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# Latest burner profiles

In this article each cement burner OEM was given the opportunity to present the main features of its burners as well as provide insight into design concepts and their evolution. The emphasis is on the latest offering of each OEM, even though several still sell burners from previous generations. As not all OEMs responded, the excersise has been completed using information found in the available literature. For more information on the evolution of burner design trends, see the February 2017 issue of *Global Cement Magazine*.

This article will present information from burner OEMs regarding the following burners:

- KHD Pyrojet;
- FCT Turbujet;
- Unitherm MAS;
- Polysius (tkIS) Polflame;
- Dynamis D-Flame;
- FLSmidth Jetflex;
- Fives-Pillard Novaflam;
- A TEC-Greco Flexiflame;
- Burners from Rockteq International.

Each entry comprises text from the OEM unless stated otherwise, followed by the author's comments. They are in no particular order. Companies that offer kiln burners for lime or mineral applications are not represented. Nor are cement companies that design their own burners, for example Lafarge (prior to the LafargeHolcim merger) and Buzzi Unicem, as those burners are rooted in some of the OEMs' designs.

## KHD Pyrojet

KHD has supplied kiln burners for more than 100 years. The modern burner systems from KHD started with the high-pressure gas burner without primary air in 1979. This burner featured a relatively small number of independent nozzles, from which the gas emerges at a supersonic velocity. This creates a strong suction effect on the surrounding secondary air and hence mixes the air and fuel efficiently.

The single-nozzle design was then applied on coal-fired burners. Prior to 1979, coal burners mainly used swirl air for flame stabilisation and axial air through an annular gap for additional shaping at the outer circumference. This outer axial air gap created a layer of cold air around the fuel cone, which delayed the mixture of fuel and swirl air.

The introduction of a nozzle ring for axial air, or 'jet air,' greatly improved the combustion: The jet air entrains the secondary air with high-velocity jets and mixes it in a more efficient manner, with the fuel cone in the centre. This is the KHD Pyrojet burner.

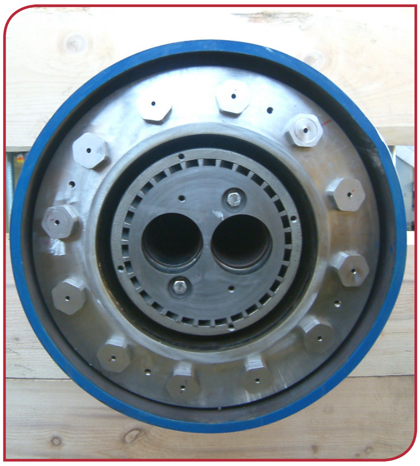
However, environmental focus in the 1980s revealed that, due to the high flame temperature and the availability of oxygen and nitrogen at the base of the flame, the burner gave rise to high levels of $NO_x$. To moderate these emissions, the amount of jet air was reduced and the pressure increased.

In 2000 the nozzle tip was simplified, leading to the current, all-welded design, with a more compact tip. At the same time, KHD introduced the cooling tube to the Pyrojet burner. The cooling tube carries the refractory of the burner and protects the support tube that bears the static load of the burner. It enables a fast exchange of the refractory in case of failures, while the emergency cooling air protects the burner support tube from further damage. The required cooling air demand is 1.5% of the total combustion air.

While 10-15 years ago, burners often featured many central channels and pipes for various alternative fuels, both operational results and CFD studies showed that burners should not be unnecessarily large. With intelligent mixes of fuels or slide assemblies that can be exchanged during operation to adapt to different fuel scenarios, the diameter of the burner can be reduced to a reasonable minimum.

The advantages of easier burner adjustment and generally better com-

**Below:** Traditional KHD design with standard cooling tube.



**Below right:** New design with cooling tube.

Left: An FCT Turbujet burner in the workshop.

bustion should be balanced against the trade-off of higher $NO_x$ emissions, an increased electrical energy demand for primary air fan/blower and, of course, the reduced cooler efficiency, as the cold primary air reduces the use of secondary air. Today's ever-changing fuel scenarios require a flexible burner design concept. KHD offers an adjustable swirl system for a better distribution of solid alternative fuels, which are injected through the central pipe.

