



# **Unlocking Accuracy: Fundamentals of Natural Gas Flow Measurement with Clamp-on Ultrasonic Meters**

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## Clamp-on “Field Installed”

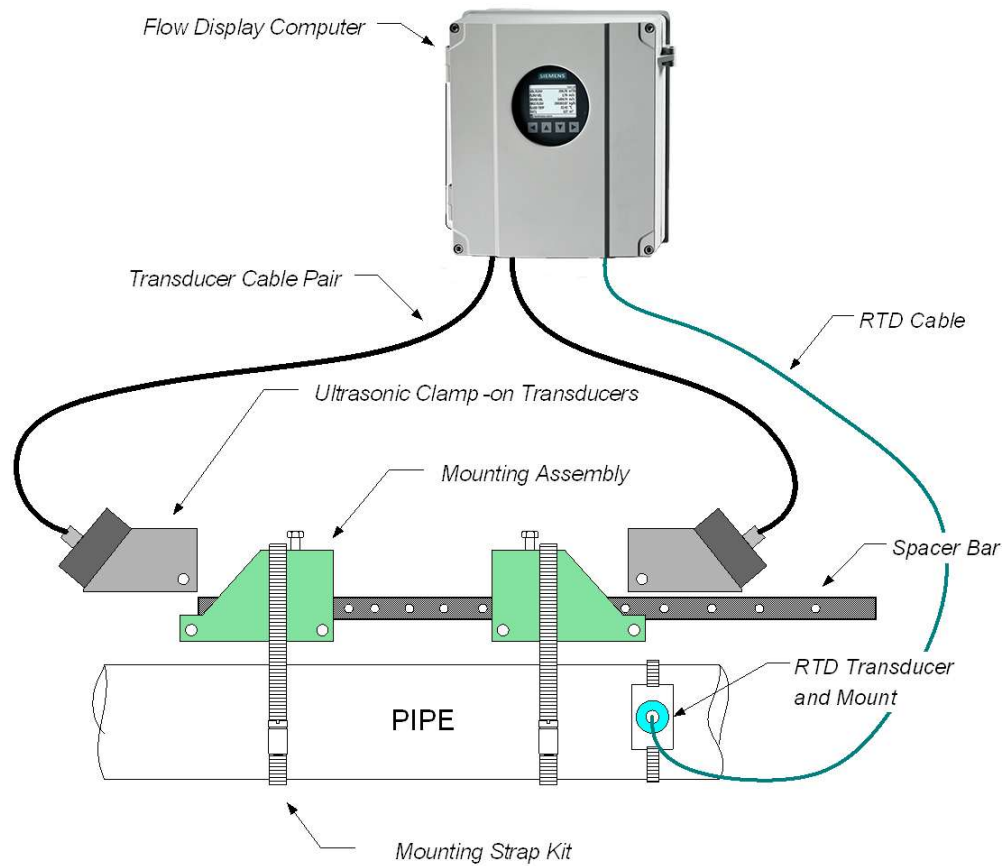
### Clamp-on – “Field Installed” meters

- External mounting of transducers designed for flexibility and convenience on existing piping
- Accuracy 0.5 – 1.0% of rate or better (**Working with some unknowns**)
- No flow calibration certificate

### What Drives Uncertainty in Field Installations (Uncertainty = installation + Fluid + meter)

- Assumed pipe geometry (ID, wall thickness, internal condition)
- Transducer placement and alignment variability
- Acoustic coupling dependent on installation quality
- Disturbed flow profile (swirl, asymmetry, insufficient straight run)
- No calibration tied to a traceable standard

## Ultrasonic Clamp-on system components



- Transmitter
- Sensors
- Mounting hardware
- Sensor cable
- Coupling compound



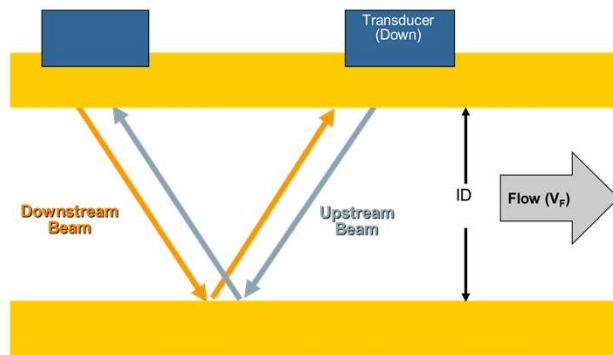
## Clamp-on ultrasonic system



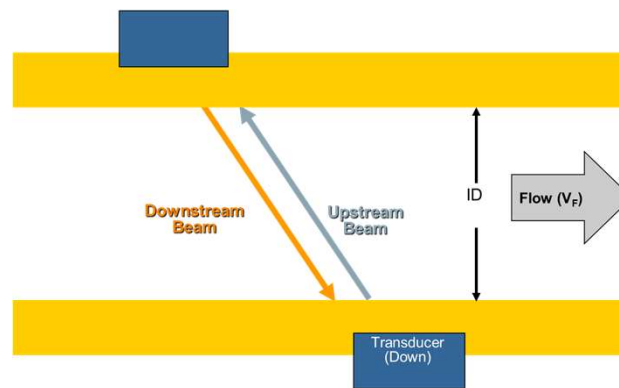
### Large-Diameter Natural Gas Pipeline (32")

