Solving the hardest problems in ultrasonic flare gas measurement

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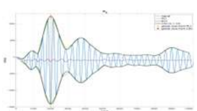
From Ultrasonic Time-of-Flight to Flare Gas Metering

PhD in **ultrasound**, Imperial College London

10 years at **Emerson** in ultrasonic wall-thickness monitoring



Signal processing, time-of-flight measurement, transducers

Joined **Fluenta** as Chief Product Officer / co-CEO

ISO 17089-3: Flare gas metering has its own hard-earned complexity

40+ Year of Flare Gas Specialisation

Born in Norway in 1985, focused on one thing: ultrasonic flare gas measurement

3,000+ installations across 6 continents, helping operators meet tightening regulations

Industry leading temperature range (-200°C to +350°C) and pioneers in non-intrusive design

Localised support capabilities delivered by exclusive channel partners across the Americas

Founded in Norway

FlarePhase Technology Development

FlarePhase CO_2 Unlocked

New developments

CO_2 is becoming a measurement uncertainty problem - not just a compliance question

Regulatory context

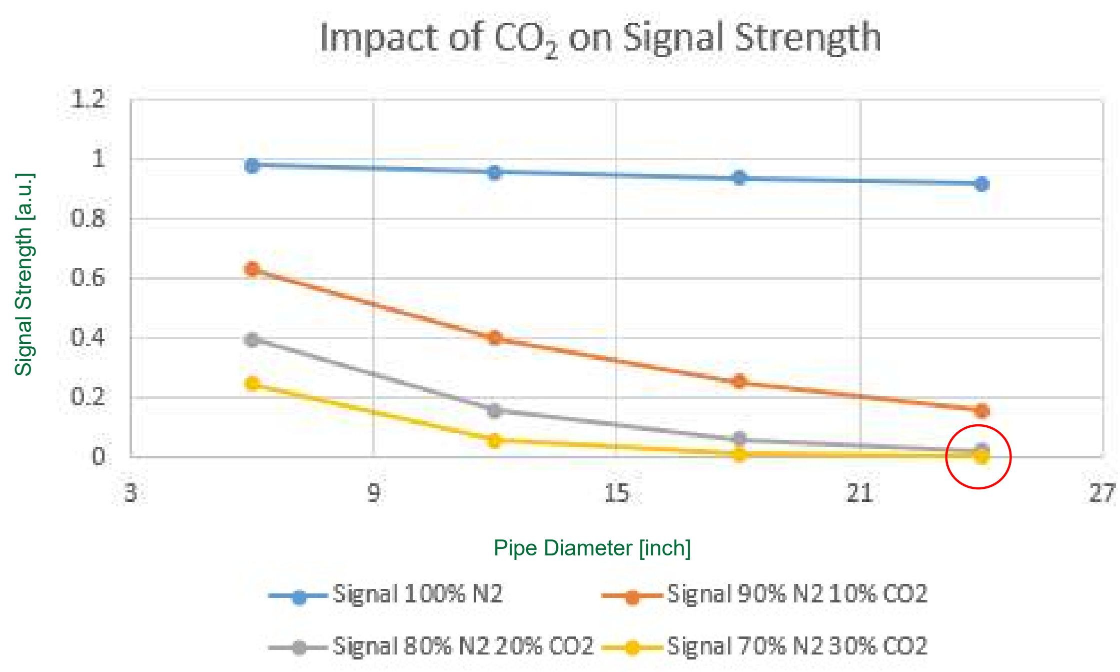
- **EPA Subpart W** requires continuous GHG reporting from petroleum and natural gas systems (since 2010).
- **NSPS OOOOb** (finalised in 2024) requires demonstrated flare performance through continuous monitoring and verifiable data.
- Compliance timelines are shifting under the current administration, but the core measurement obligation is not going away.
- The direction of travel is clear regardless of which specific provisions are in force at any given time.

The CO_2 relevance

- Permian Basin operations routinely produce gas with elevated, variable CO2 concentrations. Whether from CO2-EOR breakthrough or high-CO2 reservoir geology (shale gas), the composition is often unknown in real time without a continuous analyser.
- South America pre-salt (Santos Basin): fields such as Lula and Buzios carry reservoir CO2 concentrations of 40–80%, among the highest of any producing basin globally.
- In both cases: the challenge is not just high CO2 but *unpredictable* CO2, which compounds measurement uncertainty.

