Building on burner success

Since its launch at the end of 2020, the new and improved Pillard Novaflam® Evolution monochannel or bichannel burner has been well received by the market. With more than 60 sold around the world and over 30 already in operation on various kiln types and fuel configurations, the company evaluates some of the improvements this new burner design has delivered based on site feedback and in response to various market needs.

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Following the worldwide success of the Pillard NOVAFLAM®, with more than 500 burners sold between 2009-20, the new and improved version – the Pillard NOVAFLAM® Evolution – is already an impressive commercial success. Since its launch at the end of 2020, more than 60 Pillard NOVAFLAM Evolution burners have been sold around the world and more than 30 are already in operation firing all types of fuel including petcoke, natural gas and alternative solid fuels. Despite the current COVID-19 health crisis, this is the best start to burner sales that Fives Pillard has known in the company's history of more than 100 years.

The key principles and features of the Pillard NOVAFLAM Evolution were presented in the February 2020 issue of International Cement Review. Therefore, the objective of this article is to reveal some returns of experience from the product launch until now.

Motivation and priorities

The main motivation behind the development of the Pillard NOVAFLAM Evolution was Fives Pillard's desire and ambition to help the cement industry reduce its environmental footprint by improving burner performance, reliability and lifetime, as well as increasing alternative fuels flexibility and reducing CO_2 and other gaseous pollutants emissions such as NO_x.

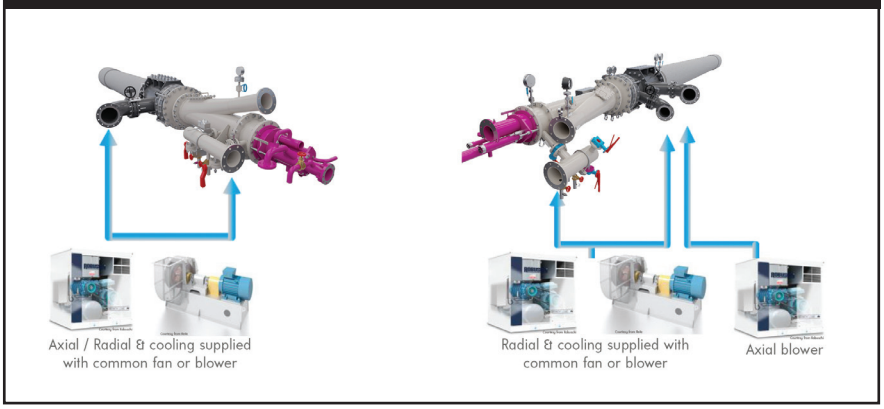
The Pillard NOVAFLAM Evolution is the result of an incremental innovation process, following 12 years of return of experience from the Pillard NOVAFLAM, combined with breakthrough innovations and a design conceived for the Industry 4.0 revolution and the challenges of CO_2 emissions reduction.

The main priorities were:

1. increase combustion efficiency to improve heat exchange in the kiln thanks to a shorter and stronger flame, and in the cooler, thanks to a better clinker nodulation.
2. increase the use of biomass, natural gas and carbon-neutral alternative fuels for a lower CO_2 footprint.
3. maximise clinker quality to enable a reduced clinker ratio in the cement while maintaining its characteristics.
4. limit primary air consumption and NO_x emissions.

The DNA behind the original Pillard NOVAFLAM success, including a short and strong radiative flame, a tailor-made solution and a low-NO_x configuration with all fuels in the centre, was maintained, but each element of the burner has been optimised.

Figure 1: Pillard NOVAFLAM® Evolution supplied in monochannel or bichannel versions



Burner main principles and improvements

To increase the mixing efficiency between primary air, secondary air and fuels, the burner design was improved as follows:

- The axial air injectors design has been enhanced thanks to inserts with a progressive air acceleration, converting all static pressure into velocity, minimising pressure losses. A reduction of the primary air pressure drop up to 50mbar is achieved by ensuring a progressive air expansion in the injectors and less friction effect. The design of the new axial air inserts allows operation at very high pressure in the burner's axial air channel, minimising the risks of wear and holes plugging at the burner tip caused by dust recirculation.
- The swirler technology has been completely rethought. It is based on the principle of controlling the swirl by adjusting the radial air angle instead of changing the swirl air flow rate and pressure. This new swirler design (named RST™) allows the flame swirl to be changed while maintaining a constant momentum. Thus, it is possible to obtain maximum swirl efficiency, optimising the swirl-induced internal reverse flow zone and allowing a large range of angle adjustment while the burner is in operation. Therefore, the burner can be set from a completely axial flame to a high-swirl flame (from a 0˚ to 40˚ swirl air angle).
- The burner tip design criteria (size and repartition of natural gas injectors as well as axial and radial air injectors) has been improved to maximise secondary air penetration. The burner momentum (impulse) efficiency ie, the secondary air

entrainment effect at the burner tip, is therefore maximised.

