# BURNING ALTERNATIVE FUELS IN ROTARY CEMENT KILNS

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## 1. Introduction

Various types of alternative fuels can be used in rotary kilns depending on the local supply availability, and each one has a specific influence on the flame pattern.

Low calorific value waste fuels must be limited to a small portion of the total heat release as they lower flame temperature, but a compromise can be reached when firing high and low calorific value alternative fuels simultaneously, which enables control of both the calcining process and the NOx emissions.

Therefore, a flexible burner is required to allow firing any kind of residue combination depending on the supply available, while maintaining kiln production levels, clinker quality and environmental standards.

Basic burner design for alternative fuels and experience from several plants firing solid and liquid wastes will be detailed in this paper.

## 2. Combustion Equipment

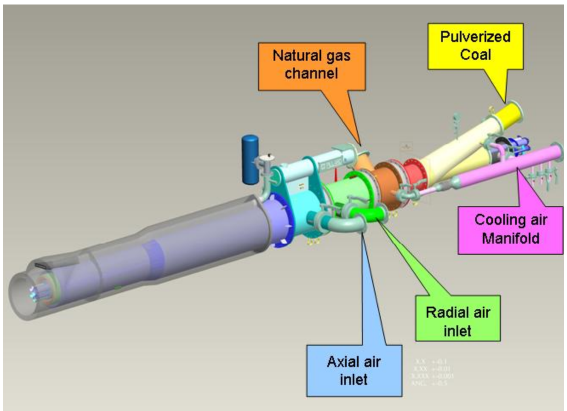
Firing alternative fuels in a rotary cement kiln presents numerous difficulties.

An efficient flame control is absolutely necessary in order to avoid increasing the burning zone length, affecting the clinker quality, reducing the brick lifetime and creating localized reducing conditions, which lead to ring formations and plugging at the kiln inlet. It is therefore a major requirement to be able to adjust the kiln burner air momentum, the flame shape and the air/fuel flow rates.

The basic burner technology for firing alternative fuels consists of a modern multi-channel type burner capable of:

- Varying the primary air flow consumption in accordance with the nature and the quantity of the alternative fuels to be fired.
- Adjusting the flame shape during operation.
- Ensuring stability of the flame front.

Such modern multi-channel burners allow an efficient injection of alternative fuels into the heart of the flame by means of jacket pipes fitted in the center of the burner which provide the following advantages:




***Modern Multi-Channel Kiln Burner***

- Concentration of main fuel and alternative fuels along the burner axis in order to avoid fuel particles leaving the main flame contour.
- Improved burner tip aerodynamics, which allows flame shaping in a wide vrange at maximum outlet velocity.
- Even heat distribution which avoids temperature peaks and decreases thermal NOx formation and reduces thermal stress of kiln lining.
- Ease of flame adjustment by changing burner tip geometry during operation.
- Early fuel ignition and improved flame stability even at cold kiln conditions.

## 3. Liquid Waste Fuels Firing

Liquid alternative fuels are injected through fuel guns fitted with high pressure atomizers or assisted by an atomizing medium such as compressed air or steam in a way to generate the smallest possible droplets in order to improve burn-out.

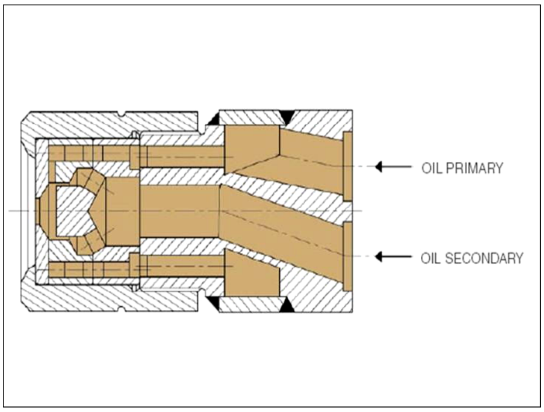
The fuel guns are inserted into jacket tubes provided in the center of the rotary kiln burner.

The choice of the atomizing principle mainly depends on two parameters:

- Liquid fuel viscosity at burner gun inlet.

- Size and content of any solid particles in the liquid fuel which could lead to wear and plugging of the gun's holes.