**Xavier d'Hubert (Xd'H):** The KHD Pyrojet is one of the best known burners in the cement industry. KHD had attempted to follow the trend of adjustable primary air jets with the Pyrostream burner but this design has not been developed futher as the mechanical adjustment is costly and requires more maintenance. A burner that could incorporate all the novelties and features of all competitors would not result in a good overall solution.

## FCT Turbujet

FCT is an Australian combustion specialist. Its approach to cement kiln burners focuses greatly on scale modelling and CFD simulation. The Turbujet™ is a high momentum kiln burner that provides a very firm and steady flame that can be designed to fit every kiln situation.

Primary air slots provide effective jets that result in better mixing of the secondary air into the flame. The swirl air channel is located on the inside of the petcoke/coal channel in order to provide better dispersion of the fuel cloud. This configuration provides an intense mixing of the pulverised coal, resulting in an ignition point close to the burner that makes it possible to burn low volatility fuels.

The flame shape is controlled by a single valve that balances the total amount of primary air between the axial and swirl air channels. The amount of primary air is controlled by a variable frequency drive.

Most FCT burners have their configuration specifically optimised for the individual kiln using CFD modelling. Parameters used include: Amount and pressure of primary air; Positioning of the burner into the kiln; Best thermal profile; Fuel injection velocities, and other parameters. For solid alternative fuels, FCT has developed the Lofting Air™ system in order to improve the trajectory of particles into the kiln. This avoids unburned particles falling to the clinker bed and associated problems with localised reducing conditions and brown clinker. The amount and pressure of the air, as well as the angle, is custom-designed depending on the specific characteristics of the alternative fuel, including its particle size, shape, lower heating value, composition and other relevant parameters, as well as the specifics of the kiln.

Typical values for used for the Turbujet™ cement kiln burner are: Primary air pressure: 250–700mbar; Primary air rate: 6–10%; Axial burner momentum: 6–14N/MW; Coal velocity: 26-32m/s; Solid alternative fuel velocity: 35-45m/s.

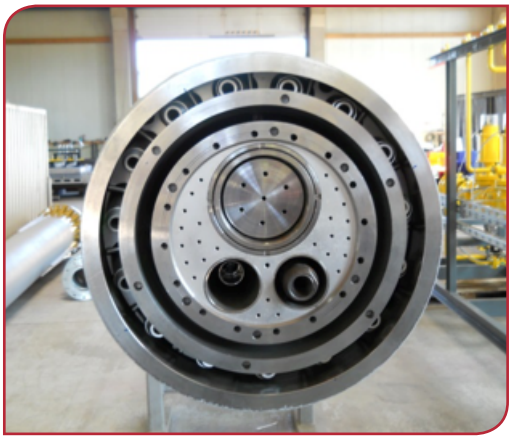
Where $NO_x$ needs to be kept at a minimum, higher primary air pressure (up to 700mbar) is used to minimise the quantity of primary air while keeping flame recirculation. FCT burners typically provide early ignition of fuel (close to the burner tip) which has been shown to reduce peak flame temperature and produce less $NO_x$. Other measures can include segmentally variable primary air, leading to variations in fuel/air proportions within the flame, or water sprays that reduce peak flame temperature.

FCT has addressed the main wear and maintenance problems on the burner with a coal channel that has protection from either ceramic tiles or a hard wearing steel, such as 'Duraplate' or similar. Alternative fuel pipes are made from specially-hardened steel to protect against wear.

**Xd'H:** Clients appear to be more and more reluctant to pay for specific studies (CFD and modeling). Therefore burners have to have features that allow the operator flexibility in fuels mix, load, $NO_x$ control, flame shape and intensity.

