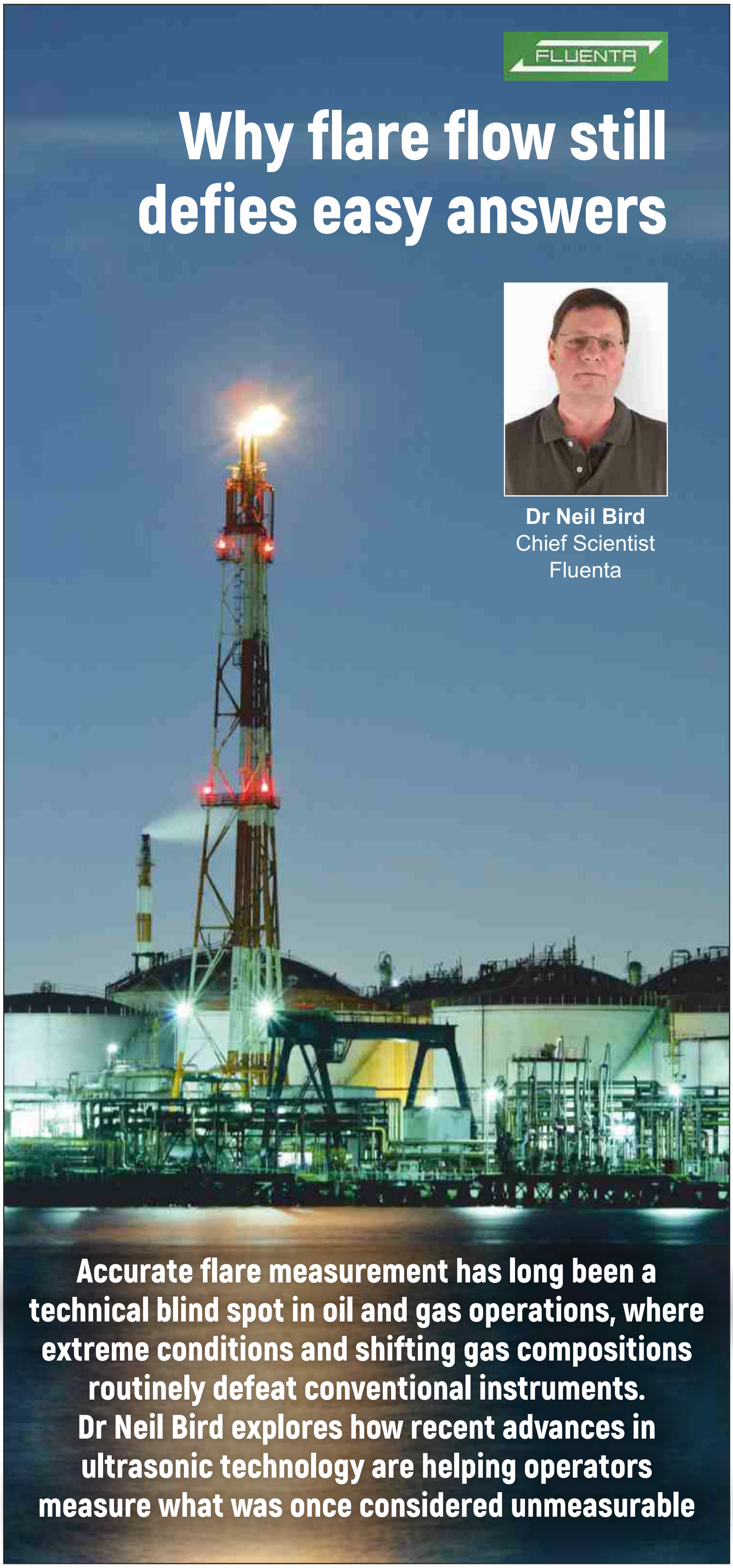


Why flare flow still defies easy answers

Dr Neil Bird
Chief Scientist
Fluenta

Accurate flare measurement has long been a technical blind spot in oil and gas operations, where extreme conditions and shifting gas compositions routinely defeat conventional instruments. Dr Neil Bird explores how recent advances in ultrasonic technology are helping operators measure what was once considered unmeasurable

Across India's rapidly growing energy sector, gas flaring remains a persistent and under-addressed challenge. While it is a necessary safety practice to prevent pressure build-up in pipelines and processing equipment, the consequences of unmanaged flaring are far-reaching. And when left unmeasured or improperly combusted, its environmental impact is severe. This is why ultrasonic flowmeters, such as those offered by Fluenta, are so integral.