Several types of atomizing guns are available and are selected with respect to the characteristics of each waste fuel. Some of them are described below:

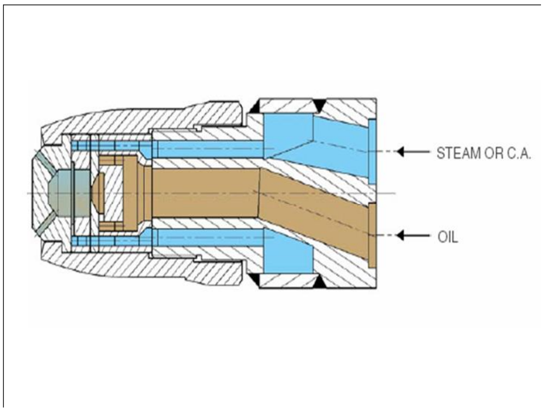



*"Type 1" Liquid Fuel Gun*

The "Type 1" gun enables a good mechanical atomization using high liquid fuel pressure (40 bar g) with a viscosity of around 20 cST. No auxiliary medium is required.

The atomizing cone angle can be adjusted during operation by acting on the differential pressure between the primary and the secondary liquid fuel pressures.

This gun can only be used for liquid fuels containing no solid particles and those which can be delivered with the correct viscosity at the gun inlet.

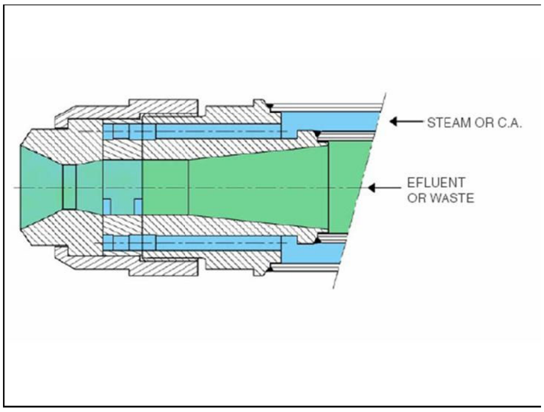



*"Type 2" Liquid Fuel Gun*

The "Type 2" gun uses steam or compressed air assistance for atomization.

The outlet angle of the liquid fuel jet is constant and the consumption of steam or compressed air is about 10 to 15% of the liquid fuel flow rate (depending on the fuel viscosity).

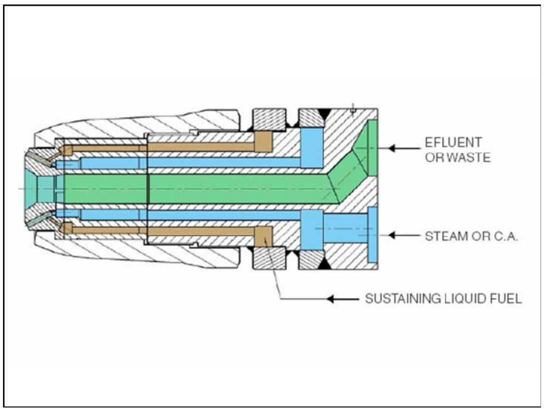
As for the "type 1", this gun can only be used for liquid fuels containing no solid particles in order to avoid plugging of the gun tip.




*"Type 3" Liquid Fuel Gun*

The "Type 3" gun is designed to atomize very heavy or even pasty residue containing a maximum of 20% of solid particles up to 5 to 6 mm in diameter.

This gun must be custom engineered on a case-by-case basis taking into account each fuel characteristics.



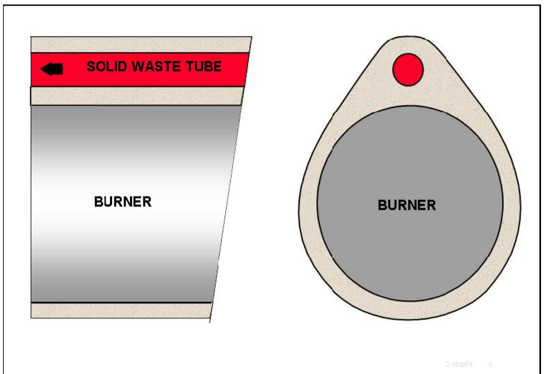

***"Type 4" Liquid Fuel Gun***

The "Type 4" gun is a "Type 3" gun (see above) with an additional channel. This additional channel allows the burning of a sustaining liquid fuel with a high calorific value (such as diesel or heavy oil) around the often "lean" flame produced by the central injection of liquid waste fuel containing solid particles.