- Multi-path clamp-on ultrasonic configuration
- External installation — no process interruption
- Minimal cost impact vs pipe size

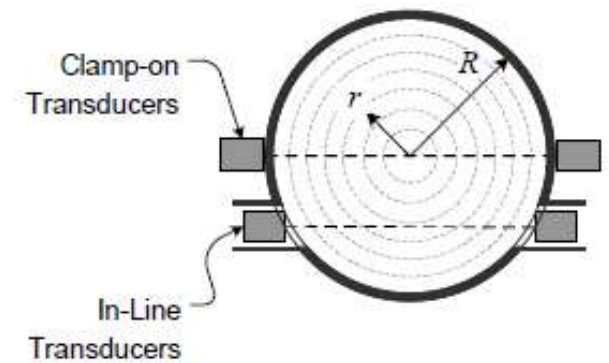
## Principles of operation (Reflect / Direct / Chordal)



**Reflect**



**Direct**



**In-line chordal**

## Sensor installation – Choosing a location

### Bad location

Insufficient straight pipe



### Excellent location

Long upstream straight pipe



Transducer location

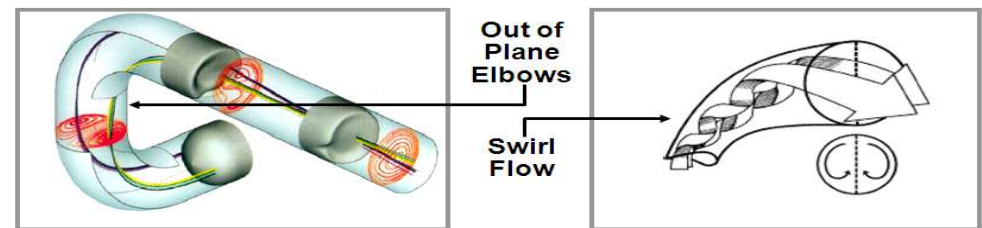


## Principles of operation – Flow profile

**Most flow meter types require sufficient straight piping run upstream to produce a fully developed flow condition**

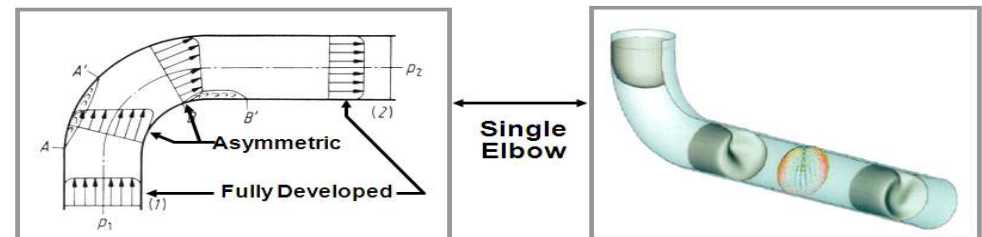
### Out of Plane Elbows

- Produces a full counter-propagating swirl that can persist for >40 diameters



### Single Elbow

- Distorts the flow profile for a short distance before resuming to fully developed





