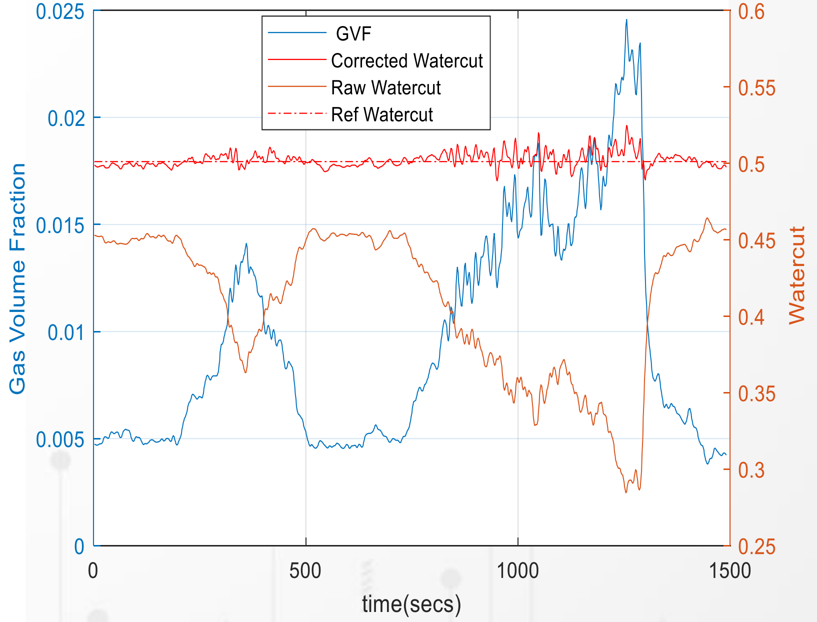
Example Data Point 50% Watercut, 3000 BPD Diagnostics



Raw Density, Mass Flow with Reference (top)
SOS, DriveGain, Pressure, and Temp (bottom)



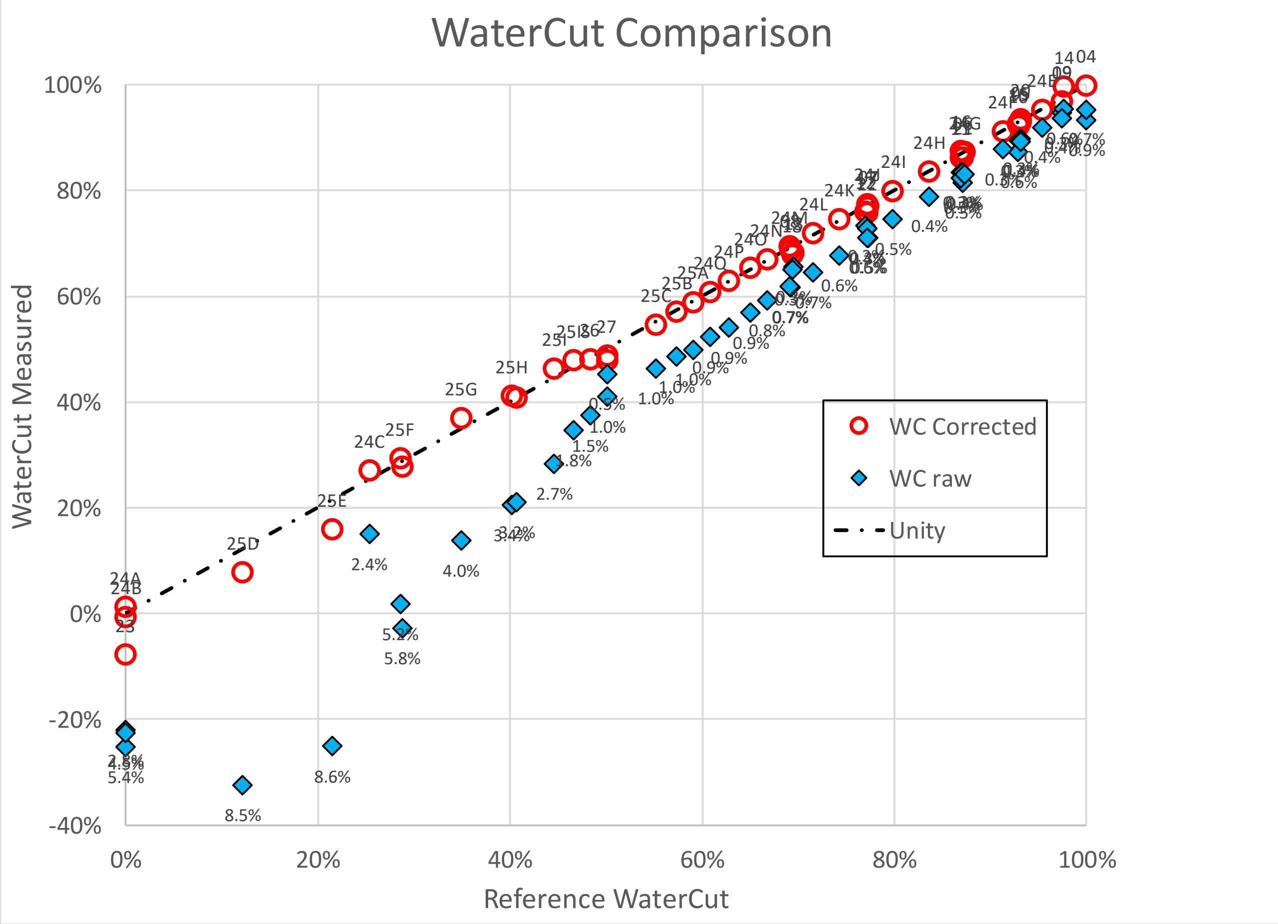
Raw and Corrected Density vs Gas Carry-Under



