EVALUATION OF SONAR CLAMP-ON FLOWMETERS FOR WET GAS FLOW MEASUREMENT

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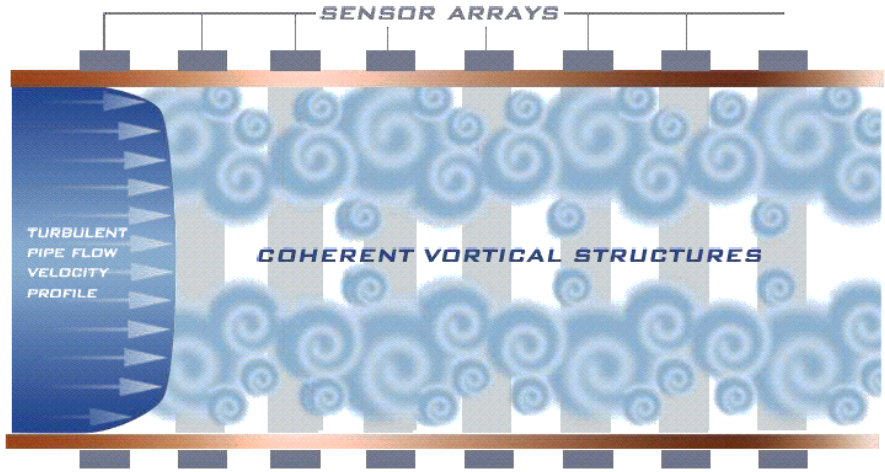
Outline

- Introduction—clamp-on devices for flow measurement
- SONARtrac™ meters performance evaluation tests
- Dry flow performance tests results
- Wet flow performance test results
- Flow measurement uncertainty/repeatability
- Conclusions

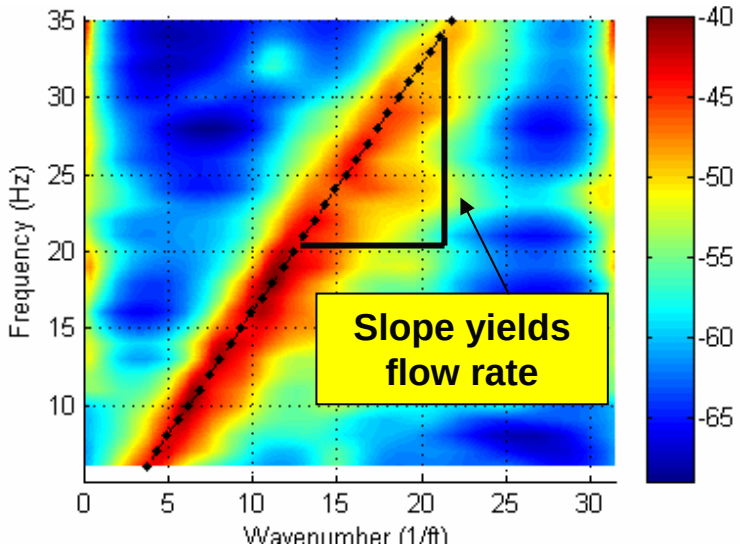
Commercial Clamp-on Devices for Flow Measurement

Fluid	Metering principle
Single Phase – Gas	Ultrasonic, sonar
Single Phase - Liquid	Ultrasonic, sonar
Two Phase - Bubbles (low GVF)	sonar
Two Phase – Wet gas (High GVF)	sonar
Multiphase	nucleonic

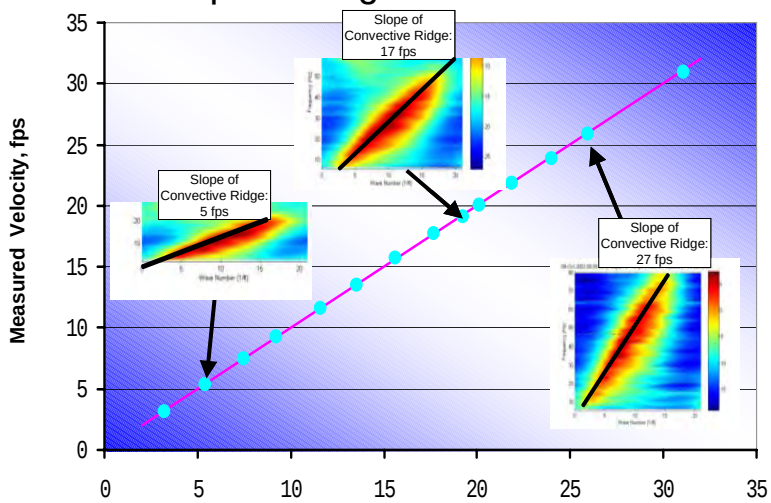
Clamp-on SONARtrac™ Gas Flow Meter



SONAR Algorithms Identify Ridge



Slope of Ridge Determines Flow rate



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Clamp-on Device for Flow Measurement

Advantages

- No pressure drop
- No pipe wall penetration
- Portable
- Lower cost

Challenges-- multiphase fluid measurement

- Improve performance uncertainty
- Widen operation range

Meters Evaluation Tests

- Chevron and CiDRA tests SONARtrac™ Gas Flow Meter
- Test conducted at the Colorado Engineering Experiment Station, Inc., (CEESI) Wet Gas Flow Facility, Nunn Colorado, USA in April 2006
- Sonar meters were mounted (4” Sch 40) upstream and downstream of 4” orifice, cone-type and venturi in series

SONARtrac™ Meters Performance Testing in CEESI Wet Gas Flow Loop

Metering System Test Conditions

- Pressures at 600, and 1,100 psig
- Dry gas and wet gas with liquid- gas flow ratio up to 150 bbl/MMSCF (Lockhart-Martinelli Numbers= 0, 0.002, 0.005, 0.01, 0.015, 0.02, 0.03, 0.05, 0.1, 0.15, and 0.2)
- Gas velocities at 20,40, 60, and 80 feet/sec at the four-inch pipe

SONARtrac™ and Orifice Meter

Definitions

Lockhart Martinelli Number (LM) is defined as:

$$LM = \sqrt{\frac{Inertia\ of\ Liquid\ Flowing\ Alone}{Inertia\ of\ Gas\ Flowing\ Alone}}$$

$$= \frac{\dot{Q}_l}{\dot{Q}_g}\sqrt{\frac{\rho_l}{\rho_g}}$$

Meter Deviation from Reference (%)

$= (\dot{m}_{\text{meter reading}} - \dot{m}_{\text{Reference}}) / \dot{m}_{\text{Reference}} * 100\%$

Typical Fluid Properties

- Gas:

  Lean natural gas (density=2.05 lbm/cu ft)

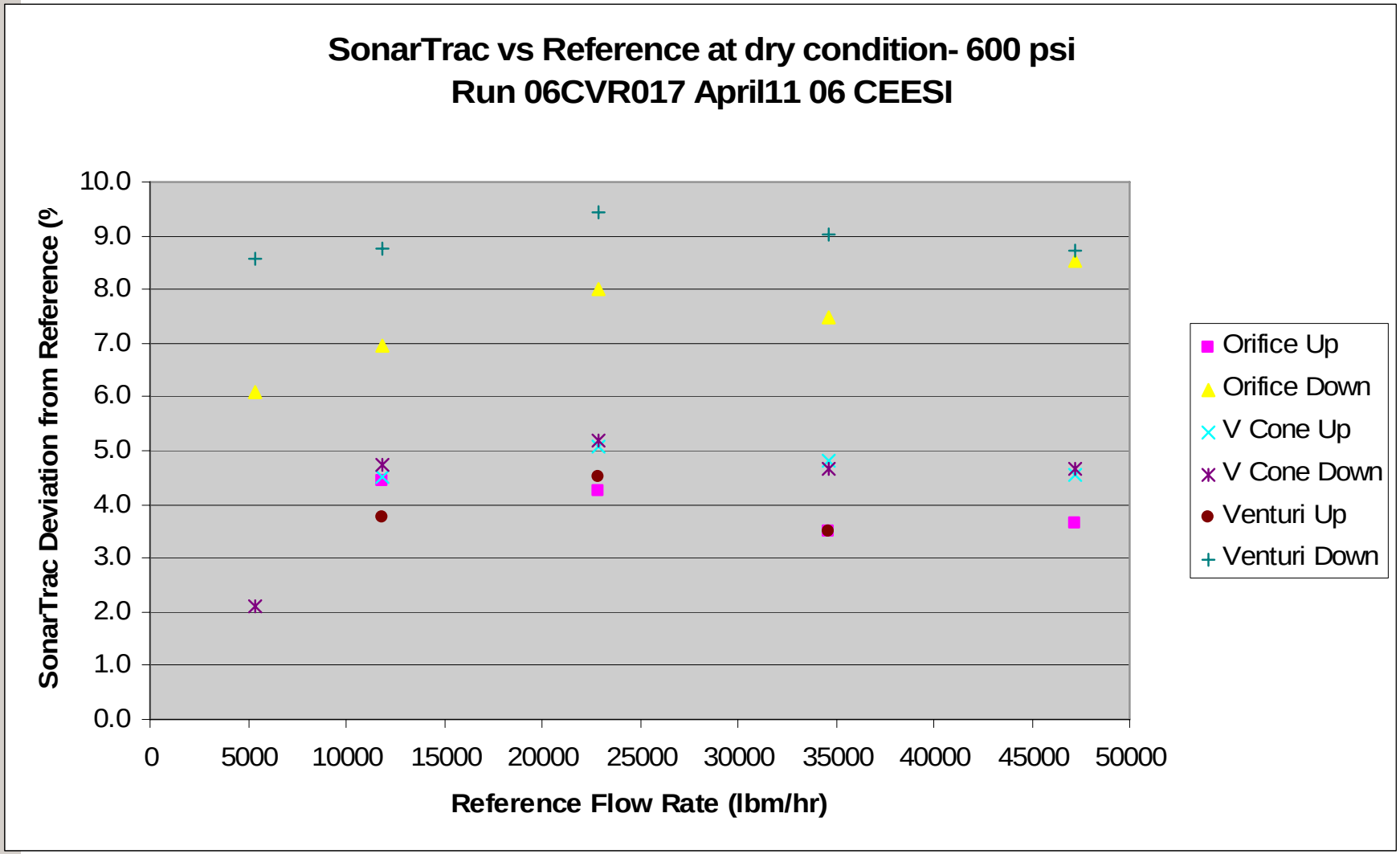
- Liquid:

