Metrology Performance of Diaphragm Meters in Hydrogen Blended Natural Gas Service

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Introduction

The objectives of the test program were to validate that the established prover testing protocols in air specified by Measurement Canada (MC) specifications S-G-02 remains applicable to positive displacement, diaphragm type meters in hydrogen blended gas service containing up to 25% hydrogen by volume

The test protocol development contained four steps….

Step 1: Establishing Meter Baselines

Step 2: Density Effects on Test Meters

Step 3: Establishing Test Points

Step 4: Establishing Meter Longevity

The Four Step Process

Step 1: Establishing Meter Baselines

Meters Under Test - Diaphragm Meters

Seven or more diaphragm meters of varying make/model were selected from the existing meter fleet. As ATCO's present fleet of meters is essentially from a single manufacturer and a single size, attempts to sample meters of various ages and throughputs were made

Test points of 145 ± 5% and 45 ± 5% of rated air capacity. The meters were tested using ATCO's designated Local Volumetric Standard (LVS) on air

The Four Step Process

Step 1: Establishing Meter Baselines

Reference Meter Characterization

A pulsation free triple precision rotary meter manufactured by Precision Gas Measurement (PGM) currently used as a check meter having a MC certified calibration curve from the VSL Dutch Metrology Institute on air was compared using the LVS at the 145%, 45%, 30% and 15% flowrates dictated by the diaphragm meters

The Four Step Process

Step 2: Density Effects on Test Meters

Qualify the effect of gas density changes on diaphragm meter performance

Problem: It is not practical to introduce H_2/NG blends into test apparatuses designed for air

Solution: Use an alternative fluid. A blend of air and He can be safely used to simulate the 5%, 10% and 20% H_2 blends in the meter's service

The Four Step Process

Step 2: Density Effects on Test Meters - Gas Mixture Proxies for H_2 - NG Blends

Component Name	Volume Ratio (5%)	Specific Gravity	Volume Ratio (10%)	Specific Gravity	Volume Ratio (20%)	Specific Gravity	Volume Ratio (30%)	Specific Gravity
H_2	5	0.07	10	0.07	20	0.07	30	0.07
NG	95	0.65	90	0.65	80	0.65	70	0.65
Blend	100	0.62	100	0.59	100	0.53	100	0.48
He	44	0.14	48	0.14	55	0.14	60	0.14
Air	56	1.00	52	1.00	45	1.00	40	1.00
Blend	100	0.62	100	0.59	100	0.53	100	0.48

The Four Step Process

Step 3: Establishing Test Points

To estimate the equivalent test point for densities of 5%, 10%, 20% and 30% blends in NG, the equation from MC's *S-G-03–Specifications for the approval of type of gas meters, ancillary devices and associated measuring instruments* was repurposed

The Four Step Process

Step 3: Establishing Test Points

$$Q_T = Q_A \sqrt{\frac{dt}{db}}$$

Where:

Q_T = true rated capacity
Q_A = apparent rated capacity
dt = density of air at test conditions (density of air/He mixtures)
db = density of dry air at standard conditions

The Four Step Process

Step 4: Establishing Meter Longevity

The diaphragm meters on blended H_2 service also provides an opportunity to help evaluate meter longevity. Here, data from the meters pre H_2 blend service performance in Step 1 will be compared to the calibration post H_2 blended service

Each meter, once out of service, will be re-tested as per established practice

Additional data is being collected by direct comparison to a rotary meter installed with the diaphragm meter in H_2 blended gas service

Tests are ongoing

Test Protocol Experimentation

Test Protocol Experimentation

Limitations

- The results are limited to the specific meter make/model/serial numbers identified, and are reflective of the vintage and service life of the meters evaluated by this test program
- Results are applicable to Natural Gas-Hydrogen blends containing up to 25% hydrogen
- All testing was conducted at temperatures above the dewpoint of ambient air, analysis and comparison against metrological performance in proxy test gas mixtures.

