Burning chamber installation for increased use of alternative fuels at Norcem Brevik, Norway[1]

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Introduction

Norcem AS, part of HeidelbergCement since 1999, is the sole cement manufacturer in Norway. The plant at Brevik (Figure 1) is one of two plants in Norway and has a staff of about 200. Three types of clinker are produced in one rotary kiln, and seven types of cement are manufactured in three cement mills. The clinker and cement production capacities are 1 000 000 t/y and 1 300 000 t/y, respectively.

Figure 1: *The Norcem cement plant at Brevik, Norway.*

Norcem Brevik started utilization of alternative fuels in 1987, and motivated by environmental [1], economical and societal benefits, the replacement of fossil fuels has steadily increased since then (Figure 2).

In 2003, about 35 % alternative fuels were used on Kiln 6. However, due mainly to operational and environmental limitations, the replacement ratio could not be further increased without reconstructional measures. Hence, to allow for a more extensive utilization of alternative fuels, it was decided to modify the kiln system, i.e. to upgrade the calciner, to install a chlorine bypass and to increase the capacity of the fuel feeding system.

[1] Based on a paper published in World Cement No. 11, 2005

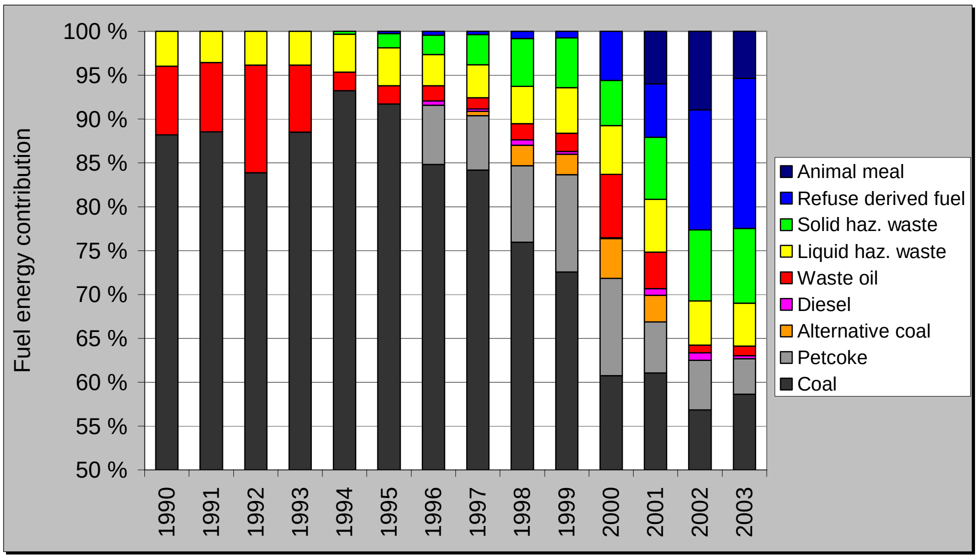

Figure 2: *Fuel energy mix on Kiln 6 1990-2003.*

Limitations of the old kiln system

A three-pier KHD rotary kiln, two KHD 4-stage cyclone preheaters, a CPAG 2-grate cooler and a KHD R-Low NO_x calciner constituted the old kiln system, previously upgraded from a SP kiln system in 1988 [2].

The old calciner was slightly modified by Norcem in the mid-nineties to allow for calciner and riser duct firing of lumpy secondary fuels. This was successful up to a certain point, corresponding to about 35 % alternative fuel energy input.

Different factors impeded higher inputs of alternative fuels:

- Combustion related limitations: To ensure sufficient burnout of large amounts of lumpy alternative fuels, a combination of high temperature, residence time, oxygen availability and good mixing is required. When this is not the case, increased concentrations of CO and TOC can be expected, and this indeed ocurred in the old system. The CO level in the stack was often in the range of 0.3-0.5 %, sometimes higher, causing EP trips (to avoid potential explosions), with accompanying high dust emissions. Moreover, the TOC emissions were often above the emission limit of 10 mg/Nm³ (dry gas at 11 % O_2).

