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CEMENT INTERNATIONAL

▸ PROCESSING ▸ PERFORMANCE ▸ APPLICATION

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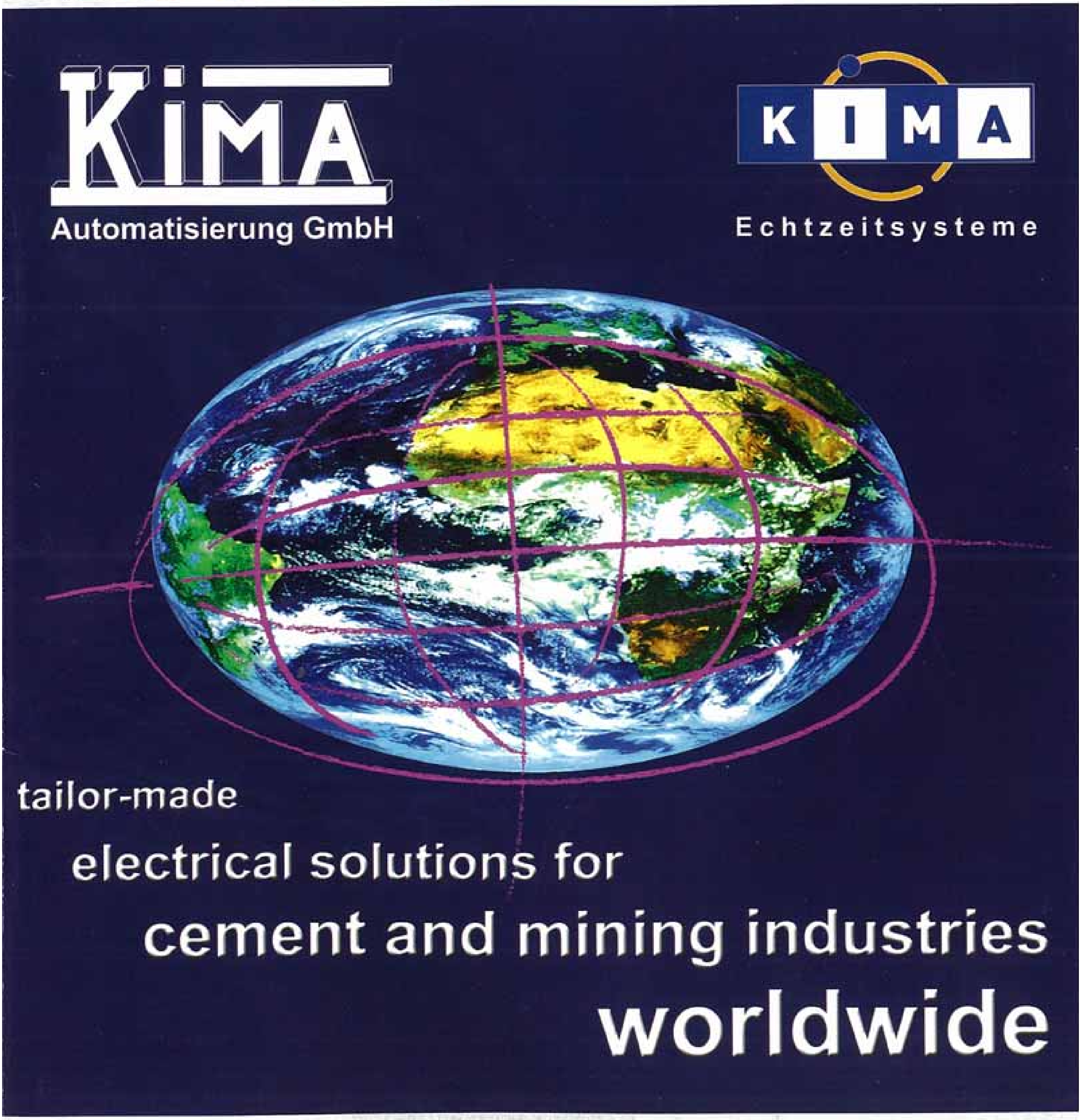
国际水泥 الأسمنت العالمية ЦЕМЕНТ ИНТЕРНЕШНЛ



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Results from burning alternative fuels*)

Ergebnisse mit der Verfeuerung von alternativen Brennstoffen

1 Introduction

The successful utilization of alternative fuels is not only a challenge but also an opportunity that is of increasing importance in every respect. On the one hand, there are the global targets, such as climate and environmental protection, that create the general underlying conditions. These include the careful and sustainable handling of natural resources within the framework of self-imposed commitments and the reduction of CO_2 emissions on the basis of the emissions trading system that was introduced in the EU on 1st January 2005.