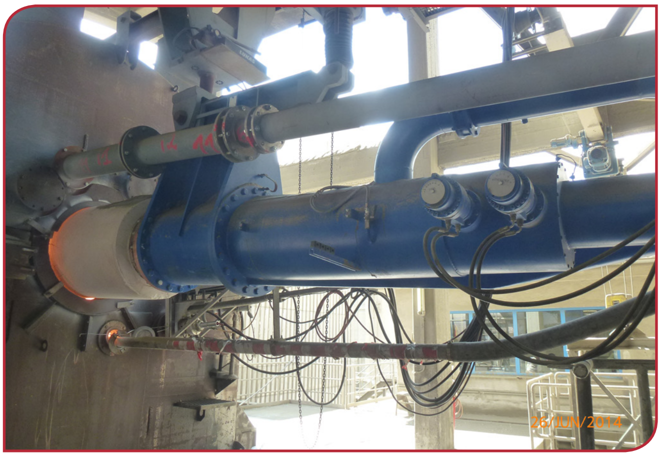
## Unitherm MAS

Unitherm has been a burner company for 60 years and, at the start, offered early versions of the then standard three-channel burners. In the 1990s the company invented the Mono Air System (MAS) burner. At the time it was the only burner that offered a combined axial and radial primary air channel that



Left: A modern Unitherm MAS burner.

**Right:** A Polflame and separate injection pipe in a German cement plant.



ends in adjustable (angle-wise) flexible jets. This was a fairly revolutionary concept that demonstrates how sound design and marketable ideas can go together.

One of the arguments for the MAS design is that a single adjustable air stream is more efficient and effective than mixing two different streams. It is more efficient as there is no energy loss in the mixing of the two air streams and is more effective as the large angle variation of the primary air exit jets strongly shape the flame. The shape can be easily reproduced using a simple crank with a scale of 0-10 that is mounted at the cold end of the burner. Because of this efficiency, lower primary air pressure (and exit velocity) can be used, avoiding the need for high pressure blowers. Also a single primary air channel reduces the diameter of the burner, an important point for good combustion.

While initially kiln engineers worried about moving parts inside a burner, the flexible hoses and the rings used to vary the angles of injection have proven to be remarkably sturdy and smooth to operate. The mechanism rarely has to be repaired.

The MAS burner offers several optional features such as a disconnectable outer-pipe tip; a pneumo-deflector© for lifting solid alternative fuel particles up into the flame, and a focus on the ejection angle of the coal stream (convergent or divergent) to help control $NO_x$ emissions.

**Xd'H:** The notion of 'effective momentum' was first brought to the market by Unitherm. Even with a large adjusting capability, some operations end-up with an extreme setting.

## Polysius (tkIS) Polflame

The industrial culture of the more than 150 year old Polysius AG now continues under the new name thyssenkrupp Industrial Solutions (tkIS) OU Cement Technologies.

Over the years Polflame burners were developed to cope with new requirements, first for direct firing of the kiln using mill exhaust gas containing coal dust, then indirect firing systems and today, the wide variety of alternative fuels.

In the 1990's fuels that were difficult to ignite, such as anthracite and petcoke, began to be used. Polysius therefore began to find a new burner technology, leading to the development of the Polflame VN burner. The concept of adjustable ejection angle with moving nozzles allows for the setting of the flame characteristics depending on the burnout of the coal or solid alternative fuel.

Alternative fuels substitution and stricter emission limits are the drivers for the ongoing development of the burner, which is designed to fulfil such requirements as high clinker quality, smooth kiln operation, (e.g. kiln inlet temperature control), and a high flexibility with regard to the fuel mix.

However, the burner is not the only means of feeding the sintering zone with fuel. In several cases separate fuel injection pipes are used. The reason is that alternative fuels can only be injected when the temperature level in the system is high enough and the complete burnout is assured. That is why the kiln, after ignition, is usually started with a 'traditional' fuel, such as lignite. For the start-up the burner nearly reaches 100% of its capacity. After reaching the necessary temperature level the standard fuel is reduced depending on the alternative fuel substitution rate, which means that the burner must have a very high degree of flexibility.

