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Meter cleaning & a new internal coating

June 10, 2026 – CEESI Conference

Overview

Previous testing background :

- Three meters sent back to lab for contamination issues, & one additional case
- Cleaning is necessary for contaminated meters
- Getting back to baseline

Cleaning techniques & equipment :

- Rags, chimney sweeps, ball hones, steam
- Appropriate cleaning methods
- Safer setup for rotating equipment

A new internal coating :

- What if meter tube contamination could be reduced significantly?
- Ceramic coating
- Quantitative data/results
- Qualitative data/results

Future Work & Conclusions

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Case 1 – Hydro water

Original Flow Calibration

In Field Run Inspection

- **Hydrotest water leftover in header caused rust in top of meter**

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Case 1 – Hydro water

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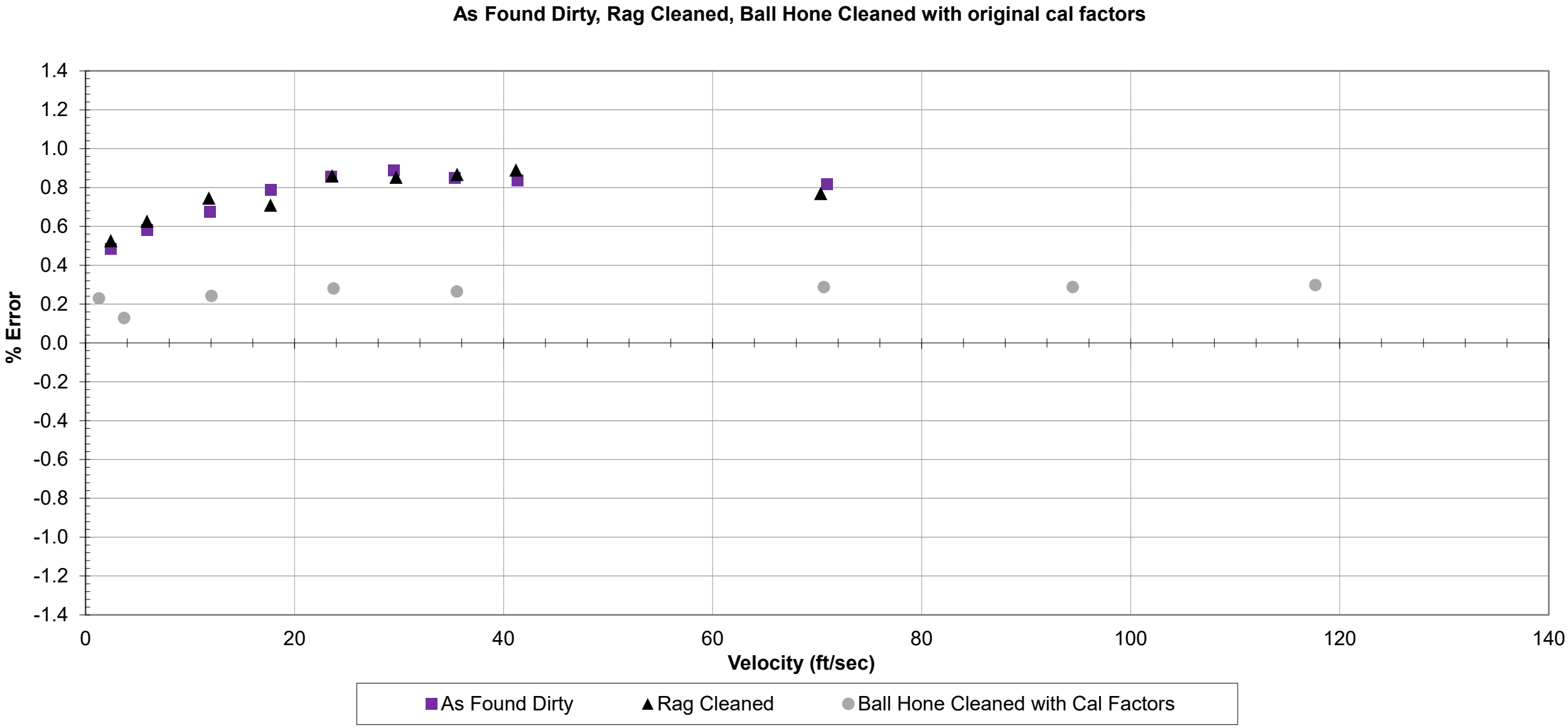
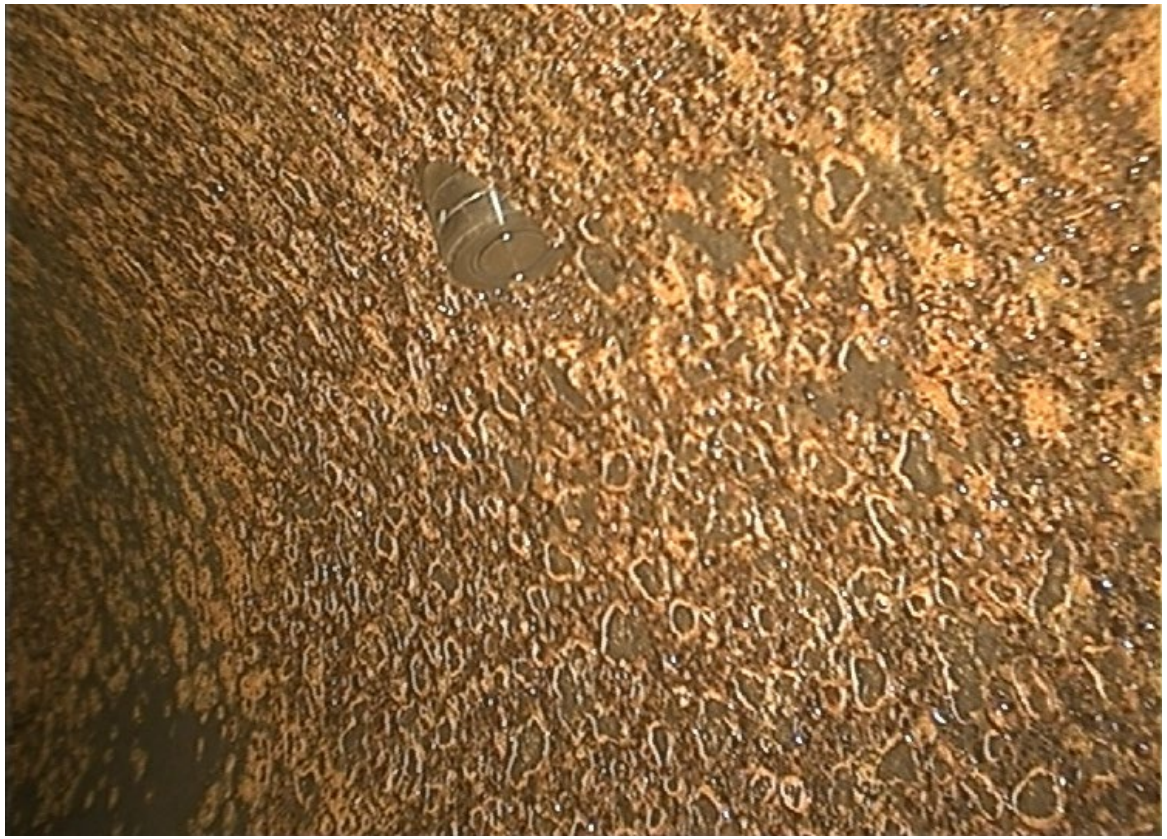
Case 1 – Hydro water

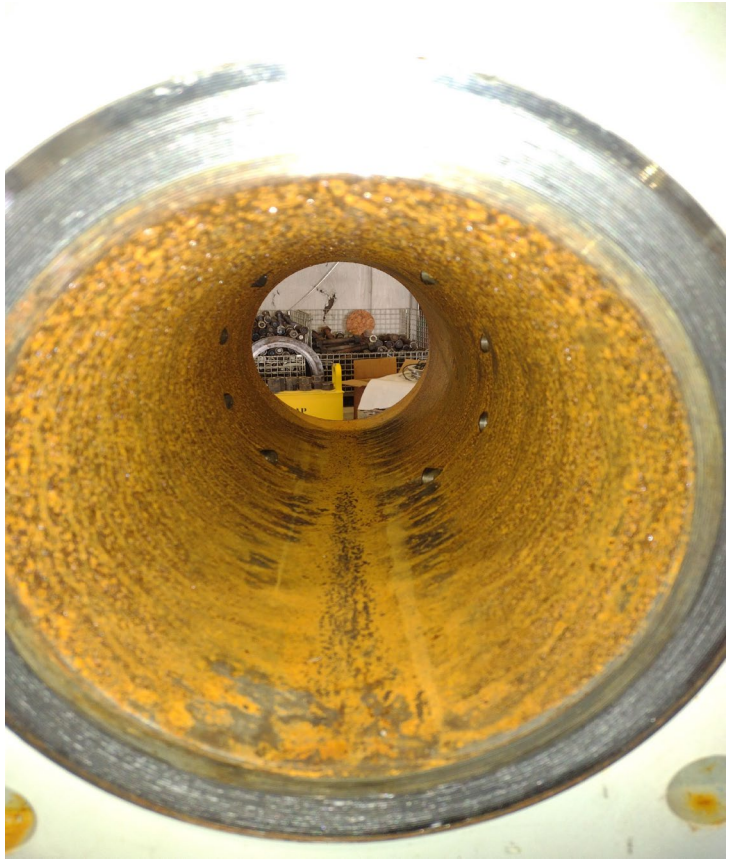


Case 2 – Open air rusting

In Field Run Inspection



AF condition @ CEESI



- **Meter was blown down for an outage and left open to ensure safety (double block & bleed) without notice to Measurement Engineering**

