REDEFINING ULTRASONIC FLARE GAS MEASUREMENT IN HIGH-CO_2 ENVIRONMENTS

EXECUTIVE SUMMARY

Purpose of the Paper

This white paper presents the findings from independent testing of Fluenta's FlarePhase transducers in high-CO_2 environments. The tests aimed to assess the transducers' accuracy in measuring flare gas flow under varying CO_2 concentrations and flow rates.

Key Findings

The tests demonstrated that FlarePhase transducers maintain high accuracy, with error margins below 2%, in environments with up to 90% CO_2.

Under extreme conditions, including 100% CO_2 concentration and high flow rates, the system operated within industry-acceptable error limits of up to 5%. The transducers also proved adaptable across a wide range of flow rates, ensuring reliable performance in both low and high gas velocity scenarios.

Business Value

Fluenta's FlarePhase transducers offer a dependable solution for industries requiring accurate and continuous flare gas measurement, especially in environments with high CO_2 concentrations. Their robust performance ensures compliance with stringent emissions regulations, such as those set by the U.S. Environmental Protection Agency (EPA) and other governmental agencies, reducing the risk of fines or operational shutdowns. By providing reliable data in challenging conditions, the transducers also support operational efficiency and cost savings, minimising gas loss and reducing the need for frequent recalibrations.

INTRODUCTION

Ultrasonic transit time flowmeters have become the preferred method for flare gas measurement. This technology plays a crucial role in ensuring compliance with environmental regulations, identifying leak points, and reconciling plant mass balance. However, new global requirements around total emissions present additional technical challenges, particularly in measuring gas with high CO_2 concentration.

Flare gas flow measurement is inherently challenging due to several factors: unsteady flow velocity, pressure fluctuations, varying gas composition, high temperatures, and a wide range of flow rates. These challenges require instrumentation capable of measuring gas flow over a vast range of velocities, from as low as 0.03 m/s under minimal flow conditions to 80 m/s and above during emergency flaring.

While flare gas ultrasonic flowmeters have seen numerous improvements over the past 40 years, one persistent technical challenge persists, which is dealing with high CO_2 concentrations. High CO_2 levels can drastically attenuate ultrasonic energy, affecting the acoustic properties of the gas mixture. This increased signal attenuation and altered speed of sound significantly impact ultrasonic flow meters.

Fluenta, a specialist in ultrasonic flare gas measurement has continuously developed solutions, since the mid-80s, to address challenges posed by high velocities and variable gas compositions. Fluenta's recent FlarePhase transducers are primarily designed to overcome the large process temperature swings that flare gas meters are often exposed to, however, the implementation of our solution to that challenge, also addresses measurement limitations associated with high CO_2 levels, ensuring stable and accurate performance both in a wide range of process conditions than has previously been possible with ultrasonic transducers.

This white paper presents the results of independent tests conducted at the Instituto de Pesquisas Tecnológicas (IPT) in São Paulo, Brazil. These tests evaluate the performance of Fluenta's FlarePhase transducers in high-CO_2 environments across different flow rates, demonstrating their capability to deliver accurate flare gas measurements where other technologies struggle.

TESTING METHODOLOGY

Overview of the Test Setup

The performance of Fluenta's FlarePhase transducers was evaluated through independent tests conducted at IPT, in Brazil. The tests aimed to assess the transducers' accuracy in measuring gas containing various concentrations of CO_2, with a specific focus on signal attenuation and flow rate measurement.

The test environment was a closed-loop system that allowed for the controlled injection of CO_2 into a gas mixture, and ability to vary the flow rate to simulate conditions commonly found in flare gas systems. The testing loop also integrated with Fluenta's equipment for accurate real-time data acquisition.

