

# Burner retrofits for fuel flexibility and flame control

As the cement industry accelerates its transition towards lower-carbon production, the adoption of alternative fuels and the reduction of process emissions have become key operational priorities. However, many existing burners are not fully suited to today's multi-fuel operating environments. This article explores how targeted burner retrofit solutions can help cement producers overcome these challenges, enhancing fuel flexibility, flame control and emissions performance while avoiding the costs and downtime associated with complete burner replacement.

■ *by Special Burner & Equipment Srl, Italy*

The cement industry is currently undergoing a profound transformation driven by the need to reduce environmental impact, increase the use of alternative fuels (AFs) and improve overall process efficiency. Within this evolving scenario, kiln burner systems play a strategic role, directly influencing clinkerisation stability, clinker quality and plant emissions performance.

However, many burners currently installed in cement plants were originally designed for operating conditions that differ significantly from today's requirements. Traditional configurations were mainly optimised for conventional fossil fuels such as coal and petcoke, characterised by relatively stable and predictable combustion properties. But growing environmental pressure and the evolution of energy markets are progressively pushing cement producers towards higher substitution rates of AFs, including biomass, refuse-derived fuel (RDF) and other waste-derived fuels. This transition introduces new operational challenges, because the variability of physical and chemical fuel properties can negatively affect flame stability, combustion efficiency and emissions behaviour.

Retrofitting existing kiln burners represents a cost-effective and flexible solution to address these challenges. By upgrading key components and optimising combustion dynamics, it is possible to significantly improve burner performance without the need for complete system replacement.

| Table 1: typical fuel-related challenges in cement kiln operation |                                  |                                   |
|-------------------------------------------------------------------|----------------------------------|-----------------------------------|
| Fuel type                                                         | Challenge                        | Process impact                    |
| Coal/petcoke                                                      | Limited flexibility              | Restricted fuel substitution      |
| Wood powder                                                       | Low calorific value, low density | Flame instability                 |
| RDF                                                               | Variable composition             | Fluctuating combustion conditions |
| Liquid fuels                                                      | High flame radiation             | Local overheating                 |

Thanks to its extensive experience in burner engineering for cement kilns, Special Burner & Equipment (SBE) has developed dedicated retrofit solutions designed to increase fuel flexibility, improve flame control and reduce emissions while maintaining high operational reliability.

## Challenges associated with conventional burner designs

The increasing use of heterogeneous fuel mixes represents one of the most significant challenges faced by modern cement plants (see Table 1). Burners originally designed for conventional fuels often show substantial limitations when operating with high percentages of AFs.

Compared to fossil fuels, biomass fuels such as wood powder introduce specific difficulties related to lower calorific value and lower density. These characteristics directly influence combustion dynamics and may lead to flame instability, ignition difficulties and variations in heat distribution inside the kiln.

The use of RDF introduces additional complexities due to the variable

composition of the fuel itself. Variations in energy content, humidity and particle size distribution can generate unstable combustion conditions, negatively affecting process continuity and clinker quality.

Based on SBE's experience across multiple cement kiln installations, the most common operational issues include:

- excessively long or poorly controlled flames
- incomplete combustion, resulting in elevated CO emissions
- high peak flame temperatures associated with increased NO<sub>x</sub> formation
- operational instability leading to coating formation.

These limitations clearly demonstrate that traditional combustion systems are often unable to fully meet modern process requirements. Therefore, targeted retrofit solutions become essential to adapt burner fluid dynamics and combustion behaviour to new operational conditions.

## Retrofit approach and engineering considerations

An effective retrofit project always begins with a detailed technical assessment of

kiln operating conditions. In addition, every SBE retrofit solution starts with a comprehensive evaluation phase, including analysis of existing burner performance, review of process parameters and definition of future fuel mix scenarios.

Based on these inputs, customised retrofit solutions are developed to improve combustion control while maintaining compatibility with existing equipment and minimising mechanical modifications.

Retrofit interventions may include:

- redesign of burner tip geometry
- optimisation of primary air distribution
- integration of additional fuel channels
- modification of swirl generation systems.