On the other hand, there are various individual targets for the cement manufacturer, such as earning the greatest possible waste disposal profits through the recycling of fuels made from waste materials. The aim of reducing fuel costs – ultimately leading to "negative fuel costs" – is essential for many plants to secure and improve their own competitive position in the global market.

The global targets are:

- Saving of natural resources
- Reduction of CO_2 emissions (emissions trading)
- Thermal recycling

The individual targets are:

- Earning disposal fees
- Reduction of fuel costs – "negative fuel costs"
- Stronger market positions.

However, to obtain the economic benefits resulting from the use of these fuels it is first necessary to realize certain preconditions, such as the establishment of a waste material fuel management system as well the storage and handling facilities and the metering and transport equipment.

The range of the alternative fuels used (liquid, solid or gaseous) is extremely wide so correct appraisal of the possible effects on the process is crucial. This requires a thorough knowledge of specific combustion characteristics and material properties of the secondary fuels, such as fuel analyses, heat values, ash content, ignition and burn-out behaviour, pollution input, etc., so that the plant operations can be coordinated with them as well as possible.

Typical key process influencing factors from secondary fuels that have to be taken into consideration are:

- Increased specific fuel demand because the heat values are often reduced
- Increased specific waste gas volume and pressure drop as result of higher volumes of excess air and fluctuating material moisture
- Higher concentrations of chlorine and sulfur.

The feed locations and quantities of secondary fuels are strongly dependent on the fuel properties and the available process technology. In a kiln system without a calciner it is only possible to feed selected secondary fuels through the kiln burner and, in addition, a limited amount can be fed in at the kiln inlet chamber, e.g. whole tyres. The delayed heat release is consumed in the calcining zone.

The basic technology of a modern multi-channel burner consists of features for adjusting the flame during operation and varying the primary air flow to suit the nature and the quantity of the relevant alternative fuels being fired and ensuring stability of the flame front. With a calciner kiln there is further potential and flexibility for firing alternative fuels. The extent is dependent on the calciner configuration with respect to burn-out characteristics and additional combustion equipment. A combustion chamber can, for example, provide the highest possible substitution rates for waste materials that have had little pre-treatment.

› Table 1 shows a number of typical alternative fuels and characterizes them in terms of opportunities for their use in a kiln burner, in a calciner (suspension tube design) and in a calciner with a combustion chamber.

2 The Norwegian approach

The Norwegian cement producers, motivated by environmental, economic and societal benefits, had already started