## Volume calculation

### Volume calculation

$$V = K(Re) \times \left( \frac{\pi}{4 \times Di^2} \right) \times v$$

$V =$

Volumetric Flow

$v =$

Flow velocity

$K(Re) =$

K factor from Reynolds number

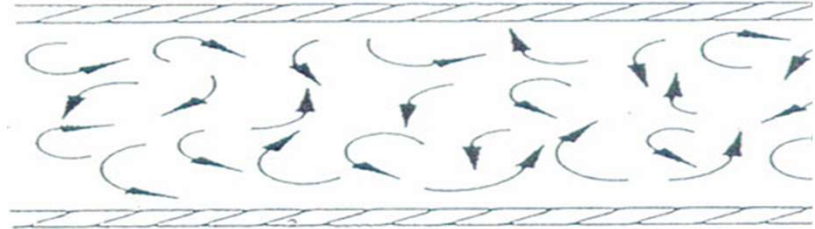
$Di =$

Pipe inside diameter

## Reynolds number

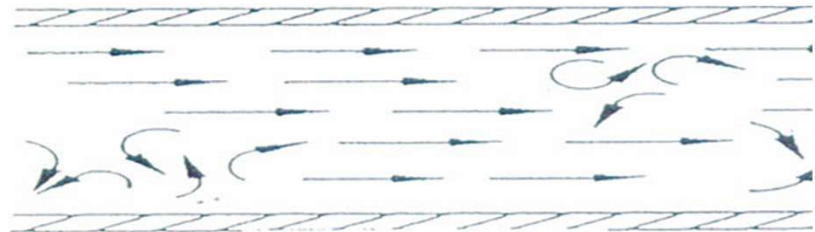
### Turbulent flow

- $Re > 4000$



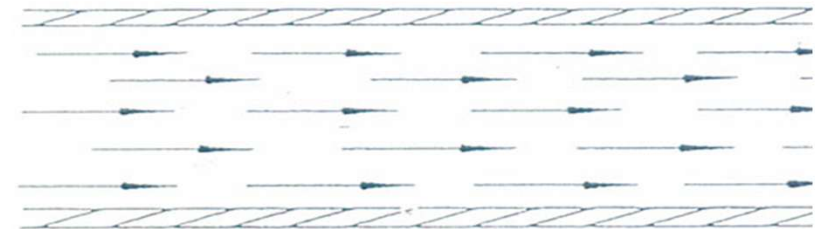
### Transition flow

- (laminar/ turbulent)
- $2300 < Re < 4000$



### Laminar flow

- $Re < 2300$
- (Re Reynolds number)



Reynolds number bigger

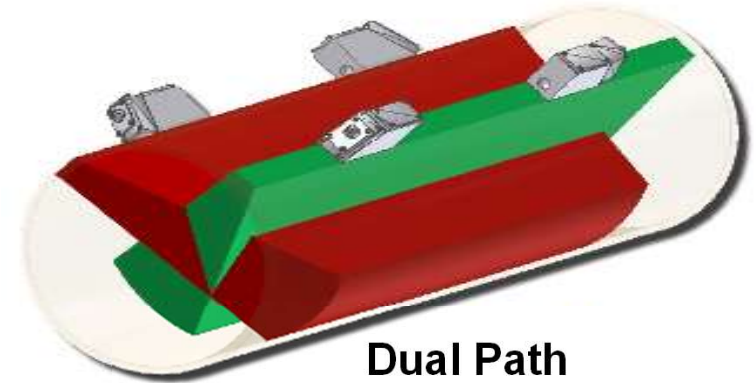
## Principles of operation – Dual / Four Path

### Dual / Four Paths

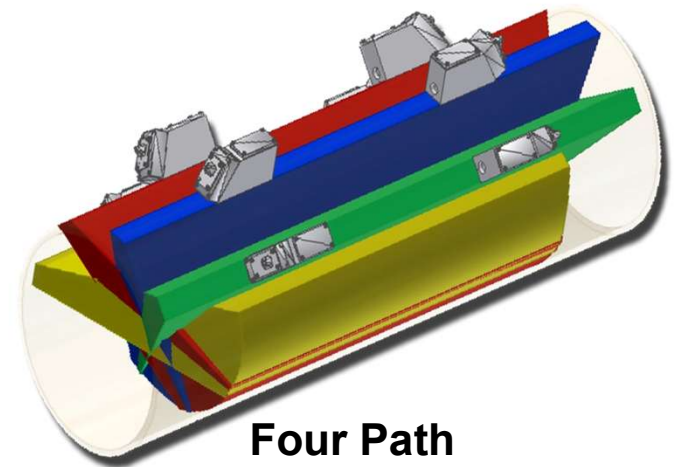
Increase flow sample averaging for greater precision

#### Benefits

- Greater cross-sectional averaging
- Improved accuracy
- Improved repeatability
- Adds redundancy
- More time in the flow stream