## 4. <u>Solid Waste Fuels Firing</u>

Pulverized dry waste derived fuels which are not sticky can be handled in a dosing and pneumatic conveying system like pulverized coal and blown over a concentric annular channel through the burner. With lumpy, fluffy or fibrous materials, a severe risk of developing deposits, and thus plugging, exists when using an annular channel; this is the reason why an obstacle free design (typically a round tube) is the preferred injection method.

Early trials of solid waste fuel burning in a rotary cement kiln were made via a separate tube fitted on the top of an existing kiln burner.




***Solid Waste Firing on Burner Top***

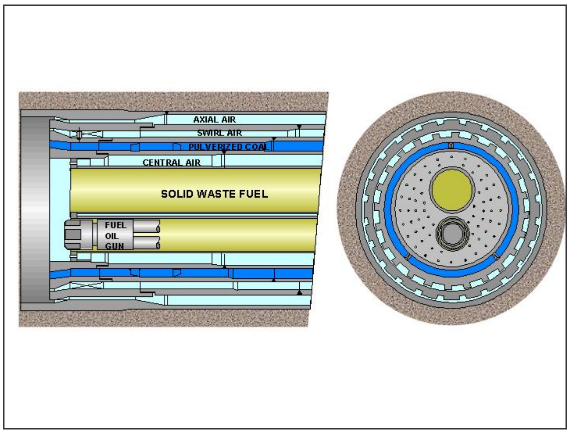
This injection method was proven to be very inefficient. As a matter of fact, fluffy and lumpy solid wastes were carried over on the top of the flame, and eventually dropped on the clinker bed and burned under localized reducing conditions. As a result, the clinker quality was adversely affected and there was an excess of CO at the kiln inlet.

Such trials have shown that injecting alternative fuels (either liquids or solids) into the flame by means of a separate tube is not a good solution and must be avoided. Indeed, the further injection point is located from the flame axis:

- the worse the distribution of fuel particles into the flame
- the more difficult the penetration of the fuel stream into the flame.

In order to improve the burning conditions, additional trials were then made with an injection pipe located in the center of a multi-channel burner.

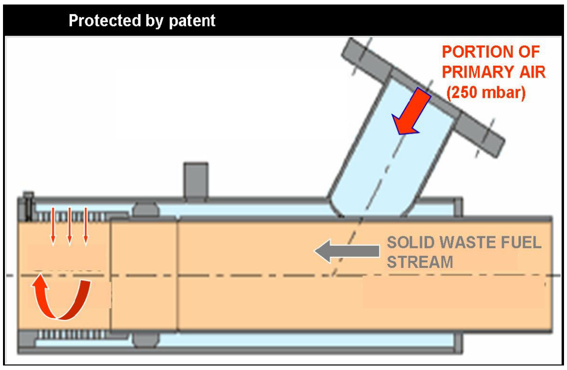
The idea was to start ignition and burn fluffy and lumpy solid wastes as much as possible inside the main flame.




***Solid Waste Firing through Burner Center***

The results were much better than the previous trials which utilized the solid waste pipe on the top of the burner. However, the length of flame when firing solid alternative fuels was drastically increased, and two temperature peaks could be observed on the kiln shell scanner.

To solve this problem, a patented solution (the "blowing system") with the purpose of expanding and aerating the solid waste fuel jet was developed and successfully tested in several cement plants. The idea was to enhance the mixing of the solid waste fuel stream inside the main flame, and therefore maintain the same flame length with or without solid waste fuels.




*"Blowing System" for Solid Waste Fuels*

A portion of the primary air is blown into a jacket pipe around the solid waste transport pipe. At the end of this transport pipe a special swirler nozzle is fitted which comprises several tangential drillings.

A portion of the primary air coming from the fan/blower (controlled by a flap) is blown through these holes, thus creating a rotation of the solid waste fuel and spreading out the solid alternative fuel.

In this way, it is possible to expand the fuel jet, increase the mixing of the fuel jet inside the main flame, and adjust its injection velocity, depending on each waste fuel characteristic (i.e. heat value, fineness, volatile matter content, etc.).