  Stoddard solvent (C10, C11 and C12 with density=45.6 lbm/cu ft)

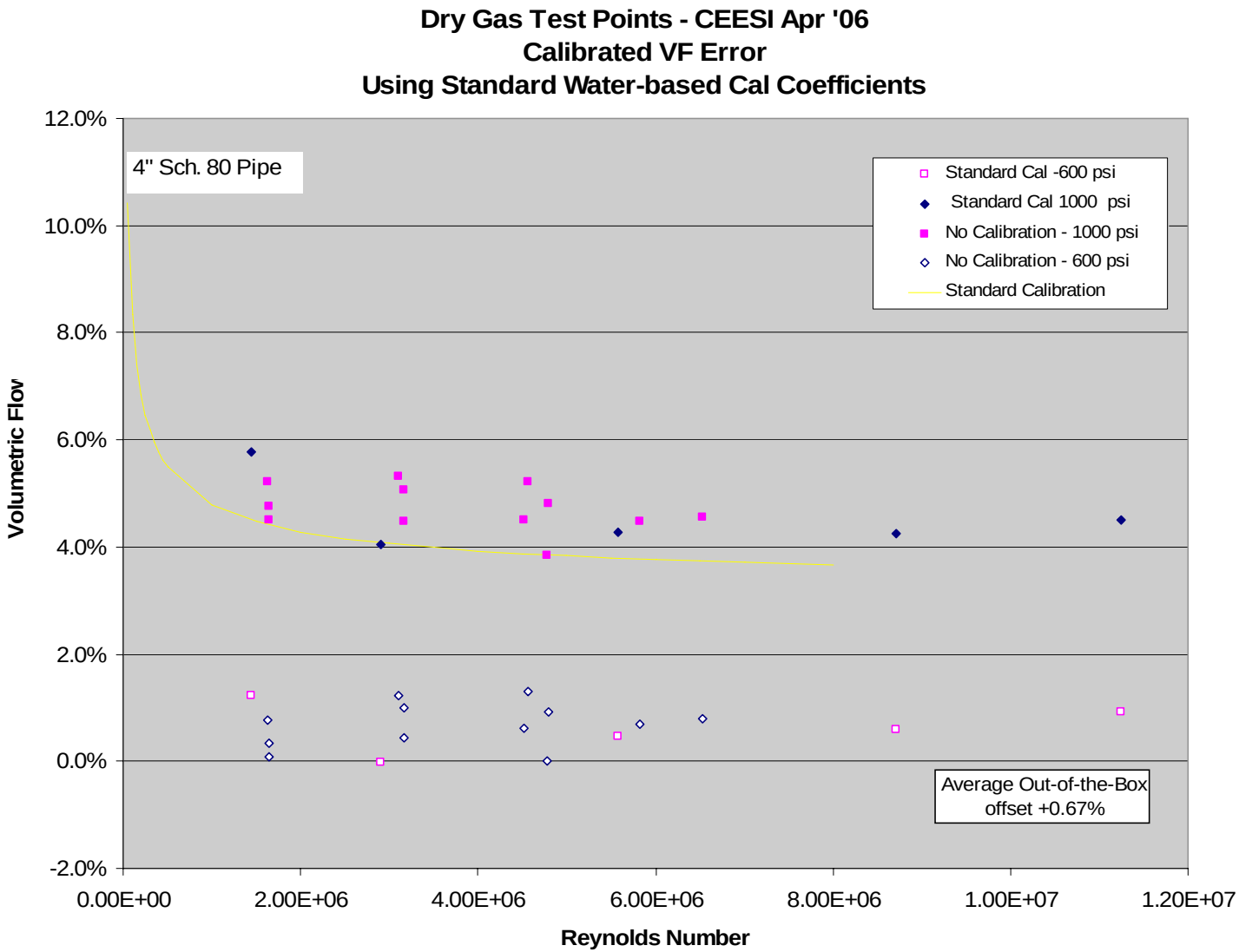
Examples of Liquid Gas Ratio with respect to Lockhart Martinelli Numbers

Lockhart Martinelli Number	Pressure, psia	Gas Density, lb/cu ft	Liquid Density, lb/cu ft	Gas Void Fraction	Liquid Gas Ratio LGR bbl/MMSCF
0.02	3,000	12.5	37.5	0.9886	8
0.02	750	3.1	37.5	0.9943	17
0.02	150	0.6	37.5	0.9975	43
0.3	3,000	12.5	37.5	0.85	118
0.3	750	3.1	37.5	0.92	262
0.3	150	0.6	37.5	0.96	649

