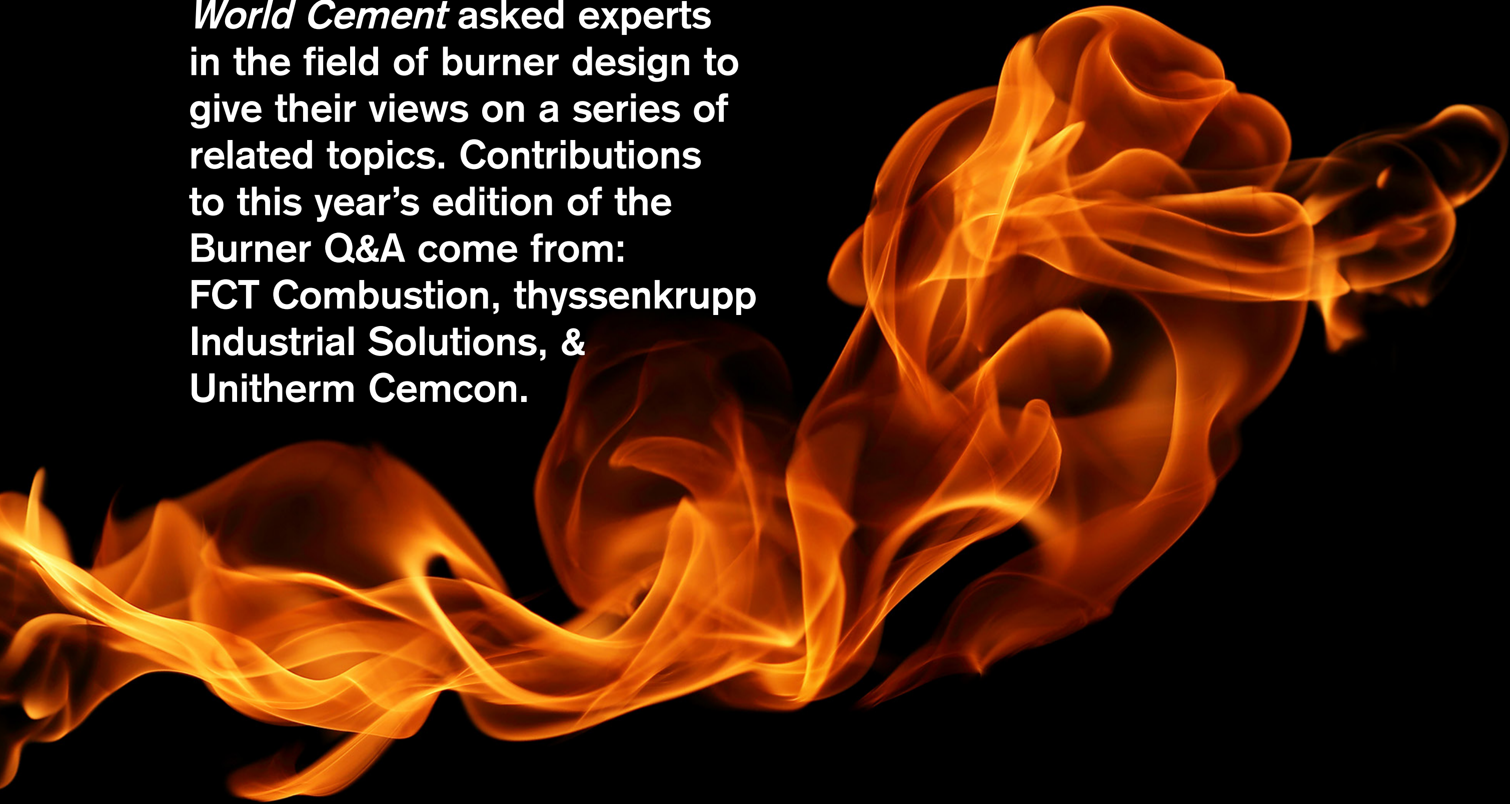
World Cement Burner Q&A

***World Cement* asked experts in the field of burner design to give their views on a series of related topics. Contributions to this year's edition of the Burner Q&A come from: FCT Combustion, thyssenkrupp Industrial Solutions, & Unitherm Cemcon.**



The increasing use of alternative fuels of varying quality and consistency can present challenges in cement manufacture. How can such fuels impact burner performance, and what can be done to mitigate the effects?

FCT Combustion: Different fuel means different particle sizes, densities, moistures, and calorific values together with different drying, ignition, and burnout times as well as combustion kinetics. The type of alternative fuel, the variation in types and the ratios in which they are delivered to the burner can impact flame length and heat flux profile inside the kiln as well as emissions. Most fuel dosing systems also work on a volumetric basis, which means that the thermal energy being supplied to the burner is variable over time, even if the volumetric dosing is constant, due to the variable fuel characteristics.