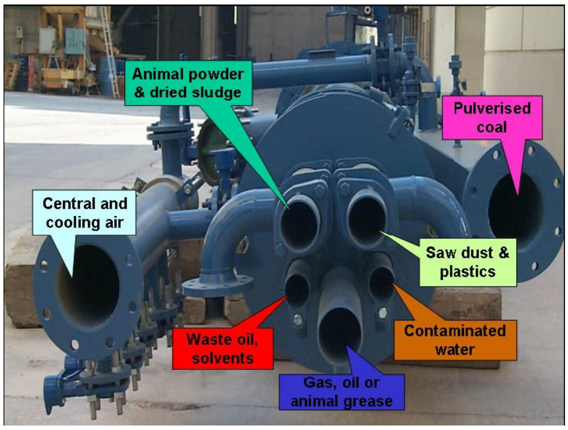
## 5. <u>Operational Results</u>

Several cement plants are already able to burn up to 100% waste fuels reaching a negative fuel cost balance, a few of which are:

**Cement Plant 1 – Switzerland**

In 2002, a modern multi-fuel kiln burner was installed in a rotary cement kiln in Switzerland.

The pyro line has a capacity of 1650 TPD and includes a rotary kiln of 3.9 m diameter and 66 m long, a 4-stage suspension preheater, and a satellite-type cooler.




*Multi-Fuel Burner (View from the Back)*

The new multi-channel burner was designed to actually burn 10 different types of fuels:

Pulverized coal, heavy oil, natural gas, meat and bone meal, dried sewage sludge, oil-impregnated sawdust, chipped plastics, animal grease, solvents and waste oil.

The burner was commissioned on April 27, 2002.

Four days later, 100% waste fuels firing was achieved.

The flame was short and compact with only one temperature peak, resulting in a very stable coating formation and a stable kiln shell temperature.

In addition, a better mixing between the primary air and the various waste fuel streams was observed which lead to an improvement of the waste fuel combustion and resulted in a CO reduction at the kiln inlet compared with the previous burner.

Also, the gas outlet temperature after the 4$^{th}$ cyclone was decreased by 35°C, thereby demonstrating that the kiln heat flux was drastically improved after the burner replacement.

As a result of all of the above, the kiln capacity was increased by 100 TPD (+ 6%) while firing 100% waste derived fuels and keeping a very stable kiln operation.

**Cement Plant 2 – Germany**

This cement plant is located within 70 kilometers of Munich, Germany.

The pyro line includes a rotary kiln with a 5.2 diameter and a length of 85 meters, a four-stage preheater and a satellite cooler.
The plant produces 3000 tons of clinker per day.

The kiln was equipped with a "Low $NO_x$" multi-channel burner of a previous generation.

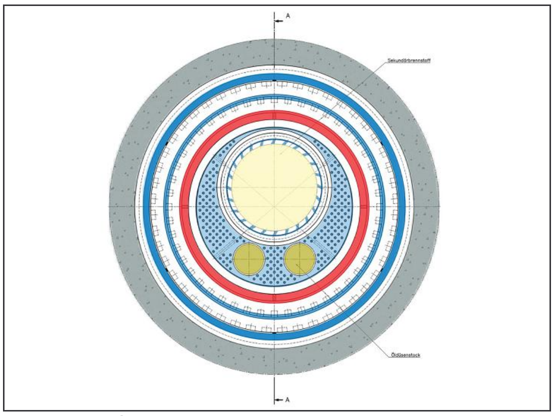
Due to economic reasons, the customer decided to increase the combustion of secondary fuels up to 80 percent.

As a result, the existing burner had to be modified.

To adapt the existing "Low $NO_x$" burner to the new requirements, the following modifications were made:

- Replacement of the tip of the existing burner with a new tip of an upgraded design, allowing a higher axial specific flame momentum.

- Installation of one new high-pressure, primary air fan with 250 mbar supply pressure.



***View of the New Burner Tip***

The burner upgrade led to the following results:

- 80% waste fuels firing.

- Improved flame shape.

- No local reducing conditions.