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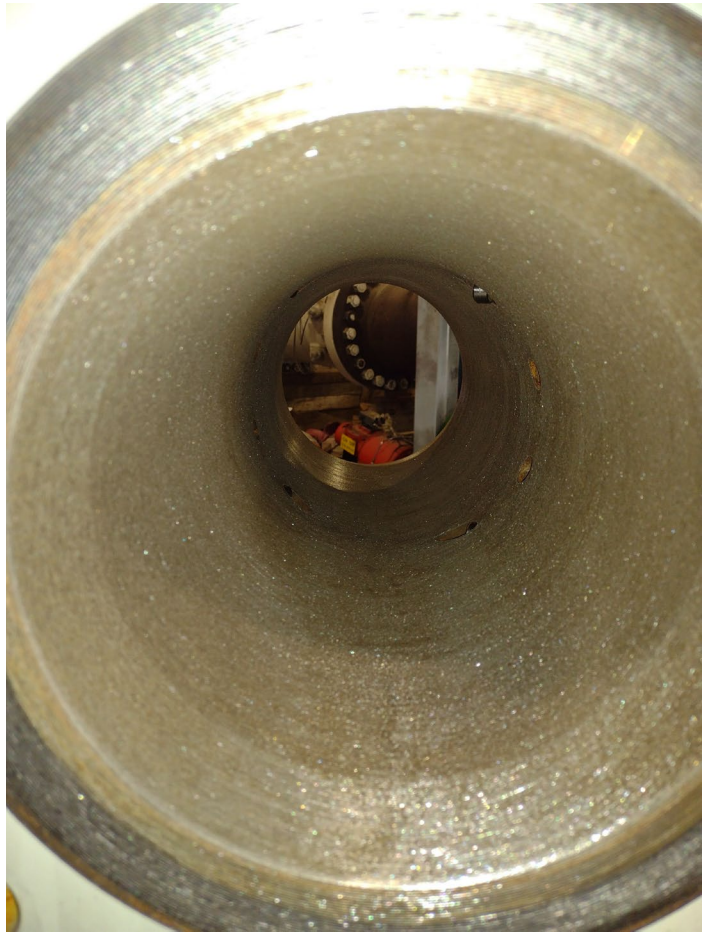
Case 2 – Open air rusting

- Meter Tube Disassembled
- Transducers Removed, Labeled, and Cleaned
- Ball Honed each segment



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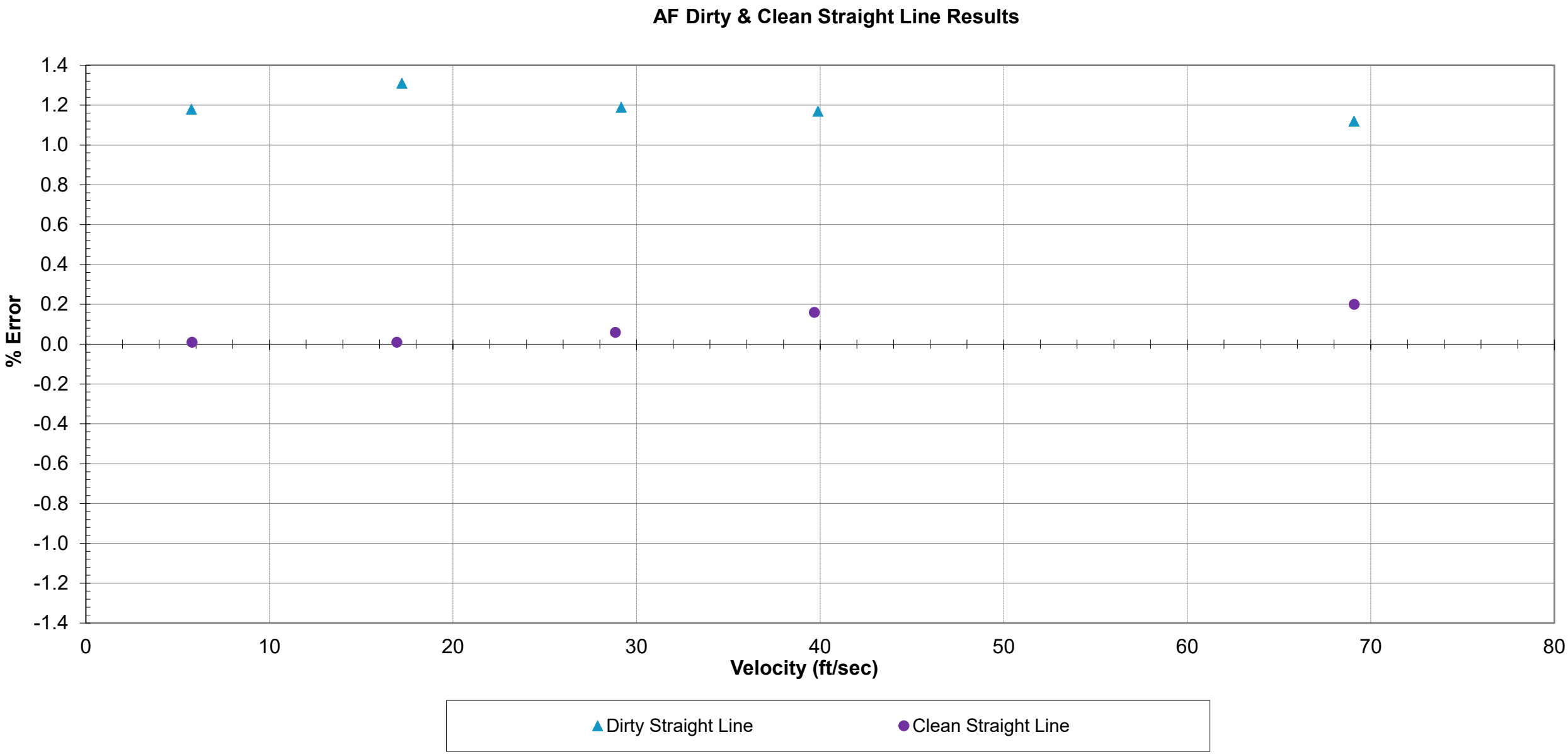
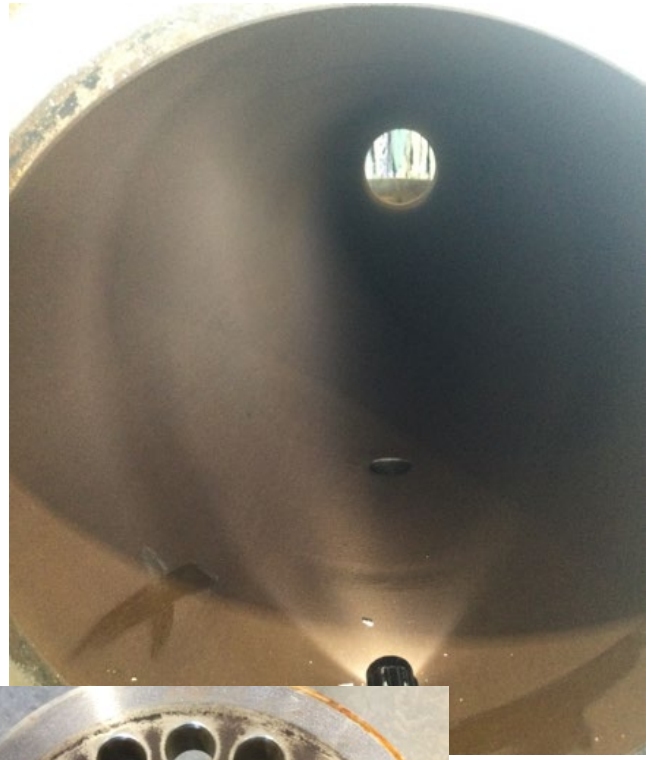
Case 2 – Open air rusting



Case 3 – Thin Dust Layer



10in Sick 4-path meter

- Cleaned with rags and wire brush
- Thin layer of pipeline dust, evenly distributed
- Same 4 points w/existing cal factors

