

SEEING THE INVISIBLE

**Keyur Shah, SB Engineers, and
Alexandra Graf, PROMECON, discuss
how real-time flow data can unlock
energy efficiency in the clinker cooler.**

In the heart of every cement plant, the clinker cooler silently defines the plant's energy efficiency. While its primary purpose is to reduce the clinker temperature from about 1400°C to below 100°C, its role extends far beyond cooling. The air streams passing through the cooler form the backbone of heat recuperation and waste heat recovery (WHR). Both are levers for modern cement plants striving for lower energy costs and carbon emissions.

As clinker leaves the kiln, immense amounts of thermal energy remain stored within it. Efficient coolers recover a large portion of this energy by returning heated air to the kiln as secondary and tertiary air. This recirculated energy reduces the fuel demand at the kiln burner and enhances the thermal balance of the system.

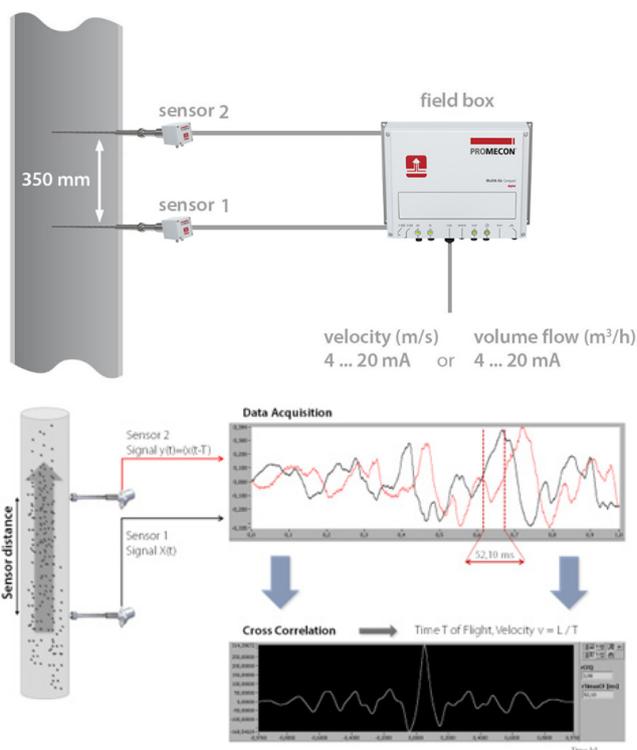
Modern plants equipped with WHR systems (WHRS) further elevate the value of the cooler. Here, the exhaust air from the cooler contributes directly to electricity generation, often covering up to 30% of the plant's total power needs. This represents a fundamental contribution to competitiveness among other cement manufacturers.

However, this
only works if
the air

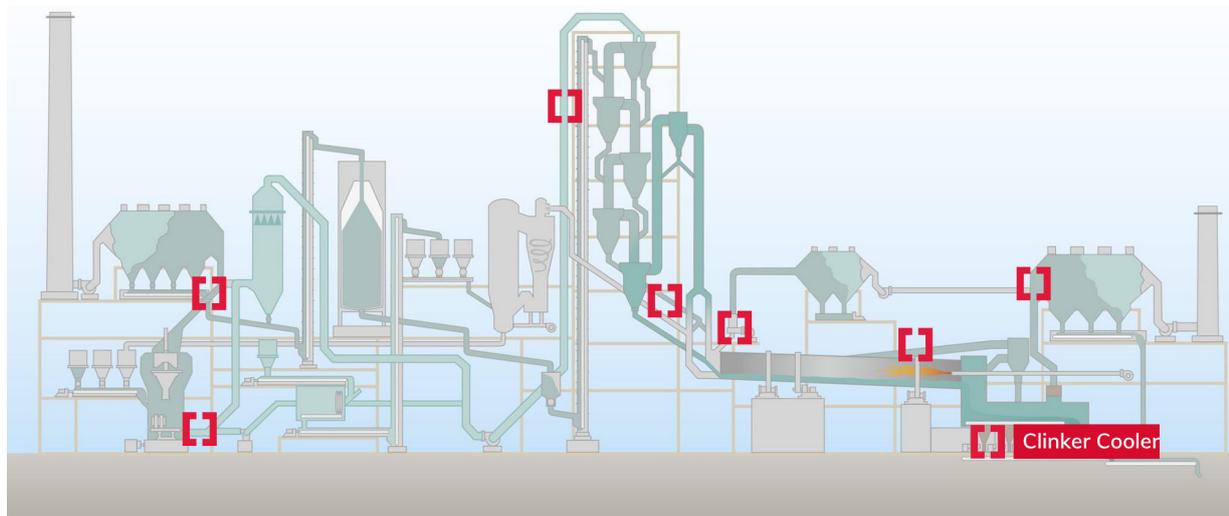
distribution inside the cooler operates exactly as designed. Even minor imbalances ('unmeasured and therefore uncorrected') can lead to high clinker outlet temperatures, excessive fan power, and poor waste heat availability. In other words, the efficiency of the entire pyroprocess depends on a parameter that remains largely invisible: the airflow within the clinker cooler.