- No increase of $NO_X$ emissions (annual average values of 300 to 350 mg/m$^3$ $NO_X$ at kiln stack were measured before the burner change)

Current fuel mixture:

| | FUEL TYPE | HEAT VALUE (Kcal/Kg) | Flow (Kg/h) | Inject. | MW | % MW |
|---|---|---|---|---|---|---|
| COAL | | 6 926 | 2 600 | Main Burner | 20,94 | 21,8 |
| ALT. FUEL 1 | Tetra Pack | 6 210 | 3 000 | Main Burner | 21,66 | 22,6 |
| ALT. FUEL 2 | Schredder | 5 732 | 3 000 | Main Burner | 20,00 | 20,8 |
| ALT. FUEL 3 | Sikula | 5 732 | 5 000 | Main Burner | 33,33 | 34,7 |
| ALT. FUEL 4 | Solvent | 5 254 | 1 425 | Main Burner | 8,71 | 9,1 |
| ALT. FUEL 5 | Used tyres | 6 210 | 1 700 | Preheater | 12,27 | 12,8 |
| ALT. FUEL 6 | Recovered paper stock | 478 | 6 100 | Preheater | 3,39 | 3,5 |

**Cement Plant 3 – Chile**

This cement plant is located 40 km north of Santiago, Chile.

The pyro line comprises a rotary kiln of 4.2 m diameter and 69 m long, a 4-stage preheater and a grate cooler.

The kiln was originally equipped with a 1980 vintage "3 channel" type burner, firing diesel oil and bituminous coal.

In 2001, a wide program targeted a decrease in energy costs by firing a maximum flow of alternative fuels according to supply possibilities:

- Dry sawdust (Cl < 0.1%, and S < 1%)

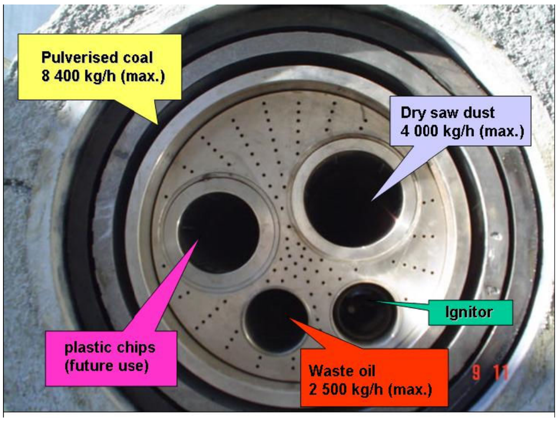
- Waste oil (Cl = 0.2 – 0.4% and S < 1%)

The original burner was not adapted to meet these new requirements. Indeed, when firing waste oil (the only waste fuel available at this time), it produced a long and soft flame, leading to unstable kiln conditions and uneven coating, with:

- high internal cycles of chlorine and sulfur, observed by high Cl and $SO_3$ rates in the hot meal at the kiln inlet (> 1.5 and 2%).

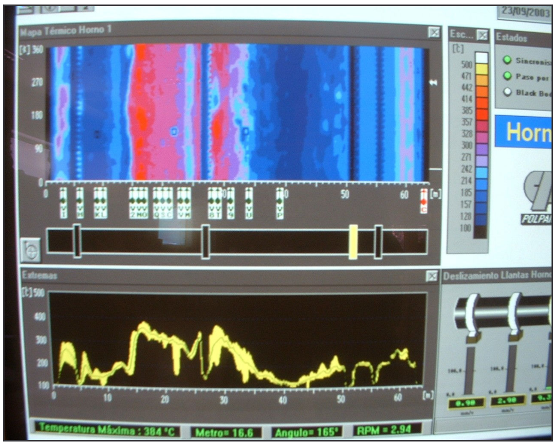
- Blockages at riser duct and in the bottom stage cyclones, leading to several kiln shutdowns, and hence, production loss.

A modern multi-fuel kiln burner firing pulverized coal, a mixture of sawdust/sludge, waste oil and diesel oil, was delivered.




***View of the Burner Tip***

During commissioning the alternative fuel flow was incresed up to 40% thermal substitution, with a very stable coating an a short (~17 m) & small diameter (~3 m) flame as shown on the kiln shell scanner below.



***View of the kiln shell scanner when firing waste fuels***

The volatilization coefficient was reduced from 0.93 to 0.72 and the rates of condensed Cl and $SO_3$ in the hot meal at kiln inlet were both reduced up to 30%.

| | 3 channel burner | New multi fuel burner |
|---|---|---|
| Momentum (N/MW) | 7 | 9 |
| % primary air | 15% | 13.30% |
| primary air pressure | 140 mbar | 250 mbar |
| % A.F.R. in heat released | < 10 % | up to 40% |
| A.F.R. | - waste oil | - waste oil<br>- saw dust |
| Kiln conditions | Unstable coating | Stable |
| % $SO_3$ in hot meal | 1,5 - 2 | 1 - 1,6<br>(-20 to 30%) |
| % Cl in hot meal | 1,5 - 2,5 | 1,0 - 2,0<br>(-20 to 30%) |
| Volatilization coeficient | 0.93 | 0.72 (-25%) |

***Comparative Data – Old and New Burner***

## 6. Conclusion

Many cement kilns currently fire large quantities of liquid and solid waste fuels through the main kiln burner, with replacement rates of 40% to 100%.