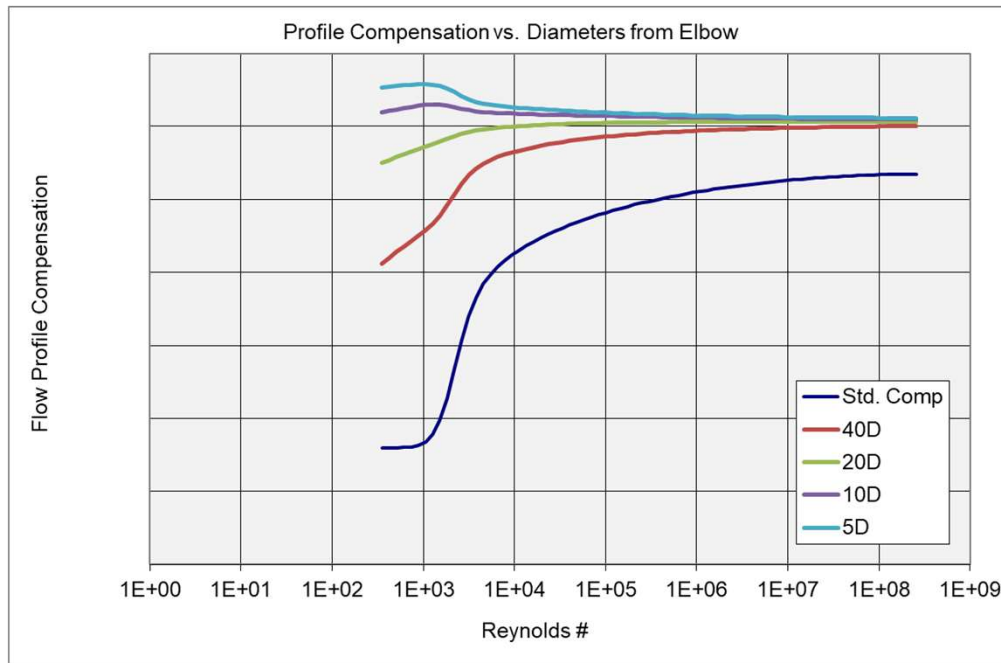


**Dual Path**



**Four Path**

## Principles of operation – Disturbed flow profile compensation



Type of upstream condition 2.1.3.2

- ☒ Straight run
- ☐ Single elbow
- ☐ Double elbow (in-plane)
- ☐ Double elbow (out-of-plane)
- ☐ Reducer
- ☐ Expansion

Upstream and downstream.. 2.1.3.3

Disturbed flow profile compensa..

Type of upstream condition

Upstream distance 5 ▶

Type of downstream condition

Maintenance alarm

Navigation buttons: Left, Up, Down, Right

## Field installation evaluation tools



Thickness Gauge



Level



Pi Tape

## Sensor Installation – Choosing a location

- Choose a location that provides at least 20 diameters of straight pipe upstream, and 10 downstream (Gas). More if possible
- Use the “Disturbed Flow” tool to program for actual pipe geometry when available straight pipe is limited
- Do not mount sensors immediately downstream of a pressure drop such as; expander, orifice plate, valves, intrusions, etc.
- Be sure pipe dimensions at selected location match meter programming!
- Remove flaky paint, rust, scale. Well bonded paint is OK and may be left alone
- Do not mount sensors on (or opposite) pipe seams

## Engineered meter run (Custody Transfer) - Let's get our heads into the pipe





## Clamp-on installed on an engineered meter run

### **Custody Transfer (CT)** – Refers to Custody Spool based meters

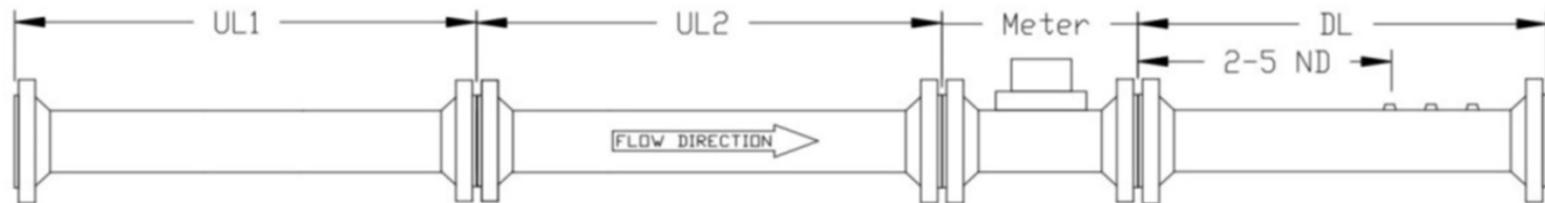
- Spool meter run with flow conditioning in accordance with AGA9
- Transducers can be external (Clamp-on) or insert (Chordal)
- Eliminates 'Field Installed' uncertainties
- Rigid, secure transducer mounting (Welded)
- Calibrated to Custody Transfer requirements (Calibration Certificate)