- Chlorine load limitations: Alternative fuels (for example municipal solid waste) usually have a quite high chlorine content. Hence, increasing the input of waste fuels, also increases the input of chlorine in the kiln system. For Norcem Brevik this lead to three different types of problems:

    - Process related problems: Because chlorine is a volatile element it recycles heavily in the kiln system and tends to accumulate in hot-meal. This may change the flow properties of the meal and may lead to increased deposits in the system, which in turn may cause cyclone blockages and other process problems (Figure 3).

- HCl emissions: A small fraction of the chlorine input is emitted to the surroundings via the exhaust gas. Because of this, Norcem Brevik sometimes exceeded the HCl emission limit of 10 mg/Nm³ (dry gas at 11 % O_2).

- Quality requirements: With a very high input of chlorine, the chlorine level in clinker may be so high that quality limits on chlorine in cement are exceeded.

• Flow-related problems: In the old calciner system the gas velocity in the kiln riser duct and in the vertical part of the tertiary air elbow were not sufficiently high to entrain unburnt lumpy fuel fragments dropping down from above. Hence, there were frequent problems with fuel fragments dropping down into the kiln inlet – giving rise to problems related to a disturbance of the internal cycles of sulphur and alkalis [3] – and into the tertiary air elbow.

The experienced problems made it clear that, to facilitate increased utilization of waste fuels, some changes to the kiln system had to be carried out.

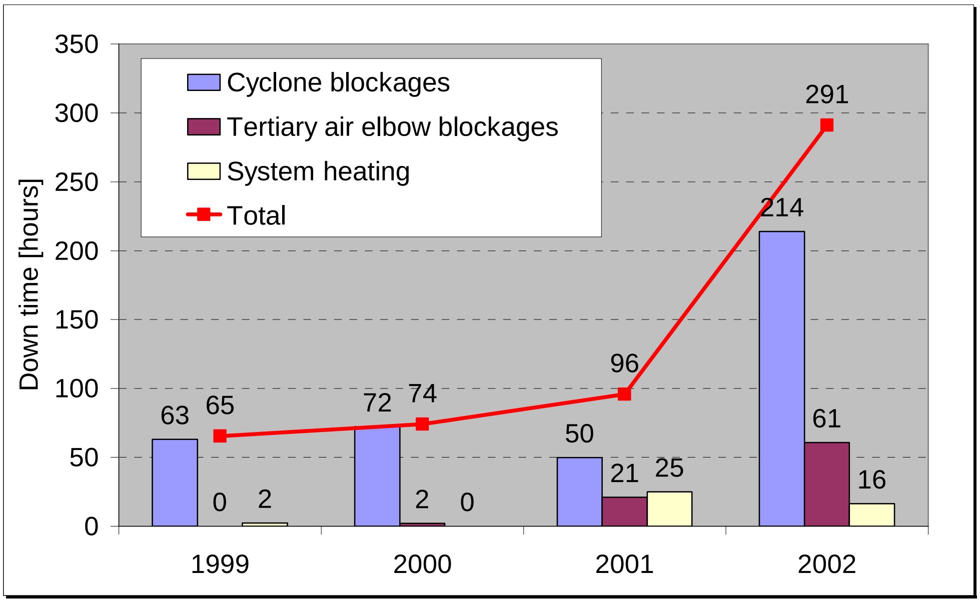

Figure 3: *Kiln 6 downtime related to high input of chlorine.*

Project goals

A €8 mill project to modify the kiln system was approved by the managing board of HeidelbergCement in October 2002.

The goals of the project were as follows:

- Increase the alternative fuel energy input to 60 %, as specified in Table 1, and reduce fuel costs accordingly. The increase from 35 to 60 % alternative fuels would take place mainly by increasing the RDF consumption from 30 000 t/y to 90 000 t/y.
- Eliminate operational problems.
- Reduce TOC and HCl emissions to levels below the emission limit of 10 mg/Nm³.
- Maintain the clinker production capacity.