The main objective is to achieve more precise flame shaping and improved air-fuel mixing. Flame behaviour is strongly influenced by the balance between axial momentum, radial air distribution and mixing intensity. Accurate management of these parameters allows the generation of a compact, stable and controlled flame, capable of ensuring optimal clinkerisation conditions.

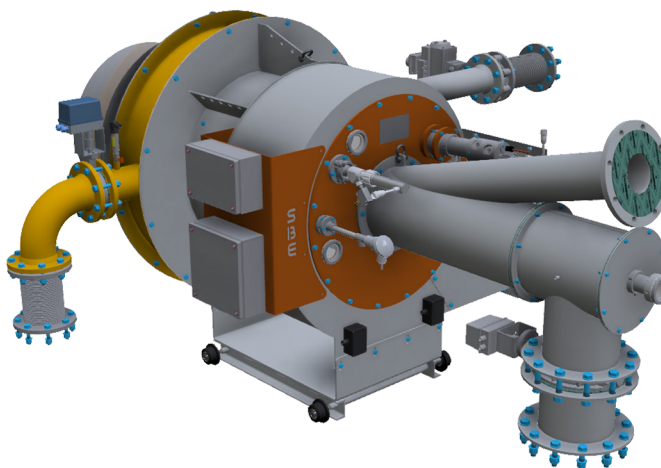
To validate proposed solutions, SBE utilises advanced computational fluid dynamics simulations and 3D modelling tools. These technologies make it possible to predict burner fluid dynamics and optimise combustion configurations before field installation.

One of the main advantages of the retrofit approach lies in the possibility of implementing upgrades during standard scheduled shutdowns. This significantly reduces downtime and investment costs compared with complete burner replacement.

### Multi-fuel and biomass firing solutions

Increasing AF substitution rates has

The increased use of alternative fuels and biomass places a different set of demands on kilns



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become one of the main objectives for many cement producers. Achieving this target requires burner systems capable of handling multiple fuels with very different combustion characteristics.

SBE retrofit solutions are specifically designed to allow simultaneous utilisation of conventional solid fuels, RDF, biomass, liquid fuels and gaseous fuels. Particular attention is paid to biomass applications such as wood powder, which require dedicated injection and dispersion systems.

In these applications, burner design includes dedicated fuel channels, controlled dispersion systems and optimised mixing zones developed to ensure stable combustion, even when low-density fuels are utilised.

The ability to precisely control fuel dispersion and interaction with primary air flows allows the flame to remain stable, even at high thermal substitution rates. This aspect is particularly important in an industrial context where CO<sub>2</sub> reduction

targets increasingly depend on the utilisation of AFs.

### Flame optimisation and process efficiency

Flame shape represents one of the most critical aspects of rotary kiln operation. An unstable or excessively long flame may compromise heat transfer to the material bed, affect burning zone stability and negatively influence clinker quality.

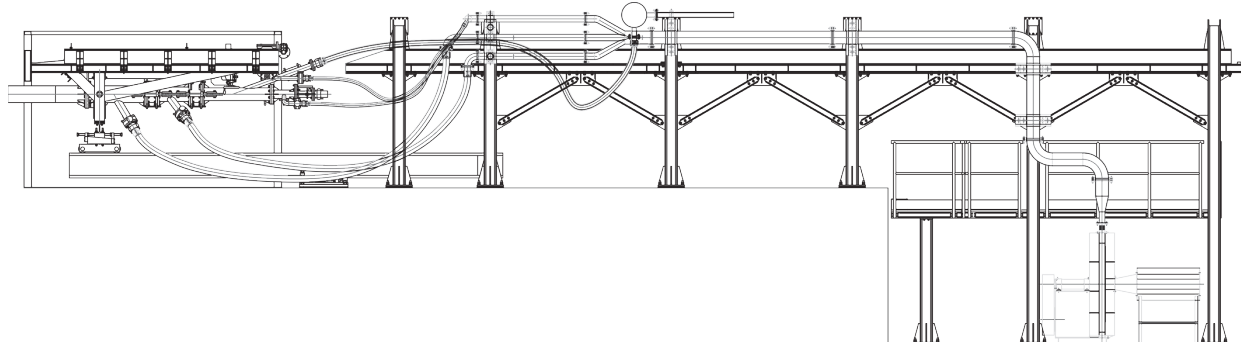
Through retrofit interventions, SBE focusses on transforming unstable combustion conditions into compact, intense and stable flame configurations.