### **What Changes in an Engineered Meter Run**

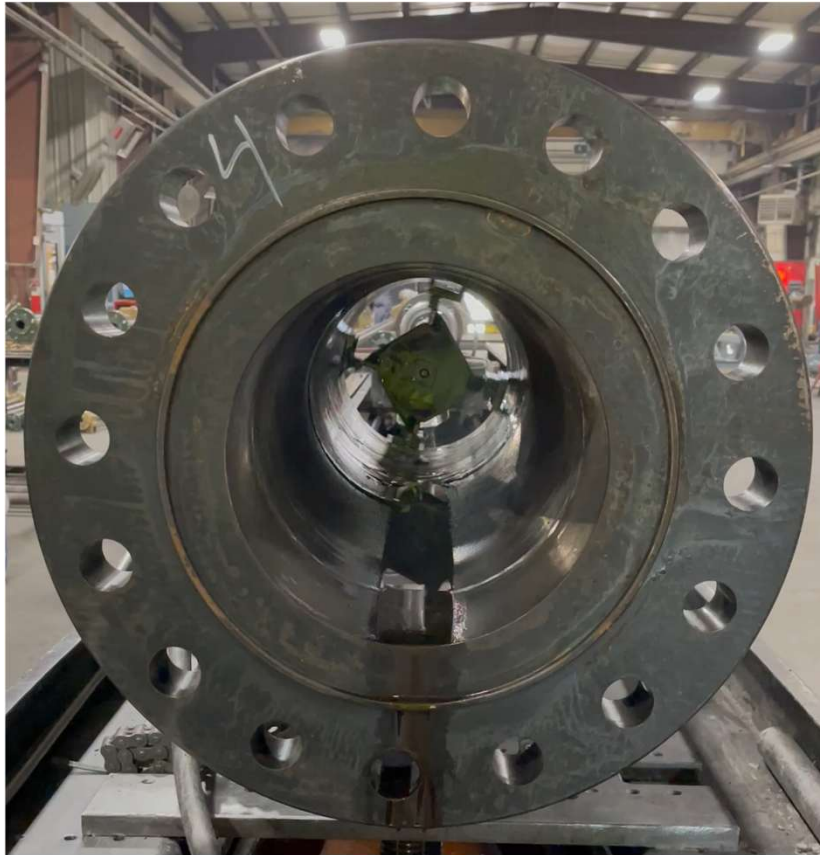
- Known pipe roughness and geometry
- Controlled transducer spacing and alignment
- Stable acoustic coupling (no field variability) – Mounting is welded
- Flow conditioning eliminates swirl / asymmetry
- Calibration ties system to traceable standard (CEESI)

## Custody transfer meter run in accordance with AGA No.9 guidelines

- Circle B Measurement and fabrication specialists built an engineered 16" meter run
  - The Meter Spool was:
    - A precision honed pipe spool
    - Precise concentricity
    - Precise cross-sectional area
  - The Meter Spool was installed with:
    - Up stream flow conditioners (CPA Plate)
    - Dual path, Clamp-on ultrasonic gas meter
  - The assembly was then calibrated and linearized at CEESI on their natural gas pipeline.
  - The meter run was not a precision honed piece of pipe, It is the spool piece that is important