The CO_2 Challenge: Double Physics Problem

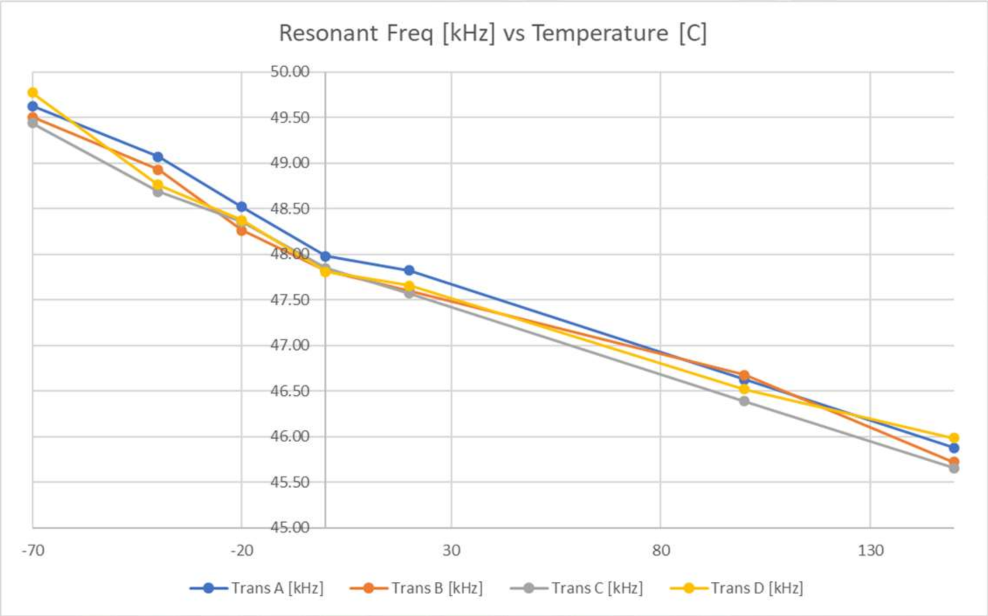
- **Challenge 1:** signal absorption
  - High CO_2 → strong ultrasonic signal attenuation
  - Signal strength drops exponentially with distance
  - At ~30% CO_2 → <1% signal received (across pipe diameters)
  - Impact increases with pipe diameter



Signal strength vs. pipe diameter and CO2 concentration

The CO_2 Challenge: Double Physics Problem

- **Challenge 2:** resonant frequency drifts from optimal operating point due to temperature swings
  - Higher temperature → lower frequency
  - Lower temperature → higher frequency
  - Impact: reduced measurement reliability
  - Needs continuous tracking to maintain accuracy