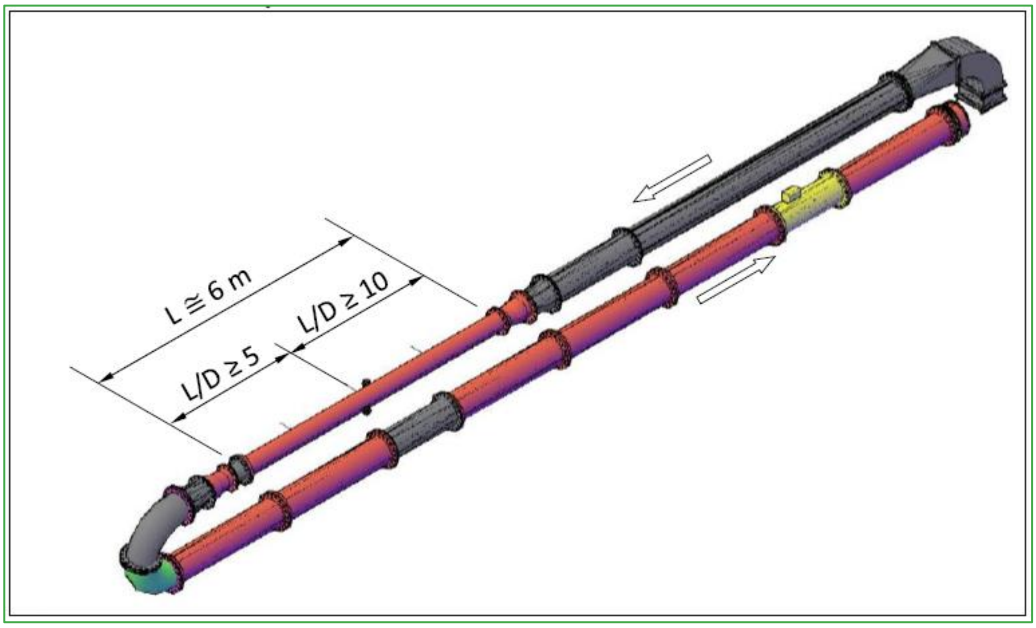

Fig 1. Isometric drawing of the bench with dimensions of the test section (L). The flow direction is indicated by the arrows. Source: IPT.

Equipment and Transducers Used

The following equipment was used to ensure accurate measurement and control of the test conditions:

Equipment	Purpose
FGM 160 Field Computer	collect real-time data from the FlarePhase transducers, ensuring high-resolution flow measurements and accuracy analysis.
Fluenta Flarephase Transducers	transducers sporting Active Phase technology developed to handle high concentrations of CO_2 across wide range of flows and temperatures.
Pressure and Temperature transmitters	used to continuously monitor the test environment and ensure that changes in gas conditions were accurately captured.
CO_2 Gas Analyser	provide real-time data on CO_2 concentration in the gas mixture, ensuring that each test phase was conducted at the correct gas composition.
Reference Flowmeter (Elster-Instromet G10000)	a highly calibrated flow meter was used as a benchmark to verify the accuracy of the measurements taken by the FlarePhase system. All tests were traceable to international calibration standards, adding confidence to the results.