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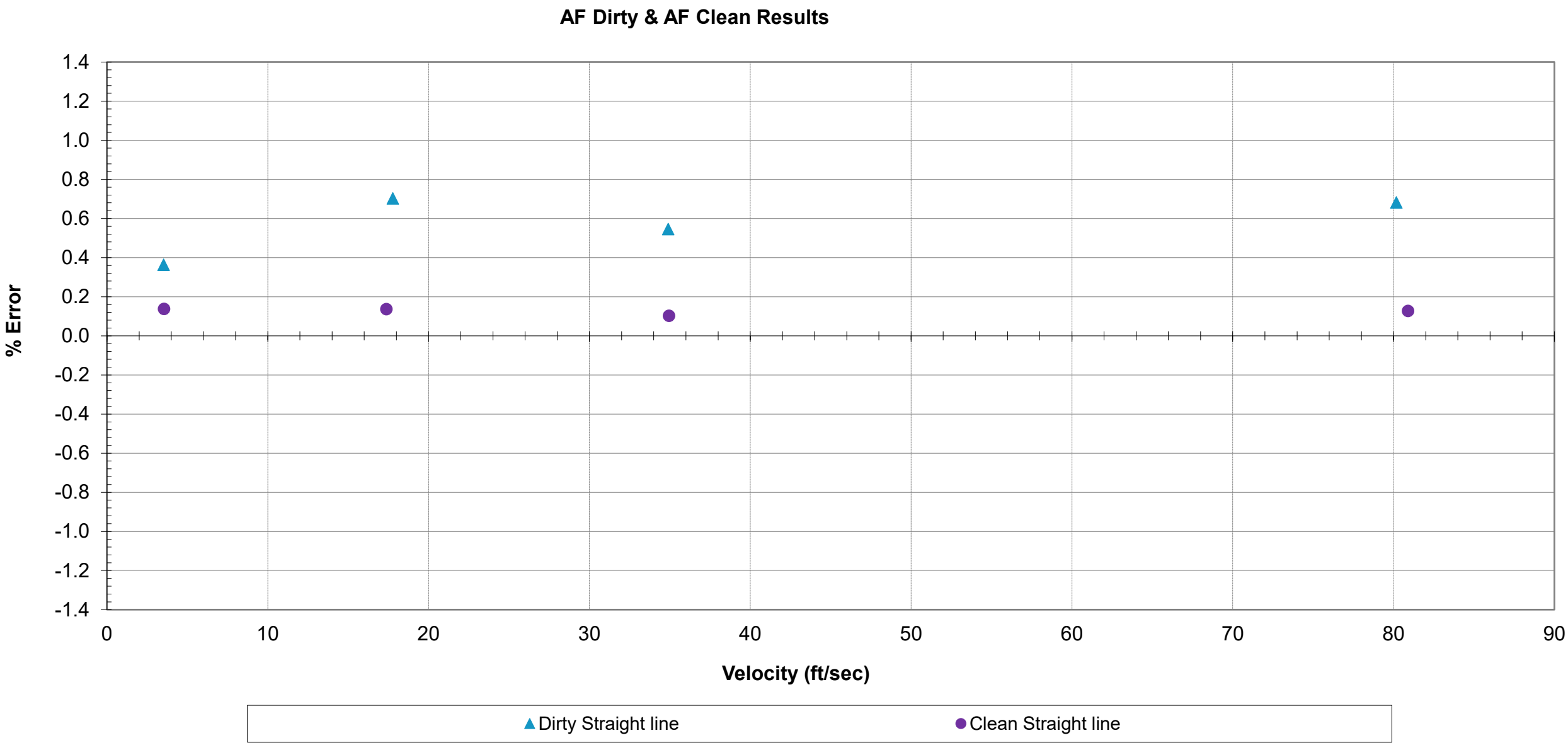
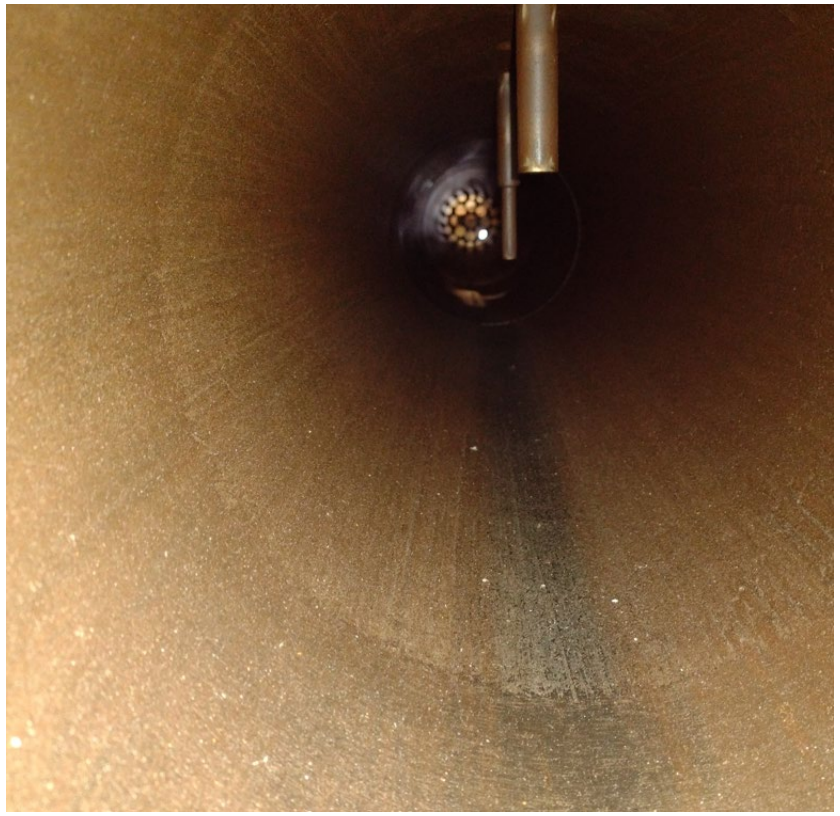
Case 3 – Thin Dust Layer



Case 4 – Clean Meter Transducer Swap



Dirty

Clean

- Dirty vs. Clean testing completed prior to T-200 transducer install
- Meter was largely free of rust, dust, debris. Some discoloration/patina.
- Some buildup on transducers & thermowells

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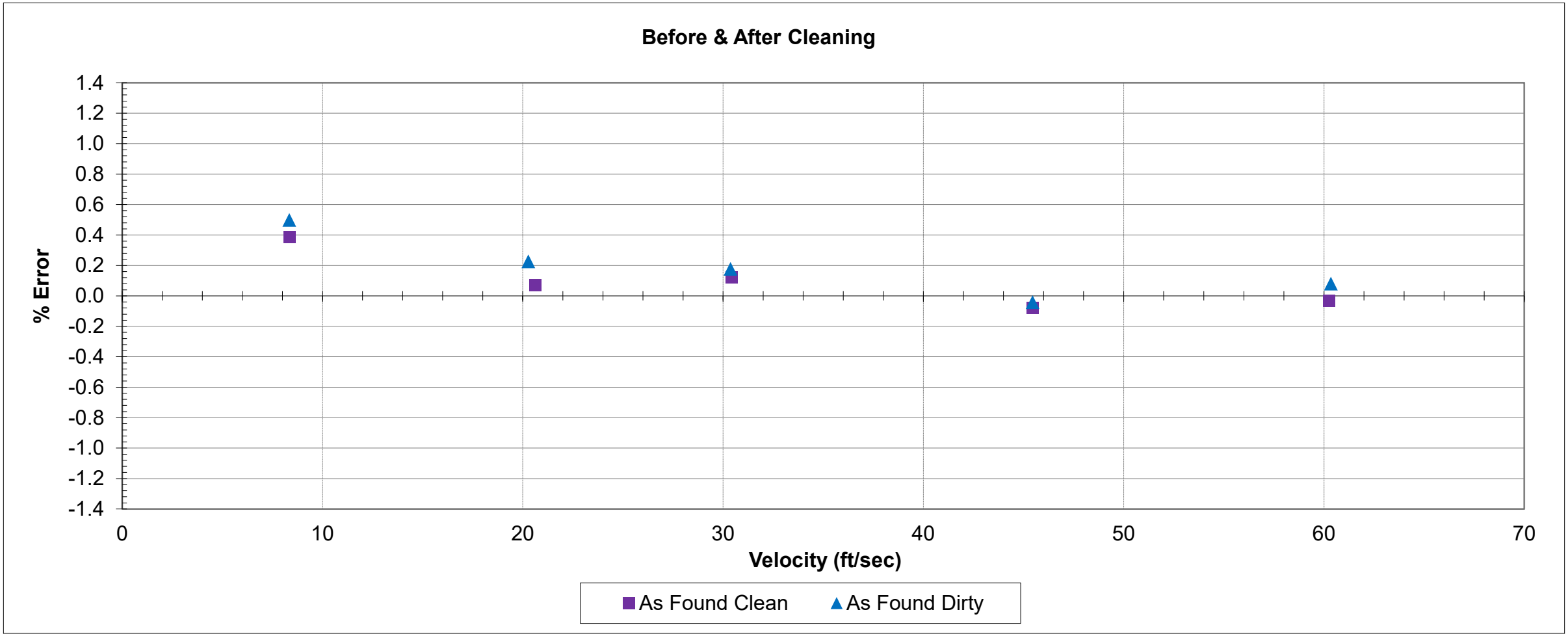
Case 4 – Clean Meter Transducer Swap



- Five point as found tests at CEESI-Iowa. Average of 0.1% difference.
- Original calibration factors from 2004 still in the meter during this 2023 test

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Back to Baseline

- **Successful cleaning is likely to return the ultrasonic meter back to original accuracy when taking repeatability & uncertainties of both the meter and the lab into account.**
- **Case #1**
  - Rag cleaning had almost no effect on accuracy
  - Ball honing did not remove all rust. Accuracy went from ~0.8% to ~0.25%.
- **Case #2**
  - Ball honing brought meter back from ~1.2% to ~0.1%
- **Case #3**
  - Wire brushing brought meter back from ~0.6% to ~0.15%
- **Case #4**
  - Relatively clean meter showed ~0.1% difference when comparing dirty to clean results

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Cleaning Techniques – Part 1

- **Debris removal & grabbing**
- **Chimney sweeps**

Removal of a piece of poly pig using a grabbing tool with borescope taped to the grabber

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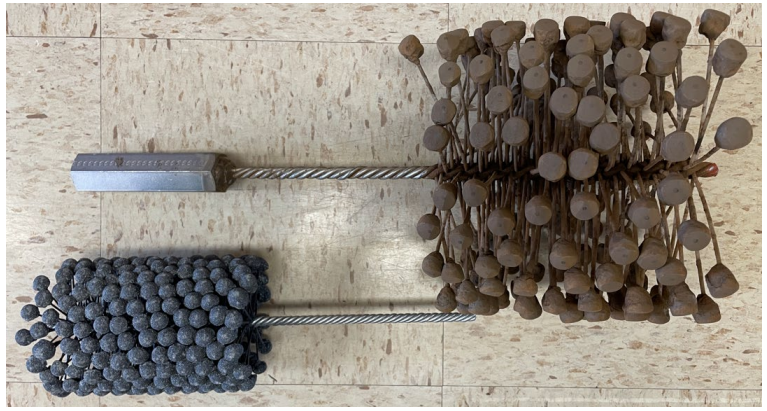
1) https://en.wikipedia.org/wiki/Chimney_sweep
2) MEECO'S Chimney Brush — 6in. Round, 1/4in. NPT

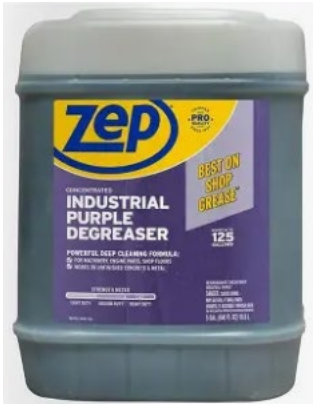
Cleaning Techniques – Part 2

- **Ball hone**
  - Rotary tool with plastic rods with abrasive balls on the ends.
  - Comes in different grit and abrasive media
  - Wears down over time
  - Used with or without towel/rags depending on the type of cleaning required.
- **Degreasers**
  - Clear usage with your Environmental folks beforehand!