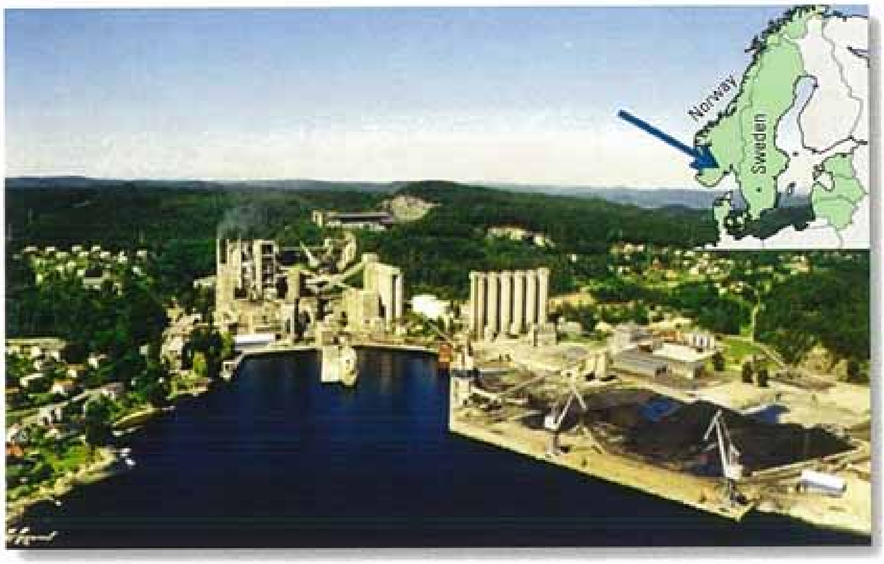


Figure 1: Plant site at Brevik, Norway

Table 1: Feed points for typical alternative fuels

	Heat value [MJ/kg]	Kiln burner	Calciner	Calciner and combustion chamber
Waste oil Animal meal	~ 33 ~ 17	+ +	+ +	+ +
Petrolcoke Anthrazite	~ 33	Max. 5 % R 90 µm	Max. 5 % R 90 µm	Max. 10 % R 90 µm
Hard plastics	~ 27	0 to 4 mm	0 to 5 mm	0 to 50 mm
Tyre chips / rubber residues	~ 32	-	Max. 40 x 40 mm	Max. 70 x 70 mm
Fluff-RDF	~ 18	0 to 10 mm	0 to 30 mm	0 to 100 mm
Biomass/ sewage Sludge	~ 15	0 to 4 mm	0 to 5 mm	0 to 50 mm

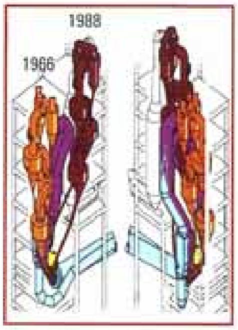
to use alternative fuels by the eighties. The plant at Brevik is situated approximately 150 km south of Oslo and is one of the two cement plants in Norway (❯ Fig. 1). It produces about 1.05 million t/a clinker or 1.3 million t/a cement. The products are three different types of clinker, produced in one rotary kiln, and seven different types of cement.

The plant has certain advantages in respect of harbour facilities, production flexibility, high workforce competence and market relations. However, the disadvantages concerning the cost of limestone and electrical power because of the general cost levels in Norway should also be mentioned.

2.1 History of the plant

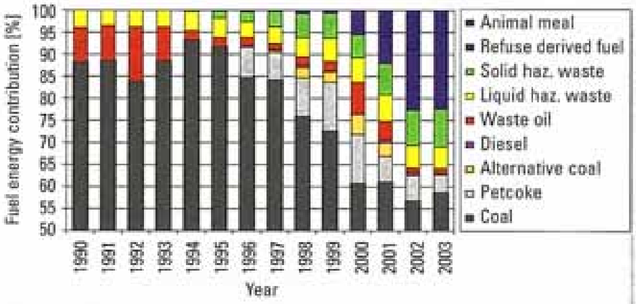
The origin of kiln line 6 goes back to 1966. A 4.4 m diameter x 68 m kiln with a 4-stage suspension preheater and a grate cooler was supplied to provide a production capacity of 1600 t/d clinker (❯ Fig. 2). The first upgrade in 1988 increased the clinker production to 3500 t/d. An additional preheater and one of the first so-called LowNO$_x$ calciners were installed, which initiated the usage of a number of different alternative fuels (❯ Fig. 3).

These fuels were mainly Liquid (LHW) and Solid Hazardous Waste (SHW), Refuse Derived Fuels (RDF), petcoke, alternative coal, and animal meal (AM), which were used in accordance with availability and the economical benefits. About 35 % alternative fuels were used in kiln 6 in 2003. The replacement ratio could not be increased further without modifications, due mainly to operational and environmental limitations. It was therefore decided to modify the kiln system once again to allow for more extensive utilization of alternative fuels.



1966: "Basis" 1600 t/d
1 string SP
Preheater: 1 string/4 st.
Kiln: ∅ 4,4 m x 68 m
Cooler: 54 m^2
1988: "Prod. Increase" 3500 t/d
Preheater: 2nd string/4 st.
TAD + Calciner: LowNO$_x$ type
Cooler: 70 m^2
2004: "Secondary fuels" 3500 t/d
Calciner with combustion chamber

Figure 2: Modification stages of kiln line 6



Limitation of the "old system" at 35 % alternative fuels due to:

Combustion related limitations

- increased amount of CO and TOC
- lack of residence time, low combustion temperature, oxygen availability and mixing of gases

Chlorine load limitations (RDF)

- Chlorine reacts with alkalies and may lead to increased deposits in the system causing process problems
- Chlorine level in cement up against 0,1 %. (0,1 % is the limit in the quality standard)