Table 1. Overview of equipment used during the test

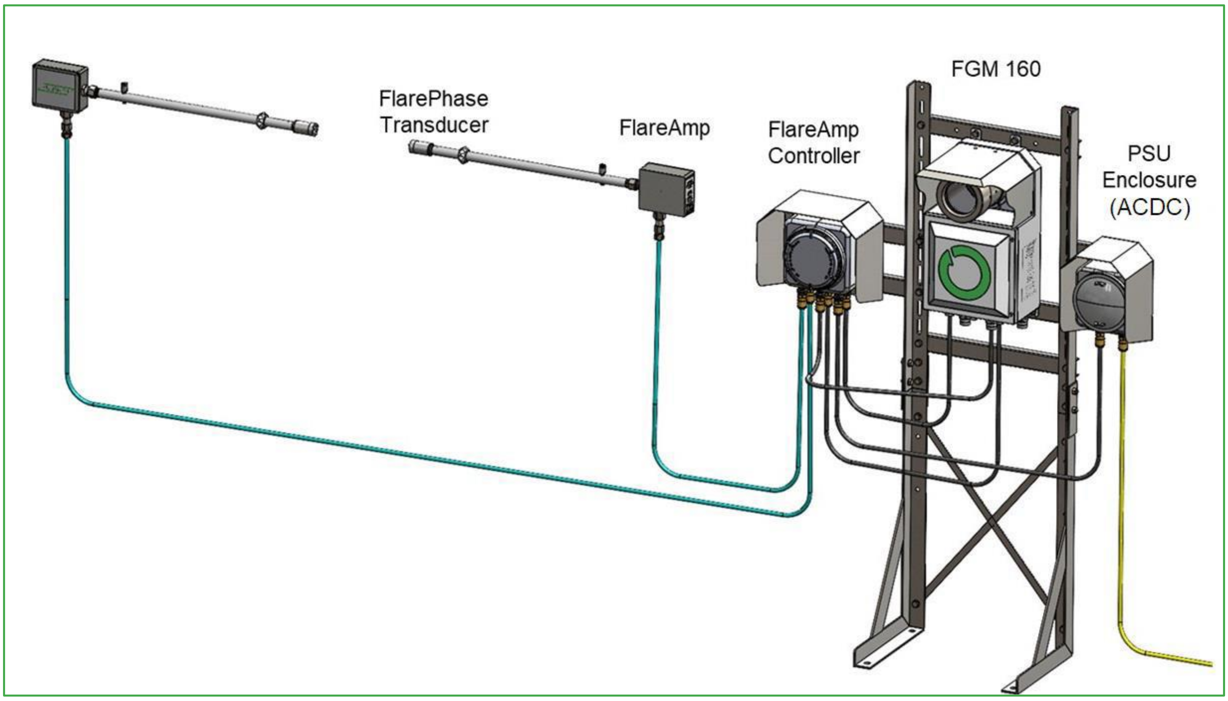

Fig 2. Assembly of the Fluenta ultrasonic flow measurement system

Fig 3. Fluenta transducers mounted on 16" pipe. Source: IPT.

Fig 4. Fluenta transducers mounted on 12" pipe. Source: IPT.

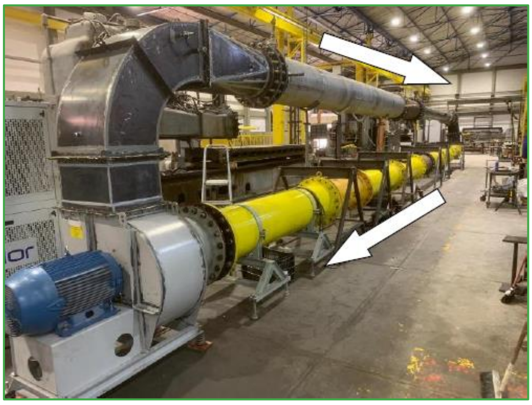

Fig 5. Front view of the circuit with the fan on the left. Source: IPT.

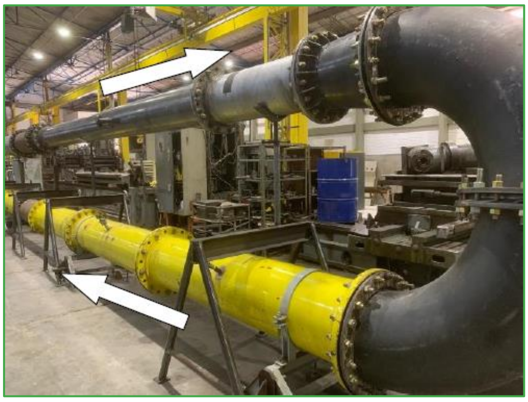

Fig 6. Rear view of the circuit showing the curve for fluid return to the fan. Source: IPT.

Test Parameters

The tests used two pipe sections—12" and 16" in diameter—to simulate real-world industrial piping. Gas mixtures were tested at CO_2 concentrations ranging from 0% (air) to 100% (0%, 60%, 70%, 80%, 90%, and 100%), ensuring comprehensive evaluation under varying conditions.

Flow rates were set at five levels, approximately 2000 m^3/h, 5000 m^3/h, 8000 m^3/h, 11,000 m^3/h, and 14,000 m^3/h, to cover a range of operational scenarios. Each flow rate was tested in both increasing and decreasing sequences to assess any hysteresis effects, and all measurements were repeated three times to ensure repeatability.

Procedure for Each Test Phase

- **CO_2 Injection and Mixing:** CO_2 was injected at controlled rates, and a mixing chamber ensured consistent gas composition before entering the test section.
- **Flow Rate Tests:** at each CO_2 concentration, the system was stabilised for 60 seconds, after which measurements were taken over an additional 60 seconds to ensure accuracy and consistency across all tests.

- **Data Acquisition and Validation:** the FGM160 flow computer recorded the flow data from the FlarePhase transducers, which was cross-checked against the reference flowmeter for validation. Error percentages were calculated to determine the accuracy of the transducers under varying CO_2 concentrations.

Fig 7. Continuous gas analyser used during tests. Source: IPT.