To achieve the highest flame shaping capability:

- The principle of two separate injections for the axial and radial air has been kept. This enables the generation of a strong internal reverse flow zone thanks to the swirl effect, while keeping the flame diameter under control using the strong axial momentum to confine the flame and avoid impingement on the kiln's refractory lining.
- Compared to the original Pillard Novaflam, the radial air angle adjustment possibilities have been enlarged (from an angle range of 0° to 40°), to master the internal reverse flow zone for the better ignition of low-grade fuels.
- While the original Pillard Novaflam was only available as a monochannel version, the Pillard Novaflam Evolution can be supplied as a bichannel version for cases where a maximum of adjustment possibilities are required. This bichannel Pillard Novaflam® Evolution+ is fitted with two dedicated air circuits for axial and swirl air allowing an independent flow rate adjustment of each circuit.

For 100 per cent natural gas burners

The RST swirler technology can also be applied for burners firing 100 per cent natural gas. In such a configuration, the majority of the burner's momentum is generated by the gas itself due to the high injection pressures (often between 400-800mbar). Therefore, being able to control the natural gas momentum and swirl while the burner is in operation independently of its flow rate is critical. In addition the gas RST swirler also enables the adjustment of the gas tip cross-section while the burner is in operation, allowing a constant gas momentum and a stable thermal profile to be maintained whatever the kiln operating conditions.

In addition to the RST swirler, the Pillard Novaflam Evolution can be equipped with a flame front stabiliser, ie, the Pillard PGZ™ nozzle. The nozzle uses Pillard Bluemix™ technology, a "permanent flame" where a small amount of natural gas is premixed with air at sub-stoichiometric conditions. The Pillard Bluemix is located in the burner centre and allows stabilisation of the main gas flame, thus reducing the ignition distance and generating HCN and NH_3 radicals in the flame front helping to reduce NO_x formation.

The Pillard Novaflam Evolution is 'Smart ready', meaning that the burner is equipped with basic instrumentation as standard, but its conception includes a large number of instrumentation and features that can be added and have been specially developed to facilitate burner maintenance and optimise its operation. Depending on the options installed, the burner can be automatically set to any swirl and momentum configuration directly from the control room.

All these improvements allow the following:

- optimise burner settings during operation to achieve the right level of swirl and momentum to maximise clinker quality while keeping NO_x under control
- use as little primary air as possible for solid fuels firing and a minimal amount of cooling air for gas firing (as gas injection generates enough momentum by itself)
- achieve high fuel/air mixing efficiency and control the ignition distance and flame shape, whatever the fuel mix.

Maintenance

The cement kiln is characterised by high temperatures, a dusty environment and harsh operating conditions that may cause premature wear of the burner refractory. If the burner design does not respect some simple rules, such as no moving parts and ensuring that uncooled surfaces exposed to fire and dust recirculation are sufficiently cooled, any early successes can result in failure in the long run.

The Pillard Novaflam Evolution outer tip – the part of the burner that is most exposed to radiation and dust – has been completely changed and made sturdier. The tip cooling has been significantly improved, reducing its thermal expansion by 40 per cent and consequently the risk of refractory failure. Moreover, the burner can be equipped with thermocouples to continuously monitor the tip and refractory conditions.

To optimise burner primary air consumption and to get the best flame setting possibilities, it is mandatory to avoid oversizing the burner and especially the burner tips. However, following the early days of a burner installation, the kiln system is sometimes improved and the production rate is increased. To adapt the burner to such new running conditions, most burner suppliers would require that the full burner tip be changed. To address this situation, the Pillard Novaflam Evolution ion was thought of and designed as an evolutive burner, making it possible to adapt the axial and radial air tips cross-section for future use without completely replacing the tips thanks to the use of dedicated insert designs (see Figure 2).