Constant high alternative fuel use may lead to extremely large burners as the air velocity is limited at the burner tip and more than one extra alternative fuel channel is needed. This is the reason that tkIS recommends having a certain amount, for example up to 50%, of the solid alternative fuels injected through the burner and installing separate injection pipes for the remainder. This means that burners can stay at a reasonable diameter. Injected above the main burner, the poorer grade solid alternative fuel gets more time to dry out, will have a greater chance of dispersing and better burning and will not drop on the clinker bed.

The challenge at present and in the near future remains limits to gaseous emissions. Furthermore suppliers are requested to design the burner without knowing the fuel that might be used after a new plant was completed. Despite this, the sintering zone length and temperature must still be controlled carefully.

**Xd'H:** With its coal channel located inside or outside the primary air (or both) true flexibility can be achieved. As a full cement engineering provider tkIS takes a larger view and goes in the direction opposite to mainstream thinking. Clients may have to be convinced - for many years they have heard the message that all fuels must go through the burner!

Right: Dynamis D-Flame burner.

## Dynamis

Dynamis was founded in 2003 by Eng. Guilherme who studied and worked with professor Clemente Greco from Brazil. At that time it offering consulting services but is now an engineering and project company as well as a supplier of customised equipment.

The Multichannel D-Flame burner is designed with both axial and radial primary air channels, which are fixed. It has 18 orifices for the injection of external and tangential primary air. Some operational improvements include: **1)** Finer $C_3S$ crystals; **2)** The ability to use high sulphur fuels without fouling; **3)** Stable kiln operation, and; **4)** Increased refractory lifespan.

For Dynamis, maximising secondary air entrainment is a very important concept, followed by minimising primary air injection. With respect to momentum, Dynamis uses the concept of kinetic energy, with a bigger emphasis on the speed than mass flow to design burner tips. When designing a burner, calculations of such values as flame impulse, turbulence index and swirl number are important to match the design with the fuels, secondary air temperature, kiln diameter and other parameters. These complement the geometrical design characteristics of the burner tip, including the respective locations of air and fuels injection, number and size of air jets and so forth.

Dynamis has published several articles about its studies in the optimum number of primary air axial jets. The findings indicate that fewer jets, down to a certain minimum value, are more effective than a large number of jets.

**Xd'H:** Dynamis demonstrates how a newer company with fewer references can design a good burner of a simpler design but yet one that is still very effective. It has focused on key burner tip geometry to optimise a well-known design.

## FLSmidth Jetflex®

The Jetflex burner is a good illustration of the development of a new burner to satisfy the changes imposed by the market.

In a similar way that Pillard developed its Rotaflam® burner back in the late 1980s to match the requirements of low-$NO_x$ burners, or the way that Greco developed the Flexiflame® in the early 2000s to handle the high momentum 'fad' of the decade, the Jetflex®, the successor to the well-known Duoflex™, is geared to the ever increasing alternative fuel substitution rate, especially the use of solid alternative fuel in the main burner.

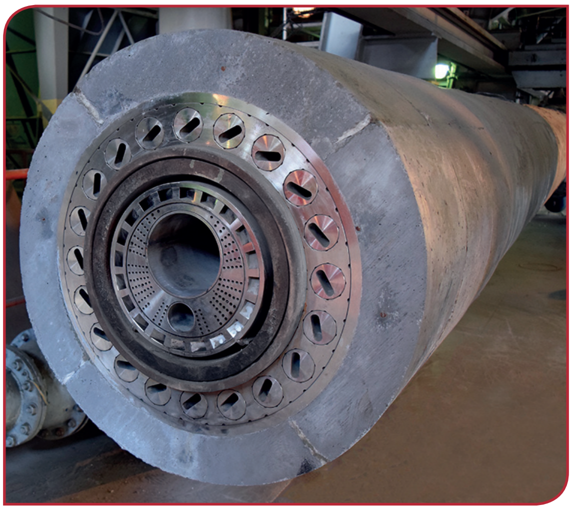
Several new ideas were incorporated into the design of this burner and many more were assessed during development. The intensive use of CFD and modeling is a characteristic of the development of new burners in the 21st Century.