To mitigate all these effects, the burner must be designed to enable very flexible operation in such a way as to allow for proper aerodynamic and combustion control, enhancing entrainment of secondary air into the flame. FCT recommends the Turbu-Flex™ Burner with its axial air tip design, reconfigured swirl, and alternative fuel lifting air which is split between lifting the material from the bottom of the conveying pipe and dispersion air which disperses the fuel into the primary and secondary air as it leaves the burner tip.

Apart from the challenges at the kiln burner, it is important to mention that some fuels are inherently better suited to the calciner, and it would not make sense to overcome the difficulties of using them at the kiln, when it would be much easier to use them at the calciner. Such fuels include those with higher moisture, lower calorific value, larger particle size, longer required combustion time, or low volatile content, among others.

As a general rule, easier to burn alternative fuels should be targeted at the kiln burner, and harder to burn fuels at the calciner. In case there is no calciner available, a mix between hard and easier to burn alternative fuels would be the best compromise to increase the overall substitution rate while having a lower impact on the kiln operation. Another solution could be the use of satellite burners. CFD modelling could also be a good option for specific problem solving.

The use of hydrogen as a fuel in cement production is also an emerging trend which can impact burner performance. Due to its high cost and low availability at present, hydrogen could be considered an alternative fuel in the short- to medium-term. Production of hydrogen through electrolysis also produces oxygen, so that the availability of either or both for the burner systems opens new possibilities for control of flame characteristics optimised for cement production.

What steps can be taken to minimise harmful emissions such as NOx?

FCT Combustion: It is generally believed that minimising primary air amount is one way to reduce NOx generation at the burner. However, in practice, the answer is not so simple. In isolation, the reduction of the primary air amount can lead to an increase in NOx if it causes a delayed ignition of the fuel, for example. Furthermore, the reduction of primary air alone can also affect clinker quality, decreasing cement strength and can cause issues with the kiln operation in terms of slower responsiveness, increased alkalis and sulfur cycles in the kiln, and uncontrolled combustion.

The important point is that NOx emissions can be minimised with reduced primary air, as long as it comes with the same or better combustion control. Apart from the quantity of primary air, the distribution in the flame can have a significant impact on NOx emissions. Delayed entrainment of secondary air can decrease NOx, as long as it does not cause delayed fuel ignition. Early ignition of the flame has long been known to reduce NOx and burner tip and primary air design is critical to the ignition point. The location and momentum of the primary air at the burner tip is critical in how and where secondary air is entrained into the flame. It should allow for a fast fuel ignition but a slower combustion overall – a very fine balance. Water injection into the flame from the burner tip can also be useful in controlling peak temperatures which are another factor in NOx generation, but this obviously it has its penalties.

Where possible, an effective and economically advantageous strategy to reduce NOx emissions is to use alternative fuels. Their characteristics such as higher moisture, larger particle sizes, or low calorific values, among others are such that they slow down the combustion. Fuels with lower nitrogen content can also be used to reduce NOx, though with limited results. A flexible burner that can be adjusted to different conditions and fuels is paramount.

The actual burner technology can, in some cases, have a huge impact on NOx emissions, for example, the Gyro-Therm™ burner for natural gas uses completely new technology for mixing fuel and air that minimises NOx formation while producing a short hot heat flux profile ideal for cement kiln operation.

Generally speaking though, it is undesirable to compromise product quality, kiln output, fuel consumption, refractory life, etc., to control NOx emissions, and it is better to treat the flue gases to remove NOx from the exhaust stream.

What role can satellite burners play in modern burner systems?

FCT Combustion: Satellite burners can play a role in modern burner systems up to a certain limit. Satellite burners are located in a high oxygen area in the kiln and are usually positioned behind and above the main kiln burner. They can allow for better drying of the fuel before it enters into the flame, allow for increased flight time (especially for 3D or larger particles), and when the design is right, they can allow for operational flexibility and certain aerodynamic and combustion control.

However, in the main burner, although the AF is injected in an area of lower O_2, where reduced drying can take place before combustion and flight time is slightly reduced, the benefits of the all the fuel being in the burner bring enhanced operational flexibility and aerodynamic and combustion control. Additionally, there is the relative positioning of the satellite burner and main burner, which limits the amount of fuel that can be delivered by a satellite burner as it is not ideal to move the majority of the fuel energy input to a position far from the kiln centre (as the satellite burner does). Hence satellite burners are a great tool to begin using alternative fuels without investing in a new burner, or to complement the operation of an alternative fuel burner, especially with harder to burn fuels.

What design steps can be taken to ensure consistent and reproducible flame shaping?

FCT Combustion: There are some basic design rules that need to be followed to maintain the flame shape despite the operational fluctuations that occur in the kiln – with the main parameter relating to the burner momentum being sufficient to overcome fluctuations in secondary air flow and temperature.