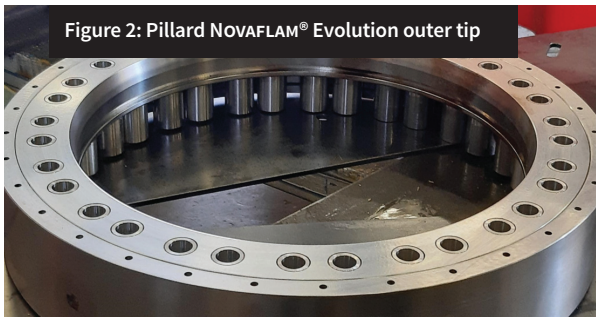


Figure 2: Pillard Novaflam® Evolution outer tip

The right options for individual needs

The Pillard Novaflam Evolution innovations go beyond improvements to the axial and radial tips or the bichannel version. The burner can be supplied with a full package of options to address the various problems faced by cement plants. This tailor-made approach enables customers to master the cost of the burner according to their specific needs:

Optional features include:

- 3D printed airless stabiliser in SiC to minimise burner cooling air and reduce NO_x formation
- a unique device to ensure early ignition and perfect stability of gas flames
- a tool to clean the burner tips while in operation using a 3D printed patented scrapper inserted via a jacked tube in the burner centre
- a full package of ceramic parts for abrasive fuel
- a full set of captors to monitor the burner position, tip temperature, tip positions, momentum, swirl, etc
- a dedicated alternative fuel injector equipped with a specific device allowing a wide range of ASF ballistic adjustments (different technologies available depending on particles size).

Case studies

With more than 30 Pillard Novaflam Evolution already operating on various kiln

types and fuel configurations, it is possible to evaluate some of the improvements this new burner design has delivered thanks to its high efficiency and flexibility. Presented below is some site feedback with different fuels mix.

Petcoke firing

Market need: Fives Pillard has been present in the active Indian market for almost 10 years through its subsidiary Fives Combustion System (FCS) and has enjoyed sustained strong growth. In 2020 FCS inaugurated a new manufacturing workshop in the Indian state of Gujarat, enabling the production of burners with Fives Pillard's high-quality standards at a competitive price by mastering the complete production chain.

In terms of burner performance, the market is very challenging. Even if clinker C_3S standards are not as high as in other regions of the world, customers require stable kiln operations using high sulphur petcoke and low primary air consumption while ensuring low NO_x emissions.

To respond to this very demanding market requirement, Fives Pillard recommends the NOVAFLAM Evolution+ (bichannel) with a very high pressure blower supplying axial air (up to 900mbar) and a fan operating a lower pressure dedicated to radial and cooling air. The cooling is minimised using a Fives Pillard airless stabiliser and the burner's total air consumption is low, generating the necessary momentum for proper burner operation. Thanks to the RST swirler, the swirl angle can be adjusted at a lower range, even close to zero (fully axial flame), to improve sulphur trapping in the clinker and reduce its volatilisation in the kiln.

The main Indian cement players that have chosen the Pillard NOVAFLAM Evolution+ have obtained successful results such as:

- stable kiln back end NO_x emissions as low as 650mg/Nm^3 at 10 per cent O_2
- less than seven per cent primary air consumption
- less than 40 per cent sulphur volatilisation firing 100 per cent petcoke with more than six per cent sulphur and only 2.5 per cent O_2 at the kiln back end.

In Europe petcoke is normally fired in combination with alternative solid fuels (ASFs). The high burning temperatures required for European C_3S standards and the high ASF substitution ratio generally lead to an increased risk of sulphur volatilisation. To minimise such risks the primary air swirl has to be sufficient to improve the ASF ignition and should remain under control to avoid reducing conditions due to 3D particles dropping in the material bed. In such a case, burner momentum must be very high (up to 12N/MW).

Figures 3 and 4 show the first weeks of operation of a Pillard NOVAFLAM Evolution+ of 82MW recently installed in a four-stage preheater kiln firing 100 per cent petcoke in Europe. Following the burner replacement, the plant succeeded in operating with a lower ID fan draught for the same kiln feed rate thanks to lower kiln excess air and a drop of more than 30 ˚C in the preheater tower exit gas temperature. The kiln specific heat consumption dropped by two per cent and the SNCR ammonia consumption necessary to control NO_x emissions was reduced by up to 30 per cent. These first results seem quite promising and are expected to be confirmed in the long-term operation.