The new ideas include: Rectangular flat shaped primary air nozzles that are either fixed or that can be adjusted in orientation in order to shape the flame; A common and adjustable (in and out the main body of the burner) centre pipe for solid fuels, which gives the fuel the possibility to expand prior to coming into contact with the combustion air (for a higher retention time).

Central air (with or without swirl air) has an important role for cooling and flue gas internal recirculation. The prime benefit is that the burner has a smaller diameter, leading to closer proximity of the primary air and solid alterantive fuels and better mixing and burning.

Another novel approach for high solid alternative fuel substitution is to mix it with the solid fossil fuel, (which represents a small fraction of the heat input), though a common pipe located in the centre of the burner.

As is the trend in the market, the Jetflex® comes with various option, such as the primary air jets being fixed or orientable, and the possible inclusion (or not) of a swirl air channel.



Right: An FLSmidth Jetflex burner at the CRH Rohožník plant in Slovakia.

**Xd'H:** This represents quite an innovative design. Still a new burner, the main features such as flat nozzles and the deceleration and expansion chamber for solid alternative fuels will have to be further demonstrated. It is interesting to see the many differences there are between the previous DUOFLEX and the JETFLEX, which demonstrates the capacity of suppliers to challenge themselves to offer the right burner for the prevailing market requirements.

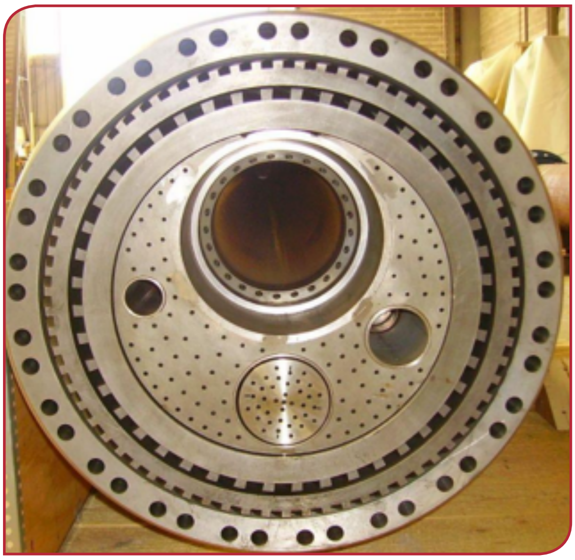
## Fives Pillard NOVAFLAM

Fives Pillard has, for a long time, been the only independent cement kiln burner supplier, having led the way with the conventional 'three-channel' burners and then the well-known ROTAFLAM® burner. This was the first to depart for the traditional axial air-solid fossil fuel-swirl air channel arrangement and the beginning of the evolution of burners to lead or follow market needs.

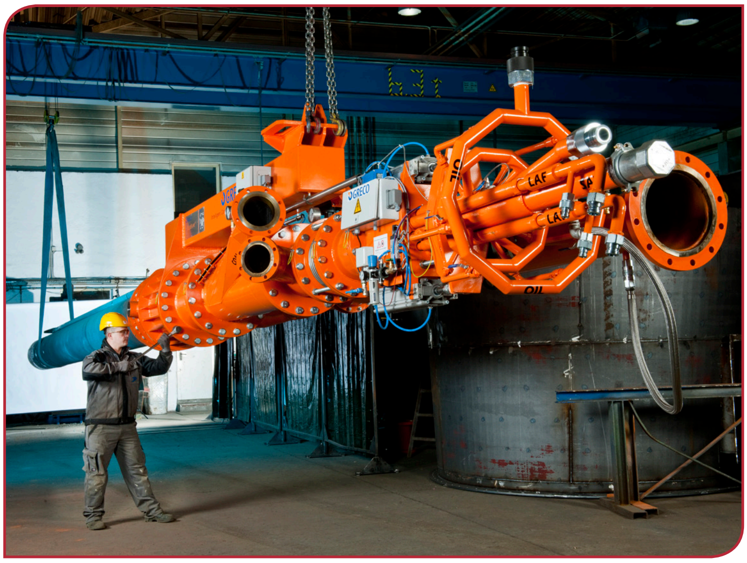
For about eight years Pillard has been offering the NOVAFLAM, which incorporates many ideas in one burner. Several variants have since either been added or tested 'on the drawing board.'