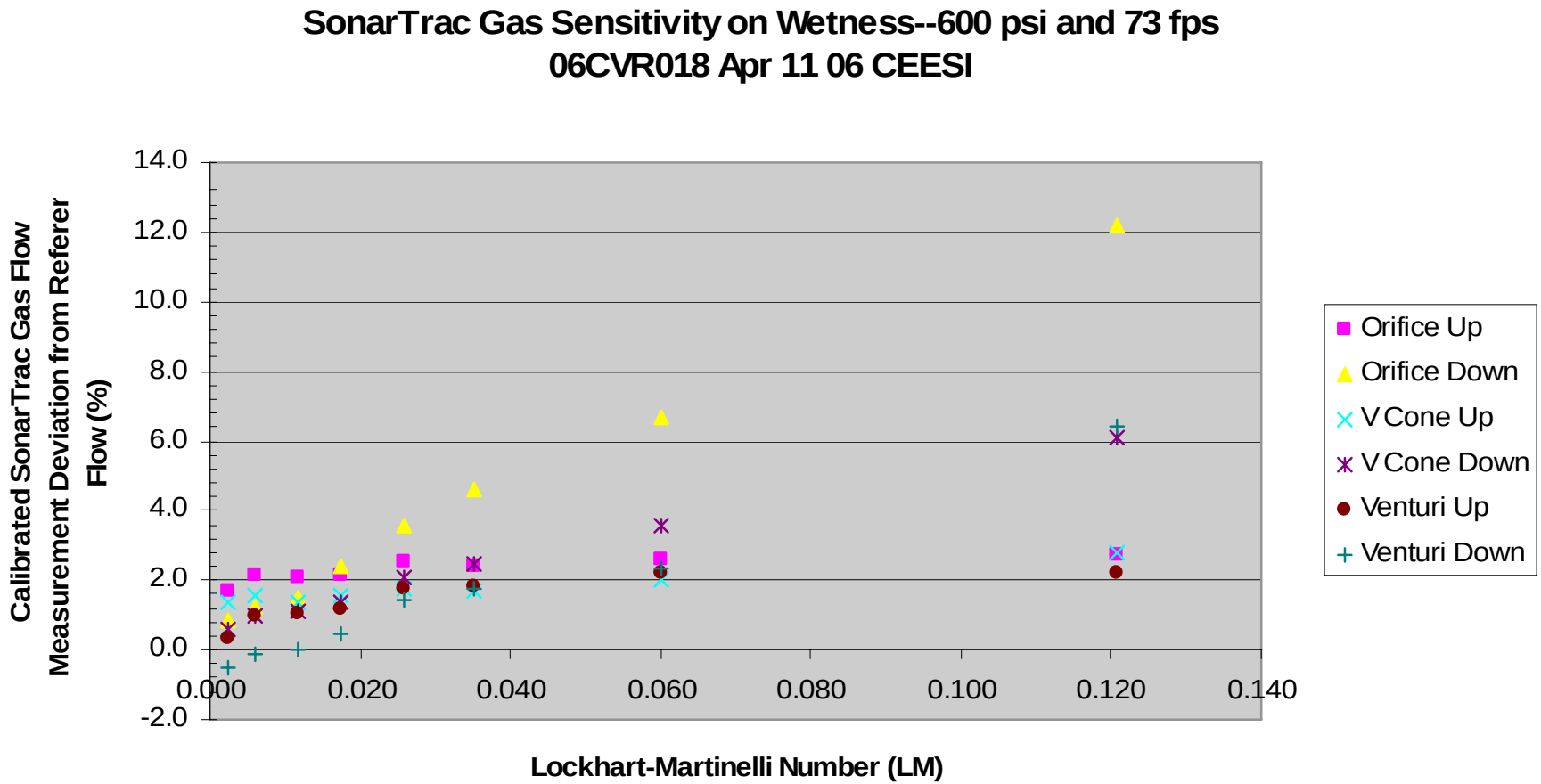
Dry Test (LM=0) Results



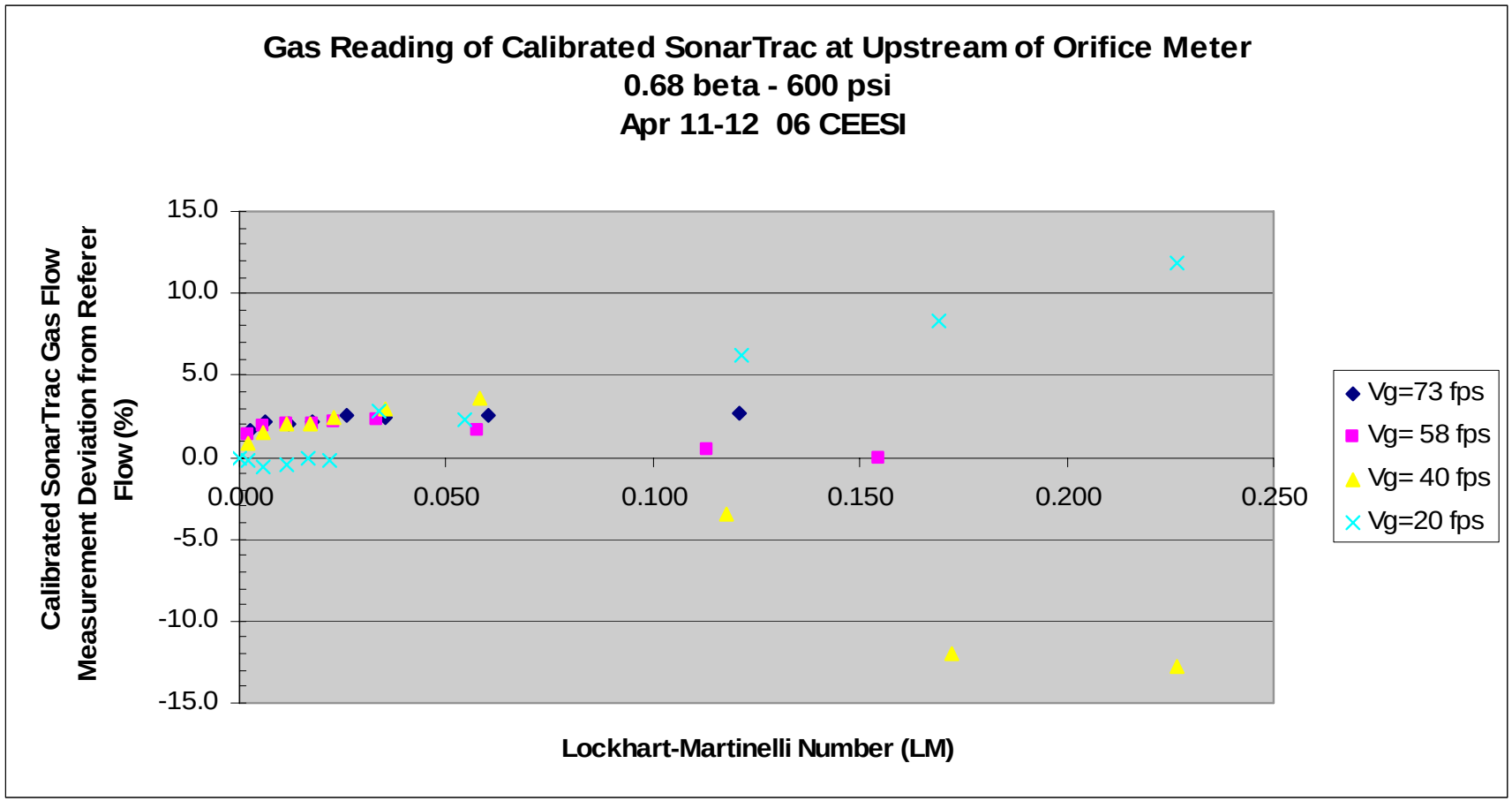
Dry Test Results Comparison



Meter Installation Tests



Meter Wet Gas Performance Tests



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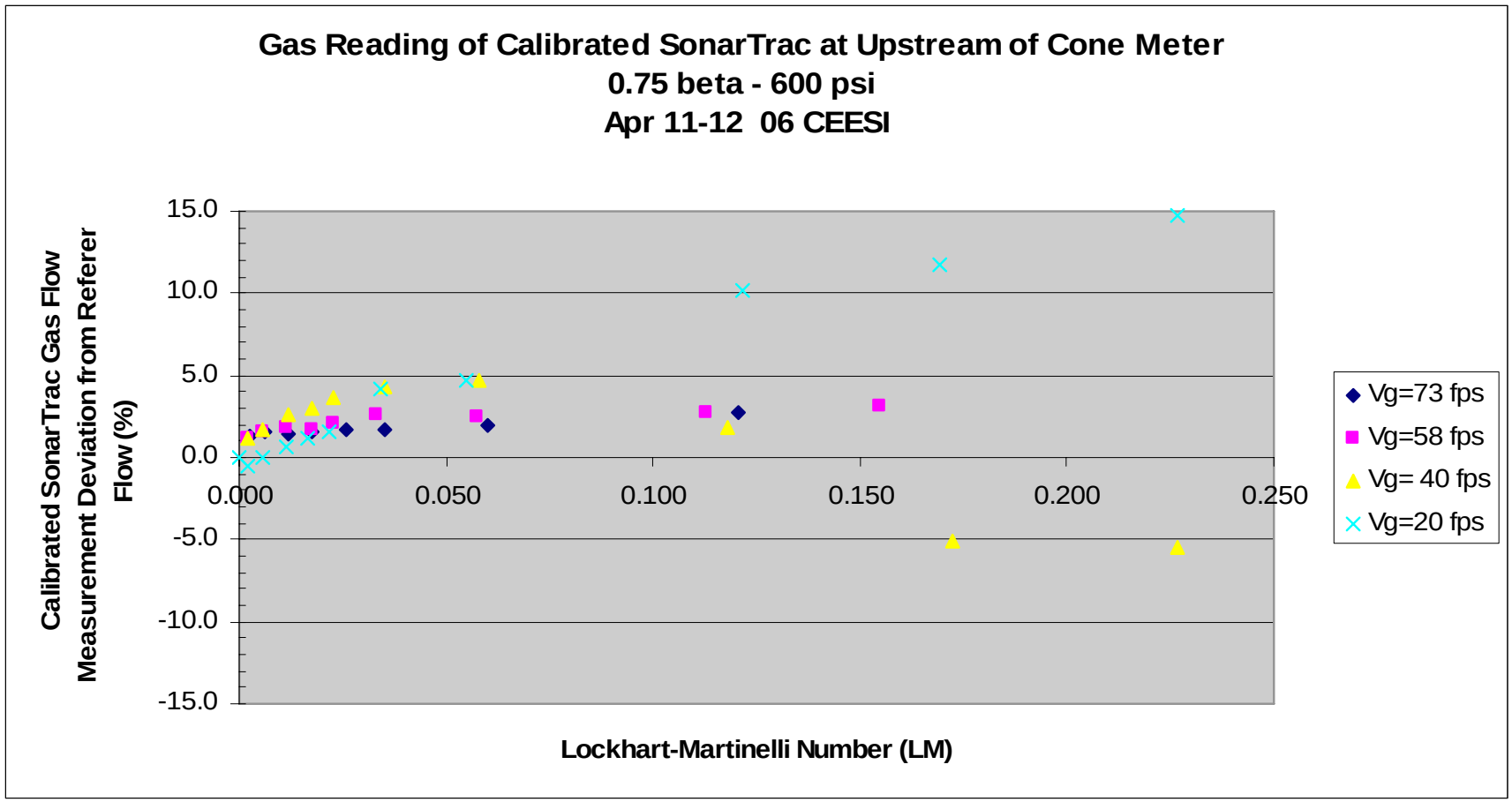

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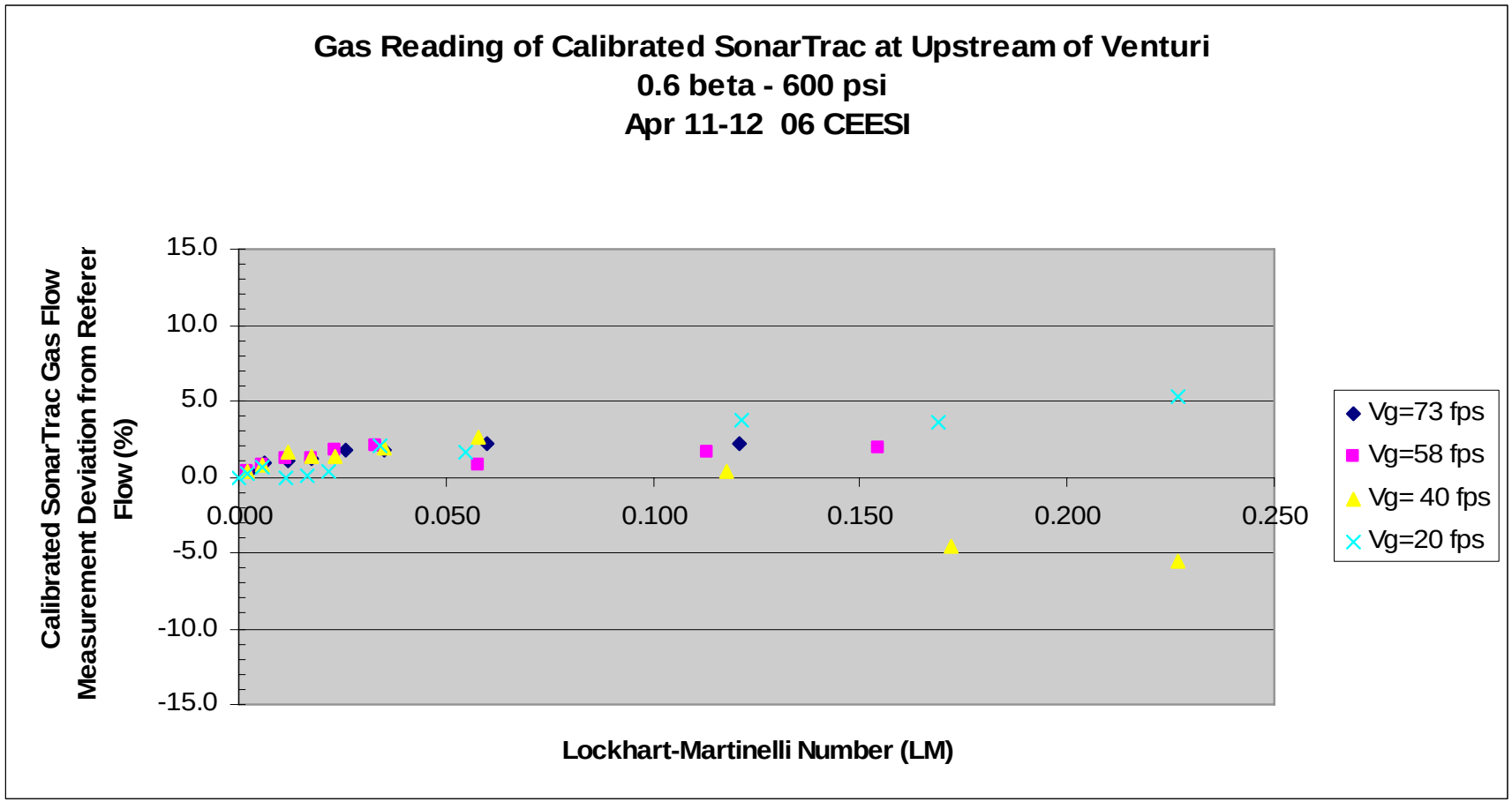