Gas	Known Proportion (% CO_2)	Measured on the Analyser
Compressed Air	0.038%	-0.1% (zero)
N_2	0.0%	-0.2% (zero)
Certified Blend	5.9895%	6.2%

Table 2. Results of the verification carried out after using the gas analyser. Source: tests carried out at IPT.

DN 12”			
0% CO_2 (m^3/h)	**70% CO_2 (m^3/h)**	**80% CO_2 (m^3/h)**	**90% CO_2 (m^3/h)**
2 000	*2 000*	*2 000*	*2 000*
3 500	*3 000*	*3 000*	*2 500*
5 000	*4 000*	*4 000*	*3 000*
6 500	*5 000*	*5 000*	*3 500*
8 000	*7 000*	*7 000*	*4 000*

Table 3. Flow rates in the DN 12” test line.

TEST RESULTS

Performance of FlarePhase Transducers

For the purpose of this paper, we will focus on results from 12" pipe section, given the similarity of the results and supplied graphs. The full IPT testing report is available on request.

The FlarePhase transducers demonstrated consistent performance across all tested conditions. The system maintained a high level of accuracy in measuring flow rates even as the CO_2 concentration increased.

Key Results by CO_2 Concentration:

- **0% CO_2 (Air):** as a baseline, the FlarePhase transducers showed minimal error (less than 2%) when compared to the reference flowmeter, confirming accurate performance in a low-attenuation environment.
- **60%–80% CO_2:** the transducers maintained accuracy with an error margin of less than 1%, proving their ability to handle medium CO_2 levels with minimal signal loss or attenuation.
- **90% CO_2:** at higher CO_2 concentrations, error rates increased slightly but remained within acceptable bounds, showing a small reduction in signal strength but without major disruptions in measurement.
- **100% CO_2:** the FlarePhase transducers continued to provide stable measurements, although with a higher error margin (up to 5%) as the CO_2 concentration reached its maximum. This demonstrated the limits of the transducers' performance in extremely high attenuation conditions.

Key Results by Flow Rate:

The system was tested across a wide range of flow rates (from 2000 m^3/h to 14,000 m^3/h) at each CO_2 concentration. Results showed:

- **Low to Medium Flow Rates:** at lower flow rates (2000–8000 m^3/h), the FlarePhase transducers performed with exceptional stability and accuracy across all CO_2 concentrations. This indicates that the system is highly effective in real-world operational scenarios where flow rates are often variable.
- **High Flow Rates (Above 11,000 m^3/h):** at higher flow rates, particularly with 90% and 100% CO_2, the transducers experienced a slight drop in accuracy. The error margin increased to approximately 3–5%, reflecting the challenges of maintaining signal integrity at both high CO_2 levels and high flow velocities.