Natural gas firing

Market need: firing natural gas is wrongly considered to be easy to implement in a cement kiln. If combustion is not well mastered, the lack of radiative heat exchange can negatively impact the temperature profile in the kiln, and therefore, clinker quality and kiln specific heat consumption. In recent years Fives Pillard has intensively studied natural gas firing using CFD simulation tools and performing pilot tests at the Fives European Combustion Centre, the company's research centre in Italy. This work has been carried out to better understand and master the key burner parameters required to produce the best possible gas flame. The Fives Pillard R&D team also studied the real impact of a controlled soot formation in the flame which is supposed to improve flame luminosity and compared it to the effect of clinker dust recirculation within the flame. In addition, the impact of primary air and the way to anchor the gas flame on the burner tip even at sonic gas injection velocities were studied. The use of H_2 was also part of Fives Pillard's R&D work as it is a growing trend in energy-intensive industries and an area in which Fives Pillard has already gained strong expertise from the boiler industry.

To respond to the market need for 100 per cent natural gas firing burners, the Pillard NOVAFLAM Evolution (monochannel) uses as low as possible primary air. When co-firing natural gas and coal, the Pillard NOVAFLAM Evolution+ (bichannel) is preferred due to its higher flexibility. As previously mentioned, adjustment of the gas tip cross-section is essential to master gas momentum independently of its flow rate and it can be perfectly combined with the new Pillard BLUEMIX technology to stabilise the gas flame.

In the North American market, ASF co-firing with natural gas is developing

Figure 3: preheater exit gas temperature and ID fan speed, previous burner vs the Pillard NOVAFLAM® Evolution

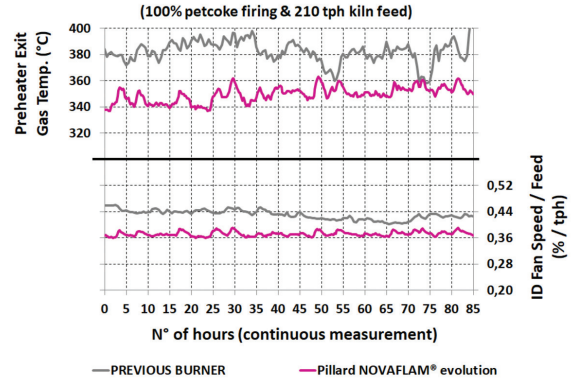


Figure 4: SNCR ammonia consumption, previous burner vs the Pillard NOVAFLAM® Evolution

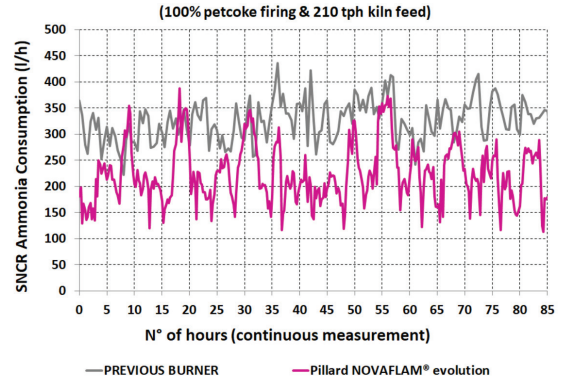


Figure 5: Gas flames during Pillard BLUEMIX™ injector trials at the Fives European Combustion Centre