Frequency shift with temperature

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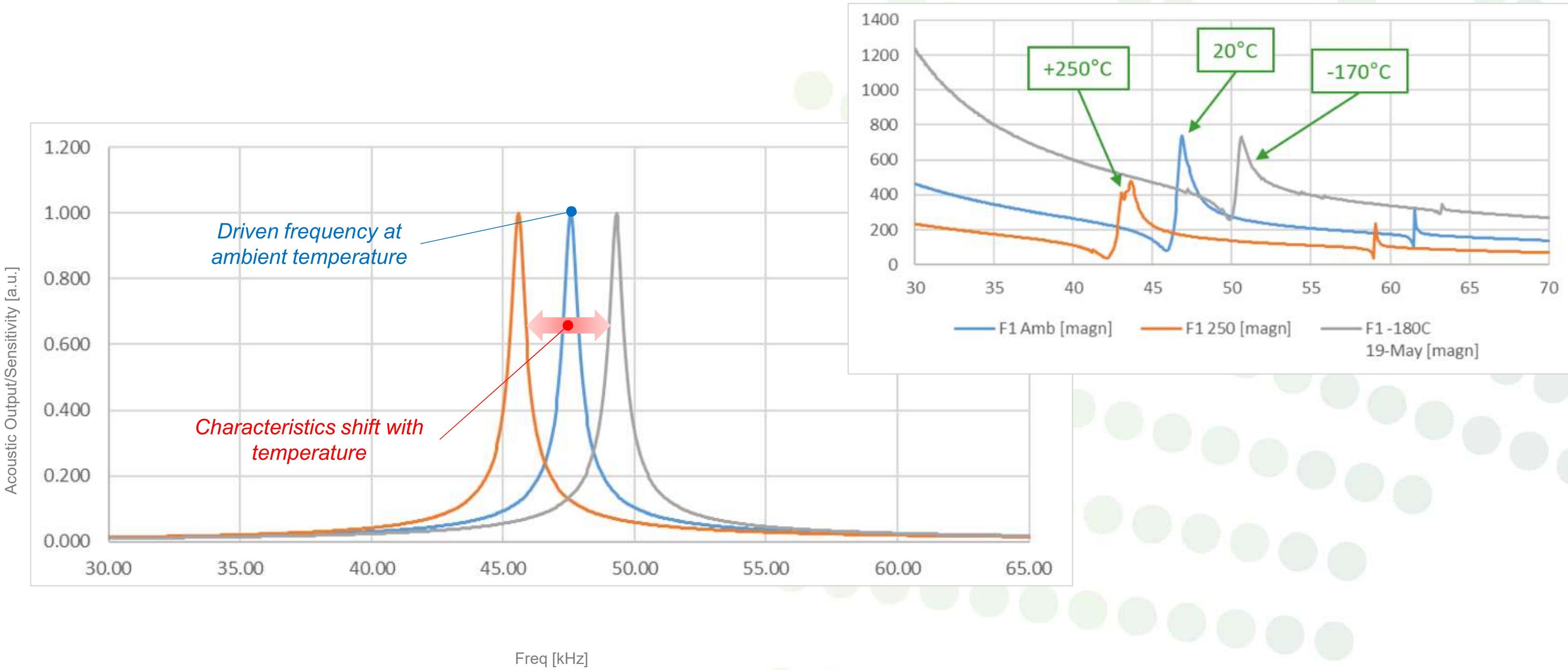


Temperature changes shifts the resonant frequency,
detuning the system and reducing measurement performance

How We Solve the CO_2 Measurement Challenge

Improved Performance in CO_2

[A]
Higher Transmit Power
→ Limited Applicability

[B]
Reduced Transducer Separation
→ Mitigates High Attenuation

[C]
Signals Processing
→ Optimised for CO_2

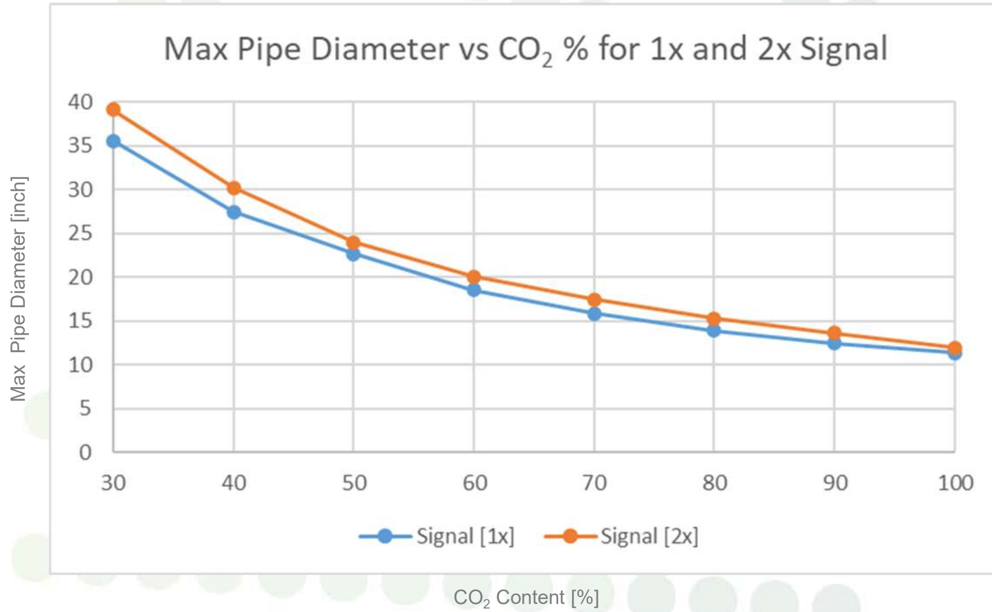
[A] Higher Ultrasonic Power

Increasing power is limited by Ex rules in 2 ways:

- There are prescribed limits on the ultrasonic sound pressure level.
- The transducers are Zone 0 devices (intrinsically safe), so the electrical power that can be supplied (voltage, current) is strictly limited.