Used 8” hone (top) and a new 4” hone (bottom)



Hone in a 8” meter tube



Ball hone wrapped in rag, post cleaning

3) Picture courtesy of 10X Measurement & Controls

Cleaning Techniques – Part 3

- **Steam or Hot (or cold) water pressure wash**
  - Good for greases, sludge.
  - Not great for rust/corrosion

Power wash extension wand – prior to BHE GT&S glove rule

Hot water pressure washing trailer[3]

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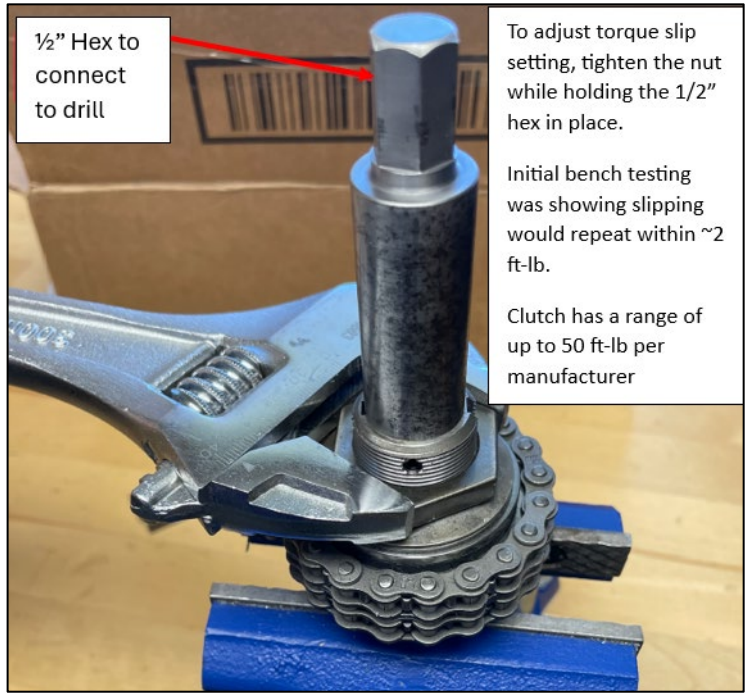
3) Picture courtesy of 10X Measurement & Controls, Inc.

Custom Honing Setup

- **BHE GT&S has minimized safety risk related to ball honing via:**
  - Customized equipment
  - Revised cleaning procedures

Custom Honing Setup

- **Drill**
  - Cordless 60V
  - Electronic clutch in case of anything jamming
- **Mechanical clutch**
  - Slips at 50 ft-lb, and is adjustable
  - Protects operator if anything jams
  - Drill adapter only comes with the clutch end. This makes it harder to bypass
  - Custom cover
- **Teflon covered pipe stand**
  - Optional, but sometimes convenient. Won't tear up equipment



Slip clutch without it's cover & installed in vise to adjust the slip setting.

Dewalt 60V drywall mud mixing drill w/clutch sitting on Teflon blocked pipe stand.

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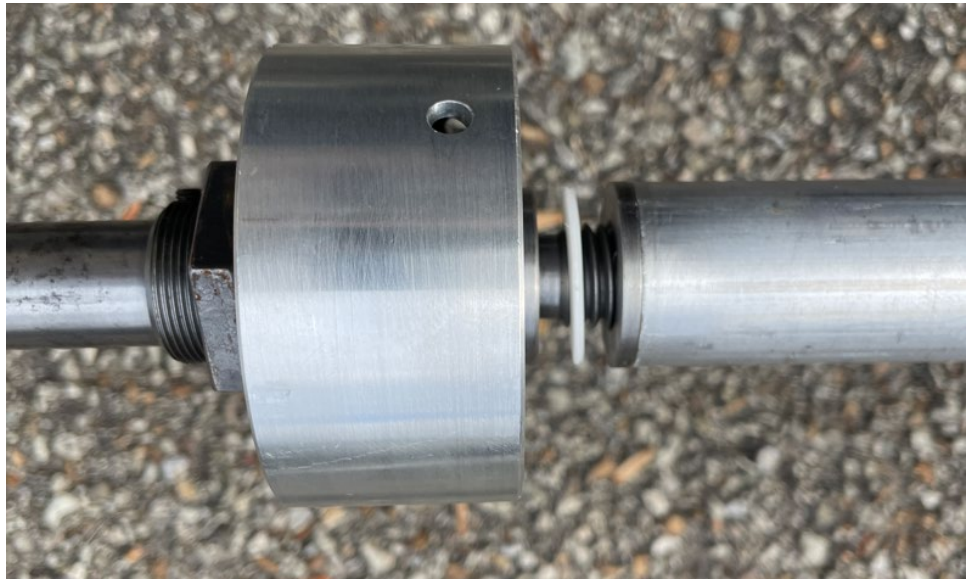
3) Picture courtesy of 10X Measurement & Controls

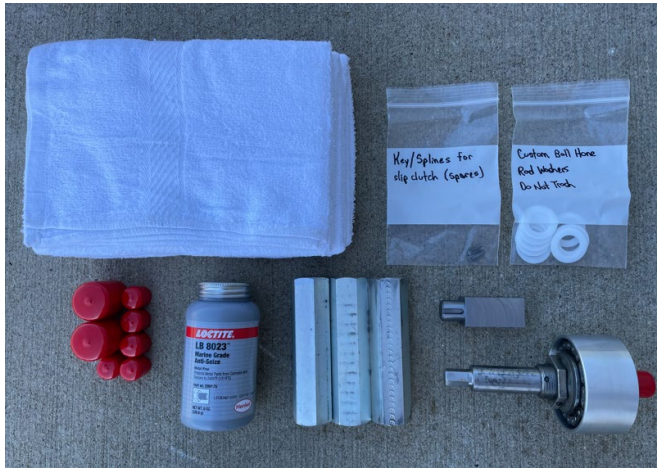
Custom Honing Setup

- **Threaded connectors**
  - ¾ inch all thread
  - No protrusions that could catch on anything, including hands.
  - Electronic clutch in case of anything jamming
  - Teflon washers make disassembly much easier
- **Rods**
  - 1 inch aluminum conduit
  - No protrusions that could catch anything
  - 5’ or 3’ lengths
- **Hone Connection**
  - Long hex nut, welded
  - Hone’s braided shaft often needs straightened before each job.

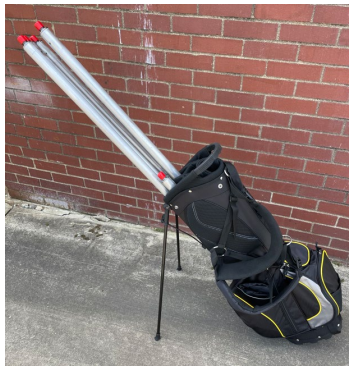
Tight rod to rod connection.



Clutch to 1st rod connection, loose.



Accessories for ball honing kit



Golf bag storage & transport

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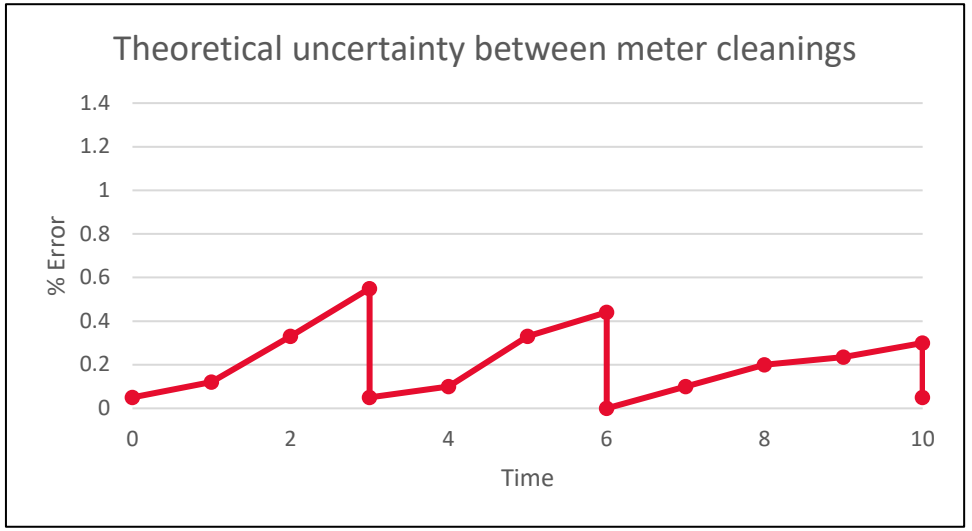
3) Equipment purchased by BHE. Drawings & machining by Avanti Engineering (Delmont, PA).

Why an Internal Coating?