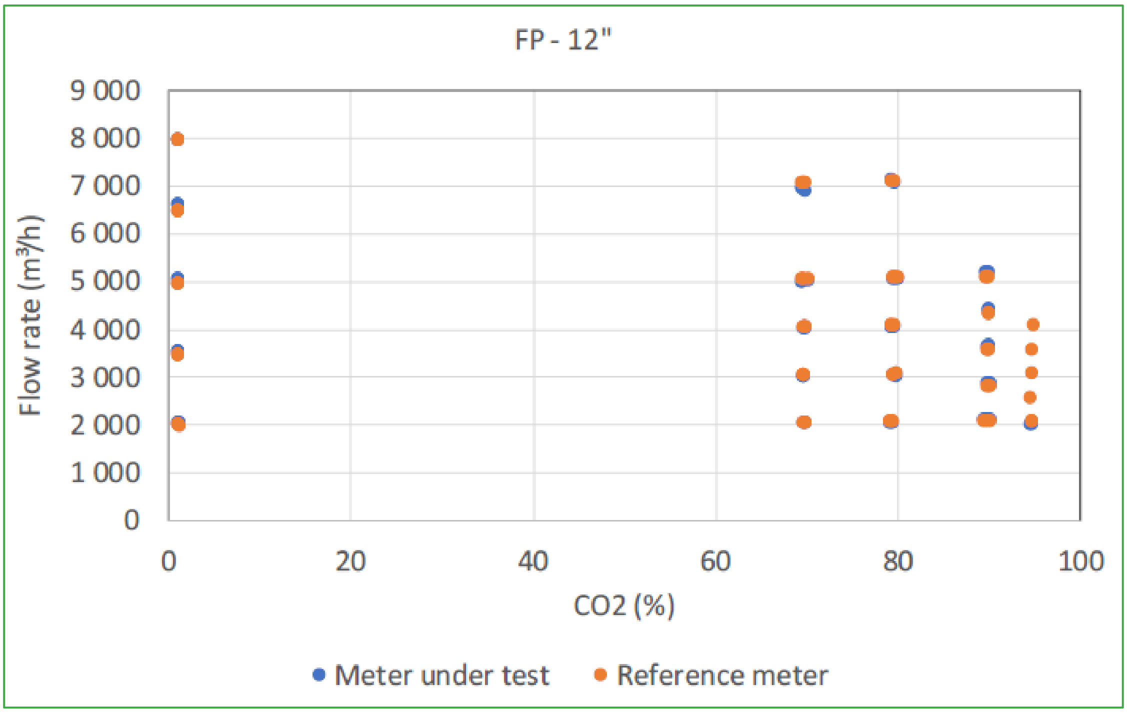

Fig 7. Measured flow rates and CO_2 ratio with the 12" tube

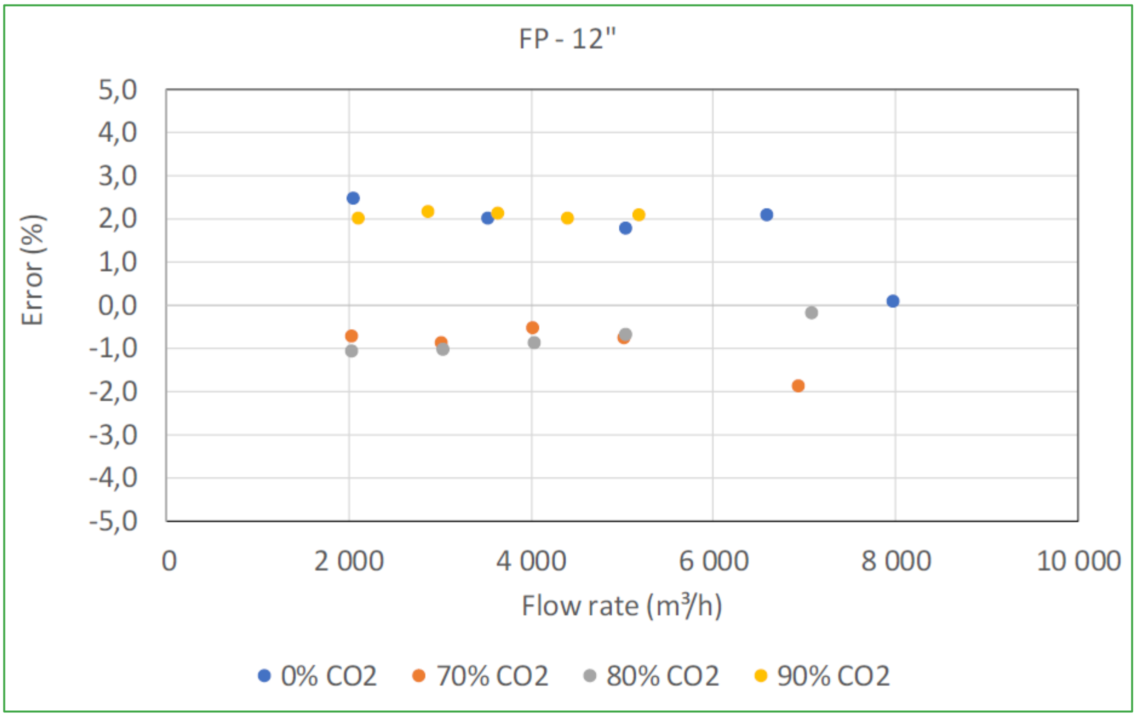

Fig 8. Errors measured with all mixtures in the 12" pipe. Source IPT.

- **Results with approximate proportion of 70% CO_2**

MUT (m^3/h)	Reference Meter (m^3/h)	Error (%)	S_X (%)	Coverage Factor (-)	Expanded Uncertainty (%)	DoF (-)
2039.9	2054.7	-0.72	0.088	2.00	0.72	569
3022.6	3049.0	-0.87	0.110	2.01	0.74	248
4032.3	4054.2	-0.54	0.080	2.00	0.72	796
5021.1	5059.0	-0.75	0.187	2.06	0.82	40
6938.4	7070.8	-1.87	0.320	2.32	1.10	10

Table 4. Results with approximate proportion of 70% CO_2. Source: IPT.