FCT also believes that the burner and particularly the burner tip should have no moving parts. Maintaining openings in channels as originally designed means the performance of the burner will not change over time. It is difficult to reproduce the exact geometry when parts move and where 1 mm can make a difference. Operational flexibility is provided by giving the operators the ability to change total momentum and swirl ratios by adjusting air supply settings and proportioning air to different channels with valving at the back of the burner. It is also important to have enough instrumentation to get data from the process and the burner operation so changes to settings can be made on the basis of such data. Consistency in all areas of kiln operation, including standardised operating procedures and stable raw meal chemistry, all lead to stable firing rates, better combustion and aerodynamic control. Consistent mixes of fuels and steady feeding of alternative fuels leads to reproducible flame. However, it is a known fact that there is no such thing as a stable operation. When fuel mixes or alternative fuel properties, raw materials, temperatures and others do change, it is important to have a flexible burner design which can be adapted to cope with the new conditions.

Avoiding downtime and reducing maintenance costs is key for cement producers. How can burner and refractory lifetime be enhanced?

FCT Combustion: The interaction of the flame and kiln aerodynamics can be a critical determinant of refractory life. The burner design drives the heat flux profile, which is a key driver of coating building and stability. Good stable coating in the burning zone is the best way to increase refractory lifetime in the kiln region under the most thermal stress.

However, the burner works in a certain environment, which is different in each kiln. The burner design should be tailored to the specific kiln in which it is installed, taking into consideration specificities in terms of secondary air conditions, kiln, kiln hood and cooler geometries, temperatures in different streams and parts of the process as these can influence how the burner should be designed, how the flame and kiln heat flux profile are affected, and how these impact on stable coating, and volatile cycles among other factors. In some extreme cases, such as when a new burner is being sought to solve an existing problem in the kiln, modelling can be an effective tool for optimisation.

The fundamental design choices underlying the burner's architecture can have a major impact on the lifespan of the burner itself. Moving elements at the front of the burner are key weak points, where wear or thermal damage can cause significant alteration of the burner's performance, potentially leading to kiln refractory damage. FCT's design philosophy is based on simple and robust construction methods, which are intended to maintain the aerodynamic integrity of the burner, coupled with science- and modelling-driven detailed design aimed to meet the specific kiln's operational requirements.

The right choice of materials against wear, as well as better instrumentation to monitor and adjust operating conditions, are extremely important for extended burner lifetime. FCT also uses innovative thermal treatments on burner tip components to improve cooling. Burner thermal management is a very important component in the work required to extend burner operational lifetime and the ability of the burner to survive adverse events such as power failures.

A maintenance-friendly design is paramount to bringing the burner back to its original state if a problem does occur.

A major trend seen across the cement sector in recent years has been the spread of digital technologies and 'Industry 4.0'. What role has this development played in burner operation?

FCT Combustion: Industry 4.0 and digital technologies are powerful trends that allow for a larger quantity, and higher quality, of information gathering from burner and process operation. With these benefits, better and faster decisions can be made and replicated time and time again. Improved learning about the process can also be achieved more efficiently.

As initiated by the expert supervisory systems from the past, the interaction between different equipment, sensors and processes can be better coordinated when more information is available, allowing for easier operation, better quality, lower costs, and lower emissions.

What do you see as the next steps in burner design? What developments can the cement sector expect to see in coming years.

FCT Combustion: The next steps in burner design depend on which global region is being considered, as different areas have different environmental concerns, expectations, fuels, different stages of technological development, and so on.

In very broad terms, the obvious next steps are going to be in the utilisation of hydrogen and oxygen due to their environmental appeal with regard to CO_2 reduction. Depending on the very many supply possibilities, these may be available and used either separately or together, in quite small or potentially quite large quantities.

Research into where in the burner each of these gases might be added, when in the operation and in combination with which fuels they might provide the most benefit is going to be required. Some of these questions might be provided with general answers. However, in accordance with FCT's overall philosophy, careful consideration of these and other questions has to be done on a case by case basis. Again, in some cases, modelling can be a useful tool.

Novel materials and treatments are likely to feature in near future designs, particularly in the areas of wear and thermal management.

Modular burner designs might well become the norm where plants are forced to adapt to rapid changes of their available fuels. Rather than designing a burner for several different fuels that may or may not come into operation, which may compromise the overall design in benefit of the flexibility, it may prove substantially better to provide and easily upgradeable burner with replaceable sections that allow a smaller set of conditions (for example: fuels), to be used closer to their optimum design.

Looking further ahead, the availability of real-time information on kiln operating conditions could lead to kiln modelling and some automated burner adjustments to maintain real-time optimised burning conditions as process operations fluctuate. ■