Table 1: *Goals for fuel energy input to Kiln 6 in the kiln modification project.*

	Fuel portion [%]	Alternative fuels [%]	Alternative fuels, of total [%]	Alternative fuels applied
Calciner	60	90	54	RDF, SHW
Rotary kiln	40	15	6	AM, LHW
Total	100	60	60	

The kiln system modification

The various tasks of the kiln system modification and the purpose of each task are summarized in Table 2.

The new burning chamber is illustrated in Figure 4. A special feature of the burning chamber is the high temperature of the flame (hence the term "hot-spot calciner" is sometimes used), typically reaching 1200 °C. The downdraft burner, positioned at the top of the burning chamber, has three channels and is designed to burn large amounts of lumpy solid fuels:

- A mixture of refuse derived fuel (RDF; typically 15 t/h) and solid hazardous waste (SHW; typically 3 t/h) is fed vertically through the centre channel of the burner. Hence, the fuel particles enter the chamber by gravity forces.
- Pulverised coal is blown into the chamber via an annulus in the burner. Mixing air is added at the burner in order to increase the air velocity at the burner tip.
- Cold air is supplied in an outer annulus. The cold air serves three purposes:
    1. It cools the burner and hence prevents thermal damages to the burner tube.
    2. It is (a small) part of the total oxidation air required for combustion of the fuels.
    3. A twist element installed in the outer annulus generates a swirl at the burner tip. By this the transport of hot combustion into the flame, and hence more rapid ignition of the fuels, is facilitated.

The new bypass system is shown in Figure 5. In order to avoid a new emission point, it was decided to route the de-dusted bypass gas to the front part of the clinker and re-use the oxygen rich (19-20 % O2) cooled bypass gas as combustion air in the rotary kiln and the precalciner.

Table 2: *Overview of the kiln system modification items.*

Part	Item	Purpose
Calciner/ preheater system	Installation of a "hot-spot" combustion chamber (down-draft type) with high-temperature zone, high-O_2 zone, increased residence time and increased turbulence level	Improve burnout of lumpy fuels fed to the calciner system
	Installation of mixing chamber	Mixing kiln gas and gas from the new combustion chamber
	Installation of a KHD Pyrotop swirl chamber at the top of the loop duct of the calciner	Improve burnout of lumpy fuels fed to the calciner system
	Installation of an orifice in the riser duct	Balance kiln gas and tertiary air as well as ensure sufficient gas velocity in the riser duct to avoid drop-through of fuel fragments
	Re-routing and extension of the tertiary air duct	Adapt the tertiary air duct to the new combustion chamber
	Modification of lower cyclone stage on string 1	Make space for the new combustion chamber
	Re-routing of meal pipes	Make space for the new combustion chamber
	Modification of the kiln inlet chamber	Ensure sufficient inclination of the re-routed meal pipes
Waste feeding system	Installation of new 70 m³ cylindrical silo, equipped with a rotary discharge feeder	Provide intermediate storage and waste buffer, with a trouble-free discharge, in front of weigh feeder
	Installation of weigh feeder with a waste feeding capacity of 25 t/h	Provide accurate and sufficient feeding of waste fuels to the new combustion chamber
	Extension of existing pocket conveyor and modification of screw conveying system for RDF and SHW	Convey RDF and SHW from reception bins to new waste silo and from new waste silo to new combustion chamber
	Installation of mass flow measurement equipment based on gamma radiation; mounted outside screw conveyors	Control discharge rate and mixture of different waste fuel types from the reception bins
Bypass system	Installation of air-cooled bypass quenching chamber, designed for 10 % kiln gas extraction	Relieve the kiln system of chlorine, and hence reduce or avoid chlorine related operational, environmental and quality challenges
	Refurbishment of an exisiting EP (previosly used on another, closed kiln line)	Extraction of chlorine rich bypass dust from the bypass gas
	Routing of the de-dusted bypass gas to the front part of the clinker and re-use the oxygen rich (19-20 % O_2) cooled bypass gas as combustion air in the rotary kiln and the precalciner	Avoid a new emission point, and hence avoid additional emissions of NO_x, SO_x and dust, and possibly dioxins.
	Installation of fans and ductwork for the bypass gas, including re-use of two existing in-series arranged MRD blowers	Route the bypass gas from the kiln inlet, via the EP to the cooler