CFD results clearly demonstrated that it would be possible to design the NOVAFLAM burner as a 'mono' air channel with two separate, controllable primary air outlets at the burner tip. The axial and swirl air help to achieve a sharp, low diameter flame, that is well controlled by the high air velocity in the axial air at the periphery of the flame. It has a good capability to repeat flame shapes. Cross-sections are fixed to avoid the negative impacts of kiln temperature variation on tip shape that are caused by thermal expansion.

The key feature is a single primary air inlet and double primary air outlet (axial and radial)



**Left:** Fives Pillard NOVAFLAM burner.



Right: A Greco Flexiflame being installed.

with the swirl injection at a progressive angle. Using a crank at the back end of the burner, the radial tip can be moved back and forth to adjust the flame width while the primary air pressure is adjusted to vary the burner impulse using a valve.

**Xd'H:** The Novaflam has the largest market share. As with the FLSmidth Jetflex, the Novaflam shows the ability of burner suppliers to re-invent themselves and adjust previous features in order to stay close to the competition and the needs of cement plants. On the other hand Pillard emphasises larger amount of axial air but stays with having many and small air injection slots.

## A TEC-Greco Flexiflame

The Greco burner company became well known in the 1990s thanks to its founder Prof. Clement Greco who travelled around the world promoting his burner concepts such as the 'all concentric design.' However at the time the company was offering engineering only, having its clients manufacture the burners from Greco's supplied drawings. The company later became a full OEM.

The main principles of the Flexiflame burner are the fact that it has no moving parts and three main primary air channels, axial, radial/swirl, and dispersion, with the fossil solid fuel channel being located between the axial and swirl channels and the dispersion channel.

The benefits are to offer a robust and flexible burner, with the relative amount of primary air between the swirl and the dispersion channels offering adjustment between lower $NO_x$ (more swirl) and higher solid alternative fuel (more dispersion).

The Flexiflame is capable of a larger turn-down. Sometimes plants anticipate an increase in production output but don't want to have an oversized burner initially. The burner has the ability to plug (and later unplug) some of the air slots to allow for the optimum amount of primary air flow – in relation to the stoichiometric requirement – over a large burner output capacity.

A recent variation is the Flexiflame Ecopro® burner which injects solid alternative fuels into the flame root through a ring channel. This requires careful preparation (grinding) of the solid alternative fuels.

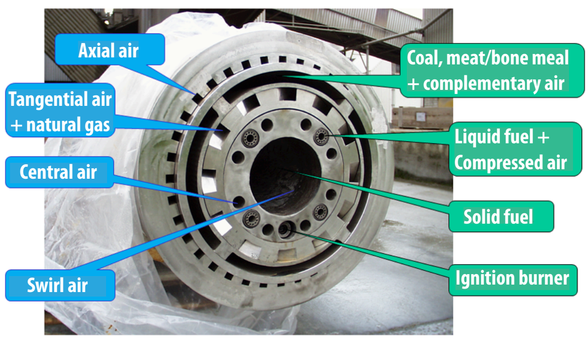
**Xd'H:** Here we again see a burner supplier that is capable of more than one offering, with concepts that would have been rejected years ago, in order to best match a given cement plant's requirements. The impact that adjusting one air channel has on the other two, when using a single primary air fan, may be viewed as difficult by some operators.