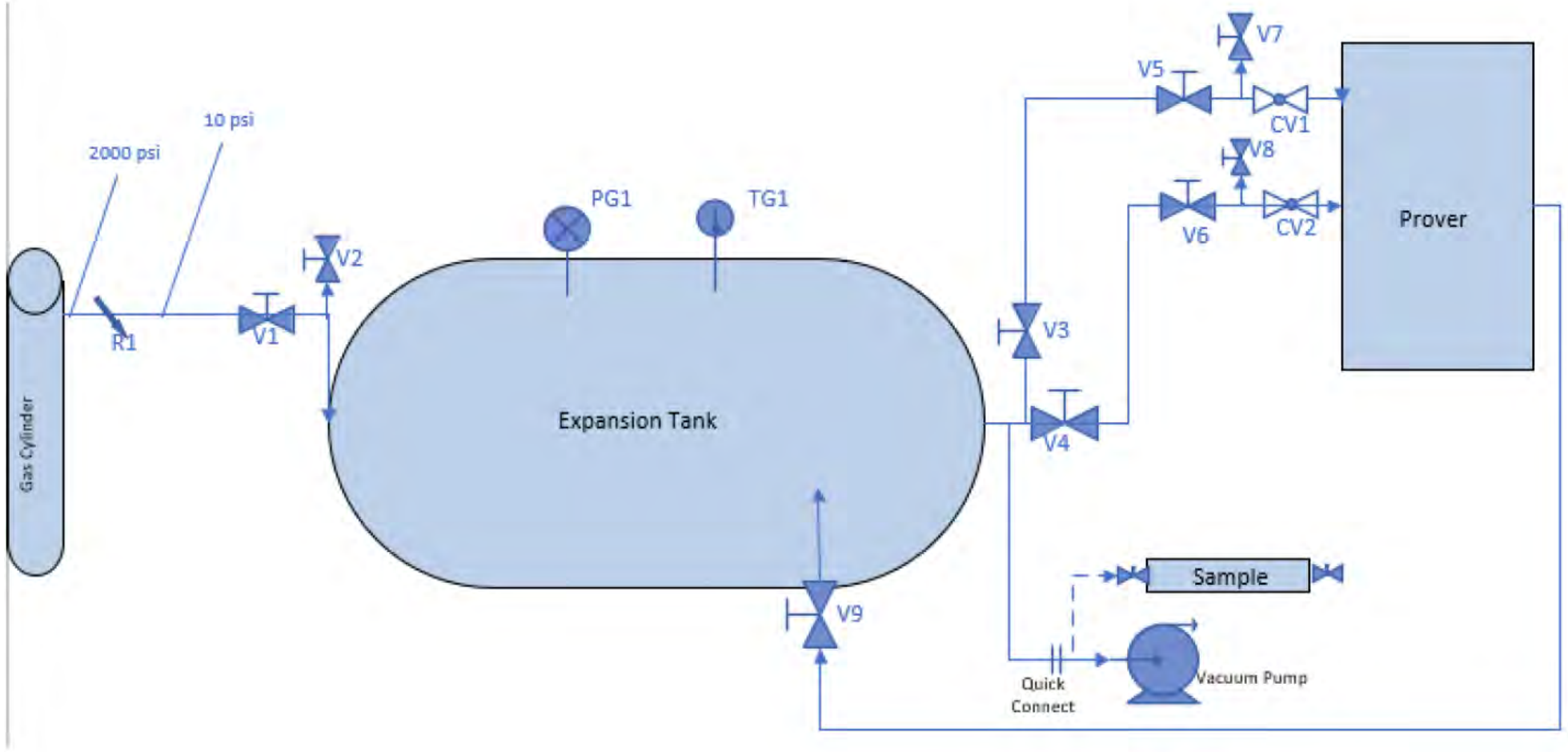
Test Protocol Experimentation

Assumptions

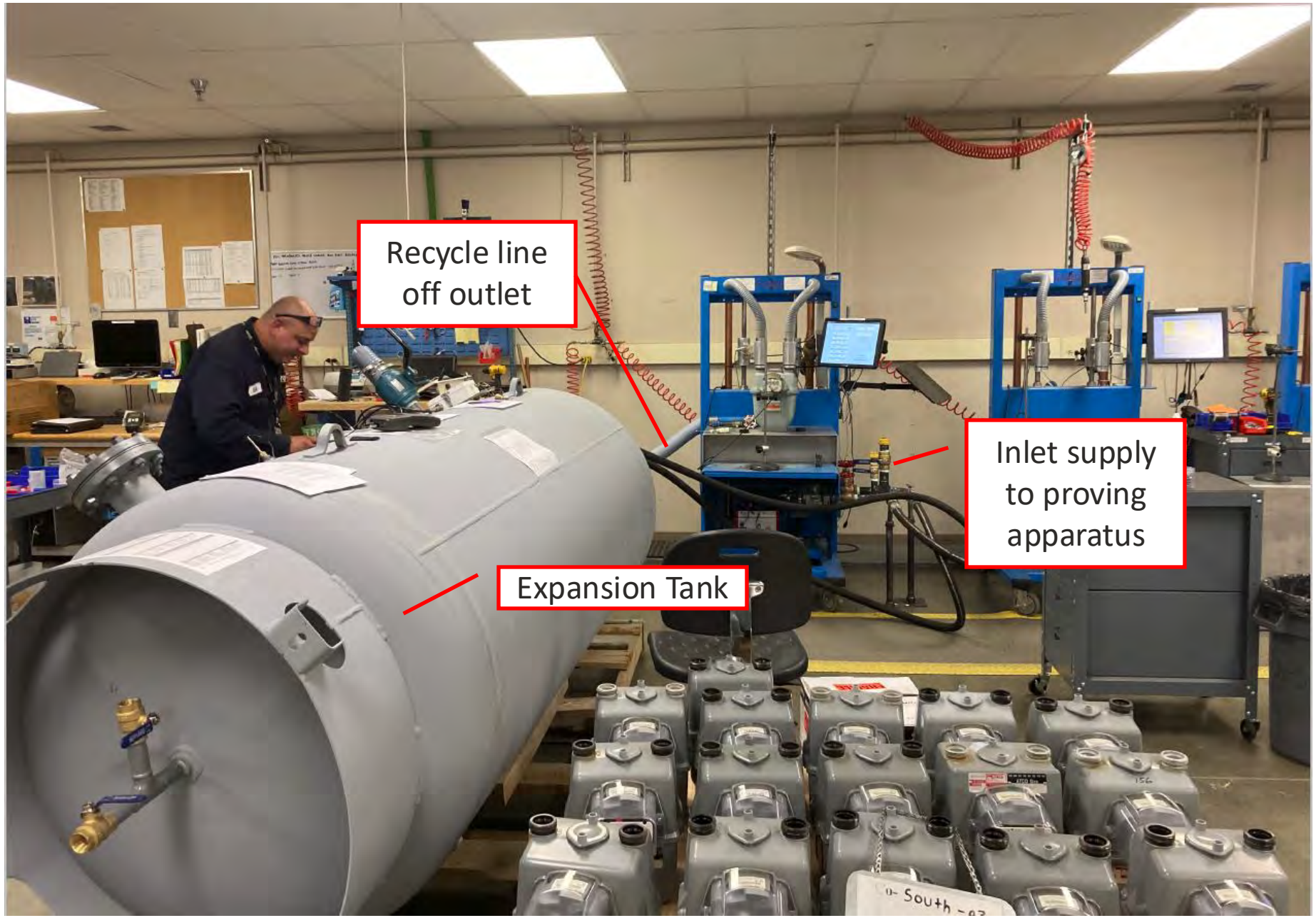
This assessment assumes the following:

- Helium – air mixtures with a specific gravity identical to a specified hydrogen – natural gas blend is a suitable proxy for the metrological behavior of diaphragm meters operating in hydrogen blended natural gas.
    - Effect of viscosity is non-impactful compared to the effect of specific gravity.

Test Apparatus and Procedure



Test Apparatus and Procedure

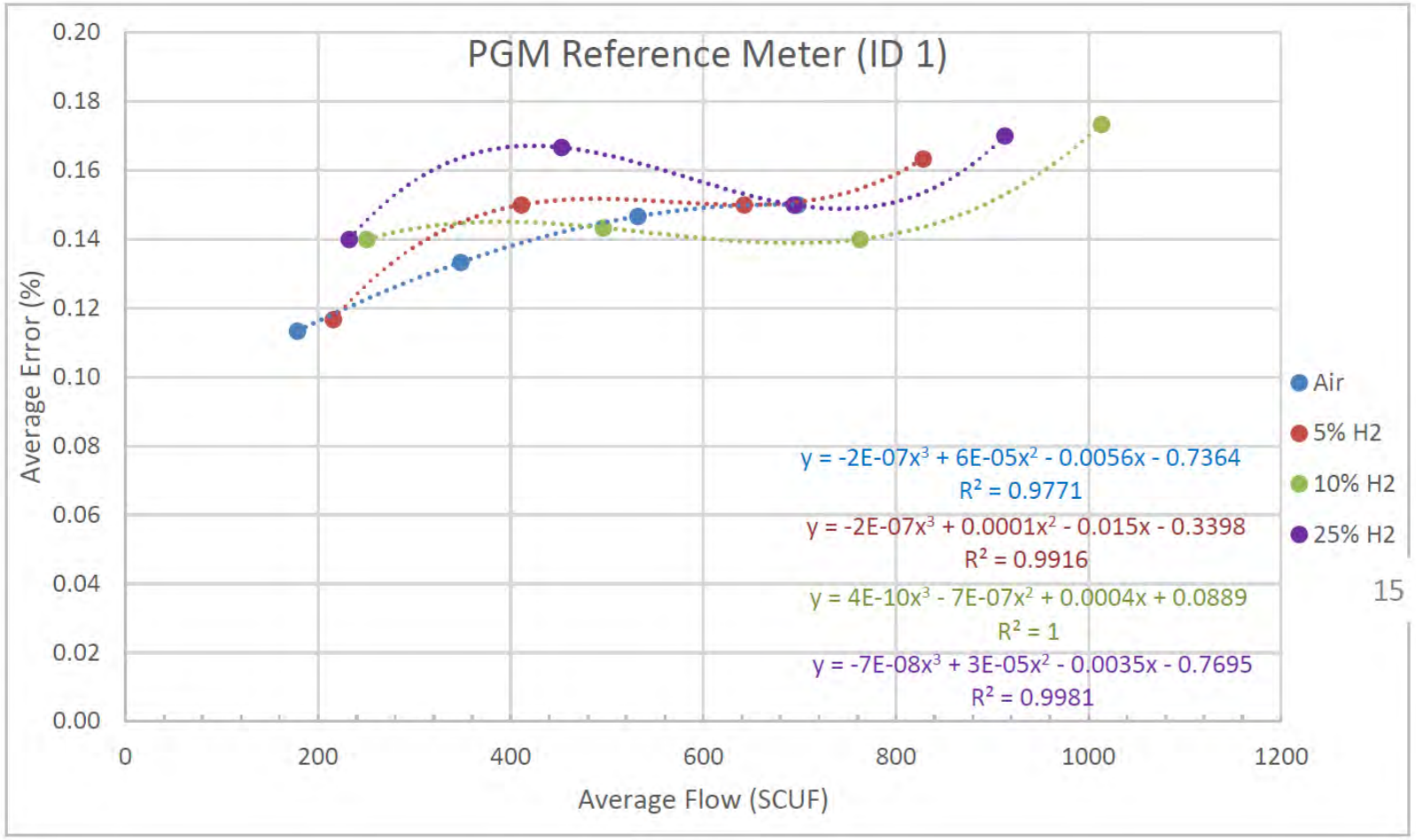


Test Gas Composition

- Before testing with a proxy test gas could commence, existing air within the test apparatus had to be purged and replaced with the appropriate proxy test gas.
- Upon completion of the pressure purging procedure and the testing on the proving apparatus, a gas sample was collected and sent for analysis by an ISO 17025 certified 3rd party via Gas Chromatograph.