Challenges in measuring airflow

Measuring air and gas flows in clinker coolers sounds straightforward. Yet, in practice, it is one of the most demanding tasks in cement process control. The environment is extremely hot, dusty, and dynamic. Temperatures can range from



Measurement principle of McON Air.



Schematic overview of different gas flow applications. Highlight mark at the clinker cooler – from hot clinker to WHR.

300 – 800°C, while fine particles in the gas stream can cause buildup and abrasion on traditional sensors. Duct geometries vary widely, often creating uneven flow profiles. Meanwhile, fans induce pulsations that lead to unstable readings.

Traditional flow measurement technologies struggle in these harsh conditions:

- ▶ Averaging Pitot tubes. These require frequent cleaning and maintenance, making them unreliable for continuous operation.
- ▶ Thermal mass flow meters. They are sensitive to dust contamination and prone to drift.
- ▶ Ultrasonic flow meters. These devices depend heavily on precise alignment and often fail when dust concentrations are high.
- ▶ Differential pressure grids. They rely on conditioned, laminar flow – a situation rarely found in the mid-tap ducts of a clinker cooler. They are also prone to drift and require regular maintenance.

The result is often a process that operates in the dark. Airflows are set by soft sensors – experience or historical data rather than actual conditions. Cooler efficiency becomes reactive instead of proactive. Over time, the imbalance costs energy: fans consume more power, the kiln requires more fuel, and the WHRS delivers less energy than it could.

Recognising this gap, engineers worldwide have long sought a measurement solution capable of delivering real-time, drift-free data, especially without maintenance interruptions or calibration drift. This is where triboelectric volumetric flow measurement enters the clinker cooler. PROMECON's technology offers a proven and robust solution for measuring gas flows under the extreme

process conditions found in clinker coolers. The system is based on a cross-correlation principle, utilising the natural electrical charge fluctuations generated by dust particles moving within the gas stream.

Measurement techniques

At each measurement point, a pair of metal rod sensors is installed parallel to the gas flow and electrically insulated from the duct wall. These rods extend directly across the gas stream and detect the charge patterns created as particle clouds pass by. The first sensor detects a pattern, and a short moment later, the second sensor records the same pattern as it moves downstream.

By mathematically cross-correlating these two 'fingerprint' signals, the system precisely determines the time shift between them. Knowing both the time shift and the fixed distance between the sensors, the process gas velocity is displayed as a vector, not a single-point value. When combined with the duct's cross-sectional area, as well as temperature and pressure data, the system determines the volumetric and mass flow of the gas.

Because the measurement is based purely on time correlation, it is independent of gas composition, temperature, or pressure, and it is truly drift-free – a major advantage in high-temperature, dusty process environments. There are no moving parts, no optical alignment requirements, and no pressure drop introduced into the system.

This measurement principle brings several key advantages to clinker cooler applications:

- ▶ Reliable in harsh environments. The system performs accurately even in hot, dust-laden, and non-laminar flow conditions.
- ▶ Stable over time. It is unaffected by gas density or buildup and requires minimal maintenance.
- ▶ Dynamic response. The system provides real-time data that is suitable for the

automatic control of air distribution and enthalpy calculation models.

- ▶ Simple installation. Sensors can be retrofitted into existing ducts without requiring major mechanical modifications.

Process optimisation and operational benefits

In operation, this technology enables plant engineers to continuously monitor and balance air flows across the mid-tap air ducts of the clinker cooler, as well as secondary and tertiary air flows in the recuperation zone. Real data replaces soft sensor assumptions, allowing operators to fine-tune fan loads, reduce uneven air distribution, and enhance both cooler and kiln stability.

Field results from plants in Asia and Europe demonstrate the impact:

- ▶ Up to 10% reduction in fan power consumption.
- ▶ 3 – 5% increase in WHRS efficiency.
- ▶ Lower clinker outlet temperatures and more stable operation.

Ultimately, the ability to measure true flow dynamics under real process conditions transforms clinker cooler optimisation from reactive control into a data-driven discipline, delivering measurable KPIs in energy efficiency and process stability.

Real-time volumetric flow data is more than a diagnostic tool; it is the foundation for intelligent process control, competitiveness, and sustainability in cement production.