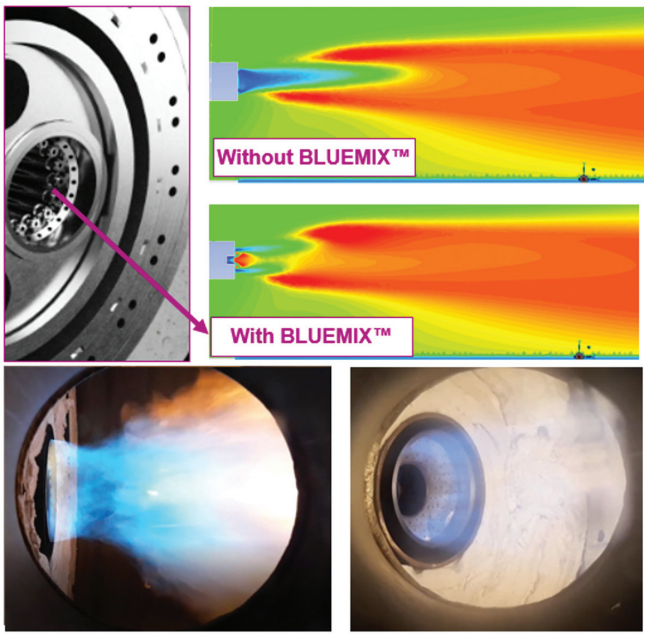
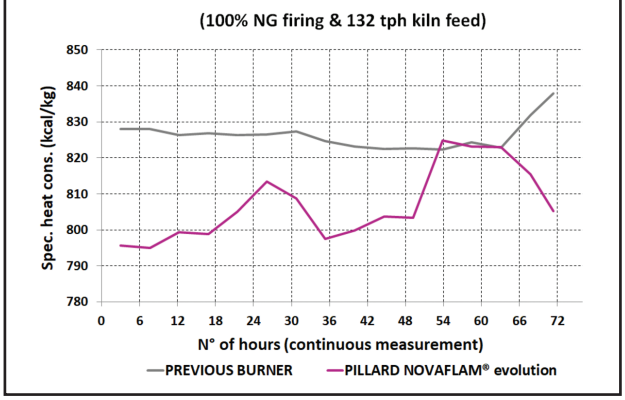


Figure 6: specific heat consumption with previous burner and with Pillard NOVAFLAM® Evolution



strongly. Fives Pillard has developed an injector using Pillard BLUEMIX technology to help ignite the natural gas and ASF mix resulting in higher ASF substitution ratios.

Figure 5 shows images taken during the Pillard BLUEMIX injector trials at the Fives research centre.

Figures 6 and 7 illustrate some of the results achieved with a Pillard NOVAFLAM Evolution of 65MW firing 100 per cent natural gas installed in a precalciner kiln in South America. The NO_x emissions were reduced by approximately 28 per cent and the kiln specific heat consumption by 2-3 per cent.

More than 20 per cent of the Pillard NOVAFLAM Evolution burners already in operation are firing 100 per cent natural gas with excellent results.

Pulverised coal firing

Market need: the generic term "coal firing" covers a wide spectrum of pulverised fuel: from anthracite with very low volatiles to lignite or peat coal with very high

Figure 7: kiln back-end NO_x emissions with previous burner and with the Pillard NOVAFLAM® Evolution

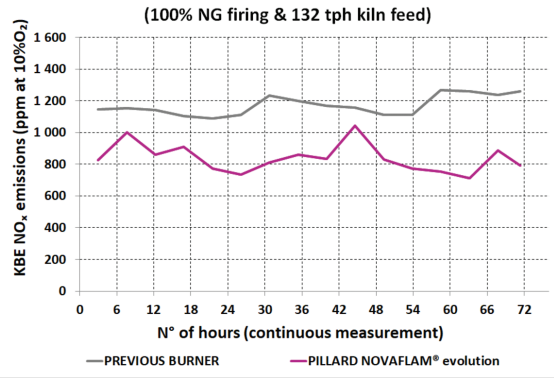
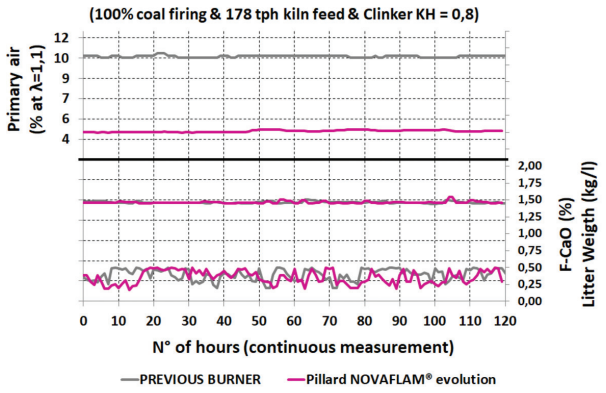


Figure 8: % primary air, F-CaO and litter weight – previous burner vs Pillard NOVAFLAM® Evolution burner