- **Uncertainty - real world conditions**
  - Contamination happens over variable periods of time.
  - Cleaning only happens at specific points in time.
  - Some types of contamination are difficult to detect with meter diagnostics
  - Cost & labor availability
- **Safety**
  - Ball hones & brushes = rotational energy hazard
    - Misaligned & bent components, bouncing!
  - Steam hazards
  - Pressurized washing hazards
  - Hazards from improvised equipment
- **Environmental**
  - Risk for spills
  - Proper disposal of solids/liquids



3” ball hone on chimney sweep rods

Extension that is shop fabricated square/hex bars & pipe nipples?

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Internal Coating Selection

- **Traditional internal coatings are focused on flow efficiency**
  - Potentially too smooth
  - Interference with transducer ports, crispness of machined edges
  - What happens when it falls off?
- **Cerakote's F-Series**
  - Used on gun parts & other items
  - Thin film ceramic coating.
  - No PFAS (forever chemicals)
  - Some corrosion testing info available, but nothing related to ultrasonic meter accuracy
- **Color**
  - Light (easier inspection)
  - Recognizable

Cerakote F-Series in orange

Comparison of Manufacturer specifications for various internal coatings

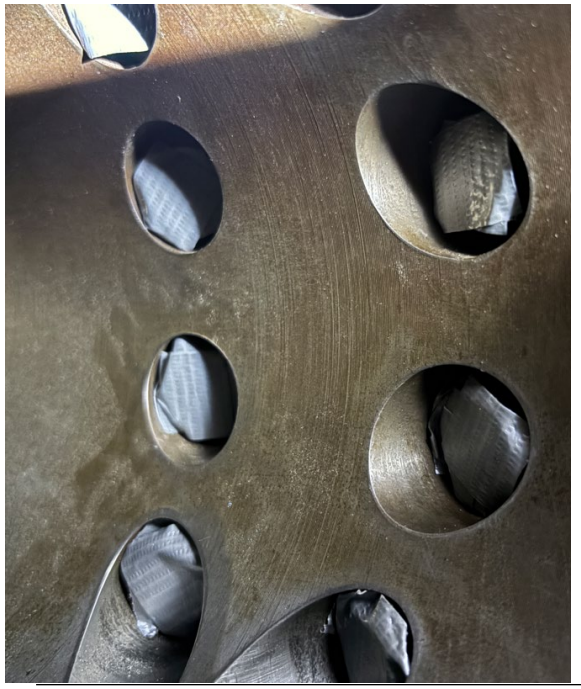
Coating Product	Dry Film Thickness (mils)	Dry Film Thickness (in)	Dry Film Thickness (mm)	Surface Roughness (Rz)
Hempel HS-87831	2.8 - 3.1	0.0028 - 0.0031	0.071 - 0.078	Not specified
Sher. Williams Pipeclad 930R HS	1.9 - 2.2	0.0019 - 0.0022	0.048 - 0.056	1.3 micron
Carboline Polyclad 956	2 - 6	0.002 - 0.006	0.051 - 0.152	Not specified
Cerakote F-Series	0.75	0.00075	0.019	Not specified

Note: Many coating systems allow for multiple coats. Numbers in this table are for a single coat.

4) Cerakote F-Series web link

Internal Coating Application

- **Surface preparation is more intense than typical pipeline external painting**
- **Thin film is not forgiving during application**
  - Already done on 6”, 8”, and 12”. Likely minimum size is 4”. Larger sizes should be easier.
- **Not easily applied in the field. Shop application is best**
- **Cure time of ~24 hours at ambient. Or shorter in heated booth**



Transducer faces protected by duct tape (prior to blast)

Portion of meter body after surface prep

Rotary applicator just after applying a coat

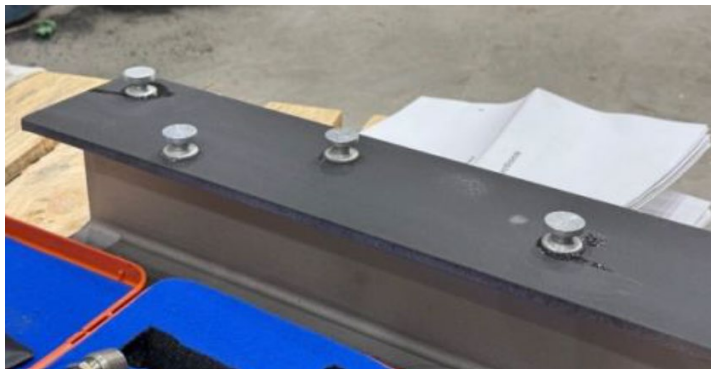
4) Cerakote F-Series web link

Internal Coating – Adhesion

Cohesive Failure

Glue Failure

- **Pipeline integrity & internal corrosion concerns**
- **Process to get approval for new coatings**
- **Results show better adhesion than typical pipeline coatings**
  - Plate steel
    - Two samples maxed out at 1000 lb/in^2
    - One sample had failure at 900 lb/in^2
  - Wide flange beam
    - two samples maxed out at 1000 lb/in^2
    - One sample failed at 950 lb/in^2. Failure of the glue, not the coating



Wide beam test setup

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Internal Coating – Thin Film Error?

- **Problems**
  - What if this coating was applied after calibration?
  - What if the coating fails & falls off?
- **Calculations below show percent change in the cross sectional area.**
  - Some relation to error in flowrates, but not directly
- **Caveats**
  - Assume that the meter ID is not updated from original
  - Assume that no calibration has taken place.
- **Thinner is likely better**

Percent change in cross-sectional area due to a 0.75 mil thick coating					
Description	**4 inch**	**6 inch**	**8 inch**	**12 inch**	**24 inch**
Uncoated ID (in)	4.026	6.065	7.981	11.938	22.624
Coating Thickness (in)	0.00075	0.00075	0.00075	0.00075	0.00075
Uncoated Cross-sectional Area (in^2)	12.73	28.89	50.03	111.93	402.00
Coated Cross-sectional Area (in^2)	12.72	28.88	50.01	111.90	401.95
% Change Cross-sectional Area	**-0.07%**	**-0.05%**	**-0.04%**	**-0.03%**	**-0.01%**

Percent change in cross-sectional area due to a 4.0 mil thick coating					
Description	**4 inch**	**6 inch**	**8 inch**	**12 inch**	**24 inch**
Uncoated ID (in)	4.026	6.065	7.981	11.938	22.624
Coating Thickness (in)	0.004	0.004	0.004	0.004	0.004
Uncoated Cross-sectional Area (in^2)	12.73	28.89	50.03	111.93	402.00
Coated Cross-sectional Area (in^2)	12.68	28.81	49.93	111.78	401.72
% Change Cross-sectional Area	**-0.40%**	**-0.26%**	**-0.20%**	**-0.13%**	**-0.07%**

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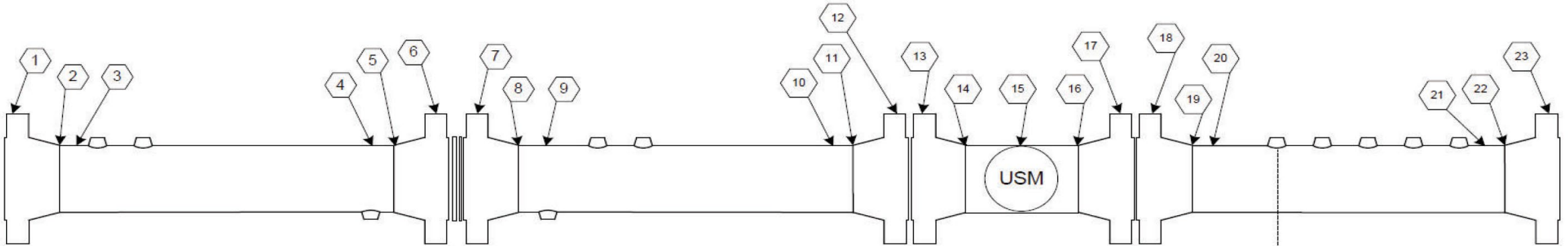
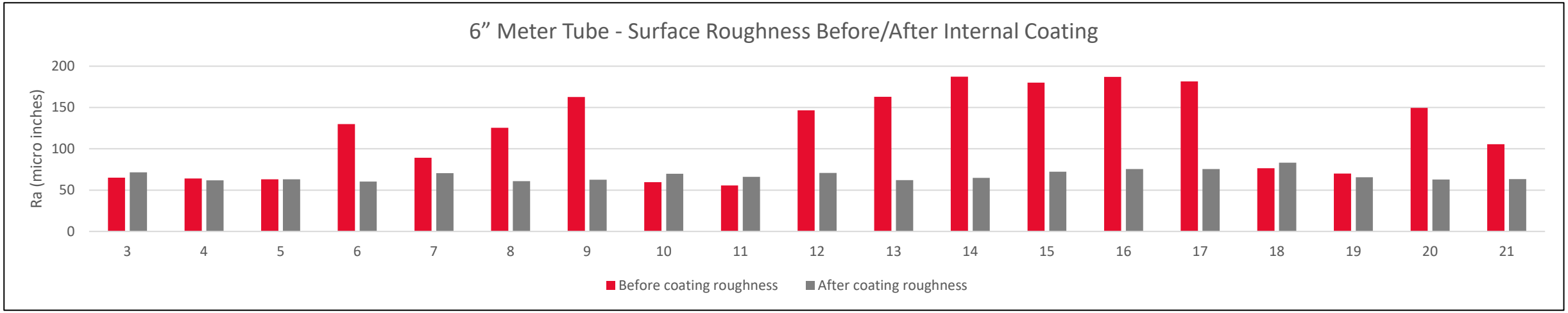
Internal Coating – Surface Roughness

- **Ceramic coating process made the surface roughness readings more consistent**
  - Positions 1, 2, 22, & 23 not taken due to concentric reducers
  - Note: PRCI research shows that surface roughness in typical ranges does not significantly affect uncertainty. Current version of AGA 9 accepts this.