The main waste fuels encountered are: animal meal, dry or impregnated sawdust, dry sewage sludge, rice husk, corn seeds, plastic chips, fluff (carpet residues, etc.), biomass, waste oil, animal grease, solvents, distillation residues, pyrolisis gas, landfill gas, etc.

Indeed, waste fuels firing in a rotary cement kiln is an efficient way to lower fuel costs and is also a benefit to the environment by reducing landfill and waste incineration.

However, when using waste materials as the main fuel source, it is mandatory to have the ability of adapting the process and the kiln operation to changing conditions. Therefore, a flexible multi-fuel kiln burner is a key advantage to be considered when switching to alternative fuel firing.

February 22, 2006
By: Max Vaccaro, EGCI PILLARD

# ROTAFLAM® VERSION 2 Upgrading at HOLCIM, HÖVER (Germany)

Cyril DUFAU-SANSOT, Deputy General Manager, Pillard Feuerungen GmbH, Taunusstein (Germany)

## CONTEXT

Pillard Feuerungen GmbH installed in 2004 a ROTAFLAM® burner (136.4 MW) in Holcim's Höver plant, located near Hannover (Germany). During the following years this rotary kiln burner was operated with more and more alternative solid fuels (especially Fluff). As a result the kiln, which is equipped with a satellite cooler, faced problems of lower clinker quality and clogging at the pre-heater tower. Additionally, increasing the quantity of Fluff was limited.

**Kiln main data:**

| | |
|---|---|
| • nominal capacity: | 2,700 to/d, dry process |
| • kiln length: | 80 m |
| • kiln diameter: | 4.9 m inner refractory |
| • pre-heater: | 4 stage |
| • cooler type: | Satellite |

(secondary air temperature approx. 600°C)

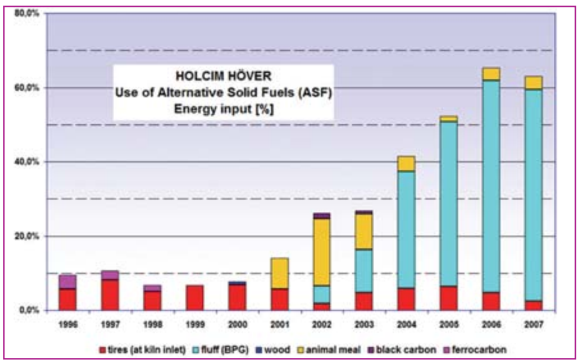
**Fluff (BPG):**

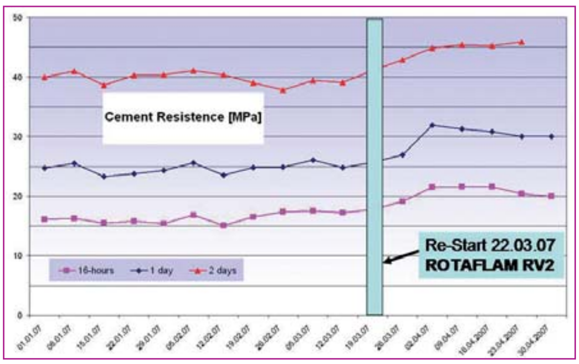
| | |
|---|---|
| • main components: | plastic, paper, textiles |
| • calorific value (LCV): | ~ 25 MW/kg |
| • fineness: | 5 – 20 mm |
| • moisture: | 8.5 % |

In March 2007 Pillard solved this problems by replacing the existing burner tip with a ROTAFLAM® RV2 version, calculated for 400 mbar axial air pressure (the fan was already installed in 2006).

The success of this upgrade was confirmed by:

- an evidently increase of the clinker quality (compressive strength from 26 up to 30MPa),
- 70% less clogging at the pre-heater tower,
- an increase of the Fluff quantity (up to 75% alternative solid fuel substitution).