## Engineered meter run



## Engineered meter run

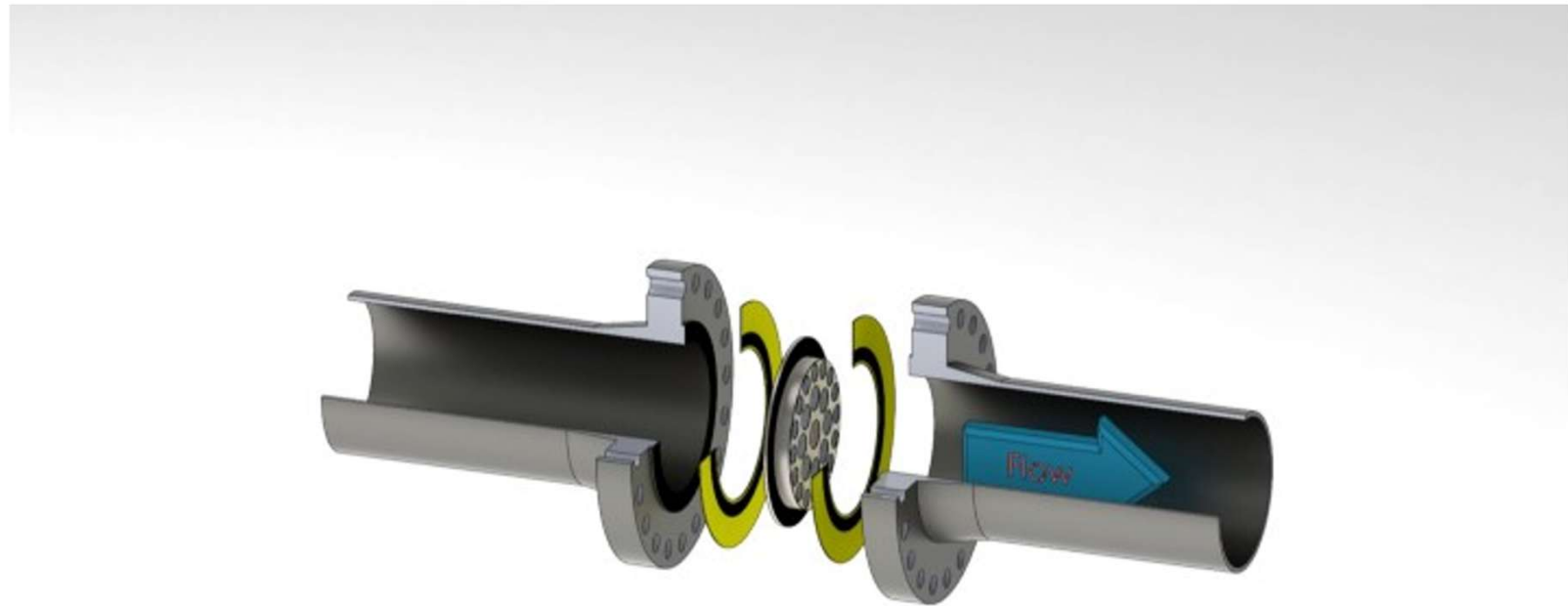


## Engineered meter run

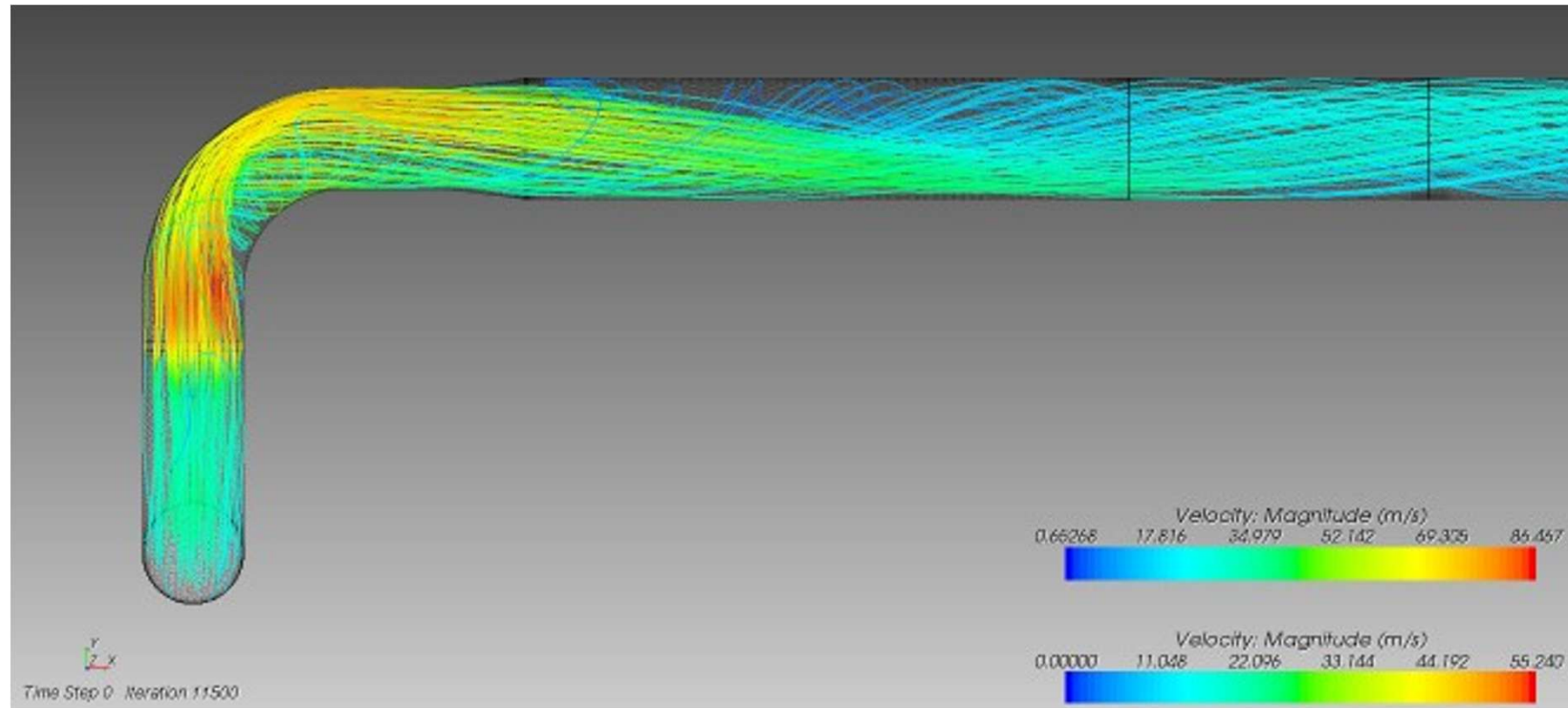




## Flow conditioning with a CPA plate



## Swirl (no conditioning)





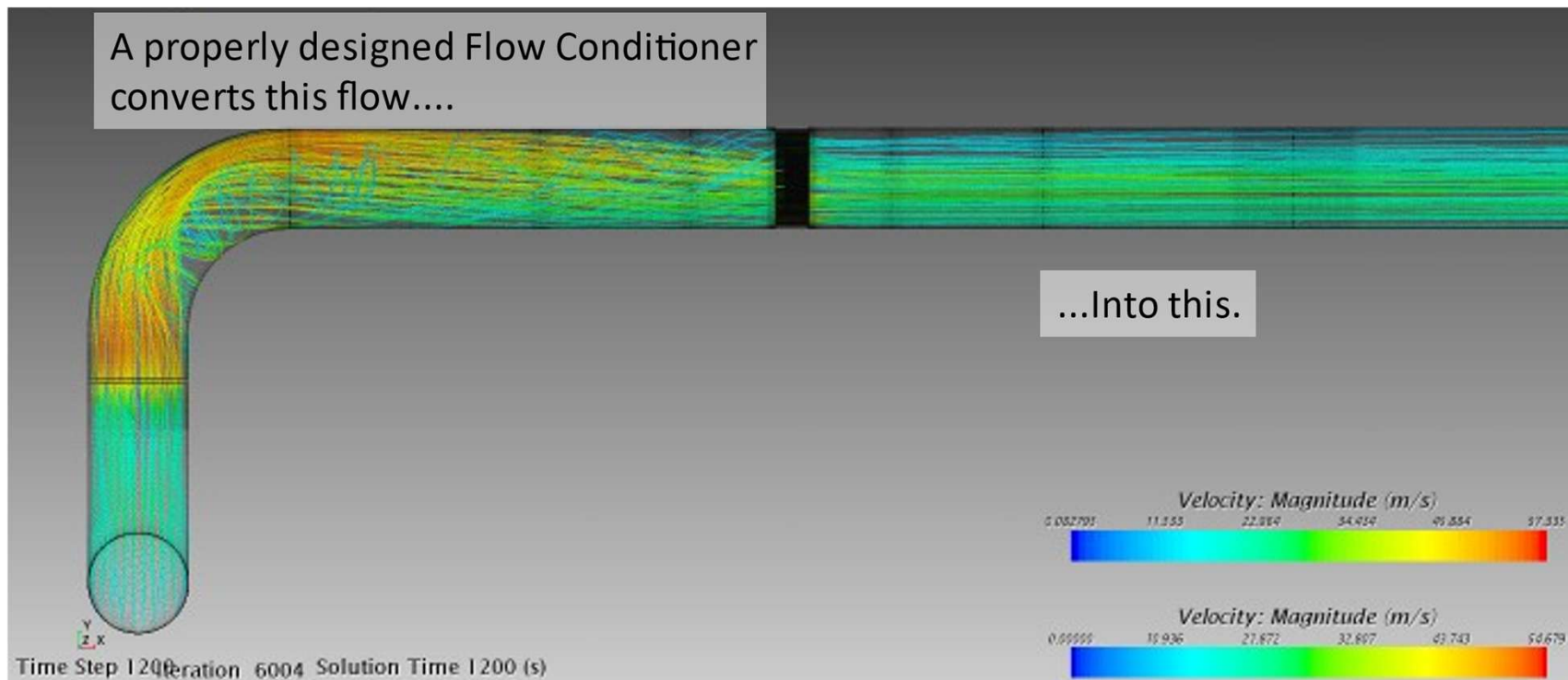
## Swirl



## Flow conditioning

A properly designed Flow Conditioner  
converts this flow....

...Into this.



## Calibration adjustment factors / CEESI Calibration test report (AGA Report No. 9)

### AGA Report No. 9 sec. 6.5 Calibration Adjustment Factors

Calibration factors are applied to minimize any meter-bias offset:

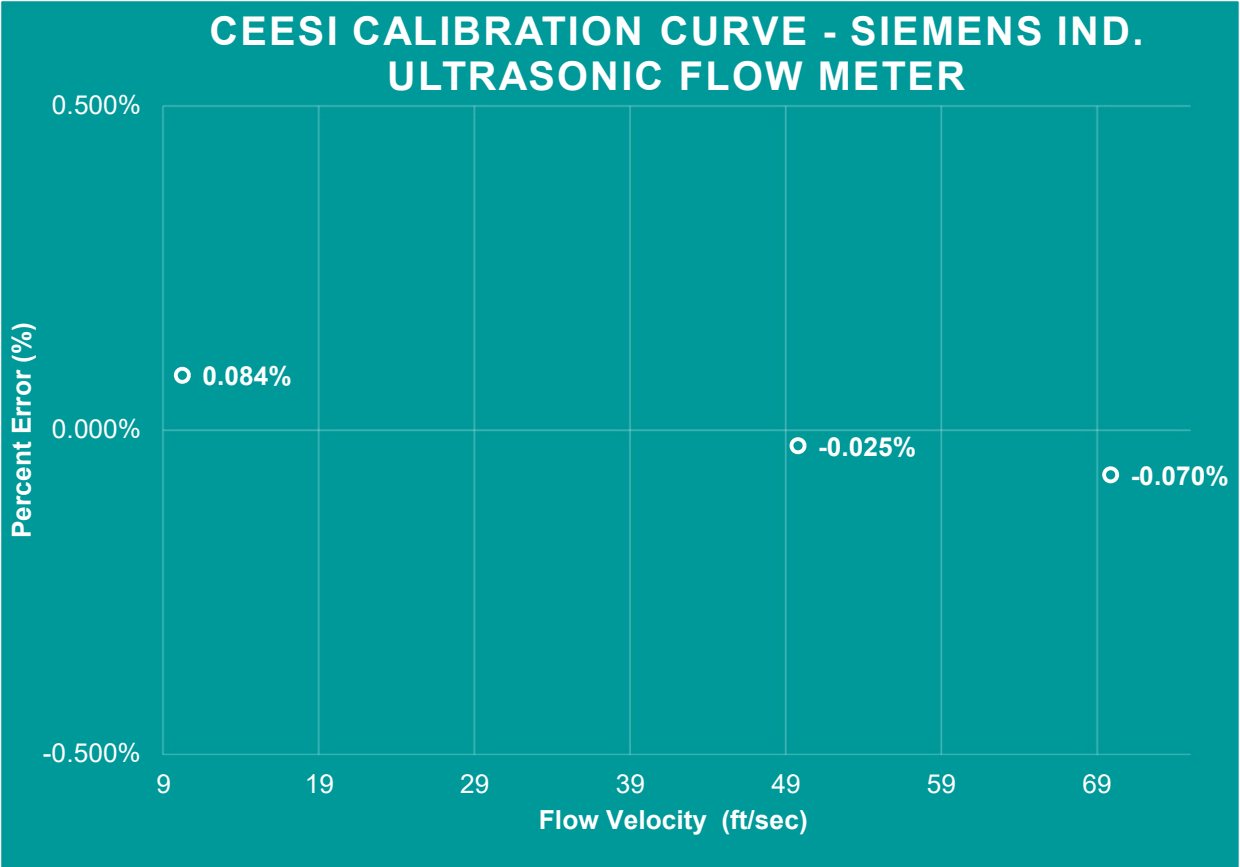
- To meet AGA 9 accuracy, meters 12" and larger shall have a maximum error of +/- 0.70% as found
- Piece-wise / Multi-point linear or (PWL) interpolation – used to linearize the meter

### Flow data after calibration and linearization at CEESI

Ceesi Flowrate [ACFH]	Meter Flowrate [ACFH]	Velocity [ft/sec]	Percent Error [%]
308530.3	308313.3	69.9	-0.070
219754.6	219700.3	49.8	-0.025
44849.57	44887.22	10.2	0.084

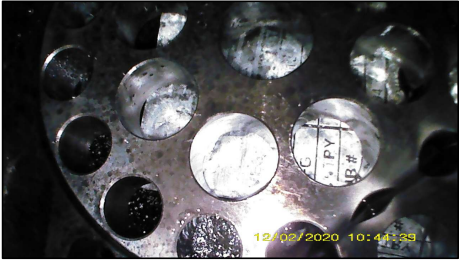
# CEESI spool and meter accuracy data

Taking the unknown and making it known!





Meter run cleaning



## Benefits of Clamp-on ultrasonic flow

- Wide range of pipe sizes, (Gas 2" to 58")
- No pressure drop (vs DP / orifice)
- Large turn-down ratio (>66:1)
- Low installation cost — largely independent of pipe size
- No process intrusion – Ease of installation & ideal for sour or hazardous gas
- As accurate as conventional meter technologies - When properly applied and/or installed on an engineered run, clamp-on technology can achieve accuracy comparable to conventional ultrasonic meters
- Ideal as a replacement for other meters or for existing pipelines with no meters in place
- Actual and Standard Volume flow measurement
- Dynamic Viscosity compensation, Pressure, & Temperature



## Summary

- Field Installed (Lot of unknowns) - Proper evaluation, installation and tools can yield high accuracy (0.5% - 1.0% or better)
  - Accurate dimensions
  - Proper placement (Upstream / Downstream diameters)
  - Upstream obstructions (What are they and how do they affect the reading)
- Custody Transfer (Engineered meter run) – Take the unknowns away and condition the flow profile
  - Spool meter run with flow conditioning in accordance with AGA9
  - Transducers can be external (Clamp-on) or insert (Chordal)
  - Calibrated to Custody Transfer requirements (Calibration Certificate)

\*Note: Important to develop an inspection/maintenance schedule to inspect the complete meter run periodically to maintain a high level of accuracy
- Clamp-on accuracy is application-dependent—not technology-limited
  - The measurement uncertainty isn't coming from the transmitter—it's coming from how the meter is applied in the field



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