Flow-related problems in the existing system

Figure 3: Fuel energy mix for kiln 6 in the years between 1990 and 2003

The problems that were experienced made it clear that some changes had to be made to the kiln system to facilitate the utilization of waste fuels. The targets for the €8 million project for the second upgrade in 2003/2004 were:

- Increasing the alternative energy input to 60 % with a corresponding reduction in fuel costs
- Elimination of operational problems
- Reduction of TOC and HCl emissions to 10 mg/m^3 (stp)
- Maintaining the clinker production capacity of 3500 t/d

2.2 The modified system

Waste feed system

The existing infrastructure of the waste feed system to the preheater tower, starting from a truck unloading station for solid waste fuel (❯ Fig. 4), had to be modified as follows to improve the usage of alternative fuels:

- Installation of a new 70 m^3 silo with rotary discharge feeder as intermediate storage and waste buffer before the weighfeeder
- Installation of a weighfeeder with a waste feed capacity of 25 t/h to provide an accurate and adequate supply of waste material to the combustion chamber

- Three bins with "push-floor" discharging system
- Total storage capacity 1300 m^3
- Buffer approx. 12 hours

Figure 4: Truck unloading station for solid waste

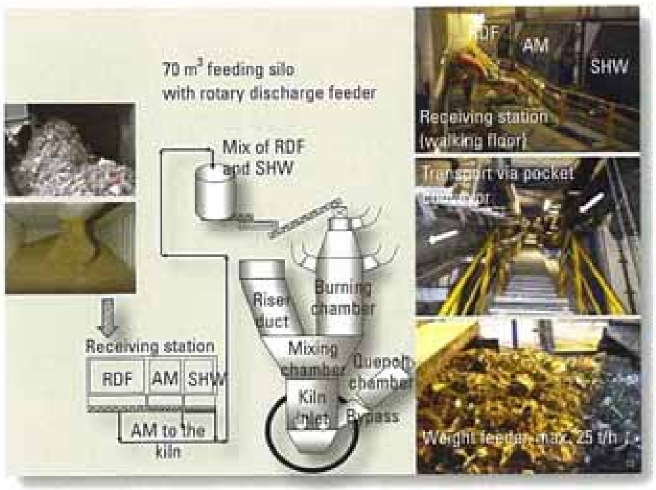


Figure 5: Waste feed to combustion chamber

- Extension of the existing pocket conveyor and modification of the screw conveyor system for transporting the RDF and SHW from the reception bins to the new waste silo for feeding the combustion chamber (❯ Fig. 5)
- Mass flow measurement equipment (gamma radiation) mounted outside the screw conveyors to control the discharge rate and the mixture of different types of waste fuel from the reception bins

Calciner and preheater

The major modifications to the system are shown in ❯ Fig. 6.

- The core equipment was a "hot-spot" combustion chamber with high-temperature and high-O_2 zone as well as increased residence time and turbulence level installed to improve burnout of lumpy fuels fed to the calciner
- Extension of the calciner and installation of a swirl chamber at the top deflection point for further improvement of the burnout of lumpy waste fuels
- Installation of an orifice in the kiln riser duct to balance kiln gas and tertiary air as well as to ensure an adequate gas velocity in the riser duct to prevent fuel particles from dropping through the duct
- Re-routing and extension of the tertiary air duct to adapt it to the combustion chamber
- Modification of cyclone sections and re-routing of meal pipes to create space for the combustion chamber
- Adaptation of the kiln inlet chamber to ensure sufficient inclination of the re-routed meal pipes

The modifications to this section were carried out in 2003 and 2004. The kiln was stopped for a period of ten weeks from January to March 2004, after which the new system was commissioned.

Bypass system

The new bypass system is shown in Fig. 6. It consists of:

- Air-cooled quenching chamber, designed for 10 % kiln gas extraction to relieve the kiln system of chlorine
- Re-used ESP (later replaced by a new baghouse) to extract chlorine-rich bypass dust from the bypass gas
- Routing of the de-dusted bypass gas to the front part of the clinker cooler and re-use of the cooled, oxygen-rich (19 to 20 vol.% O_2), bypass gas as combustion air in the rotary kiln.

This solution was selected in order to avoid a new source of emissions and to prevent additional emissions of NO_x, SO_x and possibly dioxins. The bypass installation was built while the kiln was in operation. Its commissioning in June 2004 completed the new kiln system.