Optimisation activities involve several key parameters including:

- flame length
- jet momentum
- swirl intensity
- primary air velocity.

Proper balancing of these factors improves heat transfer efficiency during clinkerisation while reducing specific fuel consumption.

Based on a detailed assessment of kiln conditions, a retrofit solution is developed to improve combustion control



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**Table 2: operations benefit with burner retrofit for rotary cement kiln**

| Flame shape                     | Challenge               | Process impact                    |
|---------------------------------|-------------------------|-----------------------------------|
| More flexibility                | Fuel cost reduction     | Burning zone under control        |
| Specific momentum under control | Flame shape more stable | Specific fuel consumption reduced |
| Stable                          | Refractory brick life   | Refractory consumption reduced    |
| Not using fossil fuels          | Dedicated engineering   | Cost and emission benefits        |

Targeted burner upgrades can significantly improve fuel flexibility and lower CO<sub>2</sub> emissions



From an operational perspective, a more stable flame also contributes to improved clinker quality consistency and better kiln process stability. These benefits become even more significant when the kiln operates with high percentages of AFs, where combustion control becomes particularly challenging.

### NO<sub>x</sub> emissions reduction

Reducing NO<sub>x</sub> emissions has become a major priority for modern cement plants due to both environmental requirements and increasingly restrictive regulations.

Burner design directly influences NO<sub>x</sub> formation because it affects oxygen distribution, peak flame temperatures and mixing conditions inside the rotary kiln.

SBE's experience demonstrates that targeted retrofit interventions can significantly reduce emissions without compromising combustion stability.

Adopted strategies include controlled air staging, optimised flame shaping and reduction of localised high-temperature zones.

Through these optimisations, substantial NO<sub>x</sub> reductions can be achieved while maintaining low CO levels and stable operating conditions.

### Case study: rotary kiln burner retrofit

A recent retrofit project carried out by SBE provides a practical example of the benefits achievable through burner upgrading.

Initial operating conditions included an unstable and excessively elongated flame, difficulties in maintaining stable burning zone conditions and limited utilisation of AFs. NO<sub>x</sub> emissions were ~1200mg/Nm<sup>3</sup>.

The retrofit solution developed by SBE included:

- installation of a newly designed burner tip
- integration of a dedicated biomass injection system
- optimisation of primary air distribution
- upgrading of fuel handling and feeding systems.

Following the retrofit intervention, kiln operation showed a significant improvement in flame stability and overall process conditions. At the same time, AF substitution rates increased considerably and NO<sub>x</sub> emissions were substantially reduced.

The entire intervention was completed during a scheduled shutdown, confirming the operational feasibility of retrofit solutions even in plants characterised by limited maintenance windows.

### Operational benefits of retrofit solutions

SBE retrofit solutions allow cement producers to improve combustion system performance with significantly lower investment compared with complete burner replacement.

Fast implementation represents an additional advantage, since upgrades can generally be integrated during standard maintenance shutdowns with minimal impact on production.

From a technical perspective, retrofitting improves:

- fuel flexibility
- flame control
- process stability
- environmental performance.

These factors contribute directly to higher overall plant efficiency and support the sustainability objectives of modern cement production.

### Conclusions

Retrofitting existing kiln burners represents one of the most effective strategies available today to enable cement plants to adapt to evolving operational and environmental requirements. The increasing use of biomass and AFs, together with the growing need to reduce emissions, requires combustion systems that are increasingly flexible, efficient and reliable.

Through its engineering expertise and extensive field experience, SBE has demonstrated that targeted burner upgrades can significantly improve flame control, fuel flexibility and emissions performance, without requiring major modifications to existing kiln systems.

Looking ahead, burner retrofit solutions are expected to play an increasingly important role in supporting efficient, sustainable and flexible cement production processes capable of meeting future environmental and energy challenges. ■