In March 2008, HOLCIM HÖVER replaced the satellite cooler by a grate cooler (secondary air temperature approx. 1,050°C) to improve the efficiency of the cement process. The ROTAFLAM® RV2 reached the same high level performance with the new cooler.

## CONCLUSION

Conclusion: The successful upgrade of the burner fully satisfies the requirements of HOLCIM HÖVER.

# ROTAFLAM® VERSION 2 Burner for HEIDELBERGCEMENT, Lengfurt (Germany)

Manfred Gemmer, Head Research & Development, Pillard Feuerungen GmbH, Taunusstein (Germany)

## CONTEXT

For the last 5 years, the HeidelbergCement AG Lengfurt plant has planned to increase the substitution rate obtained by Fluff-BPG (fuel from production-specific trade wastes) from 35% to the maximum reachable rate.

In 2003, thanks to modifications on the old 3-channel burner tip made by Pillard Feuerungen GmbH the goal of 50% substitution rate was obtained with tendentious better flame characteristics.

An improvement of the substitution rate with remaining alike clinker quality was missing however. HeidelbergCement decided then to upgrade the kiln burner to the ROTAFLAM® VERSION 2 burner.

As a clear result of clinker quality analysis made by the Lengfurt plant in 2003: only an optimized and controlled combustion can ensure an improved and equal lasting clinker quality.

However the old 3-channel burner was not able to optimize the combustion of the increasing rate of Fluff, although several modifications on the burner tip were made.

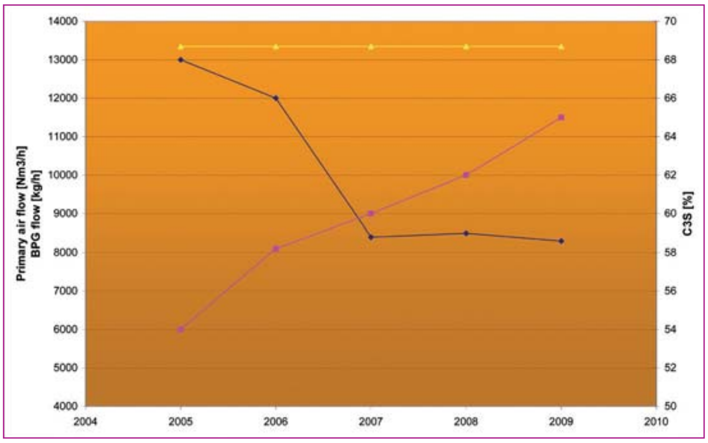
New ROTAFLAM® VERSION 2 in Werk Lengfurt (HeidelbergCement AG)

## Average substitution rates up to 80% of the firing thermal output

With the assistance of Pillard Feuerungen GmbH, the direction of HeidelbergCement technical center came to the conclusion that the newest generation of Pillard ROTAFLAM® VERSION 2 burners could optimize the high substitution rate target with an optimized combustion of alternative fuels.

In March 2007 the new ROTAFLAM® VERSION 2 burner was installed into Lengfurt plant with a initial substitution rate from 55% after commissioning.

| | Design | Commissioned | |
|---|---|---|---|
| **Burner capacity** | 113 | 99.7 | MW |
| **Fuels** | | | |
| Coal-Petcoke mix | 11.2 | 2 | to/h |
| BPG (Fluff) | 8 | 11.5 | to/h |
| Animal meal | 1 - 5 | 1 - 3 | to/h |
| or sewage sludge | 3 - 13 | 0 | to/h |
| Solvent | 0.5 - 5 | 0.5 - 1 | to/h |
| **Primary air** | **13,764** | 7,606 | $Nm^3/h$ |
| (Calc. With lambda 1.1) | 11.5 | 7.1 | % |




By further modifications at the burner tip and plant (dosing systems, etc) the kiln could reach a Fluff substitution rate of 80% - with simultaneous reduction of the primary air quantity and equal high clinker quality, as shown on measurements made by HeidelbergCement.

## CONCLUSION

For 2009 further modifications are planned, which correspond to the current level of development of the ROTAFLAM® VERSION 2 burner. Pillard Feuerungen GmbH is confident to be able thereby to reach the substitution rate from 90%.
But the HeidelbergCement AG Lengfurt plant has already the highest alternative solid fuels substitution rate in Europe.