Has a relatively small impact:

- Signal level decreases exponentially with distance.
- How does maximum pipe size change if the signal is doubled?

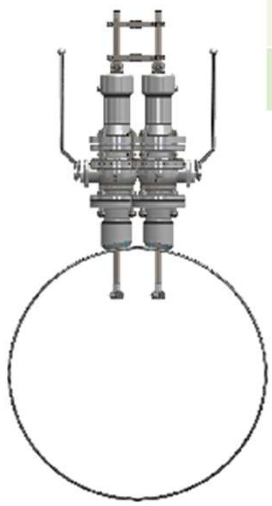


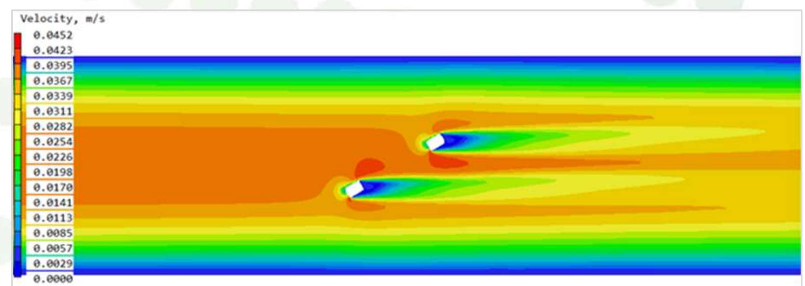
Signal attenuation grows steeply with CO_2 concentration and pipe diameter doubling input power buys only modest additional range.

[B] Reduced Transducer Separation

- Bias-90 Configuration
- Alternative mounting/insertion of the transducers
- Transducers are situated in the flow (intrusive)

	Characteristic	So what?
Pro	Transducer separation independent of pipe diameter.	Enables measurement of high absorption gases in large pipes.
Con	Only a part of the flow profile is sampled.	Mitigated by variable k-factors and CFD analysis.
Con	Intrusive transducers perturb the flow.	