Flare measurement sits at the intersection of operational necessity and technical frustration. Despite its critical safety function, the act of quantifying what passes through a flare stack has often bordered on guesswork. The gases released are unpredictable, the conditions hostile, and the instrumentation pushed far beyond its design envelope. Yet as environmental regulations tighten and emissions data becomes a matter of public record, what was once tolerated as an inexact science is being redefined as an area demanding precision. The push for accountability is forcing innovation in a space where traditional tools have consistently fallen short.

Unlike standard process streams, flare gas is inherently unstable. Its flow rates swing from almost nothing during routine operations to violent surges during process upsets, plant shutdowns or emergency blowdowns. In some refinery applications, velocities exceeding 120 metres per second have been recorded. These swings create turbulent, noisy, non-laminar conditions that defeat flow technologies optimised for steady-state behaviour. The flowmeter must exhibit an extremely high turndown

The Fluenta Flare Sens unit

ratio to track both the smallest pilot or purge flows and the largest flaring events using a single, responsive device.

Beyond velocity, composition is another moving target. Flare gas is not a consistent product but an ever-changing cocktail of hydrocarbons, inerts and occasionally hydrogen. The proportions can vary not just by day but by minute, depending on process operations upstream. Some flare lines will carry mostly methane and ethane at one point and then be dominated by CO2, heavier vapours the next. Many flow technologies – particularly thermal and differential pressure types – depend on stable composition for calibration. Their measurement principles are either density-dependent or rely on heat transfer properties that shift dramatically between gas species.

Then there are the thermal extremes. Flare stacks often operate in open, exposed environments, meaning the pipework can drop well below freezing at night or in LNG facilities, only to surge to several hundred degrees Celsius during sustained flaring. Rapid temperature cycling adds another layer of complexity for electronics, sensors and signal stability. Soot, vibration, corrosive gases and physical inaccessibility complete the picture. It is an environment that has defeated many otherwise capable flowmeters.

Limits of tradition

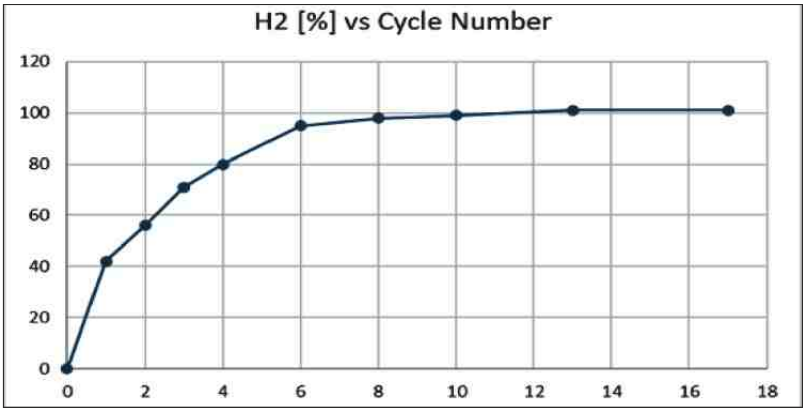
Faced with such conditions, most operators have historically deployed the tools available – often repurposing existing metering technologies designed for more benign conditions. These include differential pressure (DP) devices, thermal mass flowmeters and various optical or cross-correlation systems. Each has proven to be inadequate in at least one critical dimension.

DP flowmeters, such as orifice plates or Venturi tubes, work by measuring the pressure drop across a constriction. While well understood and widely used in stable process lines, their performance in flare gas applications is constrained by a limited turndown ratio and the need for recalibration across large flow ranges. To capture both low and high flows, multiple meters or complex switching systems are sometimes used, adding cost and maintenance.

Furthermore, DP meters are intrusive, creating pressure loss and potential fouling points. In flare lines, where soot, condensate and debris are common, this intrusion becomes a liability. Fouling can alter the flow profile and measurement accuracy, while any maintenance activity requires a shutdown of the flare line – an unacceptable risk in most facilities.

Thermal mass flowmeters rely on the principle of convective heat transfer: a heated element cools more quickly as gas flows past it, with the rate of cooling related to the gas mass flow rate. In principle, they are ideal for direct mass measurement. In practice, however, they falter in flare applications. The method assumes a known and stable composition because each gas species has a different specific heat capacity. When composition changes, for example, switching from methane to hydrogen or a CO2-heavy stream, the heat transfer dynamics shift, leading to errors unless recalibrated. While some setups attempt to pair the meter with real-time gas chromatography or analysers, these have latency, meaning a flaring event can conclude before the


Fluenta FGM System



H2 Graph

transit time measurement, is based on the speed differential between two ultrasonic signals transmitted in opposite directions across the pipe. The faster the gas moves, the more it affects the transit time in the direction of flow compared to against it. From this differential, the velocity of the gas is determined.