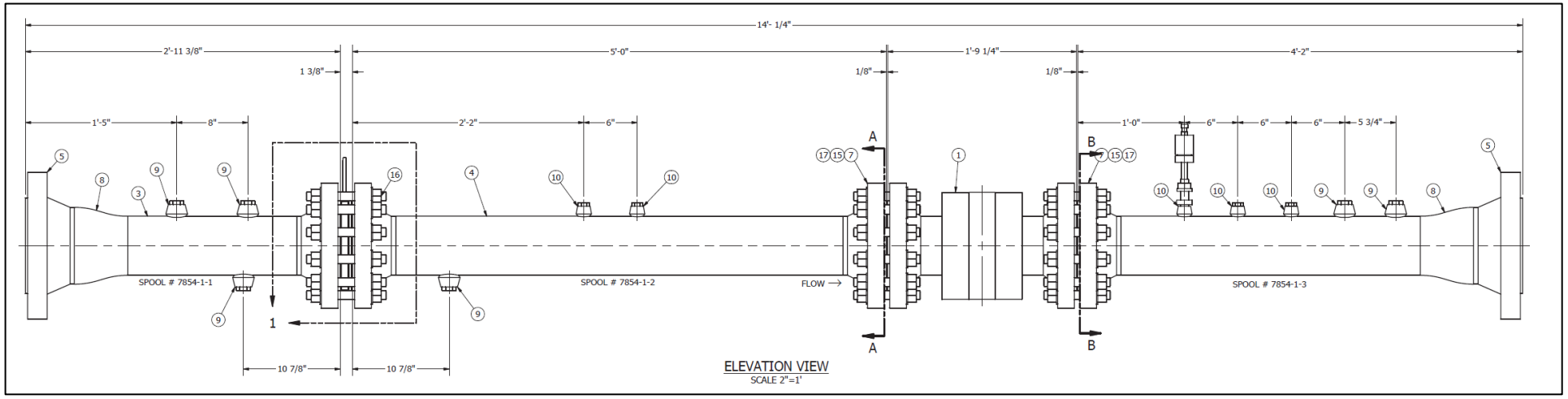




5) PR-015-20606-R01 Practical Effects of Rough-Walled pipe in Gas Metering Applications | PRCI

Flow Testing

- 6” Sensia 380Ci meter
- Replacing an 8” turbine meter in the field
- Meter body previously used in a storage suction line
- 1st = Uncoated flow test
- 2nd = Back to coating shop, disassembled, internally coated, reassembled
- 3rd = Coated flow test



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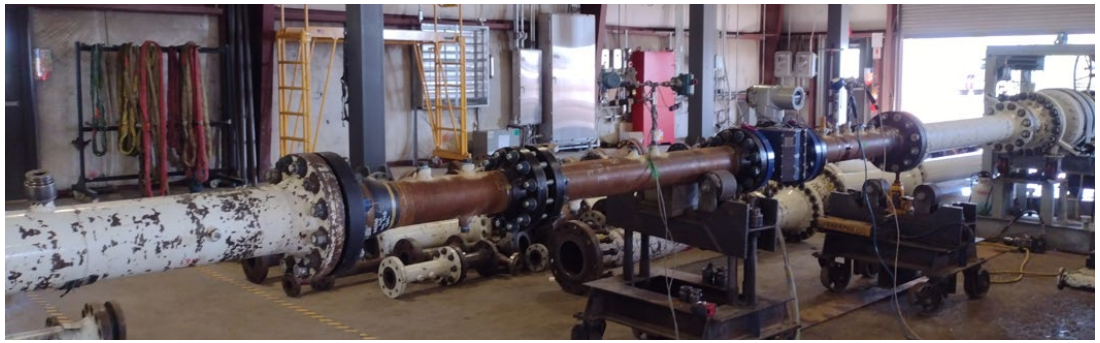
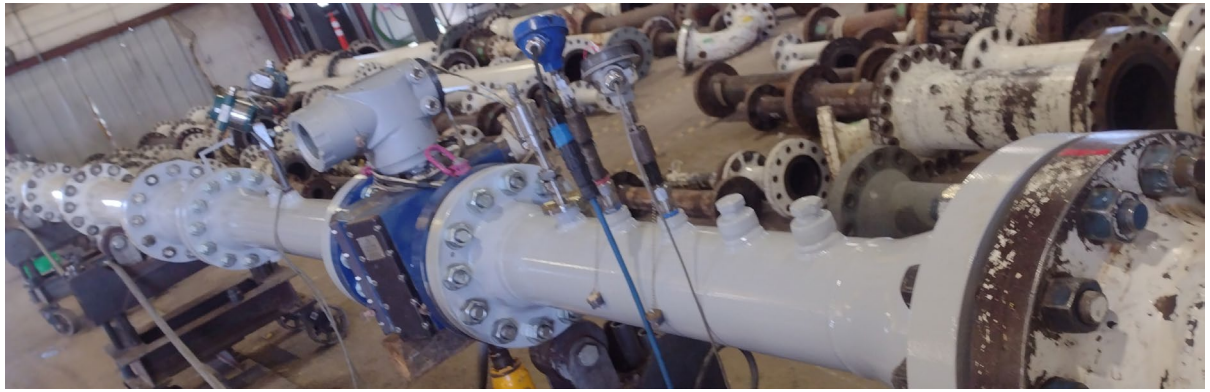
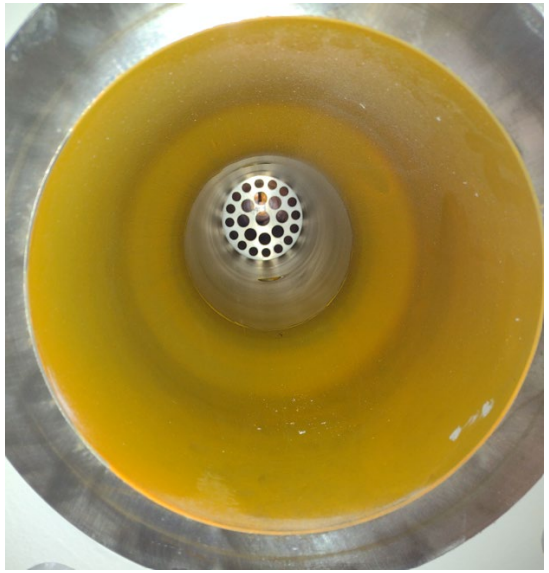
Flow Testing

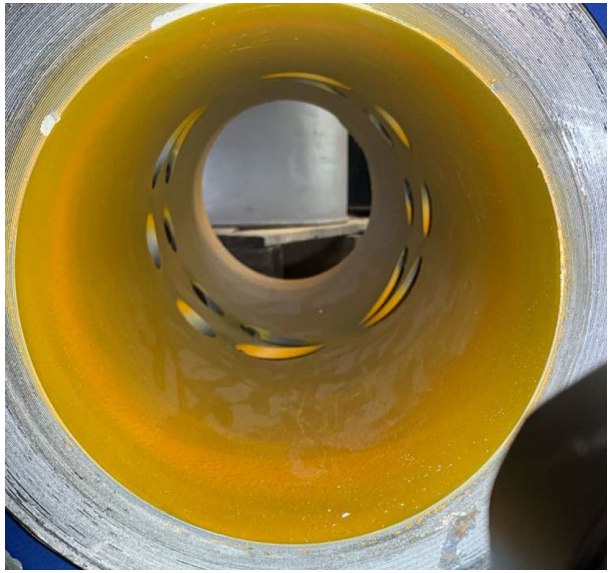
- **Uncoated**



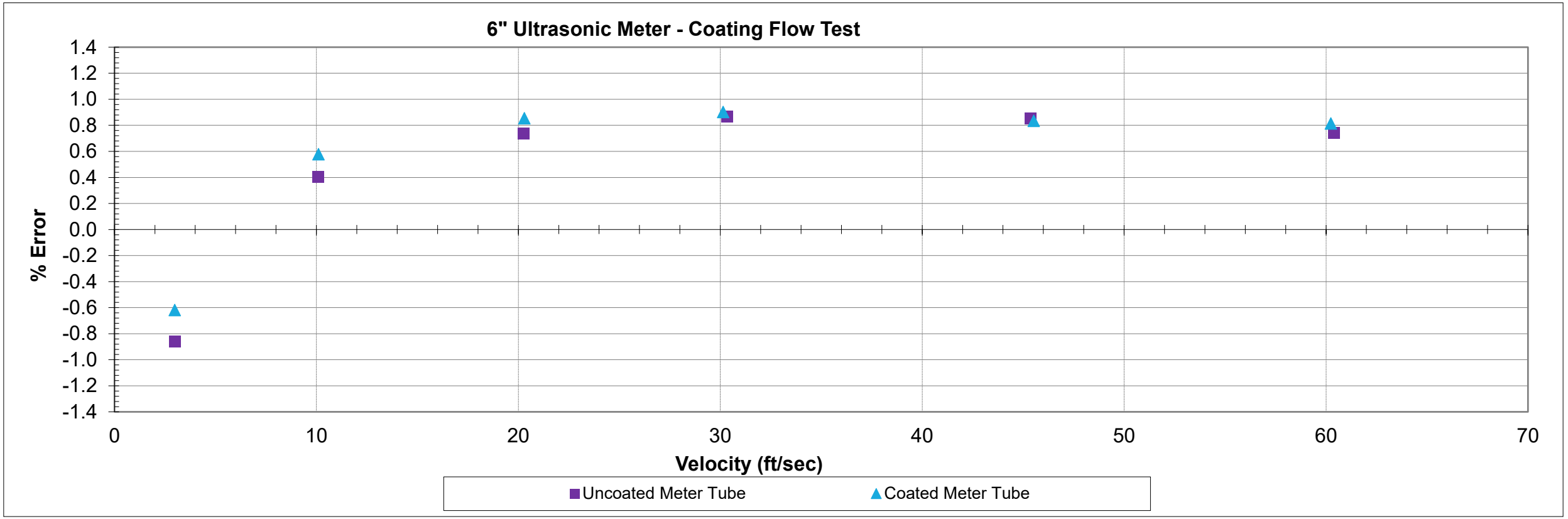
- **Coated**







Flow Testing Results



- Tested uncoated in July 2025 & coated in September 2025
- No cal factors in meter
- Average of 0.104% difference.