Combustion chamber

The combustion chamber (❯ Figs. 7 and 8) constitutes one of the major modifications and is an appropriate solution for burning coarse, lumpy, secondary fuels at reduced preparation costs. Raw meal from the two second-to-bottom cyclone stages is taken directly to the two swirl air ducts leading tangentially into the combustion chamber. The central section with the hot core zone is surrounded by a curtain of meal that forms on the wall and protects the lining from overheating and deposits.

The fuel mix is introduced through the central channel of the burner in the area of the hot core zone at about 1 200 °C. There is then a spontaneous release of the volatile components. The mixing of fuel and kiln meal and the continuing burn-out take place in the extended calciner duct equipped with a swirl chamber.

3 Problems and results of the modified kiln system

❯ Fig. 9 shows the modified calciner and preheater. Tailor-made solutions (marked in red) were necessary, especially for integration of the combustion chamber with new complex ductwork. To this extent the start-up of the modified kiln system was not entirely trouble-free, as can be expected with this type of retrofit project. Some particular problems were:

- Unexpectedly high pressure drop caused by the orifice, which resulted in an unfavourable gas flow through the kiln and reduced clinker production. Enlargement of the cross-section eliminated this problem.
- Pressure drop in both preheater strings above the target values due to a combination of different factors: lower cooler efficiency, preheater design features (1966/88) along with relatively high percentages of false air.

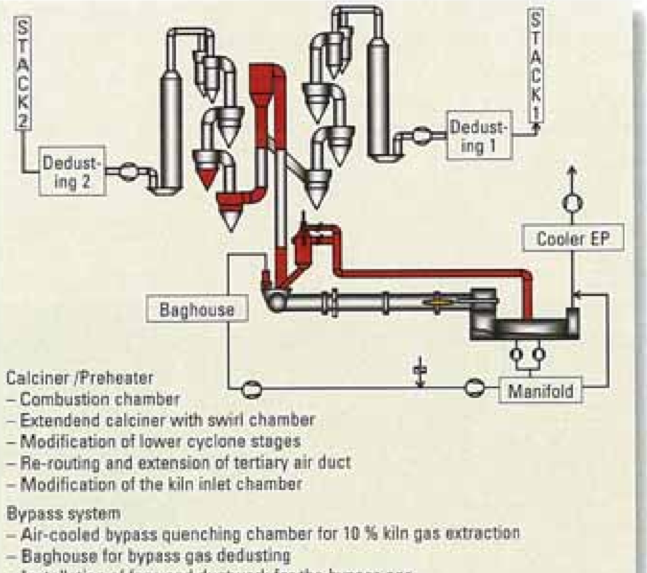


Figure 6: Major modifications to kiln 6 in 2004

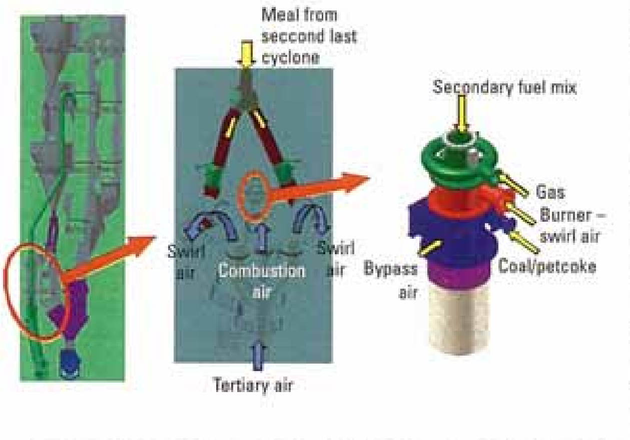


Figure 7: Calciner with combustion chamber

- Accuracy and stability of the waste feed system because of the poor flowability of the RDF material. Several measures enabled the performance of the system to be improved and adjusted to an accuracy of better than 1 %.
- Bypass: The re-used ESP performed very badly under the new process conditions with a bypass gas that was found to be very corrosive and abrasive. Under these conditions the ESP deteriorated at a higher rate than anticipated, requiring a great deal of repair work and more downtime on the bypass system than expected. The ESP was replaced by a baghouse filter in 2006.

Other troubles that were recognized but were not directly attributable to the project itself were an unstable coal feed, which was solved by re-routing the pneumatic conveying lines, and the poor quality of the limestone taken from one section of the open quarry. This resulted in poor burnability of the raw meal combined with reduced clinker production.