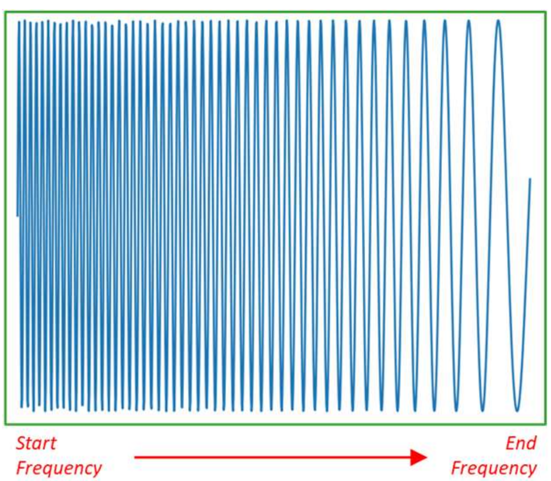




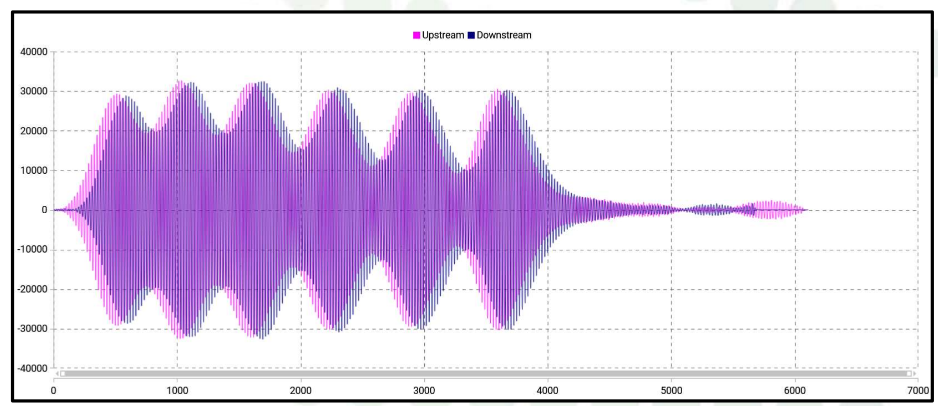
[C] Optimised Signals

- Signals in both TFS and FlarePhase systems have been optimised for high attenuation gases

TFS



FlarePhase



CO_2 Solution Overview

- Fluenta addresses high-CO_2 and thermal measurement challenges through a system of 3 specific innovations designed to maintain signal integrity in extreme industrial environments.

In-situ Tracking
Sensors measure resonant frequency in real-time, allowing electronics to adjust drive signals.

Signal Design
Custom waveforms uses 12 to 20 cycles per pulse to recover data even when buried in noise and accurate ToF determination.

Inline and Bias-90 Designs
Physical configuration reduces transducer separation, cutting the signal path length.

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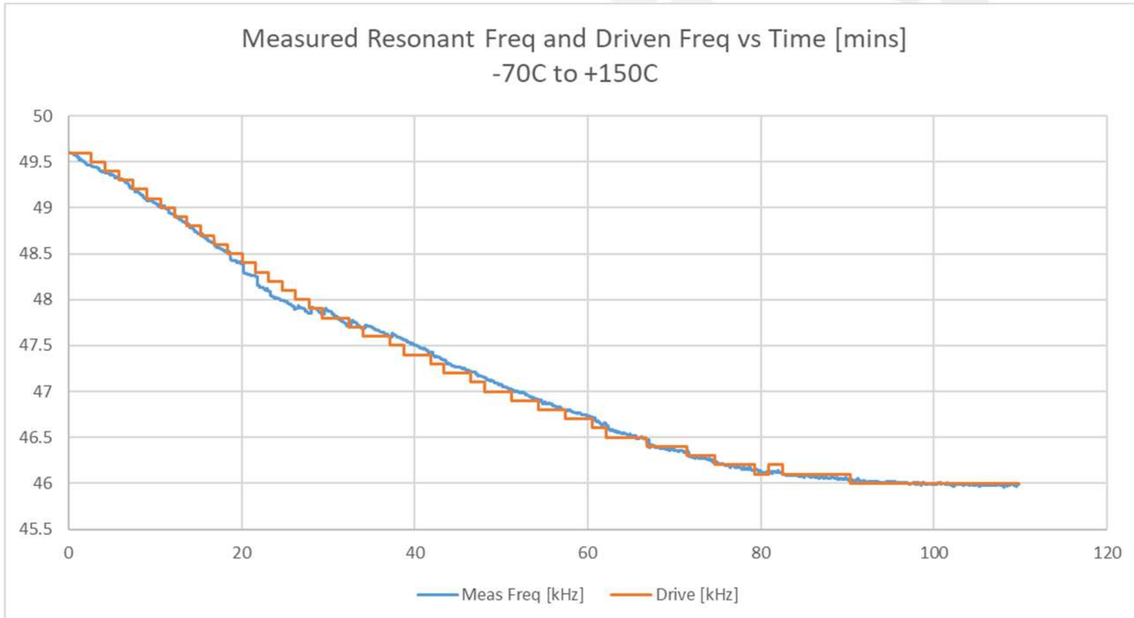