The calciner/preheater modifications (Figure 6) were carried out in 2003 and 2004, and the kiln was stopped for a period of 10 weeks from January to March 2004, whereafter the new system was commissioned. The bypass installation was built while the kiln was in operation and was commissioned in June 2004, thus completing the new kiln system (Figure 7).

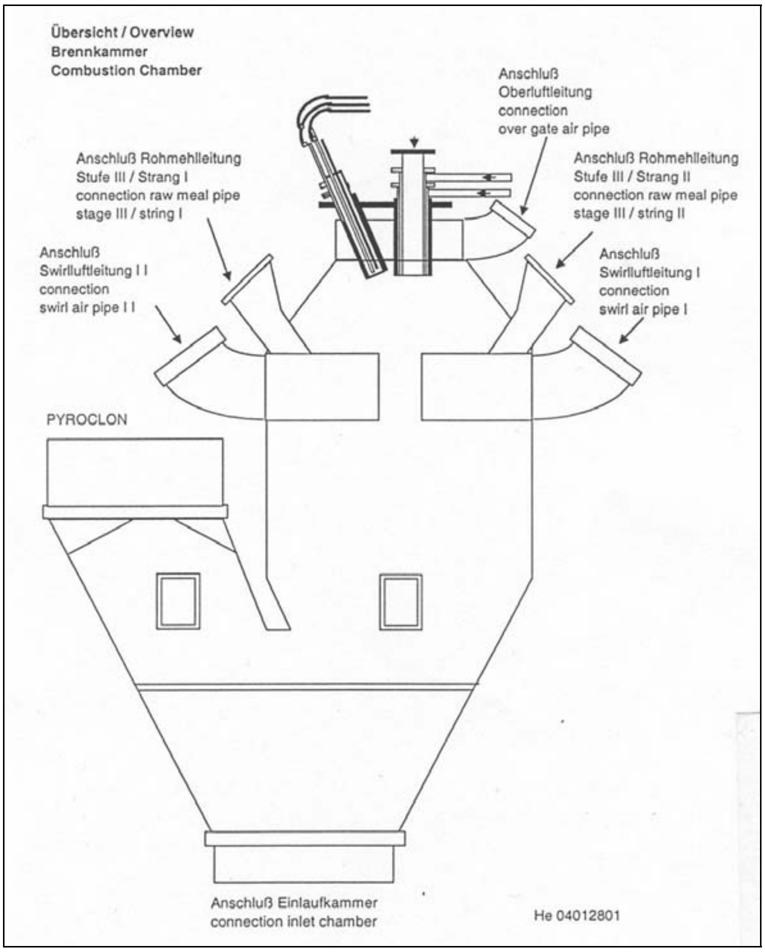

Figure 4: *The new burning chamber.*

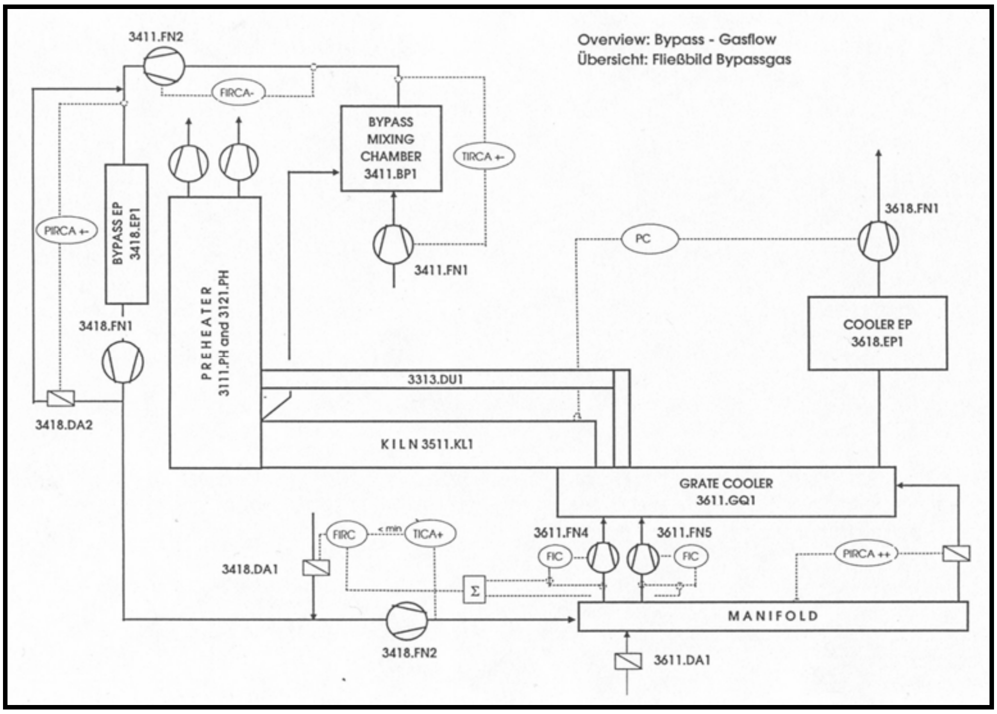