In spite of the above-mentioned problems and difficulties in the start-up phase a successful performance test was carried out in December 2004, where most of the guarantee values were achieved. These included:

Fuel substitution (% energy related)

Guarantee: 90 % solid secondary fuel for the combustion chamber at a fuel ratio kiln/calciner of 40/60 %
Test result: 87 % with the following fuel split:

Combustion chamber:

Coal/petcoke:	8 %
SHW:	16 %
RDF:	36 %
Total:	60 %

Design parameter:
- Diameter : Ø 4460 mm/4000 mm
- Height: 6 m
- Volume: 75 m^3
- Gas velocity: 10 m/s
- Retention time: 0,6 s
- Thermal load: 5,5 Gcal/h m^3 (at 100 % conversion)

Figure 8: Cross-sectional view and design parameters

- Successfully in operation since December 2004
- 90 % of the calciner fuel substituted by secondary fuels
- CO at stack, dry at 11 % O_2 : < 0.1 %

Calciner (combustion chamber)
60 % of total fuel
- Coal/petcoke/animal meal mix 6 %
- Solid hazardous waste: 16 %
- Fluff RDF: 38 %

Main burner: 40 % of total fuel
- Coal/petcoke mix 34 %
- Liquid hazardous waste 4 %
- Animal meal: 2 %

Typically: 16 to 18 t/h of solid haz. waste and heterogeneous RDF fed to the combustion chamber

Figure 9: Results of the modified system

Kiln main burner:

Coal/petcoke:	34 %
LHW:	4 %
AM:	2 %
Total:	40 %

Emissions of waste gas (dry, 11 vol.% O_2 at stack)

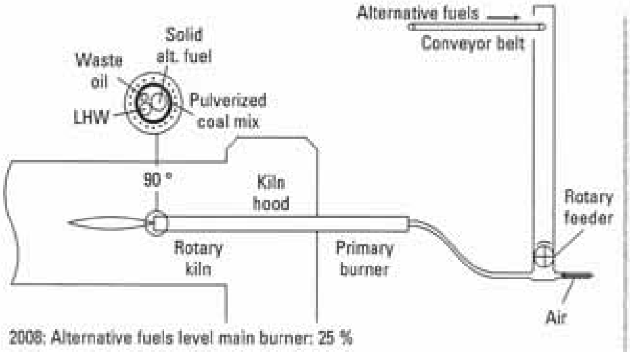
Guarantee: 0.10 % CO Test result: 0.07 % CO
Guarantee: 10 mg TOC/m^3 (stp) Test result: 6 mg TOC/m^3 (stp)

The mixture of SHW and RDF that is fed directly to the combustion chamber constitutes a mass flow of around 16 to 18 t/h. The specific heat consumption increased from about 770 kcal/kg in 2002 to approximately 860 kcal/kg, due mainly to:

- Low-grade waste fuels
- Bypass operation with additional heat losses
- Reduced cooler efficiency
- Increased false air/transport air

4 Further improvements

Although the modification of the kiln system proved to be successful, the decision was made to start a target-oriented improvement programme in 2005. A detailed process analysis in different plant sections has been carried out from 2006 based on the maxim "to stand still is to take a step backwards". The main results of the analysis were:



2008: Alternative fuels level main burner: 25 %
Target to increase by installing new Pfister feeder to 60 % at the main burner.
Combination of animal meal, SHW and plastics

Figure 10: Feed system for alternative fuels at the kiln main burner

Table 2: Fuel specification at Brevik plant in 2008

Type of fuel	Burner location	Fuel throughput [t]	[%]
Primary fuel coal/petcoke	Main burner/calciner	64 000	50.2
Waste oil	Main burner	1 500	1.5
LHW	Main burner	13 200	4.9
Animal meal	Main burner	9 100	4.4
SHW	Calciner	28 900	11.3
RDF	Calciner	81 900	27.7

Average kiln output 2008:		3 360 t/d
Average production level	OPC:	3 430 t/d
	Low alkali clinker:	3 200 t/d