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CO_2 Solution Overview

Signal Design
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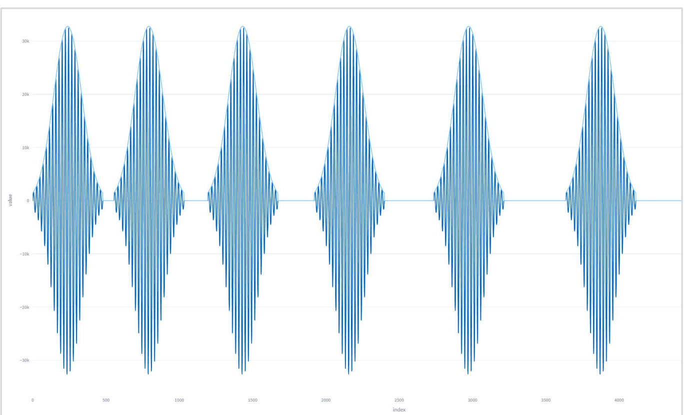
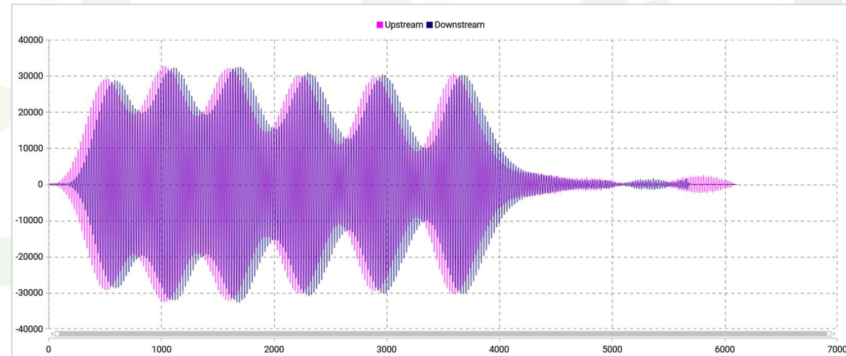
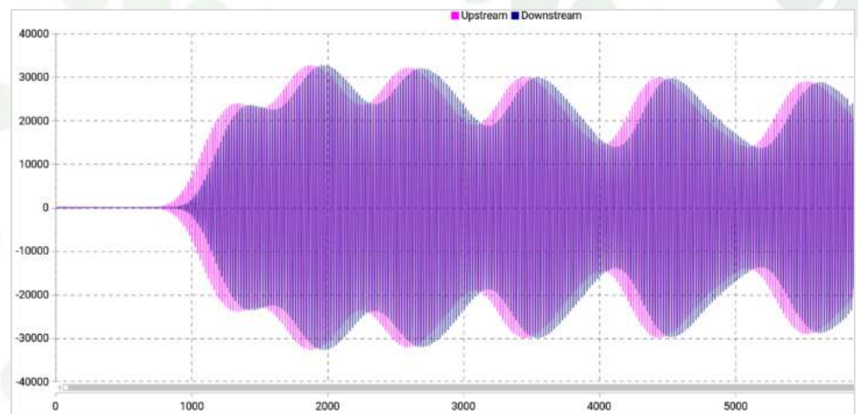




Rx Waveform at +250^{O}C



Rx Waveform at around -170^{O}C

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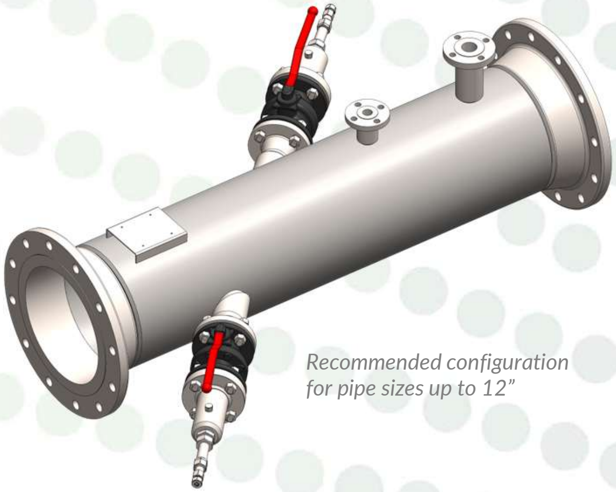
CO_2 Solution Overview

Inline and Bias-90 Designs

- Physical configuration reduces transducer separation, cutting the signal path length.
- Nonintrusive inline is recommended for pipe sizes up to 20”.
- Bias-90 configuration is recommended for up from 20” to 42” and up.
- 42” and up: CFD shows that the error in a bias-90 config increase dramatically



Recommended configuration for pipe sizes up to 12”

Recommended configuration for pipe sizes up over 12” to 42”

Bias-90 on Large Pipes: New Set of Challenges

- Signal absorption and frequency drift are addressed by solutions [B] and [C].
- Inline configuration: recommended for pipes up to 20”.
- Bias-90: required from 20” to 42”.
- Above our validated IPT pipe sections, a different accuracy problem emerges.