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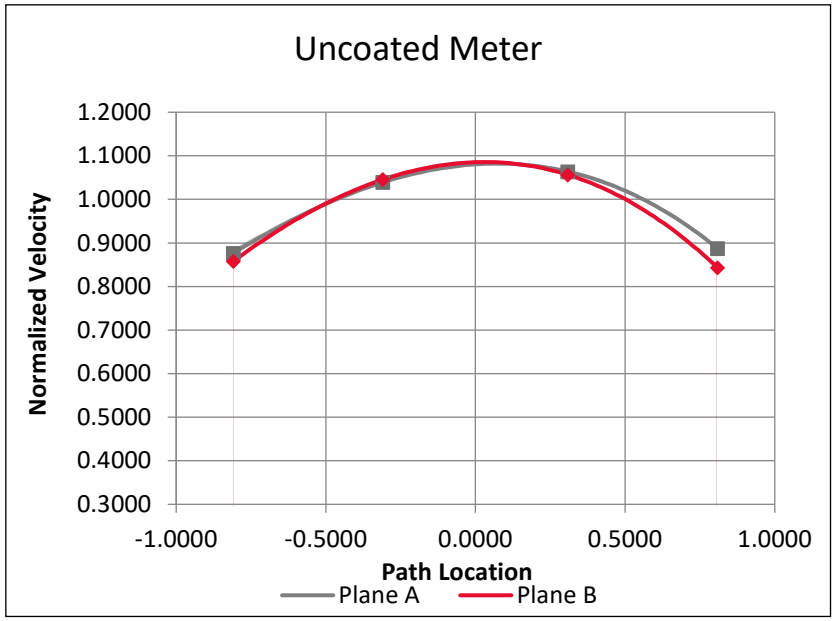
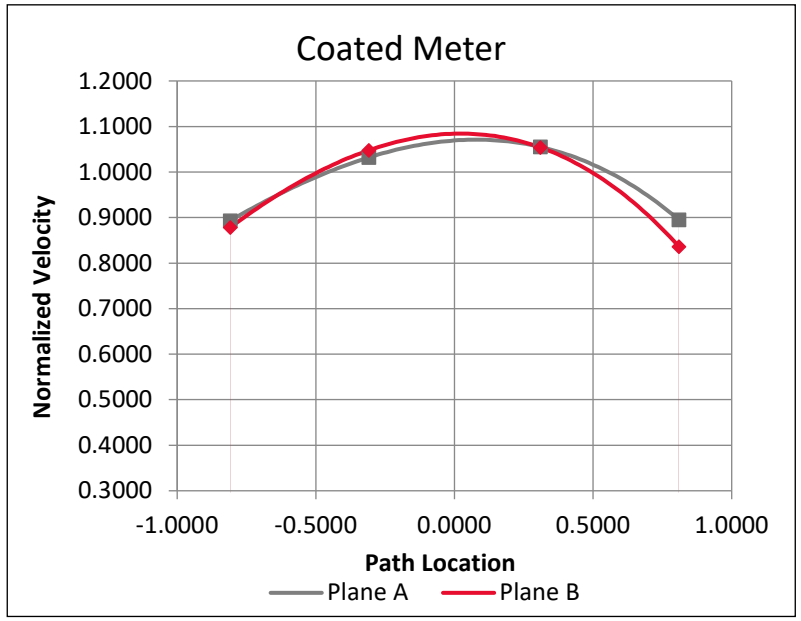
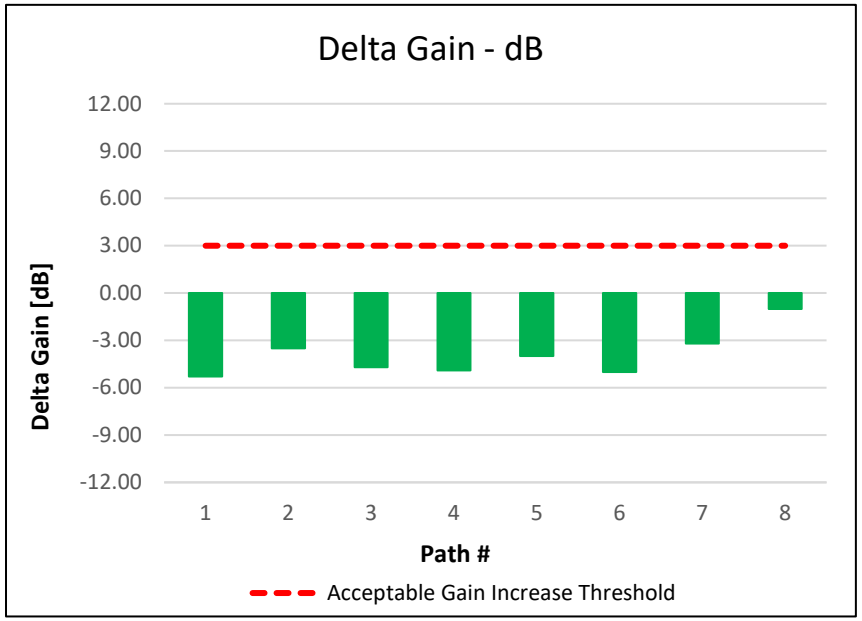
Flow Testing Results







- **Gain & normalized velocity info taken at 20 ft/s for both uncoated & coated**
- **Across 8 paths, the coated meter gains were reduced as compared to the coated meter**
  - Potential that blasting & coating process caused the gain reduction
  - Potential that ceramic coating absorbs less of the ultrasonic signal than a bare steel meter body.

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6” Field Check

- **Borescope inspection on 5/21/2026 after ~6 months of flow**
  - No signs of contamination & meter diagnostics appear good

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Test Spools

Test spools for internal coating						
ID #	Fitting/Test Description	Cerakote Applied?	Cure Temp (°F)	Cure Method	Ball hone post Cerakote?	Install Notes
1	Cerakote spool left at Core shop	Yes	120	Heated Booth	No	Outside Core Industrial's shop
2	Control spool left at Core shop	No, control	-	-	-	
3	Cerakote - heated cure	Yes	120	Heated Booth	No	Installed in flowing pipeline on 12/3/2024
4	Control spool	No, control	-	-	-	
5	Cerakote - ambient cure	Yes	~70	Amb. Shop	No	
6	Cerakote - heated cure & honed	Yes	120	Heated Booth	Yes	
7	Hydro water test - control	No, control	-	-	-	Added water on 11/6/2024, left in pipe yard to be exposed
8	Hydro water test - Cerakote	Yes	120	Heated Booth	No	
9	Pipe left open test - control	No, control	-	-	-	Added water on 11/8/2024, left in pipe yard to be exposed
10	Pipe left open test - Cerakote	Yes	120	Heated Booth	No	
11	Pipe left open test - Cerakote	Yes	~70	Amb. Shop	No	
12	Pipe left open test - Cerakote	Yes	120	Heated Booth	Yes	

- **Twelve 6” pipe spools fabricated**
- **Testing internal coating over time**
  - Coated or uncoated
  - Ambient temp cure vs. 120F cure
  - In pipeline service
  - Sitting in pipe yard & open to weather
  - Undamaged coating vs. damaged coating
- **Test is ongoing**

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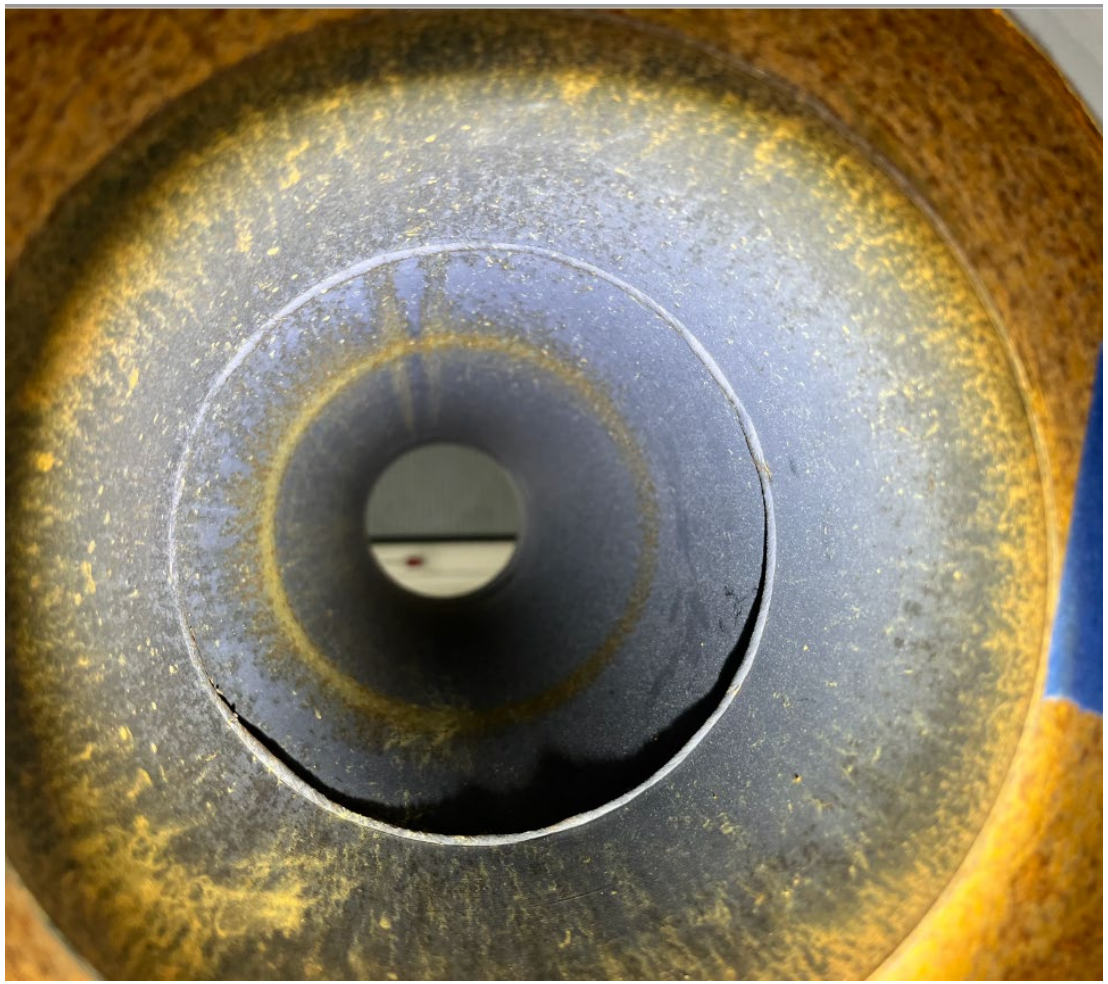
Test Spool Results (#1-2)