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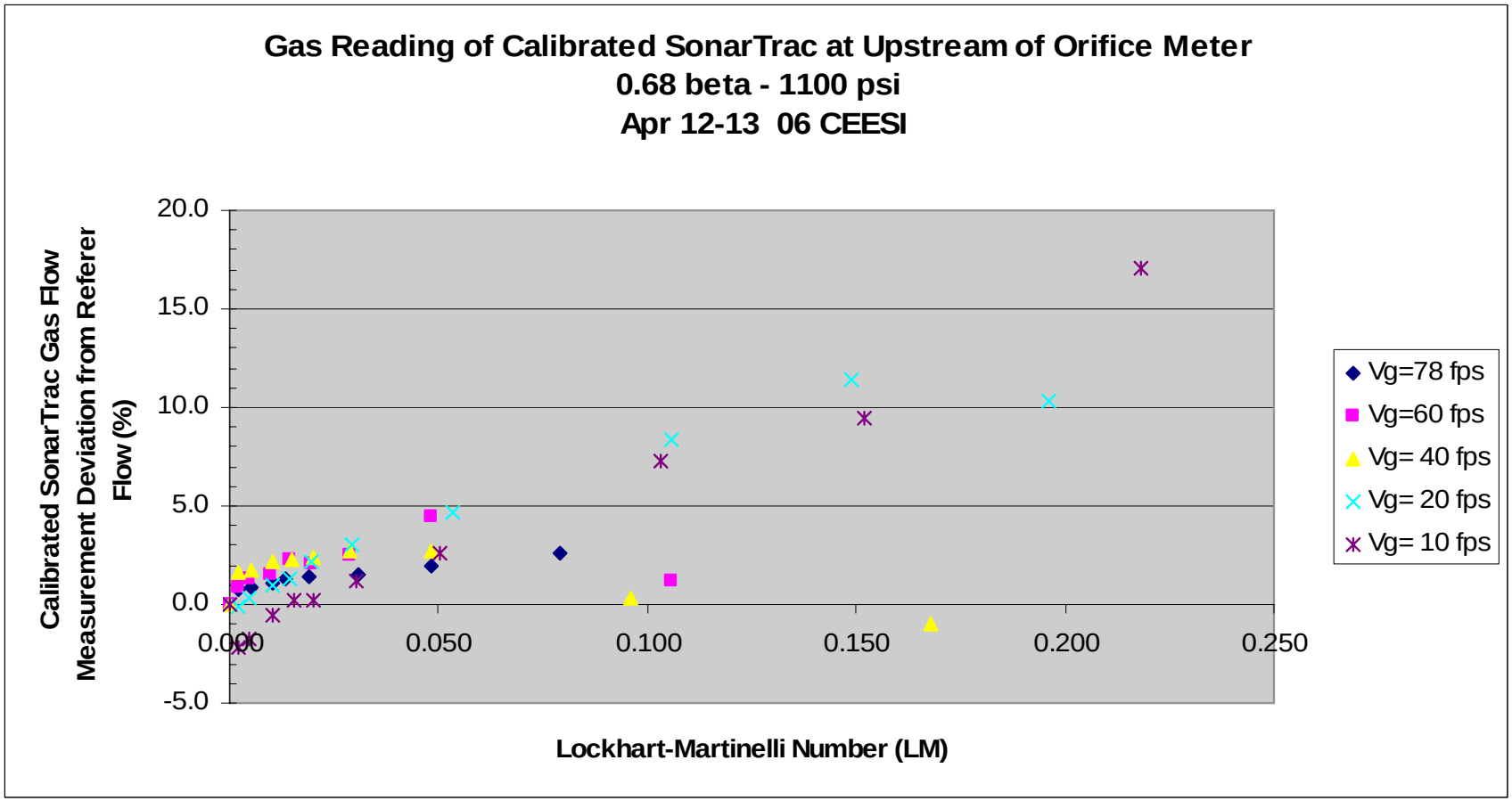

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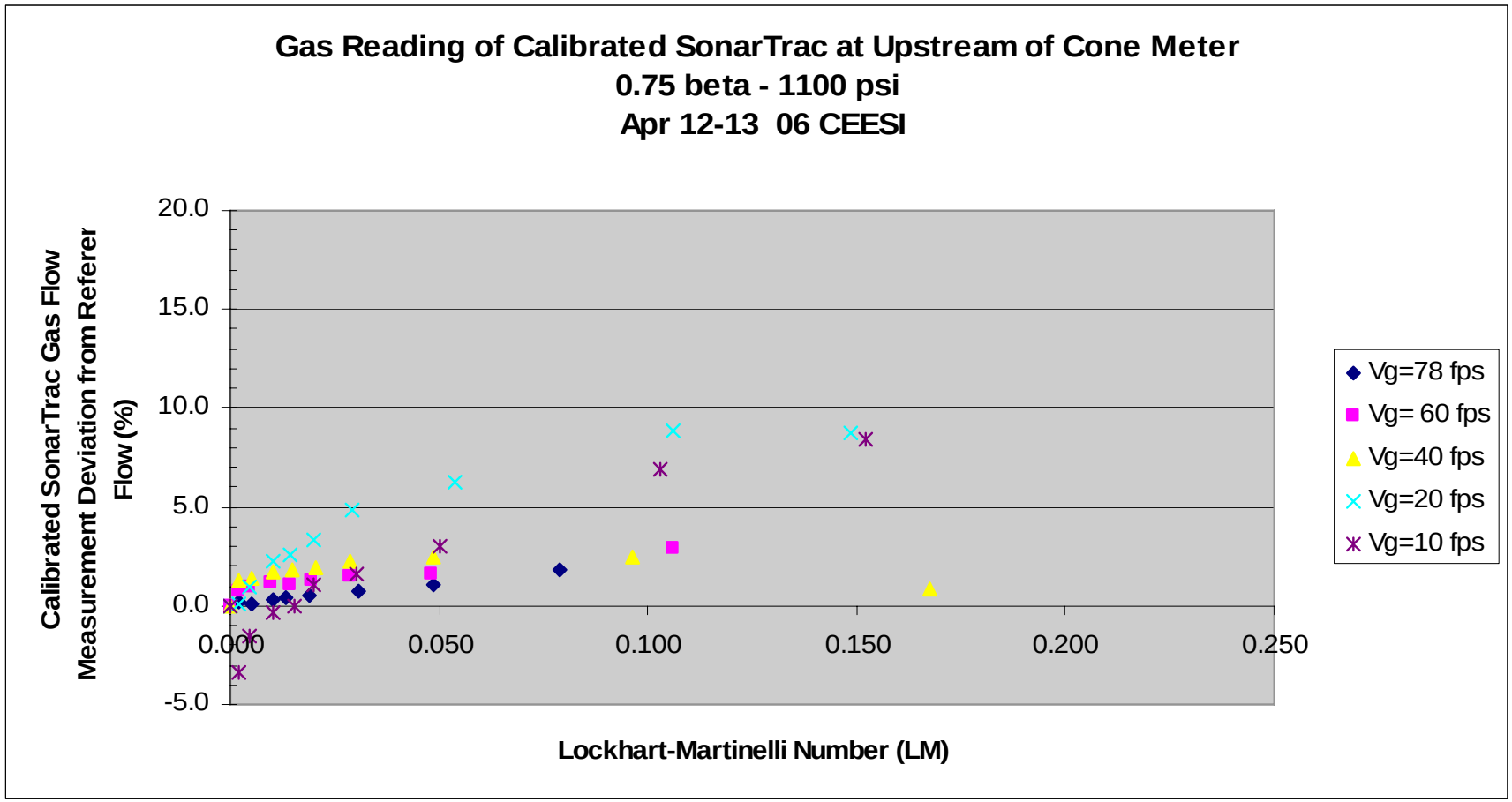