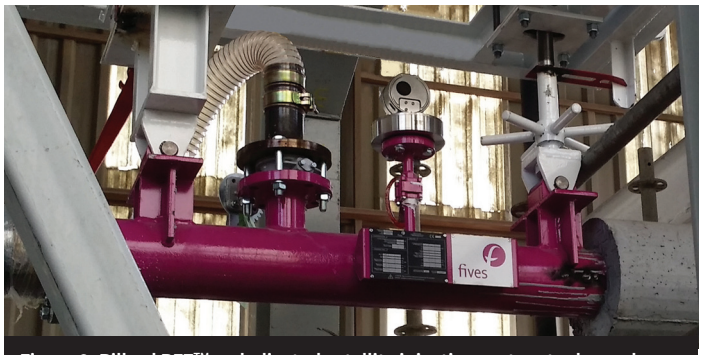
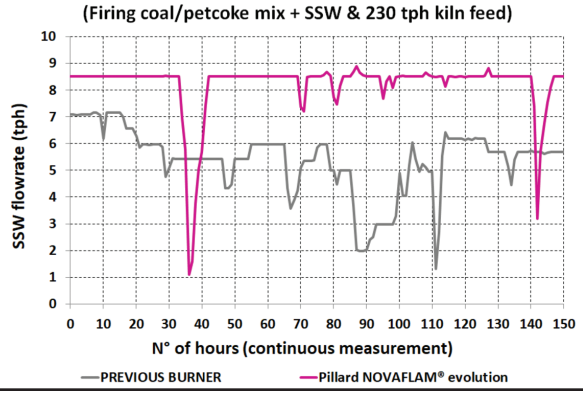


Figure 9: Pillard PFZ™, a dedicated satellite injection system to dry and devolatilise the particles before they reach the main burner flame

Figure 10: solid shredded waste (SSW) flow rate with previous burner vs Pillard NOVAFLAM® Evolution burner



volatiles. Each type of coal has its own characteristics that must be considered when designing a burner properly. Abrasiveness, but also ash rings sticking on the burner tip when the coal is too finely ground and the black plume is too short, are a challenge. Fives Pillard's Chinese clients use different types of coal as a main fuel, always with the same target: to "push" the kiln to the maximum level of production while keeping a very high level of clinker burning and reduced kiln inlet temperatures.

Depending on coal quality, either the Pillard NOVAFLAM Evolution or the Pillard NOVAFLAM Evolution+ can address this market need, with ceramic protection against the abrasion of sensitive parts and the Pillard Cleantip™ tool when required. High primary air pressure is recommended for anthracite, while a lower air pressure is better suited for reactive coal. A sufficient level of momentum and a high level of swirl (up to 40˚) is required to ensure a stable and short temperature profile, without the generation of ash rings in the upper transition zone.

Figure 8 shows some results achieved with a Pillard NOVAFLAM Evolution of 42MW firing 100 per cent coal installed in a precalciner kiln in China. It was possible to reduce the primary air consumption by more than 50 per cent – from 10 per cent to 4.5 per cent (λ=1.1), keeping the same kiln production rate and clinker quality, illustrated by the clinker free lime and litter weight.

ASF firing

Market need: even though Europe is still the biggest user, alternative fuels are becoming increasingly popular in all regions of the world, especially in southeast Asia and North America. ASF characteristics are highly variable in terms of granulometry, composition, humidity, etc, and demand a case-by-case approach when firing them, notably regarding the injection method.

Since high momentum is needed when firing ASF, the Pillard NOVAFLAM Evolution+ is recommended. In particular, cases where the ASF has a high moisture content or particles that are too large, a dedicated satellite injection system (such as the Pillard PFZ™, see Figure 9) can be used to dry and devolatilise the particles within their travelling distance in the kiln before they reach the main burner's flame.

Figure 10 illustrates some of the results achieved with a recently-commissioned Pillard NOVAFLAM Evolution+ of 119MW firing coal/petcoke and solid shredded waste (SSW) installed in a preheater kiln in Europe. Thanks to the new burner, the burning zone stability was improved and SSW substitution was increased by 40 per cent, ie from 6tph to 8.5tph. The plant is still planning to go further.

Maximising performance

More than just a burner, Fives Pillard's new Pillard NOVAFLAM Evolution is a complete combustion solution for rotary kilns. Tailor-made with adaptable features, the technology can perfectly respond to each kiln need. Whatever the fuel mix fired or situation, Fives Pillard's solutions are designed to maximise pyroprocessing performance and meet client requirements. The Fives Pillard technical team are now focussing on the follow up of new burners recently commissioned and on the development of new captors to be installed on the burner, making the Pillard NOVAFLAM Evolution even "smarter" and ready for Industry 4.0. ■