- **Two spools left at Core Industrial coating shop outdoors for ~5 months.**

Cerakote spool (black) at end of test period. Post cleaning with Dawn soap &water.

Control spool at end of test period. Post cleaning with Dawn soap &water.



6) Pictures from report by Core Industrial Group (Milton, WV)

Test Spool Results (#3-6) - Part #1

Spool #3 – Cerakote (black) and heat cured. Notice more contamination lingering in the uncoated pipe adjacent to the coated spool.

Spool #4 – Control spool uncoated. Typical low grade paint used on flanges/pipe prior to sale & fabrication. Notice the contamination congregating in the uncoated spool.

- **Four spools in a flowing pipeline (storage suction line)**

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Test Spool Results (#3-6) - Part #2

Spool #5 – Cerakote (black) and ambient cured. Notice more contamination lingering in the uncoated pipe adjacent to the coated spool.

Spool #6 – Cerakote (black) and heat cured. Ball honed after coating to damage the coating.

- **Four spools in a flowing pipeline (storage suction line)**

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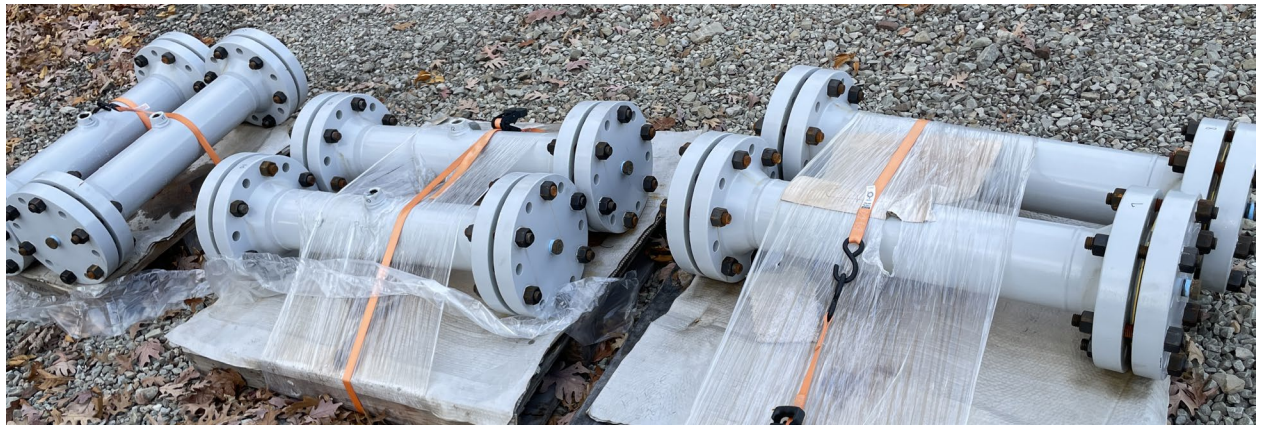
Test Spool Results - #7-#12

- **Six spools left in the local pipe yard (Pennsylvania) and left open & exposed to the elements.**
  - November 2024
    - Initial setup & added water. 1” TOL’s left open to atmosphere.
  - October 2025
    - Removed water and opened for inspection
  - May 2026
    - Added valve grease & valve sealant. Two weeks later cleaning was performed with towel covered hone, bare honing, and finally hand wiping. Degreaser was also used.
    - Only half of each spool length was cleaned to allow for test to continue.



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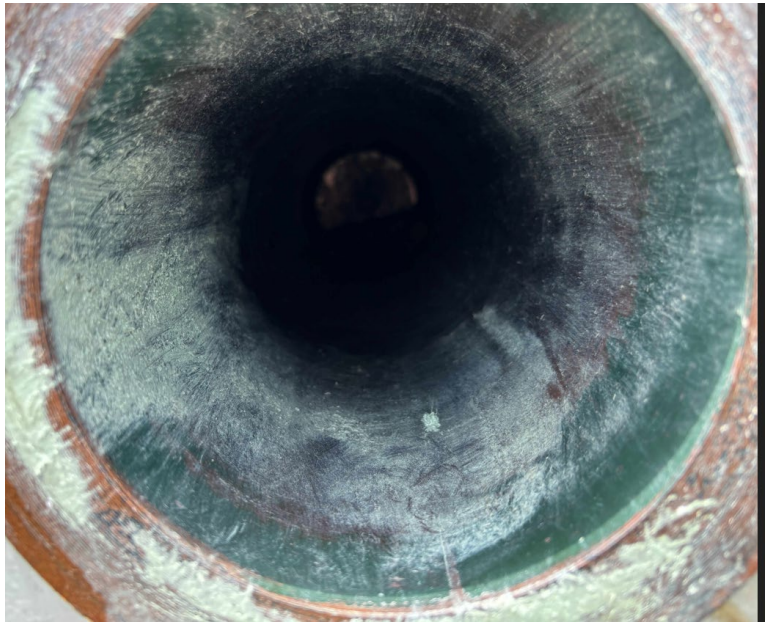
Test Spool Results - #7

Grease & sealant added

After 1st ball hone cleaning. Hone covered by towel & degreaser used.



After 2nd ball hone cleaning. Hone was bare & degreaser used.

After final wiping by hand. Final condition.

- **Spool #7 – Control spool, no coating**

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Test Spool Results - #8

Grease & sealant added

After 1st ball hone cleaning. Hone covered by towel & degreaser used.

After 2nd ball hone cleaning. Hone was bare & degreaser used.

After final wiping by hand. Final condition. Some damage to coating by bare hone.

- **Spool #8 – Cerakote, heated 120F cure**

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Test Spool Results - #9

Grease & sealant added

After 1st ball hone cleaning. Hone covered by towel & degreaser used.

After 2nd ball hone cleaning. Hone was bare & degreaser used.

After final wiping by hand. Final condition. Some damage to coating by bare hone.

- **Spool #9 – No Cerakote, control spool**

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Test Spool Results - #10

Grease & sealant added

After 1st ball hone cleaning. Hone covered by towel & degreaser used.

After 2nd ball hone cleaning. Hone was bare & degreaser used.

After final wiping by hand. Final condition. Minimal damage to coating by bare hone.

- **Spool #10 – Cerakote, heated 120F cure**

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Test Spool Results - #11

Grease & sealant added

After 1st ball hone cleaning. Hone covered by towel & degreaser used.

After 2nd ball hone cleaning. Hone was bare & degreaser used.

After final wiping by hand. Final condition. Minimal damage to coating by bare hone.

- **Spool #11 – Cerakote, ambient cure**

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Test Spool Results - #12

Grease & sealant added

After 1st ball hone cleaning. Hone covered by towel & degreaser used.

After 2nd ball hone cleaning. Hone was bare & degreaser used.

After final wiping by hand. Final condition. Damaged coating & rust showing through.

- **Spool #12 – Cerakote, heated cure, ball honed after initial coating**

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Test Spool Results - Summary

- **Reduction in corrosion**
  - Noticeable reduction in corrosion compared to uncoated spools
- **Reduction in contamination build up**
  - Noticeable reduction in the amount of pipeline fluid/solid in coated spools compared to uncoated.
- **Easier cleanup**
  - Of three personnel involved with cleaning the six pipe yard spools, all three noticed the coated & undamaged spools were smoother and easier to clean
- **Will monitor further as time progresses**

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Future Work

1. **More flow testing for similar meters & conditions.**
    1. Test a brand new meter
    2. Test different brand meters
    3. Test different path configurations
2. **Further investigation of the reduction in gain. Can this be attributed to the ceramic coating? Something else?**
3. **Further checking & evaluation of spools and meters that are already coated.**
4. **Further evaluation of surface roughness and whether or not the coating application process makes various honing/boring techniques less useful.**
5. **Suggestions?**

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Conclusions

1. The ceramic internal coating is helpful in efforts to reduce meter internal corrosion & contamination issues that are known to increase uncertainty.
2. Given a reduction in meter contamination, application of this coating will be able to reduce measurement uncertainty in real world conditions.
3. Even if the coating were to fail years or decades in the future, impact to uncertainty is likely to be minimal. This particularly applies to larger meter sizes.
4. This internal coating is suitable for use in meter tubes installed at custody transfer interconnects.
5. Reduction in contamination can reduce the amount of cleaning required. This can save labor costs, contractor costs, and methane emissions.

Thank you

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