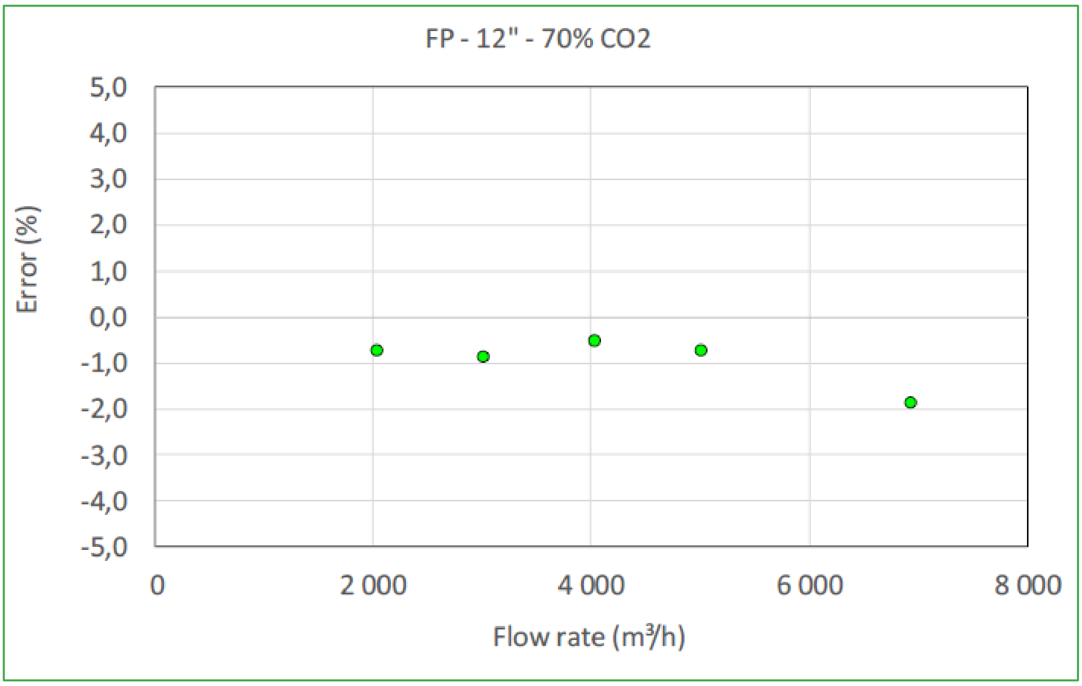

Fig 9. Graph referring to Table 4 illustrating results with approximate proportion of 70% CO_2. Source: IPT.

MUT (m^3/h)	Read CO_2 Composition (%)	Corrected CO_2 Composition (%)
2039.9	69.8	75.3
3022.6	69.7	75.2
4032.3	69.8	75.3
5021.1	69.8	75.3
6938.4	69.7	75.2

Table 5. Volume of CO_2 at each flow rate.

- **Results with approximate proportion of 80% CO_2**

MUT (m^3/h)	Reference Meter (m^3/h)	Error (%)	S_X (%)	Coverage Factor (-)	Expanded Uncertainty (%)	DoF (-)
2045.1	2067.5	-1.09	0.092	2.01	0.73	473
3035.4	3067.8	-1.06	0.162	2.04	0.79	64
4040.6	4075.9	-0.87	0.029	2.00	0.70	29669
5052.1	5088.0	-0.71	0.102	2.01	0.73	331
7095.8	7108.1	-0.17	0.327	2.32	1.11	9

Table 6. Results with approximate proportion of 80% CO_2. Source: IPT.

