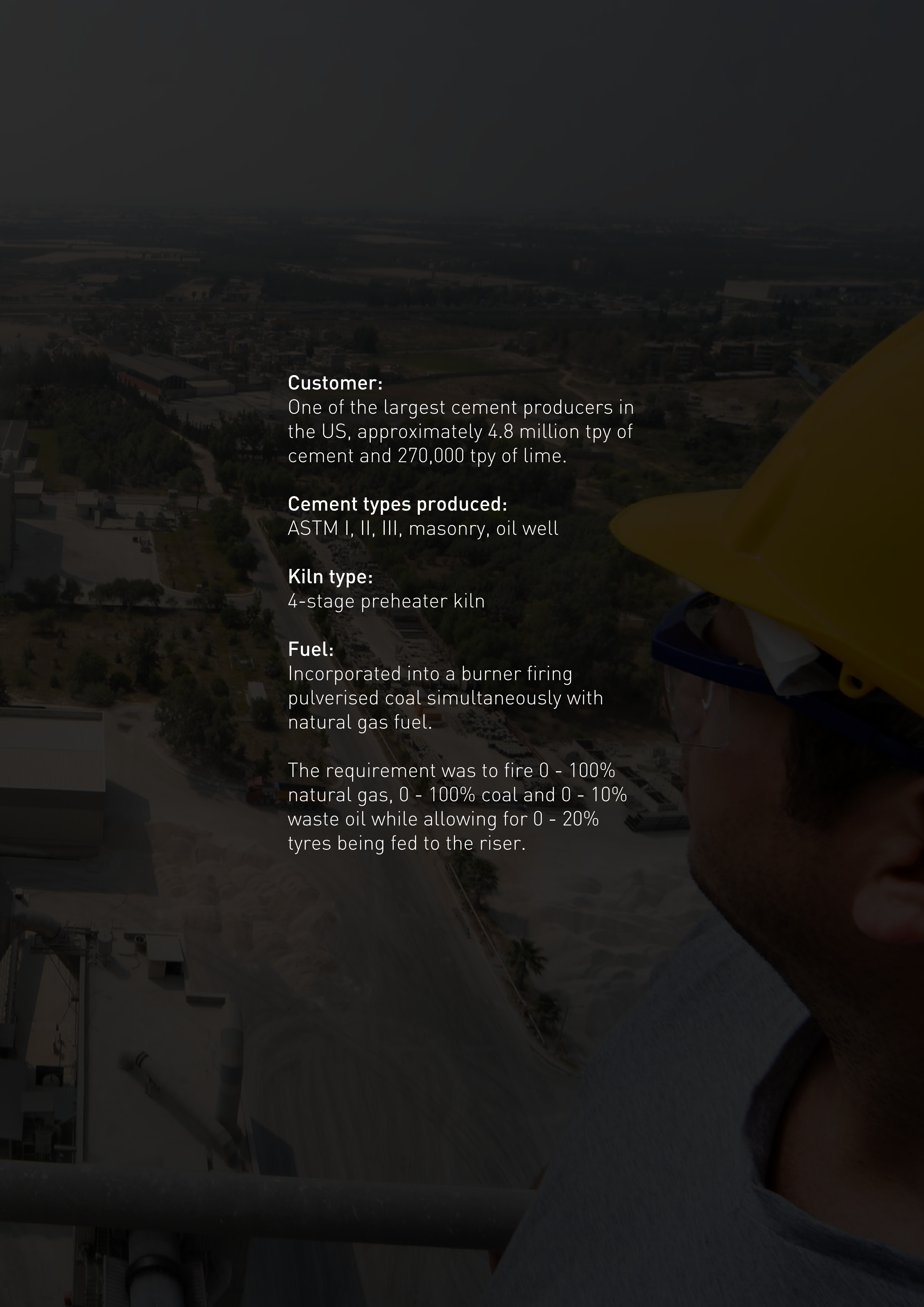
Making production rise, while sending emissions crashing down

How the Gyro-Therm burner put kiln process control firmly into the hands of operators at one of America's largest cement companies.