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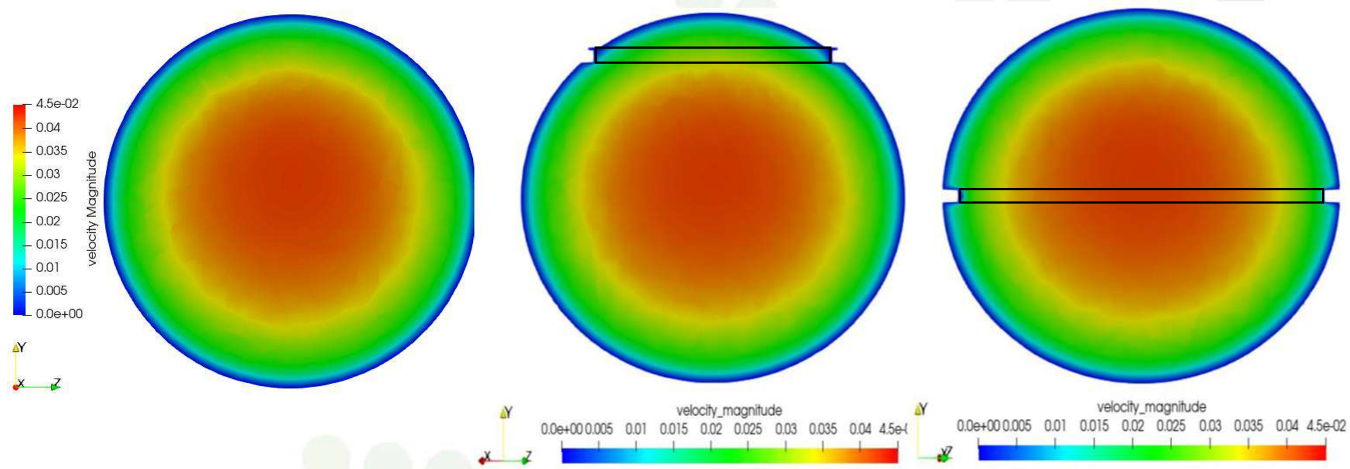
Where Bias-90 Accuracy Degrades

- Sensors sample one chord through the cross-section, not the full bore
- Upstream bends create asymmetric, off-centre flow profiles
- A single chord will over- or under-read depending on where it intersects the flow
- K-factor varies with Reynolds number (one correction coefficient is not sufficient)
- Error is largest at low velocities (crucial for flare lines)
- Emergency conditions shift gas density and temperature, changing the flow profile further



Velocity – Section Plots @ 1m/s

42" line continuous case, 1m/s Velocity

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Where Bias-90 Accuracy Degrades

- These tables show the discrepancy in measured values at 0 Offset vs. 0.75 Offset before the K-factor correction applied.
- The takeaway: the two paths can diverge by up to 40% without correction, and the problem is worst at the low velocities where flare lines spend most of their time.

Flow Velocity (m/s)	Path discrepancy (uncorrected)
0.03	**33.9%**
0.1	**22.5%**
1	**14.9%**
10	**12.7%**
120	**10.8%**

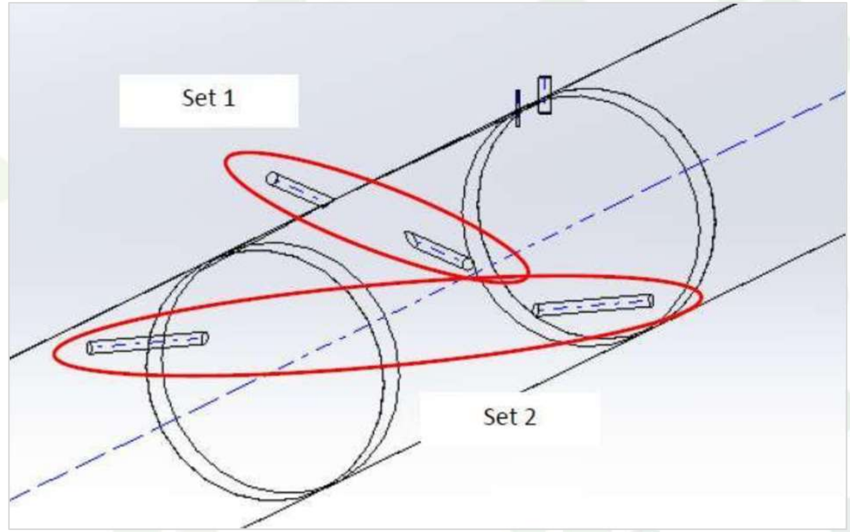
Normal Operation (continuous case)