Crucially, this measurement is largely independent of gas composition. Unlike thermal or DP meters, the ultrasonic transit-time method does not require stable gas properties to function correctly. So long as the ultrasonic wave can propagate through the medium, which is generally true for most gases – the meter will deliver a reliable velocity measurement. While mass flow still requires gas density input, this can be derived from pressure and temperature readings or updated periodically based on gas composition estimates. The key point is that the underlying velocity measurement remains accurate even during rapid transients.

Ultrasonic flare meters are also inherently non-intrusive. Modern designs use clamp-on or spool-mounted transducers that are flush with the pipe wall, with no obstruction in the gas path. This eliminates pressure drops, reduces fouling risk, and allows the meter to continue operating even with minor deposit formation. Where some degradation in signal occurs, advanced signal processing algorithms can often compensate without full loss of function.

A standout feature is the turndown ratio. Because ultrasonic meters rely on precise timing, they can resolve velocities from near zero to over 100 m/s within a single unit. This range allows them to track everything from steady purge flows and pilot gas to emergency depressurisation events. There is no need for multiple meters or complex switching logic.

For larger pipe diameters, 24, 36 or even 42 inches, multipath ultrasonic designs employ several acoustic paths across different diameters and angles. This allows them to account for swirl, asymmetry and distorted flow profiles. Ideally, long straight runs upstream and downstream of the meter improve accuracy. Where space does not permit this, such as on offshore platforms, computational fluid dynamics (CFD) analysis can be used to model the velocity profile and apply correction

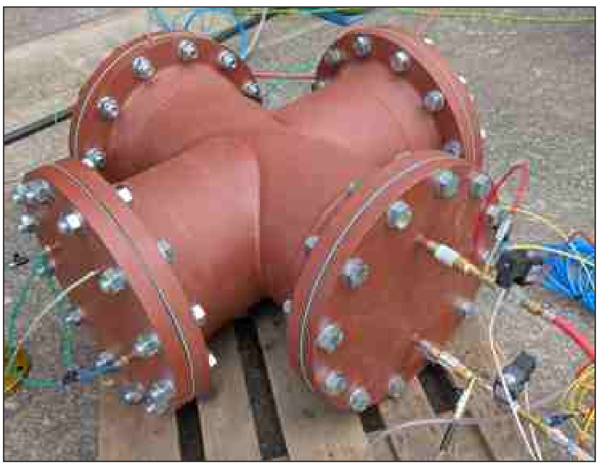
correction factor is updated. Thermal sensors are also typically insertion probes, which makes them susceptible to fouling by flare soot or entrained liquids, again requiring line shutdowns for cleaning or repair.

Optical flowmeters – including laser Doppler and photographic cross-correlation systems – avoid intrusiveness but are particularly sensitive to optical clarity. Soot, dust, or film accumulation on optical windows can render the device blind, necessitating frequent cleaning. This requirement for manual intervention limits their long-term viability in flare measurement, where maintenance access is restricted and fouling is a near certainty.

Each technology, while useful in certain conditions, is fundamentally mismatched to the extreme, unpredictable reality of flare gas flows. These limitations have compelled the industry to look elsewhere.

Listening, not guessing

Ultrasonic flowmeters have emerged as the most promising solution, offering a non-intrusive, composition-tolerant, and high-range alternative. Their core principle,



H2 Test Rig

factors. This approach has enabled reliable measurement in cramped, complex installations.

Meeting the extremes head-on

In 2025, new developments have further extended the capabilities of ultrasonic metering to applications previously thought too extreme. Fluenta has introduced several innovations targeting specific flare measurement challenges.

Showing 100 pc CO_2 in Test

One such challenge is extreme temperature. In units such as ammonia synthesis or catalytic crackers, gas temperatures can exceed 350°C, surpassing the tolerance of conventional ultrasonic transducers. The FlarePhase 350 transducer system is built to handle continuous operation from -40°C up to +350°C. Titanium sensor tips, ceramic isolation, and heat-resistant electronics are combined with internal temperature monitoring and auto-calibration to ensure performance is not compromised by thermal stress.

Similarly, for systems that alternate between cryogenic and high-temperature conditions – for instance, LNG facilities or plants with wide operational variability, the FlarePhase Cryo solution spans from sub-zero to +250°C, providing continuous and accurate measurement regardless of ambient or process heat levels.