Figure 5: *The new bypass system.*

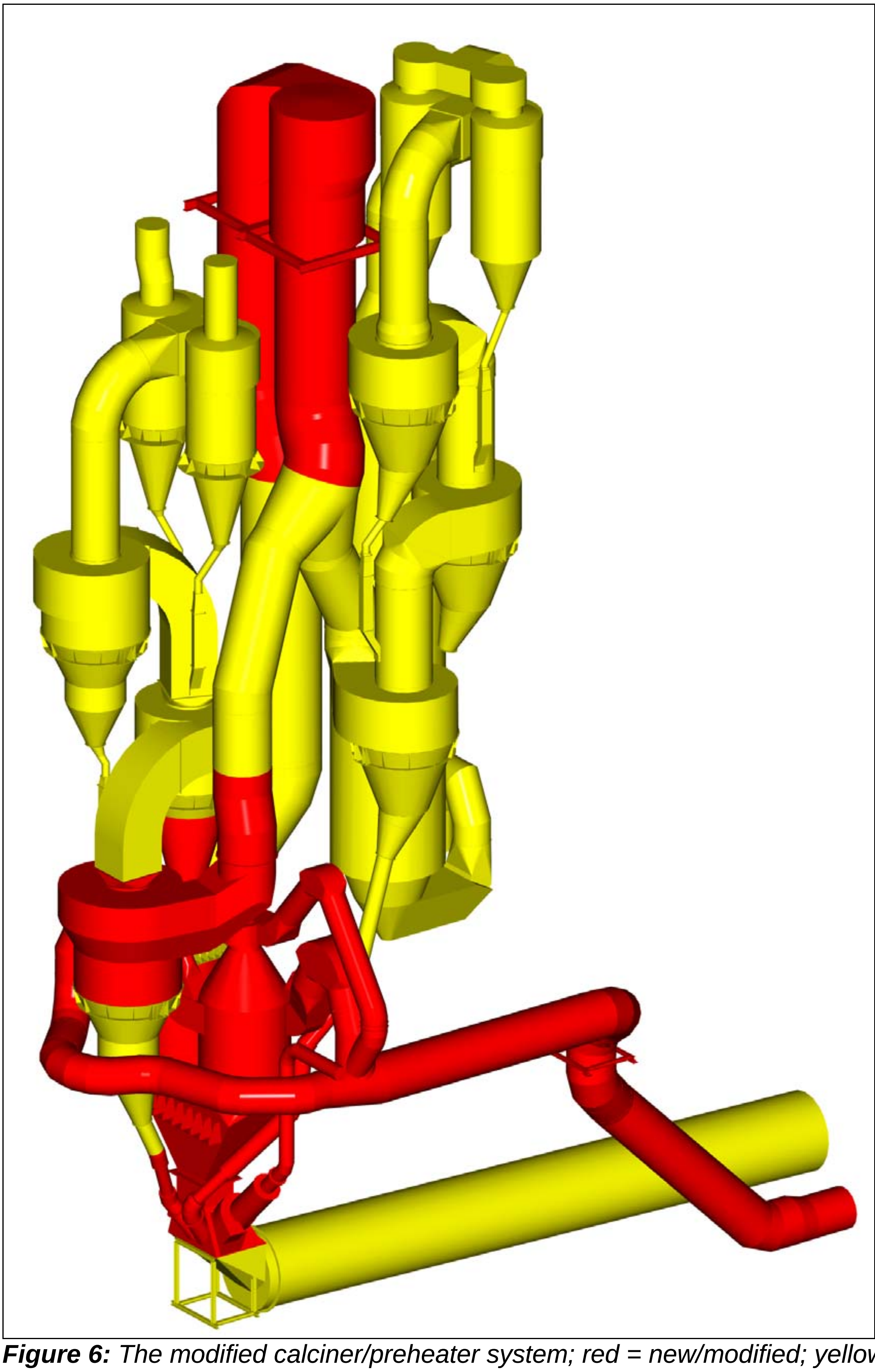

Figure 6: *The modified calciner/preheater system; red = new/modified; yellow = existing.*

KHD was awarded the contract of the calciner/preheater modification as well as the the bypass installation. AgderMaskin, a local Norwegian company, got the contract on the waste feeding system.

Some characteristics of the modified kiln system are given in Table 3, and the fuel mixture presently used on Kiln 6 is shown in Table 4.