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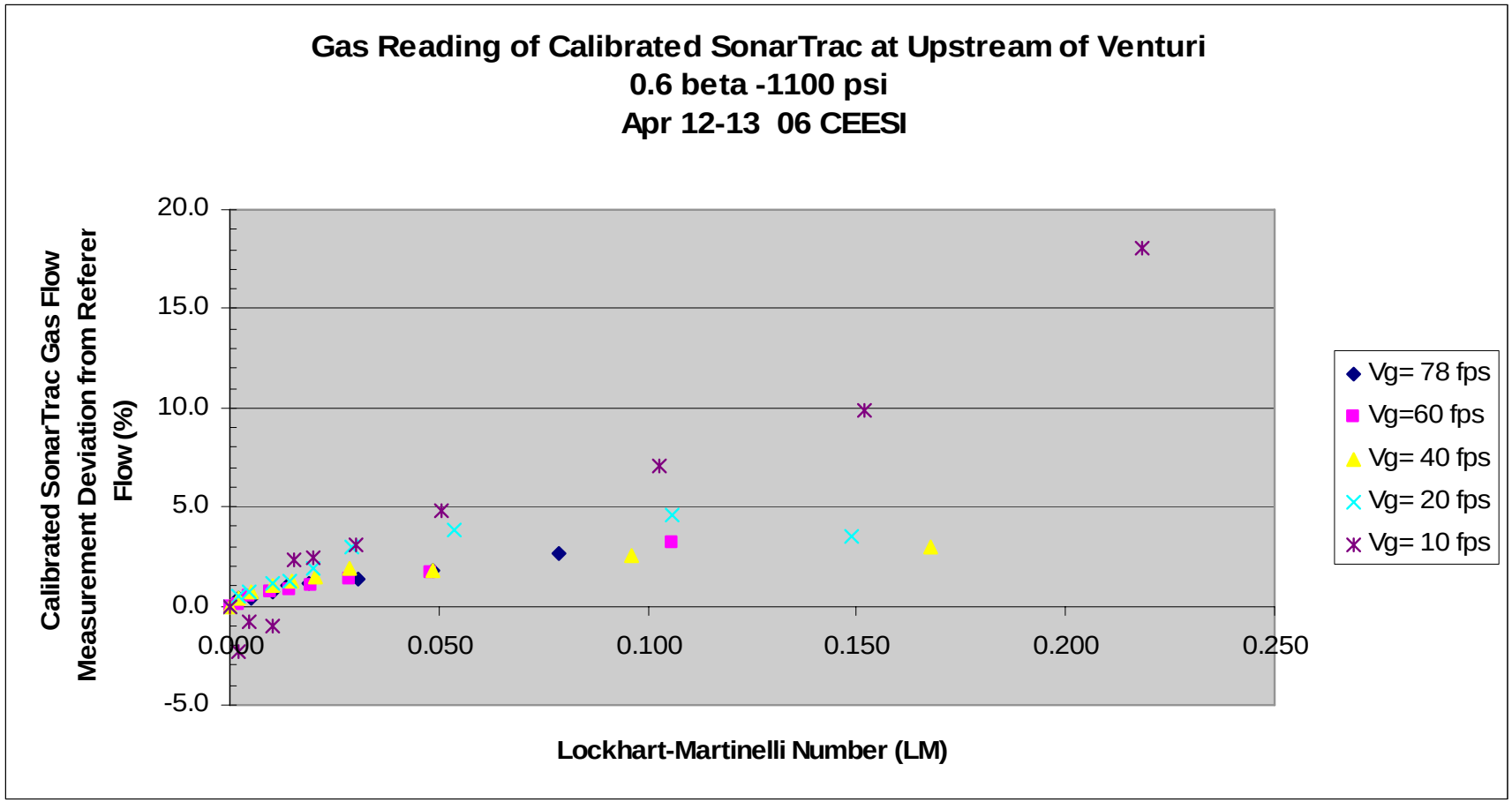
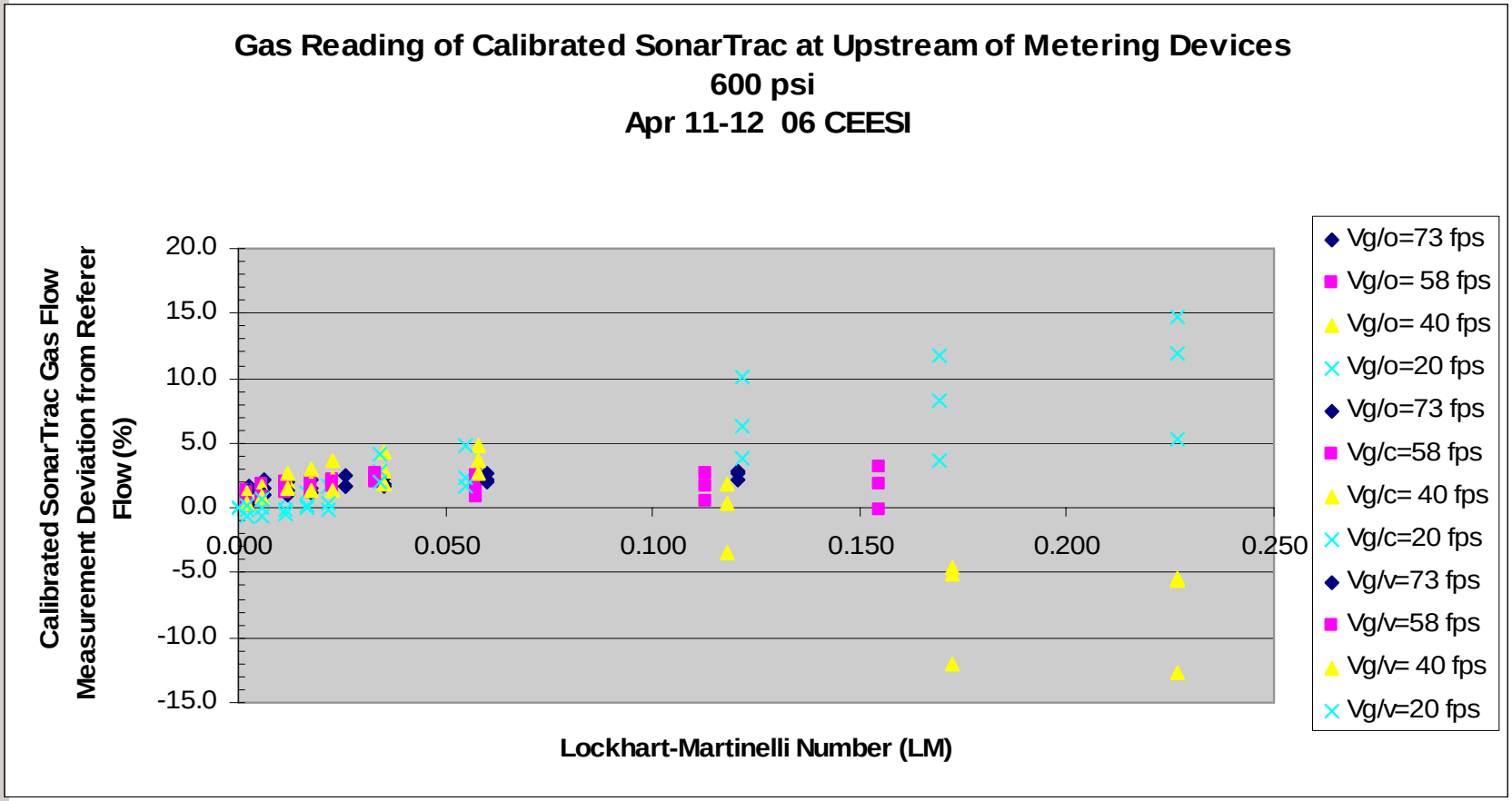


SONARtrac™ Measurement Uncertainty



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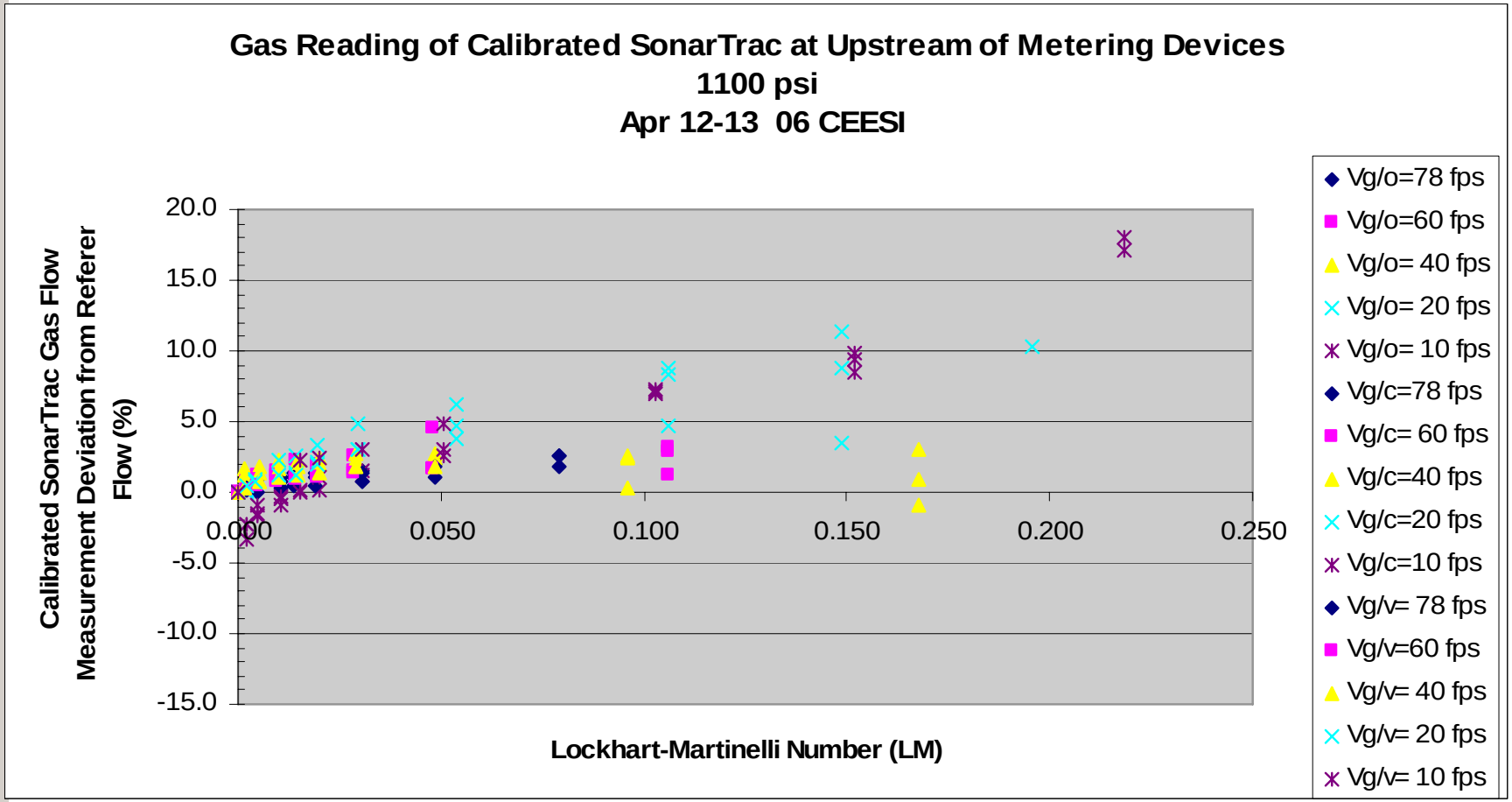


Conclusions

- Dry gas flow calibration is recommended before placing in service to reduce flow metering uncertainty
- Wet gas flow measurement uncertainty is in the range of ±5% when gas velocity is greater than 20 feet per second
- Mount meter on the upstream piping of a differential device, valve, or bends
- SONARtrac™ gas meter can be coupled with a differential device to measure gas and liquid flow rates. Liquid flow rate measurement uncertainty is larger than the gas flow rate uncertainty.