Flow Velocity (m/s)	Path discrepancy (uncorrected)
0.03	**40.1%**
0.1	**27.9%**
1	**21.3%**
10	**15.4%**
120	**16.9%**

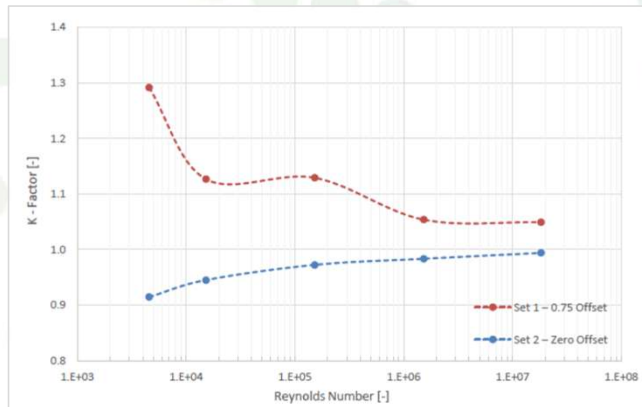
Emergency flaring

R&D Response

- Two sensor pairs at different lateral offsets sample two separate chords
- Each path captures a different slice of the velocity profile
- CFD modelling of the actual installation derives a K-factor for each path
- Corrections applied across the full velocity range
- Normal and emergency conditions are modelled separately
- Measurement accuracy is engineered
- Approach applied to a 42" pre-salt offshore installation in Brazil



Simplified view of the sensor location within the line (Set 1, 0.75 offset and Set 2, zero offset)



K-Factor comparison graph for Continuous case

High CO_2 Solution Validation

- **IPT Loop Characteristics:**
  - Pipe diameter = 20”
  - Spool diameters: up to 20”
  - Max flow 16,000m^3/h
  - Linear flows:
    - 12” → 68m/s
    - 16” → 42m/s
    - 20” → 27m/s
  - Heat exchanger to stabilise gas temperature
  - CO_2/air mixtures to 100% CO_2 verified by real-time analyser, and ex-situ GC.

Scan to download IPT testing whitepaper

Testing Results Snapshot

- Independently validated at IPT São Paulo
- Proven in continuous service at the Marathon MPLx shale plant (West. TX), measuring accurately at concentrations up to 100%

Max error at 100% CO_2 concentration	CO2 concentration	Error rate at 60-80% CO_2	Marathon (MPLx) Install CO_2
<5%	**100%**	**<1%**	**96%**
Max measurement error at maximum CO_2, IPT.	Max CO_2 concentration independently validated	Measurement error margin across all tested flow rates	Uptime in continuous service in harsh shale plant conditions

CO_2 is no longer an ultrasonic blocker Work continues for larger pipes

Proven

- Signal design and in-situ tracking solve the double physics problem
- Bias-90 enables measurement in high-CO_2 gas on pipes up to 20”
- Error under 1% at 60–80% CO_2, stable measurement to 100% CO_2
- Independently validated in a controlled environment on 12" and 16" pipe sections and validated against traceable reference meter.

In development

- Dual-path offset configuration for pipes above 20"
- CFD-derived K-factor correction calculated per path, per installation
- Normal and emergency flaring conditions modelled separately
- Live engineering work on a 42" pre-salt offshore installation

Open questions

- No lab-scale equivalent of IPT exists for large pipes → field validation is the only route
- How the approach performs across different upstream geometries is still being characterised
- Emergency flaring conditions produce more complex flow profiles and need more data
- Upper pipe size limit is not yet defined

Thank You