GVF, Raw and Corrected Watercut vs time

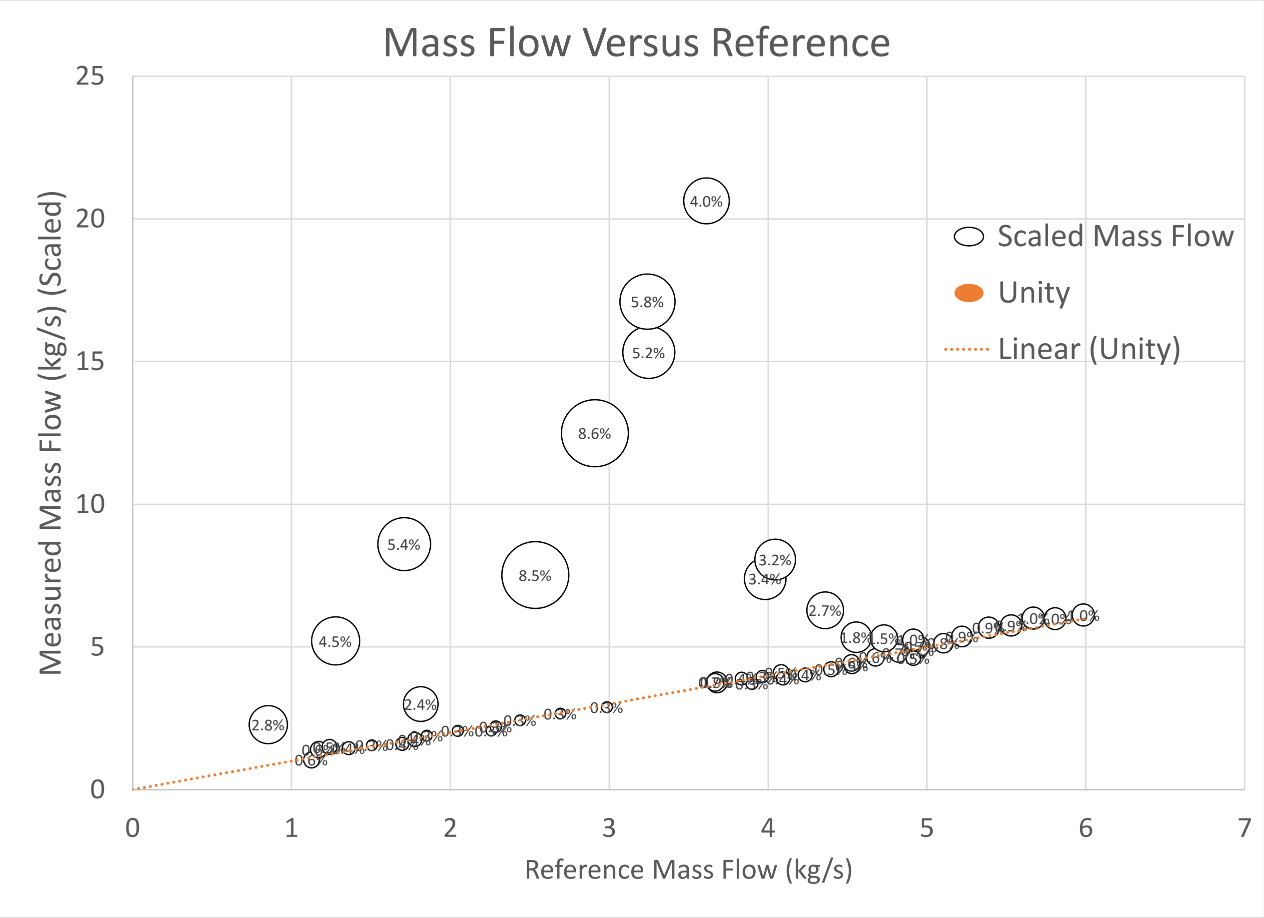
Watercut Results

- Time-averaged Raw and Corrected WaterCut data for test points spanning 0-100% watercut with time-averaged gas carry-under levels ranging from 0.2% to 8.6%
- Corrected data utilized Hemp's Density Decoupling parameter, fitted as function of watercut