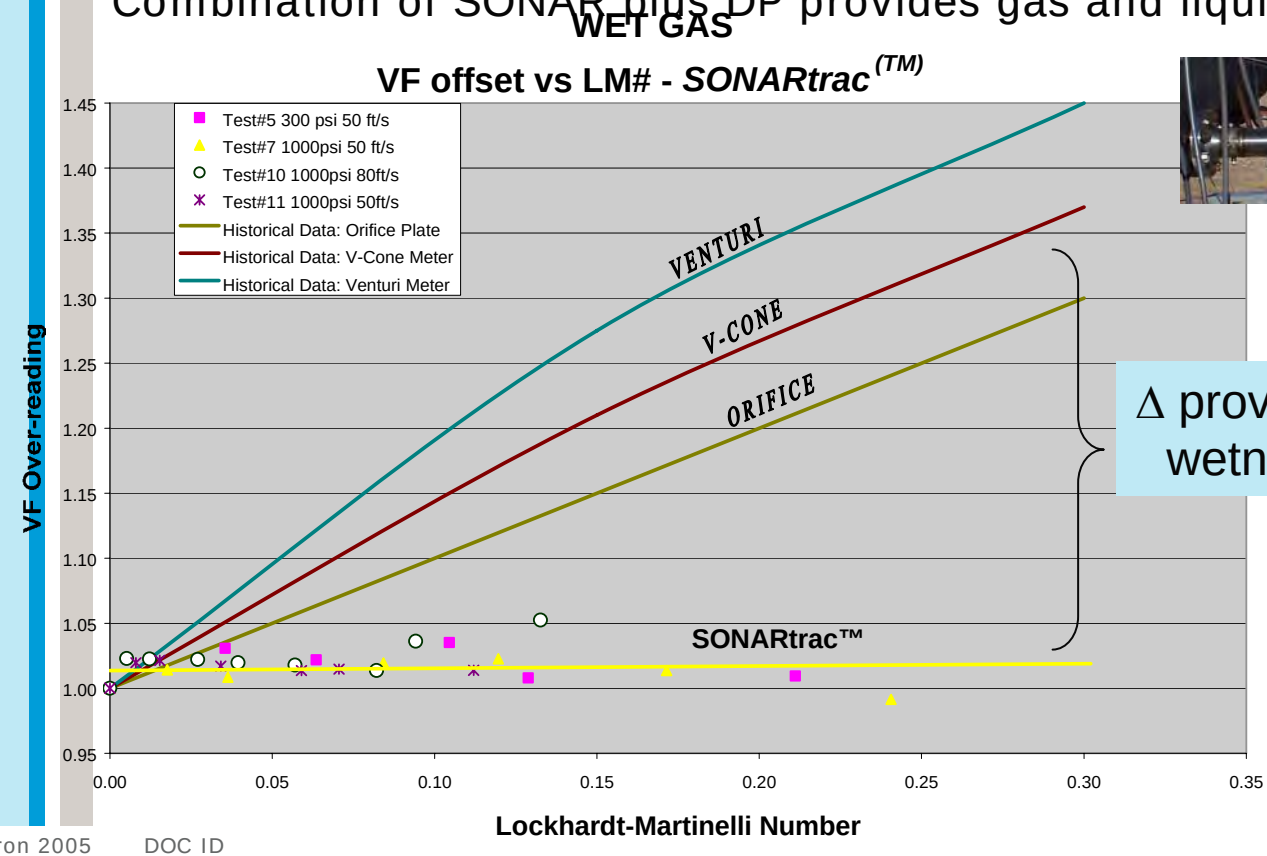
Wet Gas Measurement using Combination of SONAR and DP Meter

Combining SONAR plus DP for Wet Gas

Wetness causes differential pressure based flow measurements devices to over-report gas flow rates

SONARtrac™ provides a mixture flow rate which is significant less sensitive to wetness

Combination of SONAR plus DP provides gas and liquid flow rates



Δ provides wetness

Theoretical Over Report

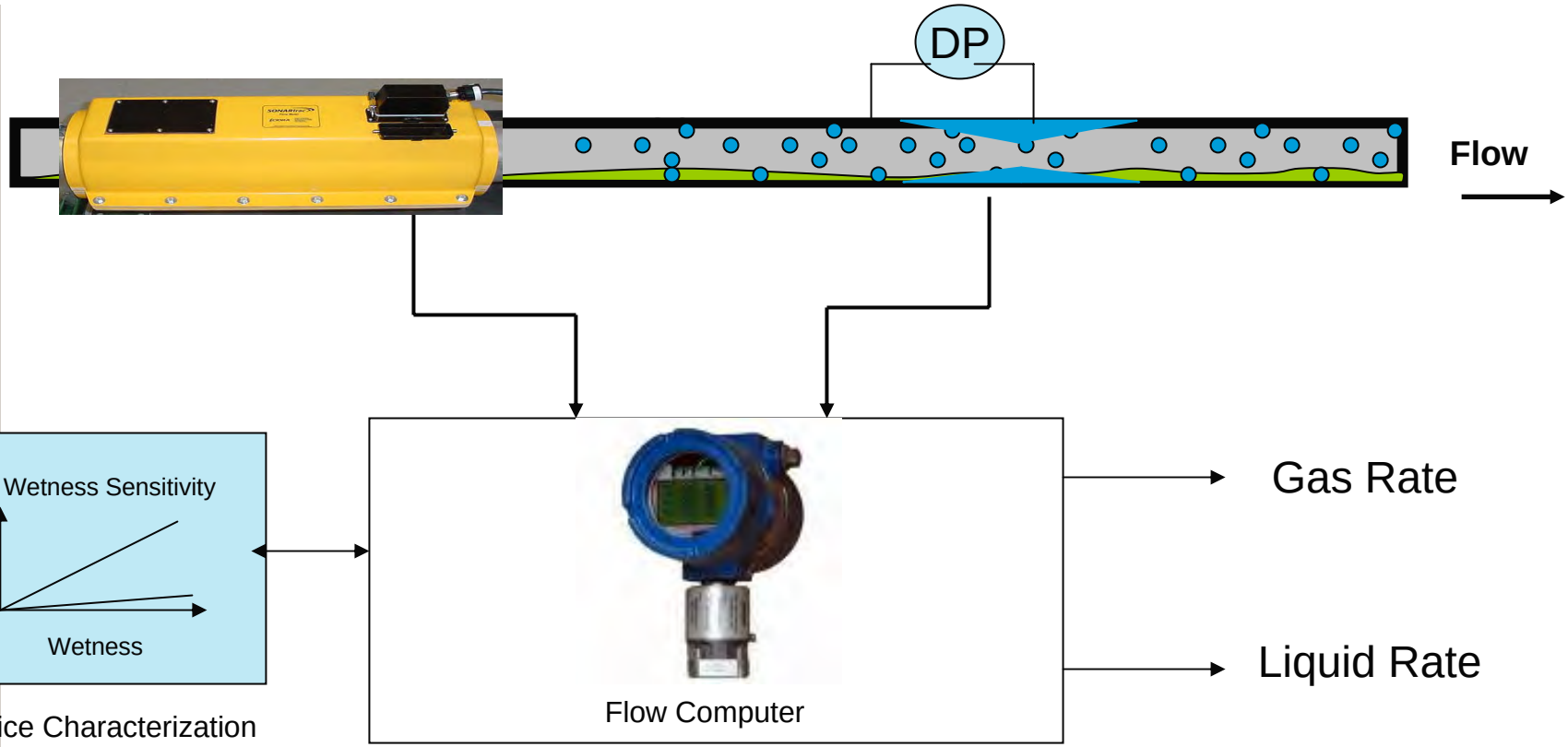
For Well Mixed Flows through a DP Device:

$$OR_{DP} = \sqrt{\frac{\Delta P_{wet}}{\Delta P_{dry}}} \approx \sqrt{1 + \frac{\dot{m}_{liq}}{\dot{m}_{gas}}} = \sqrt{1 + LGMR}$$

For Well Mixed Flows through a SONAR Meter

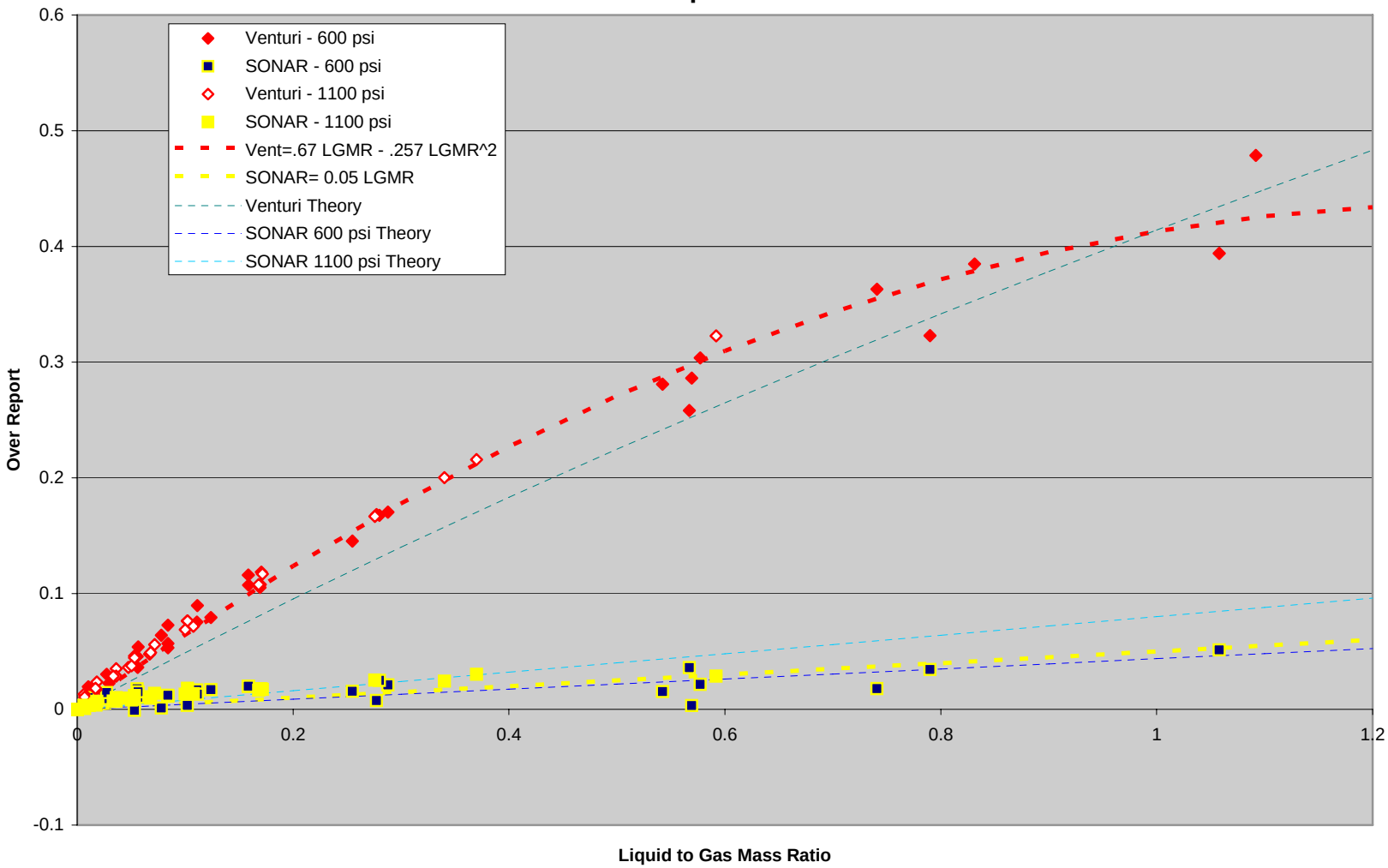
$$OR_{SONAR} \approx \frac{Q_{liq} + Q_{gas}}{Q_{gas}} = 1 + \frac{Q_{liq}}{Q_{gas}} = 1 + \frac{\rho_{gas}}{\rho_{liq}} LGMR = 1 + \sqrt{\frac{\rho_{gas}}{\rho_{liq}}} LM$$