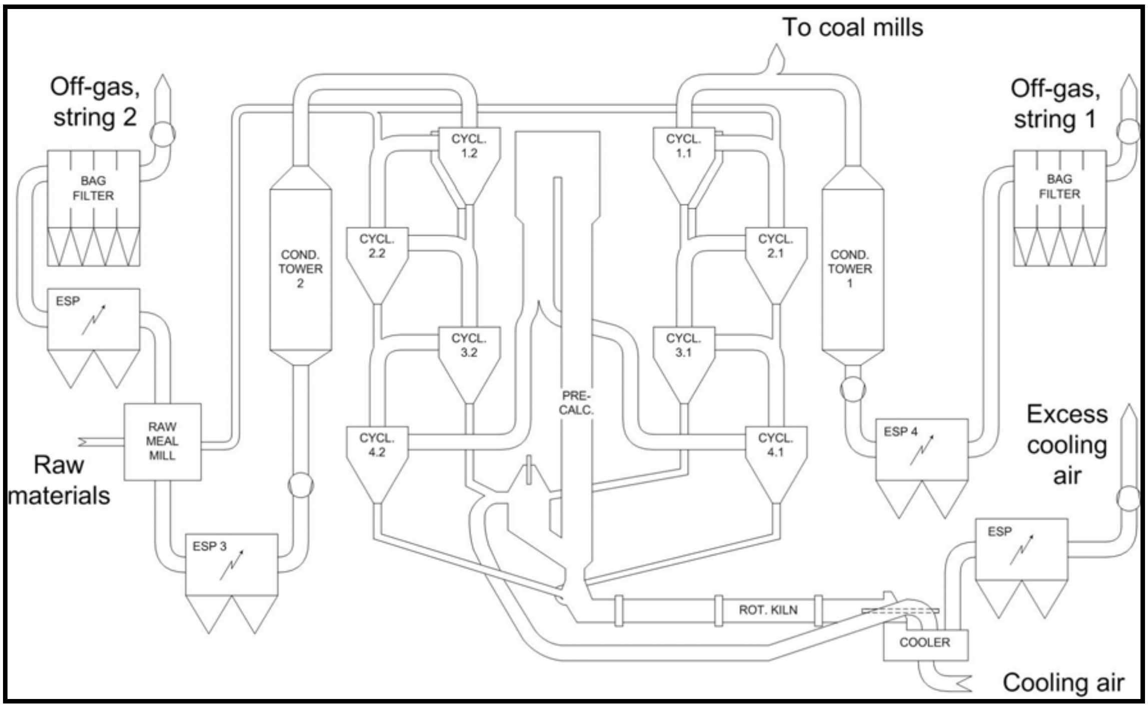

Figure 7: *The modified kiln system (bypass system not shown).*

Table 3: *Kiln system characteristics.*

Parameter	Value	Unit
Rotary kiln length	68	m
Rotary kiln (outer) diameter	4.4	m
Clinker production capacity	3300	t/d
Typical specific fuel consumption	3400	kJ/kg_cli
Representative temperature interval in the rotary kiln	1100-2000	°C
Representative temperature interval in the precalciner	840-1300	°C
Typical gas residence time in the rotary kiln	5	s
Typical gas residence time in the precalciner	5	s
Typical O_2 concentration in rotary kiln exhaust gas	3.5	%
Typical O_2 concentration in precalciner exhaust gas	4	%

Table 4: *Fuel consumption and fuel heating values 2005.*

Fuel	**Lower heating value [MJ/kg]**	**Amount [t/y]**
Refuse derived fuel	14	90 000
Coal	28	52 000
Solid hazardous waste	17	13 000
Liquid hazardous waste	17	10 000
Animal meal	16	8 000
Petcoke	30	8 000
Wood	18	7 000
Waste oil (used during startups)	34	1 500

Some particular challenges

The startup of the modified kiln system was not entirely trouble-free, as can be expected for a retrofit project like this.

The first problem encountered was an unexpectedly high pressure drop caused by the orifice (10-15 mbar), resulting in too little gas being routed through the kiln, and hence giving reduced clinker production rates. The orifice cross-section has now been enlarged, and the pressure loss has dropped (to about 5 mbar).

The waste feeding stability and accuracy was a challenge, in particular because of the poor flowability of the RDF material. However, several improvement measures have been implemented and the waste feeding system now works well, with accuracy better then 1 %.