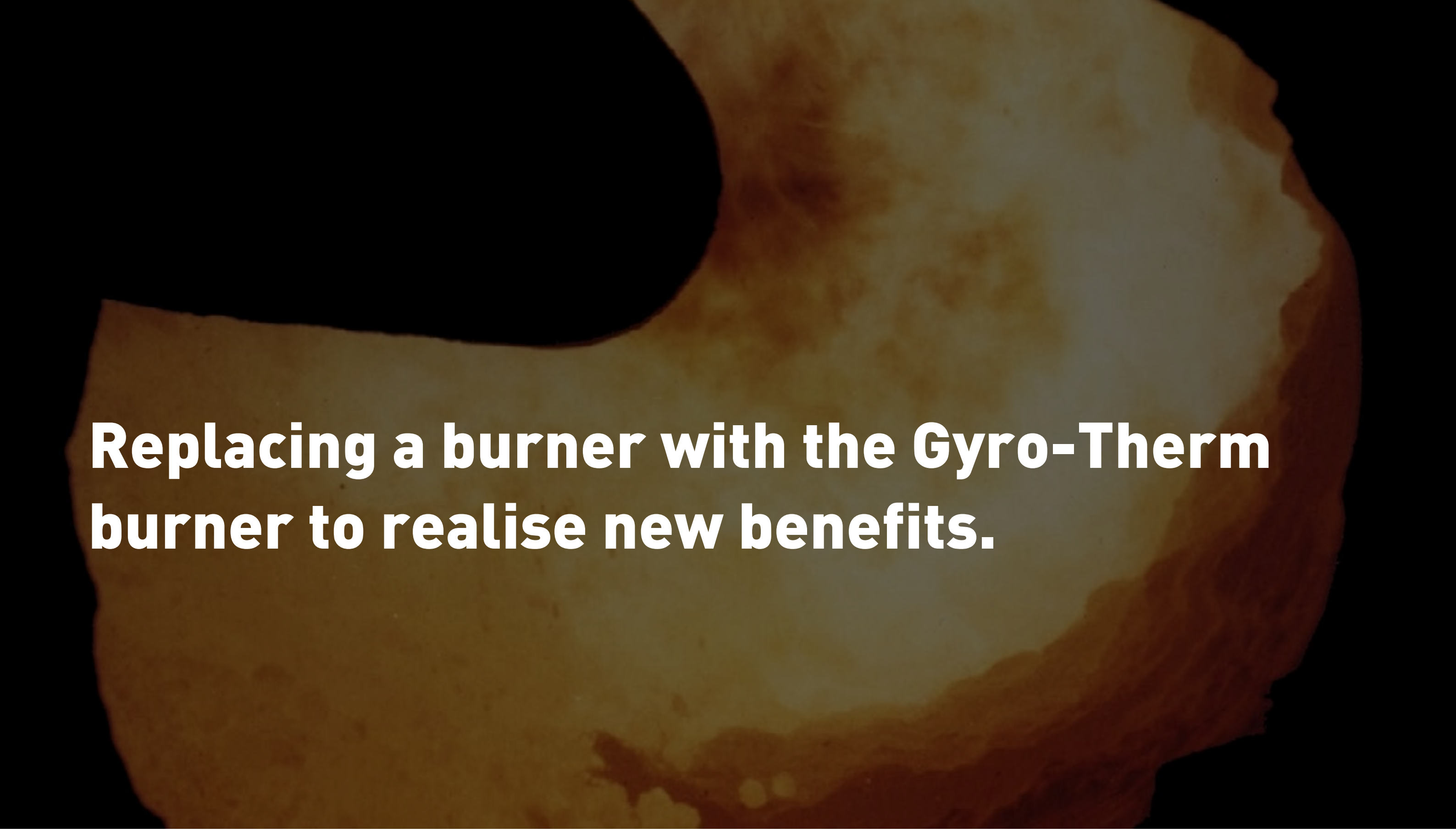
Customer:
One of the largest cement producers in the US, approximately 4.8 million tpy of cement and 270,000 tpy of lime.

Cement types produced:
ASTM I, II, III, masonry, oil well

Kiln type:
4-stage preheater kiln

Fuel:
Incorporated into a burner firing pulverised coal simultaneously with natural gas fuel.

The requirement was to fire 0 - 100% natural gas, 0 - 100% coal and 0 - 10% waste oil while allowing for 0 - 20% tyres being fed to the riser.



Replacing a burner with the Gyro-Therm burner to realise new benefits.

The 4-stage preheater kiln uses a range of fuels to maximise output and burns predominantly natural gas during summer and gas with coal during winter, as well as a quantity of tyres and waste oil.