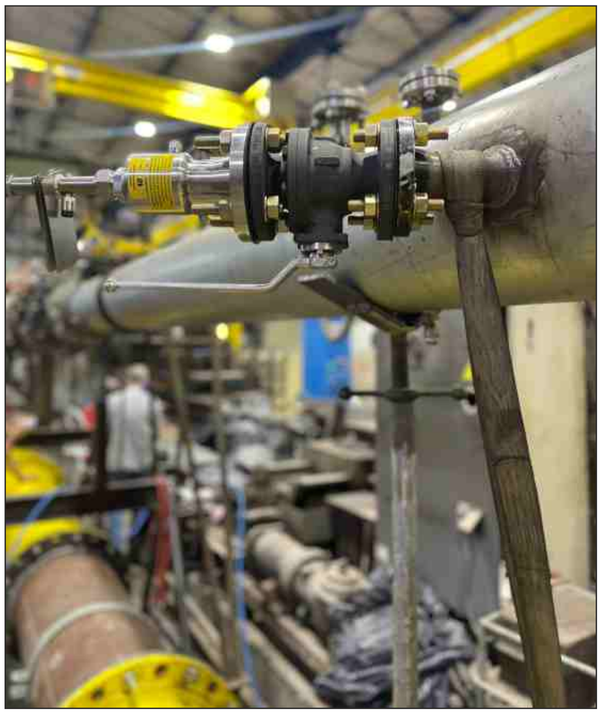
High-CO_2 content has long been problematic for ultrasonics due to acoustic attenuation. CO_2 tends to absorb ultrasonic energy, weakening the signal. Fluenta has developed a frequency-optimised system that overcomes this, allowing accurate flow measurement even in flare lines carrying 100% CO_2, such as those in carbon capture or enhanced oil recovery operations. Independent testing has confirmed consistent signal strength and accuracy across the entire CO_2 concentration range, using adapted transducer spacing and signal processing.

Hydrogen, a rising component in many industrial and energy transition scenarios, presents a unique set of issues. Its extremely high speed of sound (~1300 m/s) alters the timing dynamics significantly, and its low molecular mass challenges sensor resolution and material compatibility. Fluenta is currently developing hydrogen-specific ultrasonic system with the aim of launching a hydrogen-ready flare meter by late 2025. These devices will be capable of accurately measuring pure or mixed hydrogen flows, positioning them as vital tools in future-ready refineries and integrated hydrogen value chains.

Seeing the bigger picture

Beyond the hardware, measurement only delivers value when the data is meaningful, actionable and timely. Fluenta's FlareSens software platform has been developed to bridge that final gap. It integrates real-time measurements from ultrasonic meters, pressure and temperature sensors, and gas composition inputs into a comprehensive emissions monitoring system.

FlareSens calculates flow rates, totalised volumes, net heating values and combustion efficiency metrics



Testing in high CO_2 at IPT in Brazil

continuously. It applies health checks to flag anomalies in the system, alerts operators to deviations from expected behaviour, and presents data through user-friendly dashboards tailored to environmental reporting needs. It is, effectively, a continuous emissions monitoring system (CEMS) purpose-built for flaring.

For operators in India and globally, facing increasingly stringent reporting requirements and emissions reduction targets, such platforms streamline compliance while unlocking deeper operational insights. Correlating flare events with upstream process upsets enables better root-cause analysis and decision-making. Engineers can move from reactive compliance to proactive performance optimisation.

Clarity from the chaos

Flare gas measurement has, for too long, operated in a grey zone of best-guess estimates and compromised accuracy. Today, ultrasonic technology, backed by years of field validation and a new wave of engineering innovation, is turning that ambiguity into confidence. From extreme temperatures to variable compositions and emerging hydrogen flows, the latest generation of meters is designed to endure and perform.

For operators, the implications are practical and immediate: better compliance, fewer shutdowns, lower maintenance, and improved understanding of one of the most volatile parts of their process. With ultrasonic measurement and integrated analytics, flare systems are no longer a black box. They are, instead, a source of insight, a place where uncertainty has finally met its match. dewjournal.com

about the author

Neil C. Bird holds M.A. (Oxon) in Physics from Oxford University, and a PhD degree from the University of Twente in The Netherlands. He has held various senior technical positions: Philips R&D Director (UK and The Netherlands), R&D Director at ThermoFisher (Cambridge), Head of R&D at Xaar (Cambridge), Engineering Director and latterly Chief Scientist at Fluenta (Cambridge). He has a track record of innovation including more than 30 US patents in various technical areas, such as ASIC design, liquid crystal display, mobile networks, and ink jet printing. In his current role, he has developed new signal processing methods for ultrasonic gas flow measurement.