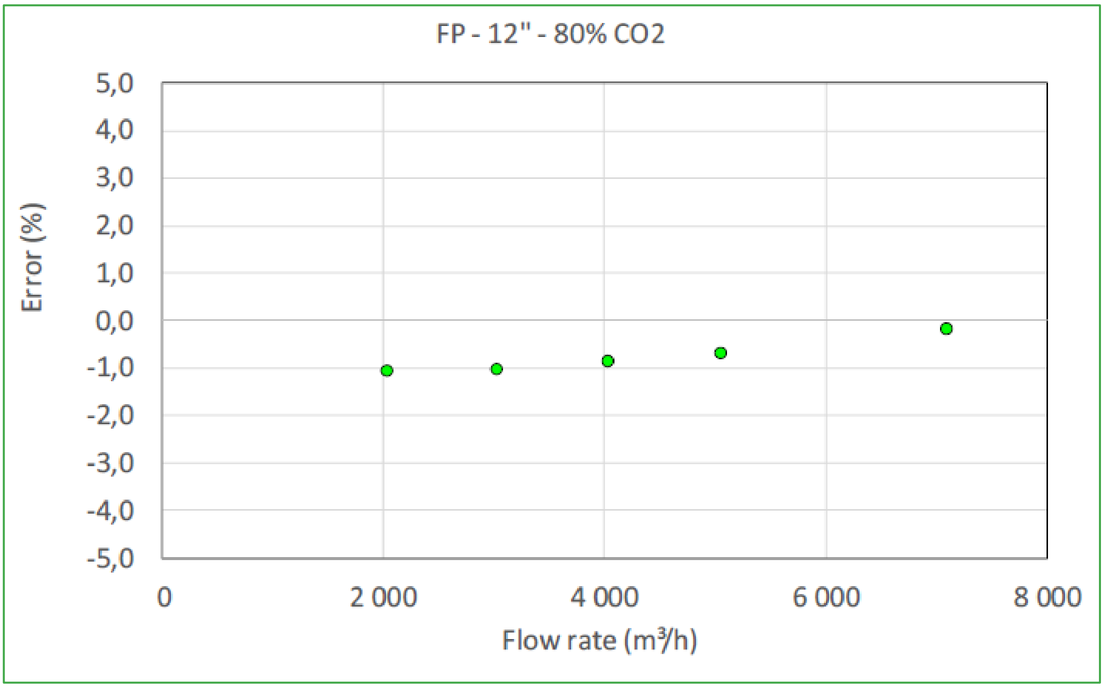

Fig 10. Graph referring to Table 6 illustrating results with approximate proportion of 80% CO_2. Source: IPT.

MUT (m^3/h)	Read CO_2 Composition (%)	Corrected CO_2 Composition (%)
2045.1	79.3	86.0
3035.4	79.7	86.4
4040.6	79.5	86.1
5052.1	79.7	86.4
7095.8	79.5	86.2

Table 7. Volume of CO_2 at each flow rate.

- **Results with approximate proportion of 90% CO_2**

MUT (m^3/h)	Reference Meter (m^3/h)	Error (%)	S_X (%)	Coverage Factor (-)	Expanded Uncertainty (%)	DoF (-)
2111.9	2070.3	2.01	0.141	2.02	0.76	104
2878.1	2817.4	2.15	0.130	2.02	0.75	137
3650.2	3573.9	2.14	0.084	2.00	0.72	657
4416.7	4329.5	2.02	0.167	2.04	0.79	58
5193.0	5087.1	2.08	0.108	2.01	0.74	262

Table 8. Results with approximate proportion of 90% CO_2. Source: IPT.