One of the requests specified for the bypass installation was that a refurbished EP, previously used on another kiln line, and two existing MRD blowers should be reused. Therefore, the decision was taken to place the new bypass fan in front of the bypass EP, which however showed a very high wear rate, and the impeller was very quickly worn-out. The impeller and the housing were repaired several times, and later the impeller was replaced, installing a better steel quality. Moreover, the wear on the impeller, as well as deposits of bypass dust, caused problems with fan vibration. Wear on this bypass fan working on the dirty side of the EP is still a challenge.

For a chlorine bypass system it is difficult to foresee excactly the corrosion and abrasion caused by the gas and dust. The bypass gas was found very corrosive and abrasive, partly because the gas also contained a certain concentration of abrasive metal pieces and unburnt wood pieces most likely originating from the RDF burnt in the calciner. Because of this, the re-used EP was actually deteriorating at a higher rate than expected, requiring a lot of repair work and giving more downtime on the bypass system than expected.

As already mentioned, the bypass installation featured an environmentally friendly concept of re-cycling the bypass gas in the system, hence avoiding a new emission source. However, the sometimes high dust concentration in the cleaned bypass gas, caused by the high wear on the EP internals, gave some problems with clogging of the cooler grate plates, which in turn resulted in poorer cooler efficiency and sometimes snowman formation in the front of the cooler due to poor cooling. To solve this problem, the bypass filter system is currently being modified mainly by installation of new baghouse filter as a replacement for the old EP.