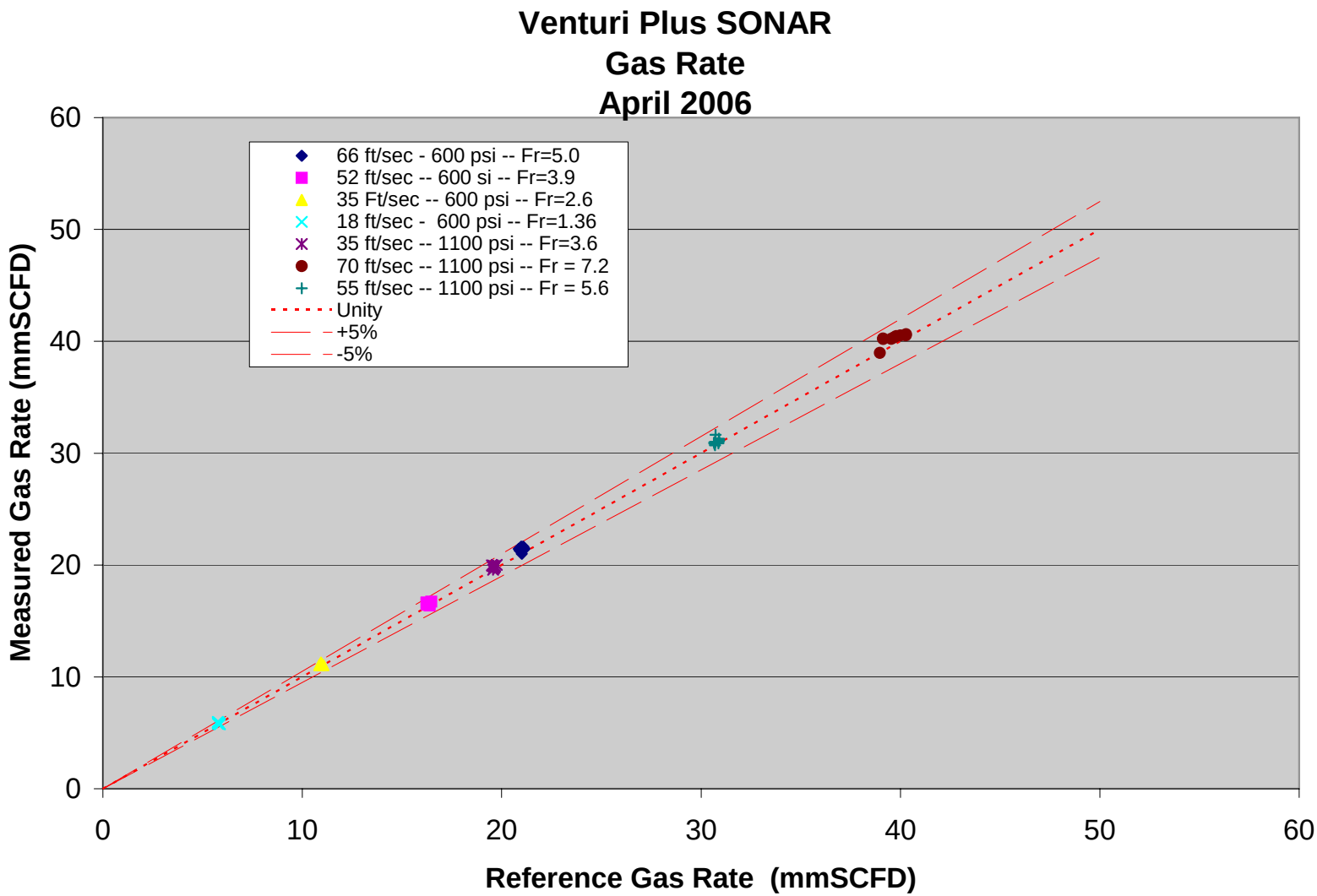
SONAR plus DP System Architecture For Wet Gas Measurement



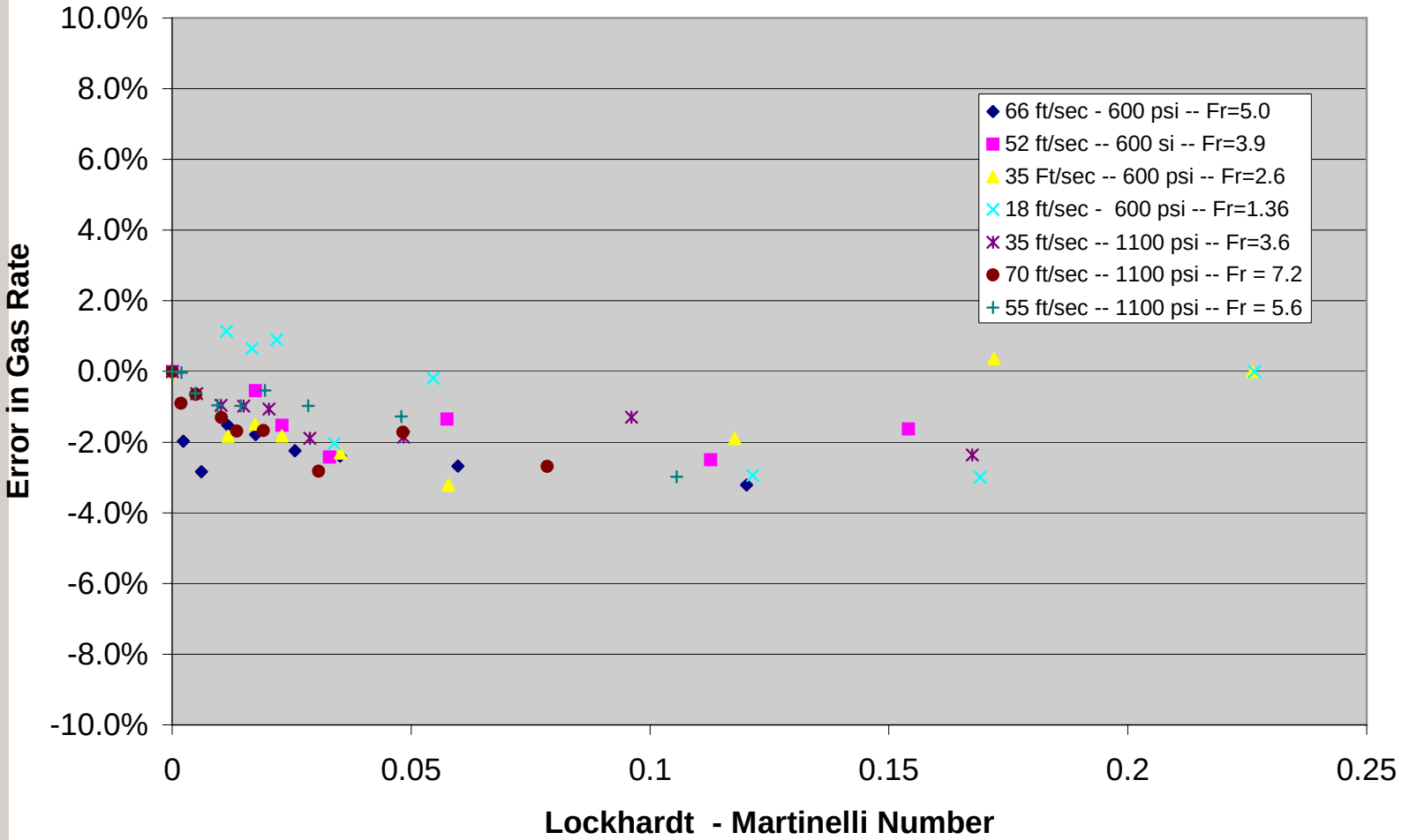
Venturi and SONAR OverReport Due to Wetness