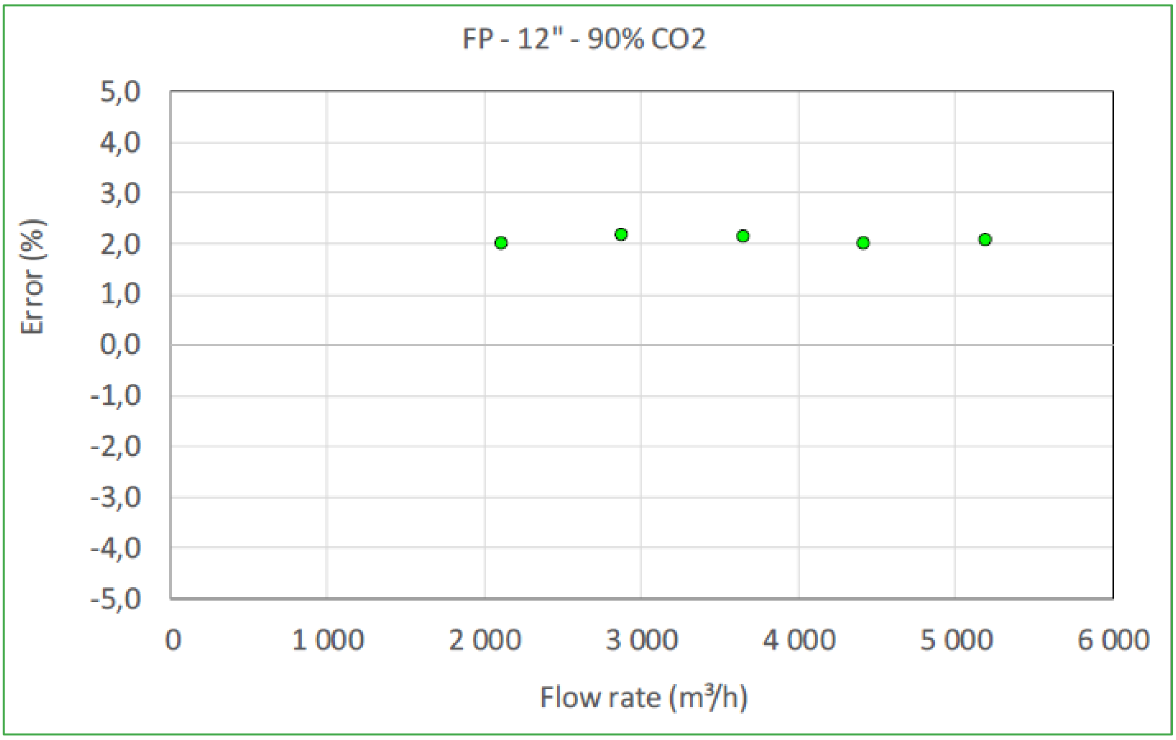

Fig 11. Graph referring to Table 6 illustrating results with approximate proportion of 90% CO_2. Source: IPT.

MUT (m^3/h)	Read CO_2 Composition (%)	Corrected CO_2 Composition (%)
2111.9	89.9	95.6
2878.1	90.00	95.7
3650.2	90.00	95.7
4416.7	90.00	95.7
5193.0	89.8	95.6

Table 9. Volume of CO_2 at each flow rate.

DISCUSSION

Performance Highlights

The FlarePhase transducers demonstrated strong accuracy across a wide range of conditions, particularly up to 90% CO_2 concentration, where error margins remained below 2%. This level of performance makes them suitable for challenging industrial environments where CO_2 content is variable. Even at 100% CO_2, the system maintained functionality with an error margin of around 5%, highlighting its robustness compared to traditional meters.

Impact of CO_2 Concentration

The tests revealed a direct relationship between increasing CO_2 concentration and signal attenuation. At levels above 90% CO_2, the system's accuracy declined, primarily due to increased signal attenuation, which is a known limitation in ultrasonic flow meters. Despite this, the transducers' ability to maintain reliable performance up to 90% CO_2 is significant for industries where such concentrations are typical.

Flow Rate Sensitivity

The system handled a broad range of flow rates, with optimal performance at low-to-medium ranges (2000–8000 m^3/h). At higher flow rates (>11,000 m^3/h), especially with high CO_2 concentrations, error margins increased slightly but remained within acceptable limits. This indicates that while performance is strong across most conditions, there may be some impact on accuracy at the upper limits of flow and CO_2 levels.

Signal Attenuation and Noise

Higher CO_2 levels and flow rates resulted in increased signal attenuation and noise, particularly in the upstream transducer. The 12” pipe showed more pronounced noise at high flow rates compared to the 16” pipe, suggesting that installation geometry may play a role in mitigating signal degradation. Despite this, the FlarePhase system continued to function effectively even in these challenging conditions.

Opportunities for Improvement

While performance was strong, potential enhancements include optimising signal processing to reduce noise at high CO_2 levels and improving accuracy at high flow rates. Further testing at extreme conditions could help define the system’s upper limits and refine its performance in those scenarios.

CONCLUSION

The testing of Fluenta's FlarePhase transducers has confirmed their suitability for accurate flare gas measurement, even in high-CO_2 environments.

The results offer confidence that the FlarePhase transducers will meet the needs of industries that require precision in emissions monitoring, regulatory compliance, and operational efficiency.

The testing has also provided useful insights into how measurement performance degrades at the limits of specification which, in turn, provides some interesting mitigation strategies where such conditions are experienced. While there are opportunities to enhance performance at the extreme ends of CO_2 concentration and flow rate, the transducers have proven robust and effective in most practical applications.

In summary, Fluenta's FlarePhase transducers present a dependable option for industries looking to optimise flare gas measurement, ensuring accuracy, regulatory adherence, and efficiency in high-attenuation environments.