In addition, the commissioning team was faced with other difficulties not directly attributable to the project itself. For example, there were a lot of problems with unstable coal feeding. Eventually the problem was solved by re-routing the pneumatic conveying lines for coal. Moreover, during the time of commissioning, part of the limestone used for raw meal production was taken from a part of the open quarry that proved to be of rather poor quality due to a special mineralogy of this limestone. This resulted in a quite poor burnability of the raw meal, which reduced the clinker production.

Present kiln system performance and further improvement measures

Table 5 gives an overview of guarantee values and operational values reached during the performance test, which was carried out in December 2004. As can be seen, most of the guarantee values were reached or nearly reached.

However, it has to be mentioned that the cooler efficiency was lower than the requirement (66 instead of 72 %) and the recuperation air was higher than the requirement (0.87 instead of 0.81 Nm^3/kg_cli). Hence, the clinker production rate given in Table 5 should be adjusted to higher value (3492 t/d), based on a compensation for the low cooler efficiency. Similarly, the pressure drop guarantee value should be increased to 73 mbar when compensating for the low cooler efficiency.

It should also be noted that during the performance test, the bypass system was running well, and with the required chlorine extraction, at a bypass rate of 4-6 %. Hence, the bypass system was not pushed to check whether the guarantee value of 10 % could be reached.

The most striking guarantee value not reached is the pressure drop, in particular that of string 2, the actual pressure drop being 18 mbar higher than the (adjusted) guarantee value. To a large extent this can be explained by the particular design that was used in the period of building this preheater (1988). But relatively high false air percentages in the system also contributed to the high pressure drop.

Norcem will take actions to reduce the pressure drop in the preheater towers, partly by reducing false air inleakage, partly be constructional improvements. Moreover, actions will be taken to improve the cooler efficiency. Commisioning of the new bypass filter system will take place in May/June 2006.

Table 5: *Main results from kiln performance test.*

Test parameter	Test result	Guarantee value
Clinker production [t/d]	3349 (3492)	3500
Daily average free lime content of clinker [%]	2.0	< 2.0
Pressure drop of the system at 10% bypass ratio, stage 1 / stage 2 [mbar]	78 / 91	69 / 69 (73 / 73)
Solid Secondary Fuel Portion for the combustion chamber at a fuel ratio kiln/calciner of 40/60 [%]	88	90
Kiln Waste Gases CO [%], dry at 11%O_2, measured in kiln stack	0.07	0.1
Kiln Waste Gases TOC [mg/Nm³], dry at 11%O_2, measured in kiln stack	6	10
Capacity of Bypass Rate of kiln gases in the kiln operation at its guarantee level, calculated without / with dust [%]	6 / 4	10 / –
Temperature behind Bypass at guaranteed conditions [°C]	294	300
Chlorine Content in Hot Meal [%]	1.2	1.5

Conclusion

Today, the kiln operation can be described as satisfactory, with a typical clinker production rate of 3300 t/d and about 55 % alternative fuels. This means that typically 16 to 18 t/h of a mixture of RDF and SHW is fed to the new combustion chamber, in addition to the alternative fuels fed to the main burner.

Further improvements are expected in the near future, when several ongoing improvement measures have been fully implemented in the kiln system.

The modification of the kiln system has proved a successful project, both economically, process wise and from an environmental point of view.

Abbreviations

AM	Animal Meal (bone meal), a fine sterilized powder (particle size < 1 mm) pneumatically fed into the rotary kiln via a separate channel in the main burner
EP	Electrostatic Precipitator
LHW	Liquid Hazardous Waste, i.e. solvents, paints etc.; pumped into the rotary kiln via a separate channel in the main burner
MRD	KHD twin stream dedusting fan
RDF	Refuse Derived Fuels, i.e. a shredded mixture of municipal solid waste without any wet organic compounds and industrial solid waste; particle size < 50 mm; mechanically fed into the new combustion chamber
SHW	Solid Hazardous Waste, i.e. solvents, paints etc. mixed with wood chippings (to improve flow properties); particle size < 50 mm; mechanically fed into the new combustion chamber

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