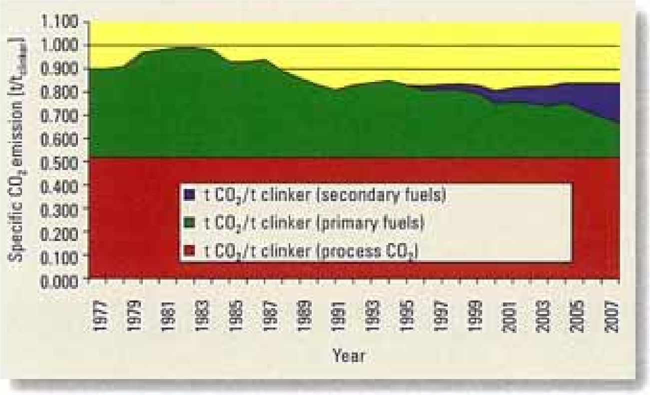


Figure 12: Trend in specific CO_2 emissions at the Brevik plant

- Enlarged kiln hood (by approx. 1 m) and shaft between cooler and kiln to reduce gas velocity and dust circulation as a pre-condition for enhanced production capacity
- Reduction of pressure drop in the preheater by reducing the false air at identified weak points along with structural measures at cyclones and gas ducts. The replacement of the "Euremy chute" at the top of the combustion chamber by a more efficient double gate system could also make a significant reduction in false air caused by leakages.
- Improved cooler efficiency and stabilization of the bypass operation through a new efficient bypass filter (baghouse) to replace the under-performing ESP. Some cooler refurbishment measures could also improve the operation. However, the long-term solution should be to install a new cooler.
- Investigation of the influence of the raw material on burnability
- Another important target was to further stabilize and enhance the alternative fuel feed to achieve the highest possible substitution ratio on a long-term basis by:
- Optimization of the availability of the waste feed system to the calciner,
- Increasing the level of alternative fuels at main burner to 60 % by installing a new rotary feeder at the main burner as shown in ❯ Fig. 10.

The positive results of these activities are shown in ❯ Table 2. More than 130 000 t of alternative fuels were co-processed in 2008 at an average kiln output of 3 360 t/d.

5 Conclusion

The Norwegian Brevik plant can now look back on 20 years of experience with the use of alternative fuels, during which there has been a significant increase in the substitution rate. This required several capital investment projects involving the handling facilities for secondary fuels as well as equipment for the clinker burning process, such as the combustion chamber and the bypass system. It can be stated that the investments were really worthwhile, both economically and ecologically.

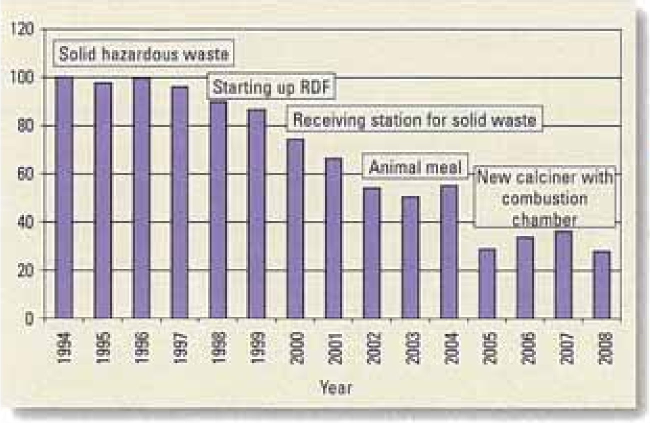


Figure 11: Trend in total fuel costs based on fixed prices in 2009

❯ Fig. 11 shows that the consumption of coal as the primary fuel was reduced to less than 50 % in the last five years since the commissioning of the combustion chamber and the bypass system, with a consequent drastic reduction in the fuel costs. At the same time (❯ Fig. 12) the emission of CO_2, which is relevant to the greenhouse effect, was lowered by 15 % due to the biogenic content in RDF and AM. When it is considered that more than 60 % of the CO_2 emission from a modern clinker burning process derives from raw materials and cannot be avoided, it can be seen that nearly half the potential reduction that is possible in the clinker burning process has been achieved.

List of 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
LHW	Liquid Hazardous Waste – solvents, paints, etc., pumped into the rotary kiln via a separate channel in the main burner
RDF	Refuse Derived Fuels – a shredded mixture of municipal solid waste without any wet organic compounds and industrial solid waste; particle size < 100 mm; mechanically fed into the combustion chamber
SHW	Solid Hazardous Waste – solvents, paints, etc., mixed with wood chipps (to improve flow properties); particle size < 100 mm; mechanically fed into the combustion chamber ◂

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