The Results

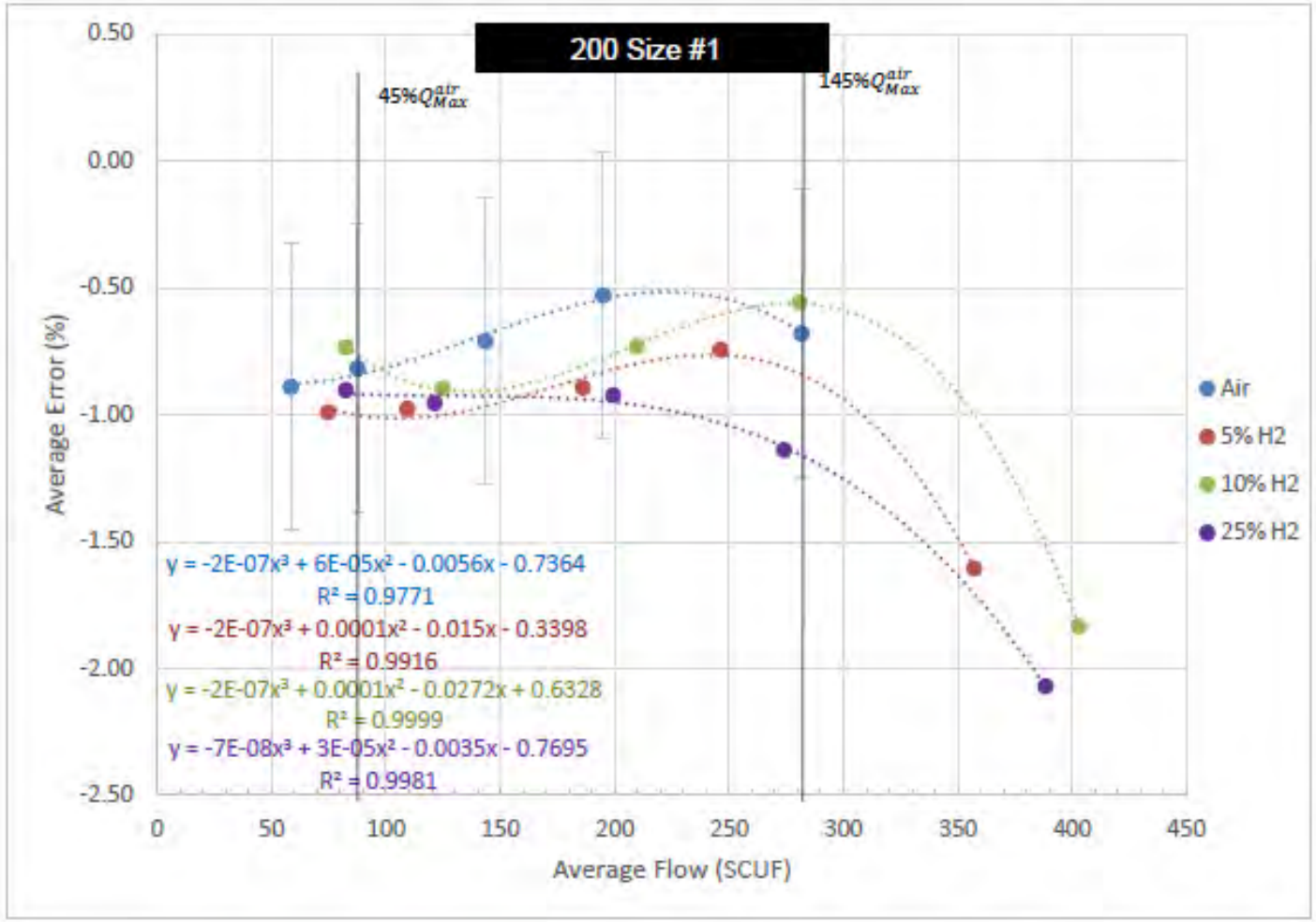
PGM Reference Meter Results



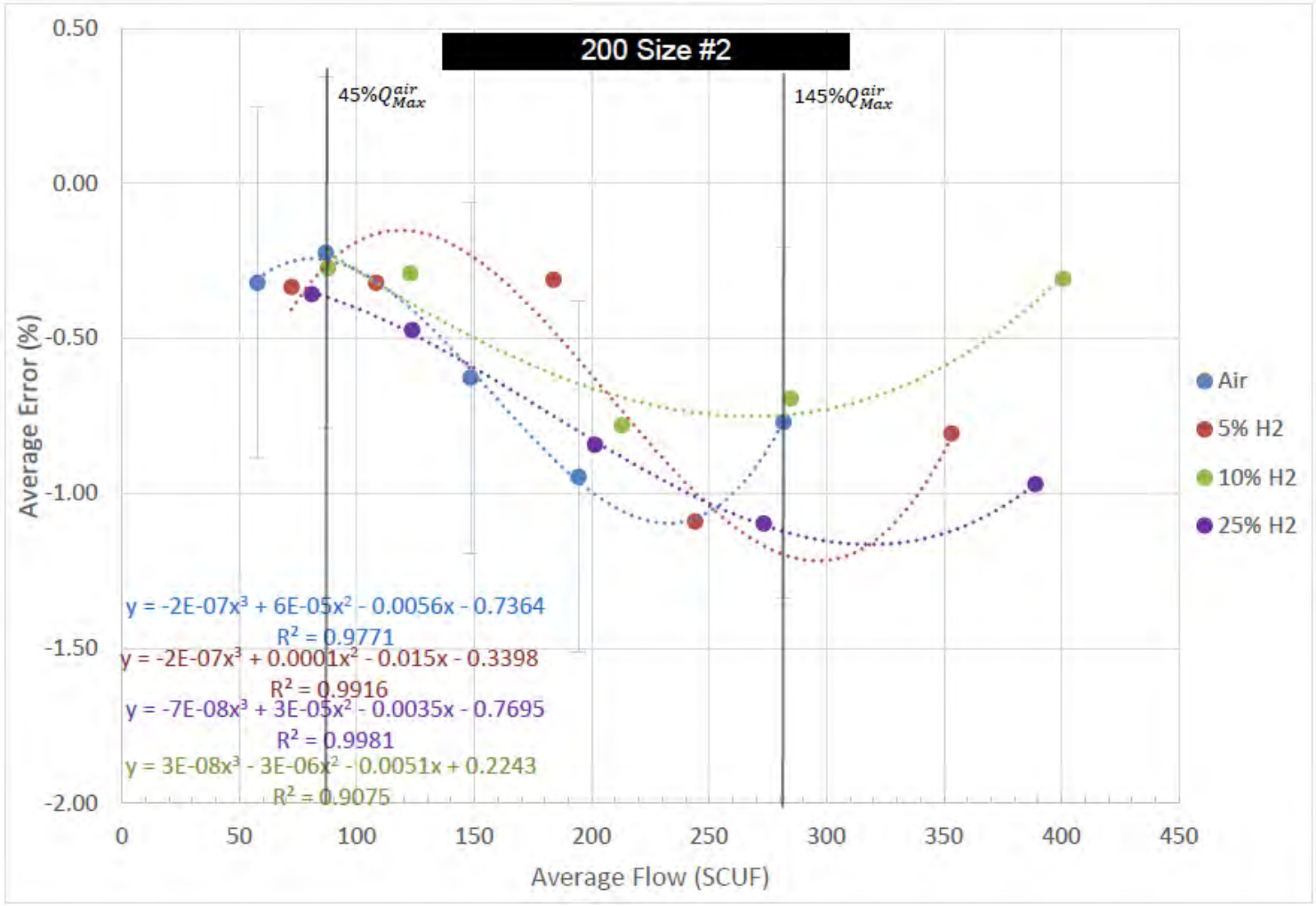
Reproducibility vs. Air (Average Error, %)			
Qmax	PGM Reference		
	5% H2	10% H2	25% H2
15%	0.00	0.03	0.03
30%	0.02	0.01	0.03
45%	0.00	-0.01	0.00
60%	0.01	0.02	0.02

Reproducibility, Run-to-Run (Max Error, %)			
Qmax	PGM Reference		
	5% H2	10% H2	25% H2
15%	-0.04	-0.05	-0.03
30%	0.00	-0.04	-0.01
45%	0.00	-0.05	-0.03
60%	-0.04	-0.04	0.00