By integrating flow measurement into the plant's control system, operators can automatically adjust fan speeds and air dampers in response to actual process conditions. This enables adaptive control of cooler air distribution, balancing recuperation and WHRS efficiency dynamically.

The benefits extend across multiple performance indicators:

- ▶ Fuel consumption drops as secondary and tertiary air temperatures stabilise.
- ▶ Power demand decreases with optimised fan load and reduced pressure drop.
- ▶ WHR improves through stable air mass flow to the WHRS.
- ▶ Lower fossil fuel demand translates directly into reduced CO₂ and NO_x emissions.

Furthermore, precise and continuous measurement supports predictive maintenance and digital optimisation initiatives. The data can be visualised in dashboards, linked to long-term process

| Parameter | Conventional dP Sensors | PROMECON McON Air |
|--------------------------------|---|---|
| Signal stability | ▲ Drift up to ± 20% | ☑ Completely drift-free digital data |
| Response time | ▲ Several seconds | ☑ Real-time data (<1s) |
| Dust impact | ▲ Clogging, degradation | ☑ No impact (time of flight) |
| Temperature range | ▲ Typically: 400–500 °C | ☑ Up to 1000 °C |
| Measurement type | ▲ Single-point, local tap | ☑ Vector velocity between antennas |
| Sensitivity to gas composition | ▲ Strong | ☑ None |
| Installation | ▲ Requires duct modification and plant downtime | ☑ Simple, plug&play, hot tapping solution for full plant availability |
| Sensor lifetime | ▲ ~ 1 - 3 years | ☑ ~ 6 - 12 years |
| Maintenance | ▲ Cleaning & re-calibration | ☑ None, annual visual check |
| Calibration | ▲ Regular Calibration | ☑ Calibration-free, No K-Factors |

Comparison of conventional flow measurement technologies versus triboelectric vector technology.

data storage, and combined with machine learning models to forecast efficiency trends.

In the broader context of Industry 4.0 and the global race toward net-zero emissions, such data-driven insights are becoming indispensable. Every percentage point of efficiency gained through better airflow management translates into both financial savings and environmental benefit. Real-time flow measurement turns what was once an invisible process variable into a strategic instrument for operational excellence. In an era where the cement industry must balance production efficiency with sustainability targets, measuring the unseen becomes the new competitive edge.

System capabilities

The McON Air System is designed for continuous, high-temperature operation under demanding process conditions. Key specifications include:

- ▶ High temperature tolerance. Operates reliably up to 1000°C.
- ▶ Drift-free performance. No calibration or purging is required, ensuring consistent accuracy over time.
- ▶ Low maintenance. Minimal intervention is needed for long-term operation.
- ▶ Wide turn-down ratio. Supports variations in airflow of up to 25 times.
- ▶ Direct measurement. Time-of-flight technology eliminates the need for K-factors.



Installation of McON air flow meter into vertical clinker cooler duct in a European cement mill.

- ▶ Hot tapping capability. Full plant availability is maintained during installation or service.
- ▶ Flexible integration. Outputs include 4 – 20 mA and Modbus TCP, with optional additional fieldbus protocols.

Conclusion

The clinker cooler may seem like a supporting component in cement manufacturing, but its impact on energy, emissions, and cost is undeniable. Through drift-free volumetric gas flow data and continuous data analysis, cement producers can unlock new levels of efficiency and stability.

As plants worldwide aim to decarbonise and digitalise, technologies that deliver real-time transparency and process excellence will define the leaders of tomorrow. Measuring flow is not just about data: it is about revealing what drives performance at the core of the process. ■

About the authors

Keyur Shah is an Electronics and Communication Engineer with an additional qualification, a Diploma in Business Management. After a brief stint as a R&D Engineer, Keyur started working as Service & Commissioning Engineer at SB Engineers, where he developed a strong foundation in industrial systems and customer-centric solutions. Keyur has 30 years of experience working in the cement industry, blending deep technical expertise with strategic business insight. Keyur has transformed business at SB Engineers from a traditional product supplier to a cutting-edge, technology-driven solution provider. Keyur is currently focused on forging global collaborations to bring innovative, high-growth solutions to the cement and allied industries."

Alexandra Graf, M.Sc. studied Biotechnology with a focus on Process Engineering at the University of Applied Science Anhalt (Germany). Alexandra is a passionate engineer with over 10 years of experience in process measurement and automation for chemical and heavy industry. At PROMECON, Alexandra focuses on implementing innovative measurement systems for hot, dust-laden gas processes to reduce emissions and improve efficiency. Alexandra regularly speaks at international conferences and drives knowledge exchange and advanced process solutions within the heavy industry community.