The major incentive for the burner change was the opportunity to increase kiln output as the kiln was at maximum capacity in a sold out market. With the plant burning gas, coal, waste oil and tyres while producing two different types of clinker (type I & II), it was a difficult task to benchmark all conditions before and after the new burner's installation. As a result, the most detailed data was collected when firing with natural gas, the principal fuel.

It was decided to evaluate the burner by comparing the old and the new using the following operational parameters:

- Production in tph
- Fuel consumption in BTU/short
- Safety of the system
- Clinker quality
- Emissions
- Refractory life

As many of these parameters as possible were compared when producing type I and type II clinker. Once the operators became accustomed to the new heat flux profile, it was found that the kiln exit gas temperature was cooler, as was the gas exiting the top cyclone. This enabled a previously fan limited kiln to increase capacity and more feed to be put on.

Production increased by a staggering 11% when firing 100% gas. When firing natural gas with waste oil and tyres, the production increased between 6.0 and 9.9% (Figure 1 and Table 1).

It became immediately apparent that maximum output (now fan and feed limited) could be achieved by firing solely with natural gas where previously maximum output could only be achieved by the addition of tyres and waste oil. The benefit of this was a considerably more flexible operation and a steadier kiln. In addition to the short heat flux profile which reduces kiln exit gas temperatures and reduction in primary air, a 2.7 - 5.7% fuel saving resulted at the increased production levels (Figure 1 and Table 1).

Stack emission data was collected before and after the burner replacement principally while producing type II clinker. Data was collected under a 100% gas combustion scenario and under a gas, tyre and used oil combustion scenario. A 30% reduction in stack NOx corrected to 10% O2 was realised under the 100% gas scenario, while a 37% reduction in stack NOx was realised under the multi fuels scenario (Figure 2).

Regarding refractory life, it is observed that coating builds more readily in the burning zone and appears to be more stable. The kiln shell is cooler in the burning zone, as thicker coating is built. The coating formed is very even and no operational difficulties are observed.

Clinker samples taken before and after the burner installation were analysed under the microscope, and it was discovered that there were no significant changes in the microscopic characteristics of either clinker types as a result of the burner installation. The company was generally satisfied with the microscopic qualities of clinker and did not want to have to react to any change in clinker quality. A reduction of 3.9% in the cement mill Blaine set point (from 3850 to 3700) for type I cement has resulted after the burner installation.

The Gyro-Therm burner utilises a unique flow phenomenon known as a precessing jet (PJ) to achieve the air/gas mixing. A precessing jet is generated in a specifically designed nozzle. Precession is a term used to describe the gyroscopic rotation of a body about an axis other than its own centre line, similar to a spinning top that is leaning to one side. At any given moment, the jet is directed at an angle to the nozzle axis, about which it precesses. The precession creates a much larger scale of mixing than occurs in, a conventional jet, as well as increased spreading of and entrainment by the jet. The precessing motion is generated without any moving parts within the patented Gyro-Therm nozzle. The nozzle consists of an axi-symmetric chamber which has a large sudden expansion at its inlet and a small lip at its exit.

Figure 1.

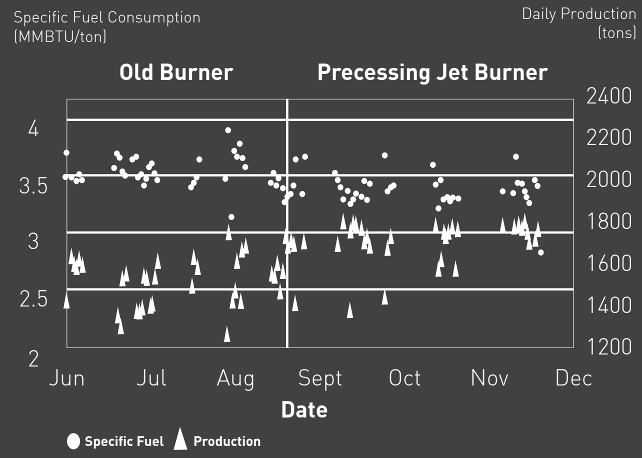
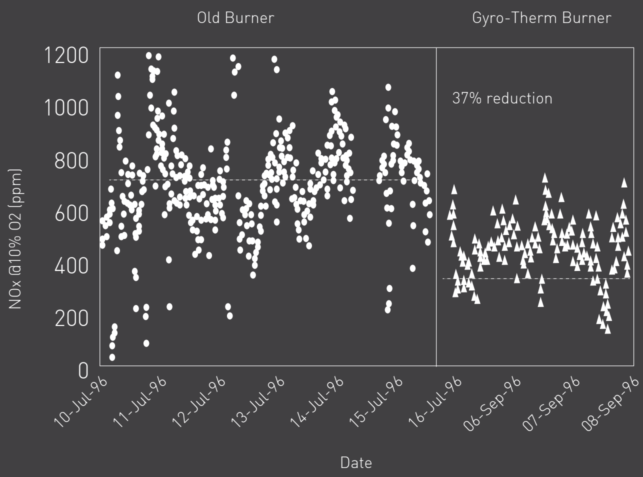


Table 1.