## Rockteq International

The Rockteq burner is a classical multi-primary air channel burner with coal sandwiched between axial primary air and radial primary air.

The features of the burners are: Concentric supply of all fuels and primary air. The primary air (axial air, swirl air and central air) is supplied by three separate concentric ring channels and is measured and effectively regulated by adjustable flaps. The triple supply of the air allows an optimum set up of the flame shape. By means of the good mixture of air/oxygen and fuels a short turbulent flame will be achieved.

The high exit velocity of the primary air at the burner tip (Venturi effect) guarantees a good interference of the secondary air, approximately 85% of the whole combustion air, and a high external recirculation, which improves the flame shape and reduces the heat load in the kiln outlet area. Thus the fire-resistant wear of the kiln lining is also reduced.




Right: A burner from Rockteq.

Good combustion of the coal is achieved by mixing oxygen into the flame core, due to the position of the coal pipe located between axial and swirl air. Therefore coal as supporting fuel for the solid secondary fuels guarantees a hot and short flame.

Central air and swirl air generate an optimum internal recirculation, with a correspondingly high residence time for the combustion of solid secondary fuels. Furthermore, by internal recirculation of the combustion gases the spontaneous formation of $NO_x$ decreases.

**Xd'H:** The Rockteq burner design has its roots in the Greco design, down to keeping the square axial air jets that were Greco's signature in the late 1990s, with the idea of having everything concentrically arranged around the axis of the burner. For instance, even the liquid fuel lances are split into four to keep to the letter of that principle.

A regional player with good manufacturing quality, it offers a strong focus on the central air, with jets instead of a perforated plate, which is a feature of burners where axial primary air injection is achieved by small jets / open channels, in order to achieve internal recirculation around the root of the flame. This offers greater flame adjustment capability for the very experienced operator.

## Conclusions

There are several key parameters that must be kept in mind when selecting a new rotary kiln burner, as well as some questions to ask. These include:

• Size, shape (round, square, rectangular, twin), number and locations of the primary air jets (either just axial or a combination of axial and swirl) as to their effectiveness, especially for multi-fuel burners;

• The effectiveness of the various built-in features of the burners designed to ensure good dispersion of the solid alternative fuels (mostly 'fluff' type) when exiting the burner in order to ensure complete combustion while in suspension.

• Effectiveness of the so-called central / cooling / recirculation air channel;

• Should multi-channel burners be equipped with one fan/blower per channel for easier control of the respective primary air flows?

As well, there may be some considerations that are not currently taken on board as 'mainstream' burner features by the major manufacturers. These could include such features such as $O_2$ injection to boost alternative fuel burning or $H_2O$ injection to control $NO_x$. These are installed on several burners but are usually upgrades conducted with compromise, instead of being inherent options at the design stage;

Operational aggravations with burners will always exist, including the premature failure of the outer concrete protection, the (lack of) effectiveness of air canons to remove the so call 'rhino horn', the need to change burner tips during commissioning to find the proper swirl angle, or excessive wear of the spacers inside the coal channel.

One can also see that EPC companies have now designed burners that stand comparison with the ones from the burner specialists

## More conclusions

Despite the research conducted towards these two articles and my 30-plus years of experience in the cement sector, I am unsatisfied with a conclusion that is limited to simply a list of important technical factors.

I have found that a lot of cement companies, either at the plant or HQ level, have their list of preferred suppliers, either published or implicit. Such lists don't evolve much with time, if at all, and are often the result of past choices usually based on the OEM's past market share.

I hope that my research, in which I have presented a large variety of designs, will assist all of those involved in buying and operating new kiln burners in the cement sector. Plants should decide first which category of burners fit their own philosophy of operation and needs. They should then approach all suppliers that they think can deliver the desired result. Otherwise a complete and fair comparison between the different designs will be very difficult.