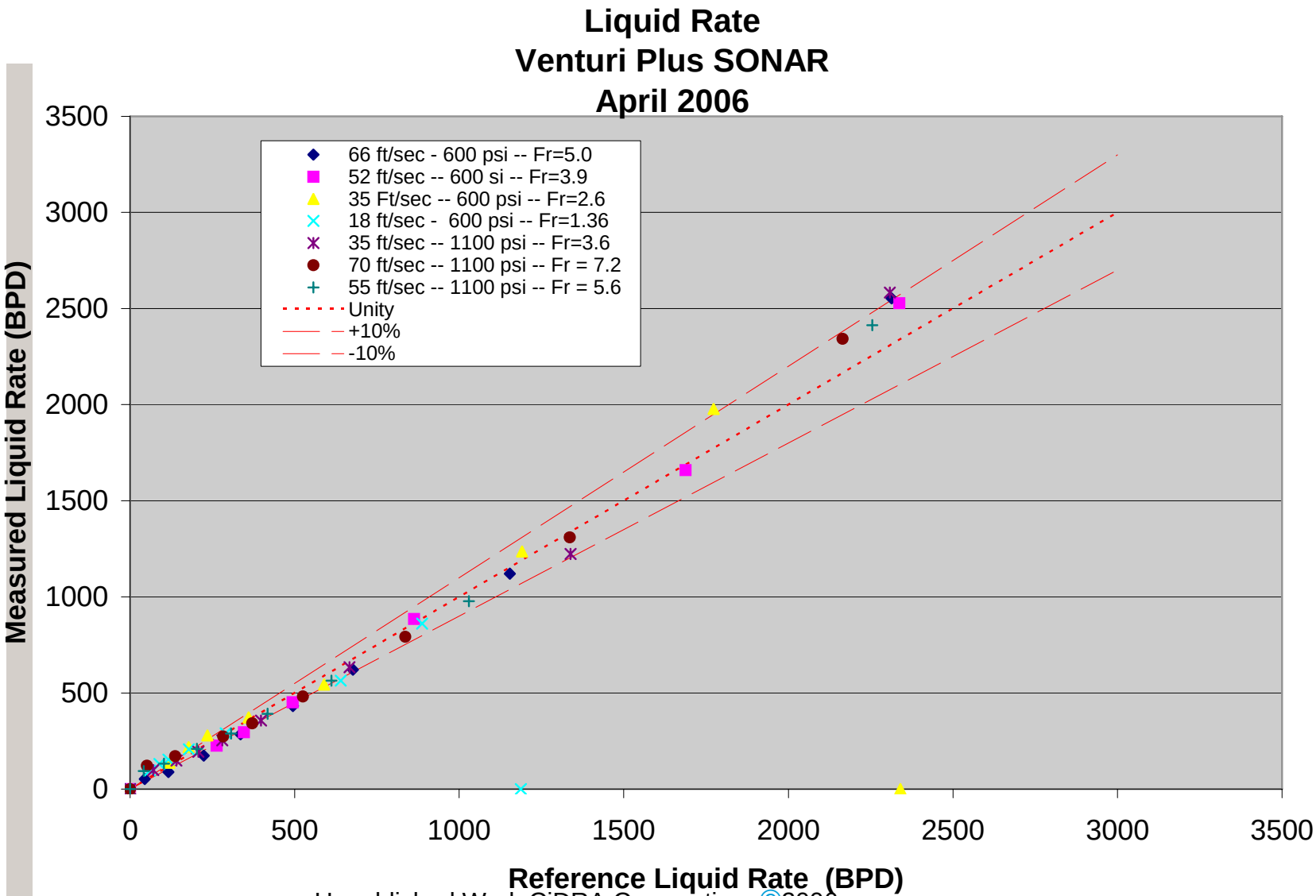
April 2006

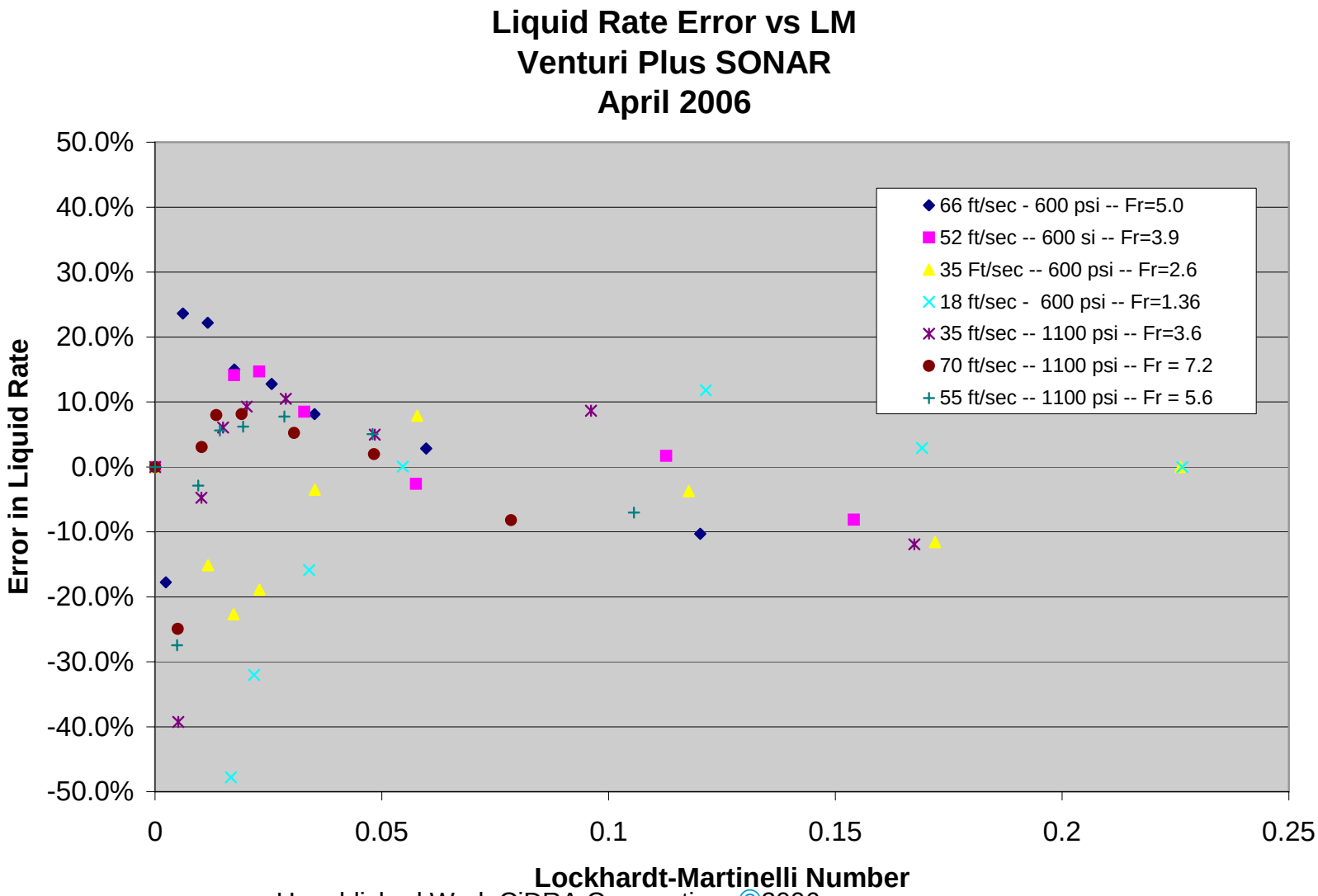




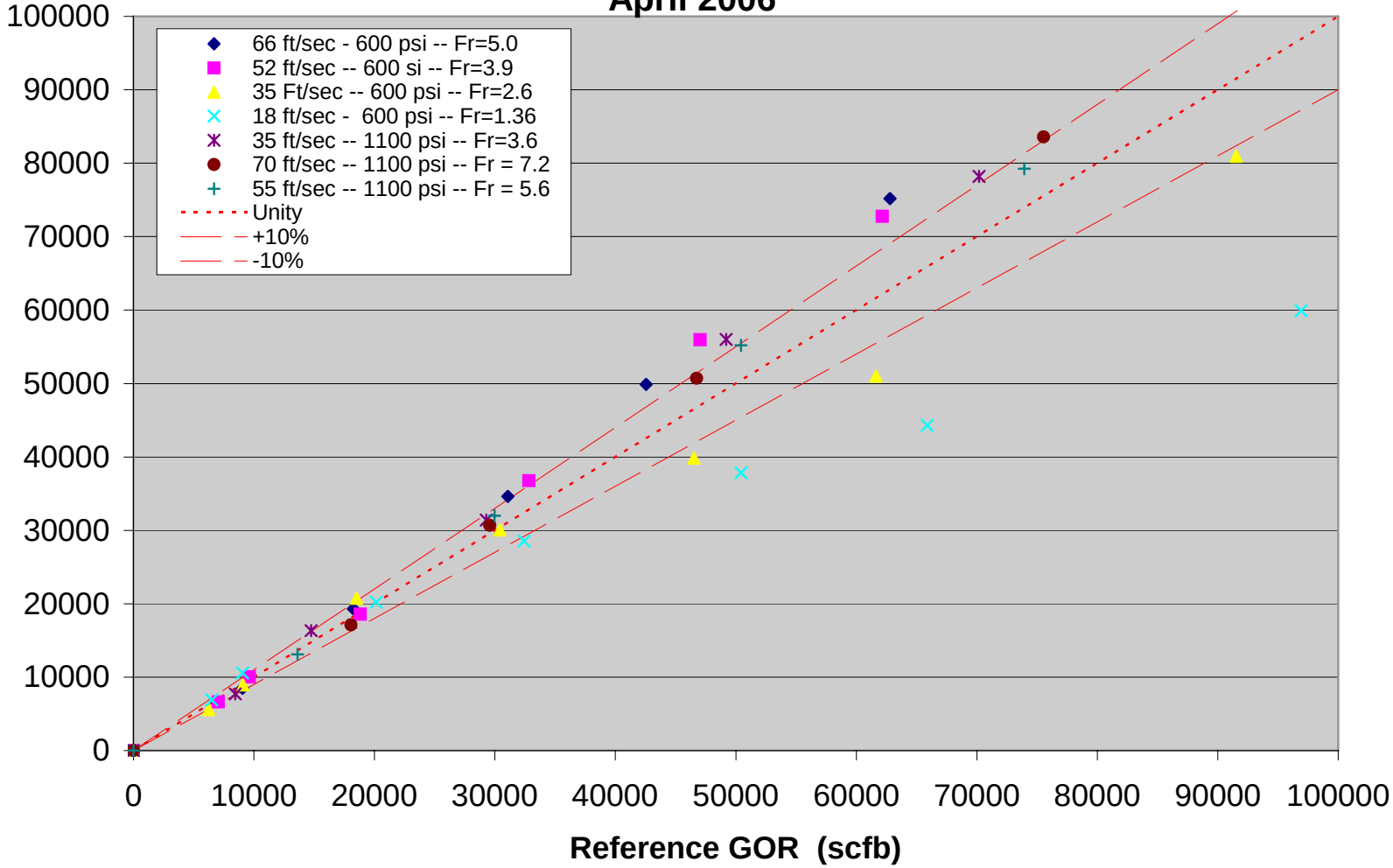
Gas Rate Error vs LM
Venturi Plus SONAR
April 2006







Gas Oil Ratio
Venturi Plus SONAR
April 2006



Summary

- SONAR-based Flow meter are well suited for Wet and Dry Gas flows
- SONAR-based flow meters are significantly less sensitive to mixture wetness than DP device
- Combining a Clamp-on SONAR meter with a DP based flow meter can provide full range wet gas flow measurement capability