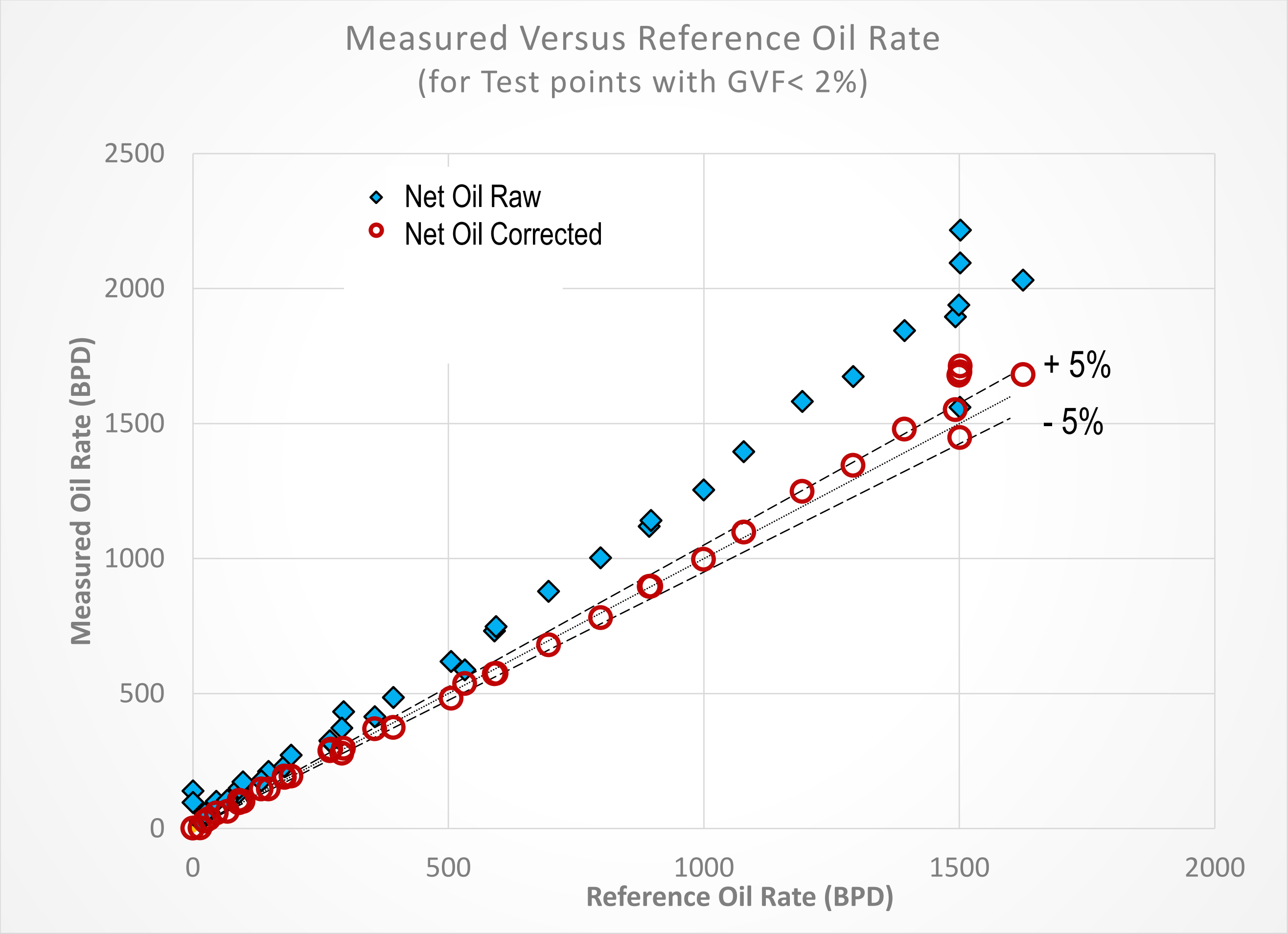
Mass Flow Data

- A linear scale factor (1.12) was applied to the all mass flow data to calibrate mass flow to flow loop reference
- Time-averaged Mass Flow well-aligned with Reference for GVF <2%
- Variations in Mass Flow were not well-correlated with Gas Void Fraction for each data point
- Mass flow was not corrected for effects of decoupling and compressibility using Hemps model
- Time-averaged mass flow for points with GVF greater than 2% may be attributed to stalling of "vintage", circa 2000, Coriolis meter



Net Oil Comparison vs Reference for Conventional and Speed of Sound Augmented Coriolis Meter

- Speed of Sound Augmented Coriolis meter improves accuracy of net oil measurement
- Data shows time-averaged net oil rate versus reference as determined using the raw and corrected watercut



Conclusions

- Multiphase Flow Loop Test validates ability of SOS-augmented Coriolis to accurately measure watercut in the presence of varying amounts of gas carry-under
- Gas carry-under is often the largest source of error in net-oil measured using density-based watercut measurement from conventional Coriolis meter
- Variations in density measured by a conventional Coriolis meter due to gas carry-under were well-captured by, and corrected with, Hemp's aeroelastic Coriolis model
- Coriolis meter provided accurate, time-averaged mass flow for test points with limited amounts of gas carry-under (~<2%)
    - Mass flow was erratic for elevated gas carry-under (~>2%)
    - Variations in Mass flow measured by the modified Coriolis meter were not well-correlated with gas void fraction measurement
    - Mass flow results from the modified and "vintage" Coriolis meter (circa 2000) may not be representative of modern Coriolis meters due to significant improvements implemented in recent years to improve Coriolis mass flow measurement operability in multiphase conditions

Contact Us

Daniel Gysling

Gabriel Dragnea

Expro Meters, Inc

50 Barnes Park North,

Wallingford, CT 06042

USA

www.exprogroup.com

Daniel.Gysling@ExproGroup.com

Gabriel.Dragnea@exproGroup.com

1 203 303 5695