Fuel savings and output increases obtained with the precessing jet burner.

Clinker type	Fuels used	Fuel consumption (MMBTU/t)	Output (tph)
I	Gas, tyres, oil	-2.7% (3.67-3.57)	+6.4% (62.7-66.7)
II	Gas, tyres, oil	-3.4% (3.55-3.43)	+9.9% (63.2-69.5)
I	Gas, coal, tyres, oil	-2.5% (3.58-3.49)	Same
II	Gas, coal, tyres, oil	-5.7% (3.50-3.30)	+5.1% (68.5-72.0)
II	100% gas	-5.7% (3.53-3.33)	+11.0 (63.3-70.3)

Figure 2.



Achieving these results with the advanced Gyro-Therm burner design

As the gas jet enters the chamber, it reattaches asymmetrically to the inside of the chamber wall, generating strong local pressure gradients which deflect the jet out of the nozzle at a 45° angle. It is the strong azimuthal pressure gradients which cause it to precess about the nozzle axis.

These pressure gradients also draw a small quantity of air into the chamber which mixes with the jet before it leaves the nozzle. The flame itself does not precess.

The effect is to produce large-scale mixing, via the 'stirring' action of the jet, and a rapidly spreading flame. The highly luminous nature of the flame and the greatly reduced NOx emissions are a result of a naturally staged combustion process. The precessing jet engulfs air in such a way that stable combustion occurs close to the nozzle under fuel-rich conditions. This forms soot internally which is later burnt out in the more air rich sections at the extremities of the flame to achieve equivalent heat transfer to the process.

Although the flame spreads more extensively than that from a conventional single jet nozzle, the amount of spread is limited and can be controlled. This fact is important in cement kilns where direct impingement of a flame on the clinker could produce instability or reducing conditions which would be detrimental to product quality. A simple but extremely effective flame shaping technique is built into the burner.

The technique for flame shape adjustment is based on a high momentum gas jet injected at a critical point into the precessing jet flow field.

This jet (termed the centre body jet, CB) is expelled through the centre body of the precessing jet nozzle, modifying the pressure fields within the vicinity of the burner in such a way that the flame is directed more toward the kiln axis.

As the proportion of gas is increased through the centre body jet, the flame spread is reduced and the heat flux profile lengthened. An air channel is provided for cooling and for flame shaping during the warm-up phase. The coal channel was incorporated as an annulus around the PJ nozzle. The mixing generated by the precessing jet nozzle is produced directly by the gas stream, utilising the potential energy available in the high pressure gas supply rather than using a high momentum primary air stream. This means that a primary air fan can be reduced in size and effectively becomes a cooling fan.

In most rotary kiln applications, a Gyro-Therm burner would only use a small quantity of air, about 1 - 3% of the total air for cooling (in the event- of a kiln stoppage) and flame shaping during warm-up. Reducing the air reduces the operating and maintenance costs of the primary air fan and, more importantly, increases thermodynamic efficiency. The efficiency gains result when the volume of hot secondary air from the cooler increases due to the reduction of cold primary air.

To summarise, the precessing jet produces a very broad, bulbous, highly luminous flame compared to conventional burners, increasing radiation (heat transfer) to the product near the front of the kiln.

OVERVIEW OF PROJECT BENEFITS

REDUCES OPERATING AND MAITENANCE COSTS OF THE PRIMARY AIR FAN

MORE IMPORTANTLY, INCREASED THERMODYNAMIC EFFICIENCY

REDUCES SPECIFIC FUEL CONSUMPTION

INCREASES KILN OUTPUT

REDUCES NO_x EMISSIONS

IMPROVES CLINKER QUALITY AS A RESULT OF BETTER HEAT PROFILES

GREATLY REDUCED PRIMARY AIR VOLUME DURING NORMAL OPERATION

IMPROVES FLAME TURNDOWN AND STABILITY

INCREASES FLAME STABILITY

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