200 Size Meter #1

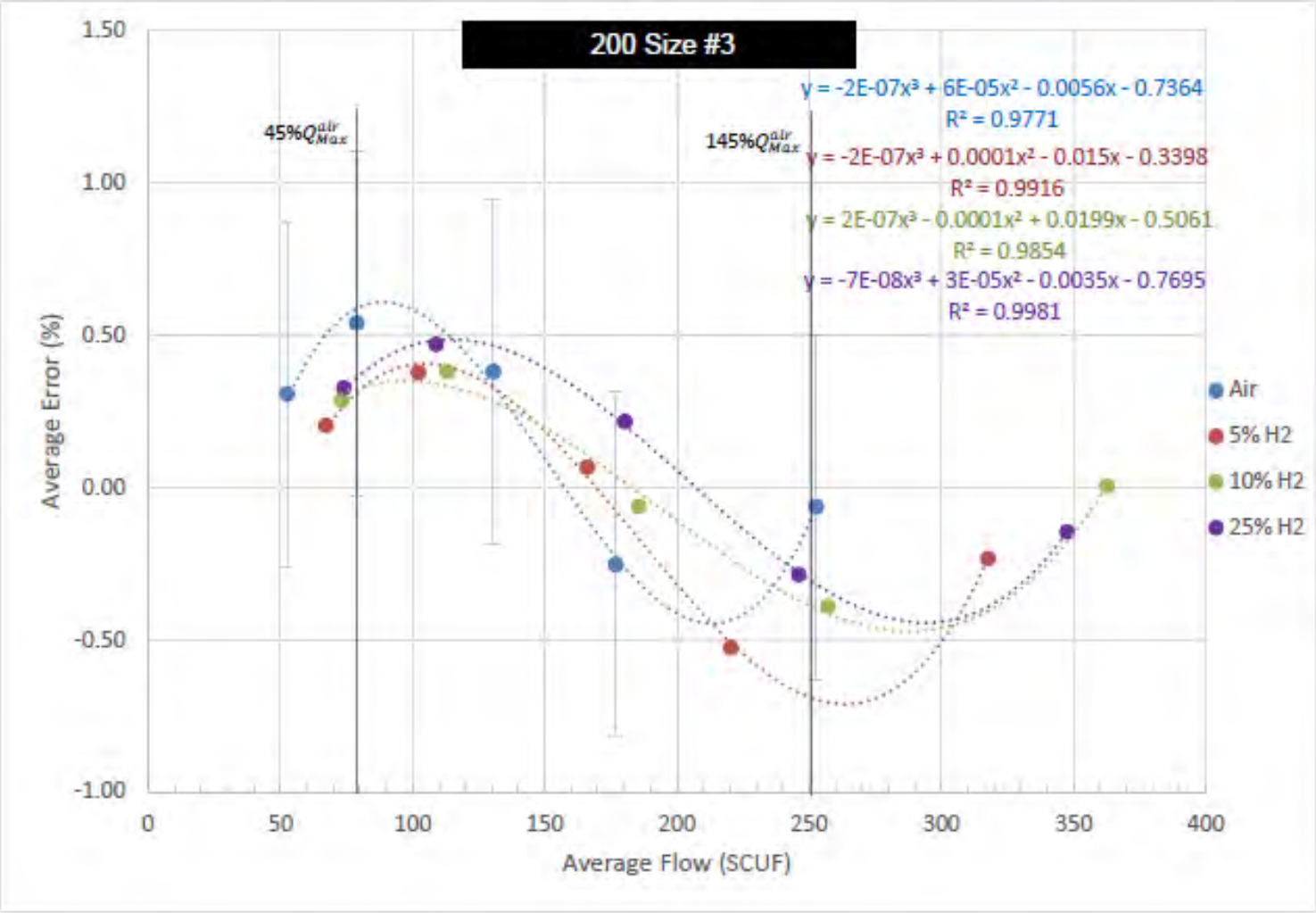


200 Size Meter #2

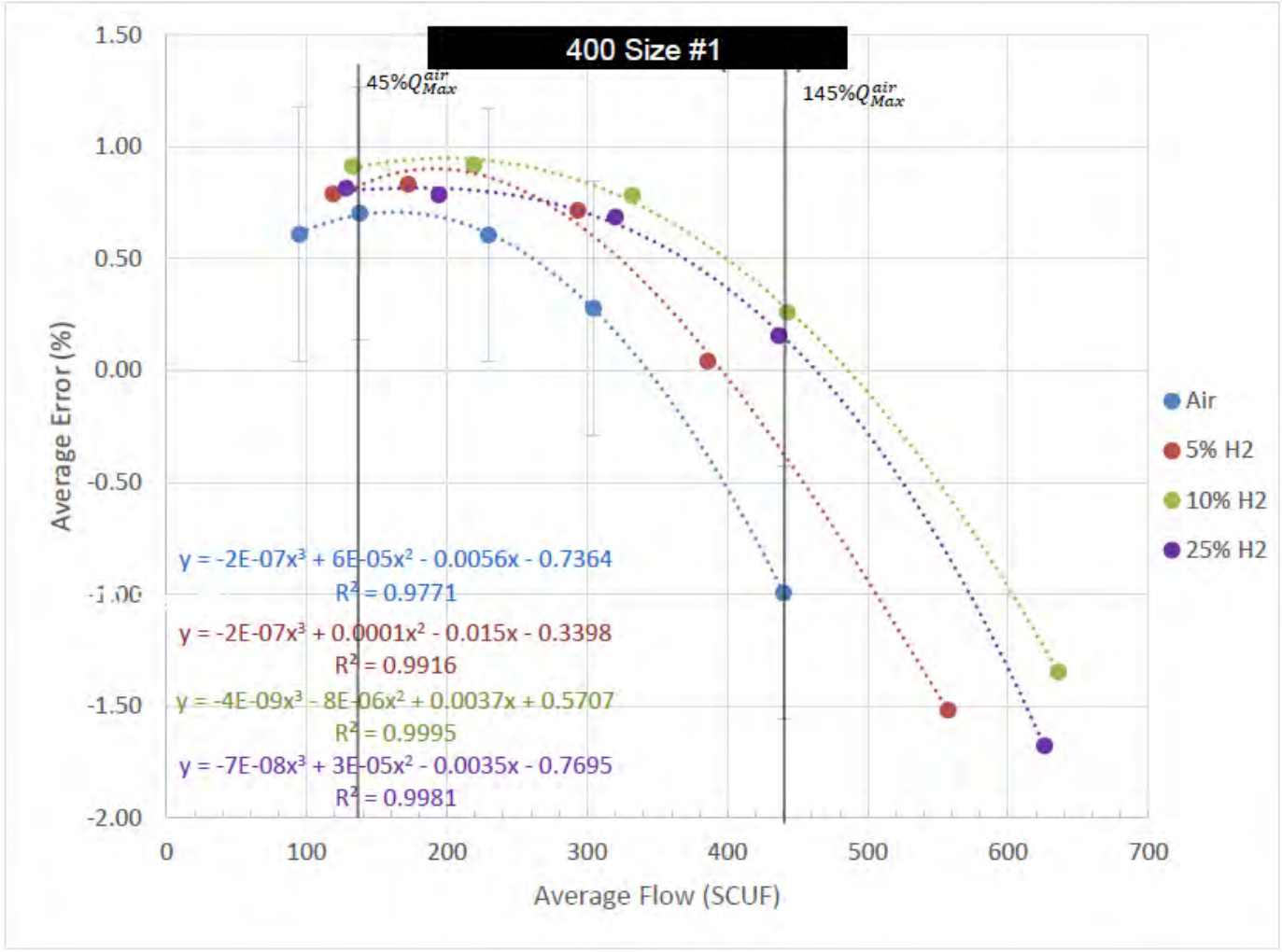


200 Size Meter #3

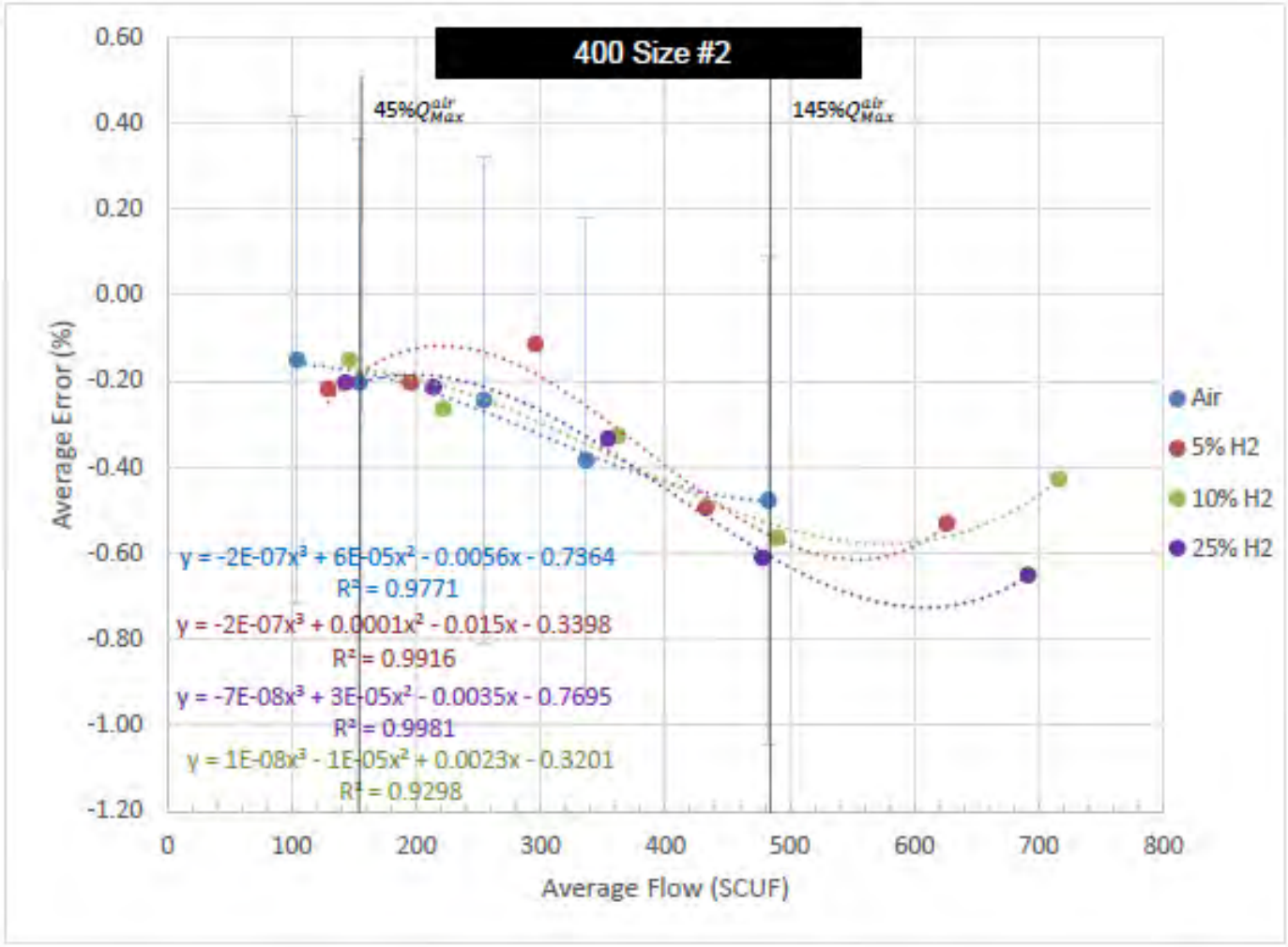
New meter manufactured In 2021



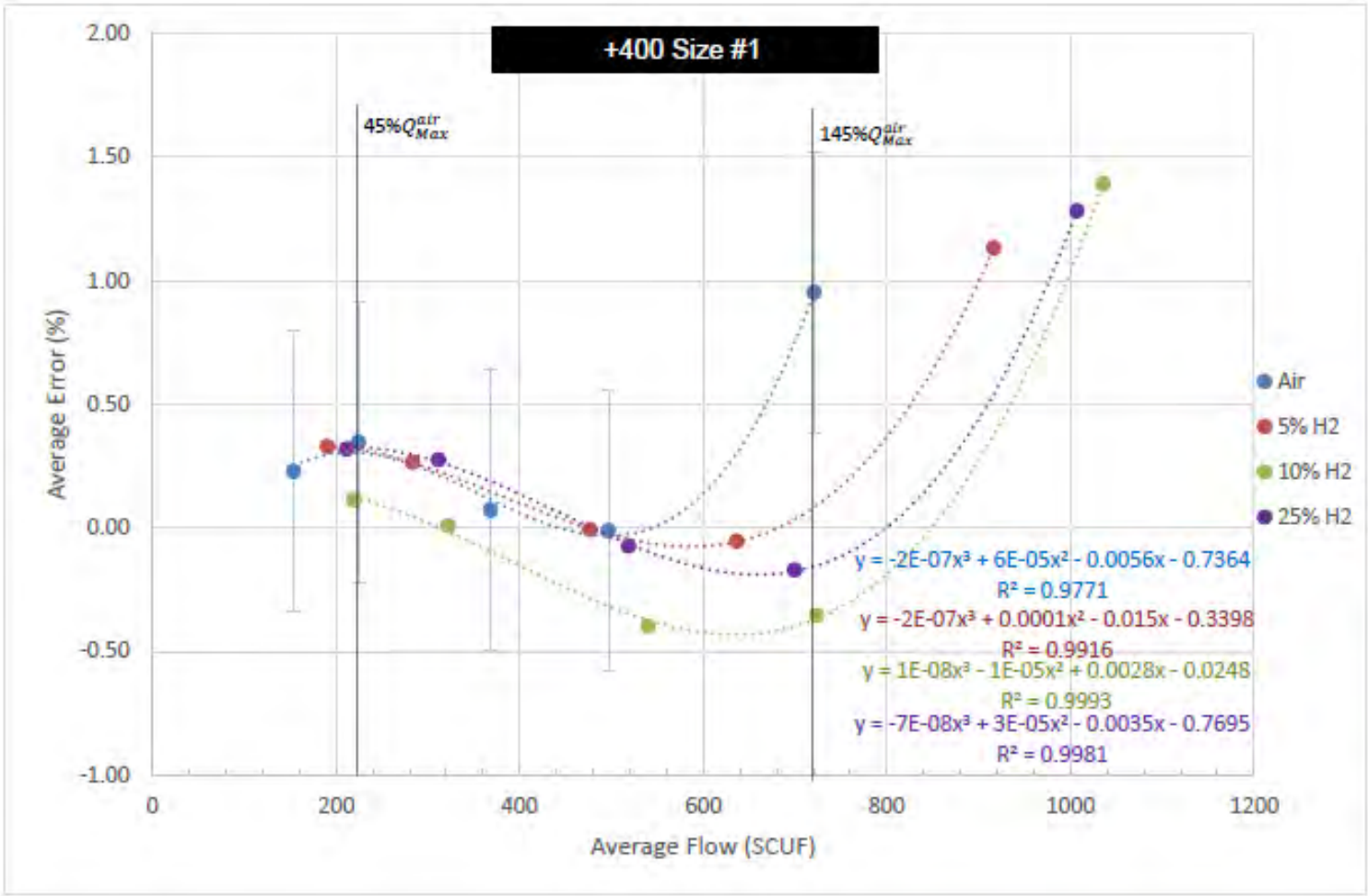
400 Size Meter #1



400 Size Meter #2



400+ Meter Size #1



Conclusions

Meter Performance Discussion

- A general trend of increasing %error with increasing equivalent %H2 in NG is observed to varying degrees.
- The magnitude of the %error observed for all meters, was still within reasonably acceptable guidelines (< |1.0%|) across all flow rates within 0 – 100% Q_{max} for all proxy test gases.
- While the trend of increasing % error with decreasing SG (or increasing %H2 in NG) may be attributable to the change in physical gas properties, it is also possible that the increasing % error is a function of the increased flow rates associated with the various proxy test gases.
- Although there were a limited number of units tested, the observations suggest that blending up to 25% hydrogen should be achievable with considerations to the appropriateness of the original meter sizing.

Next Steps

Next Steps

- An evaluation of meter durability within hydrogen blended gas service under real-world operating conditions is to be completed to further validate the non-impactful effect of hydrogen blended natural gas on metrological performance of diaphragm meters.

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Thank you