USE OF ALTERNATIVE FUELS IN LIME MANUFACTURING

Significance for the Lime Sector

As was explained in Chapter. 2.2, the diversity of raw materials and products requires the use different types of kilns and process conditions. For similar reasons, the selection of fuels (fossil or alternative) has also to take into account the quality requirements of the products. Therefore only a limited type and amount of alternative fuels is suitable for the production of lime. There are consequently limits on the types and amounts of alternative fuels suitable for use in the production of lime which are highly dependent on site specific circumstances.

Nowadays these fuels represent about 4 % of the whole energy consumed by the European lime industry. In fact, co-incineration is carried out in seven countries as shown in Fig. 1.

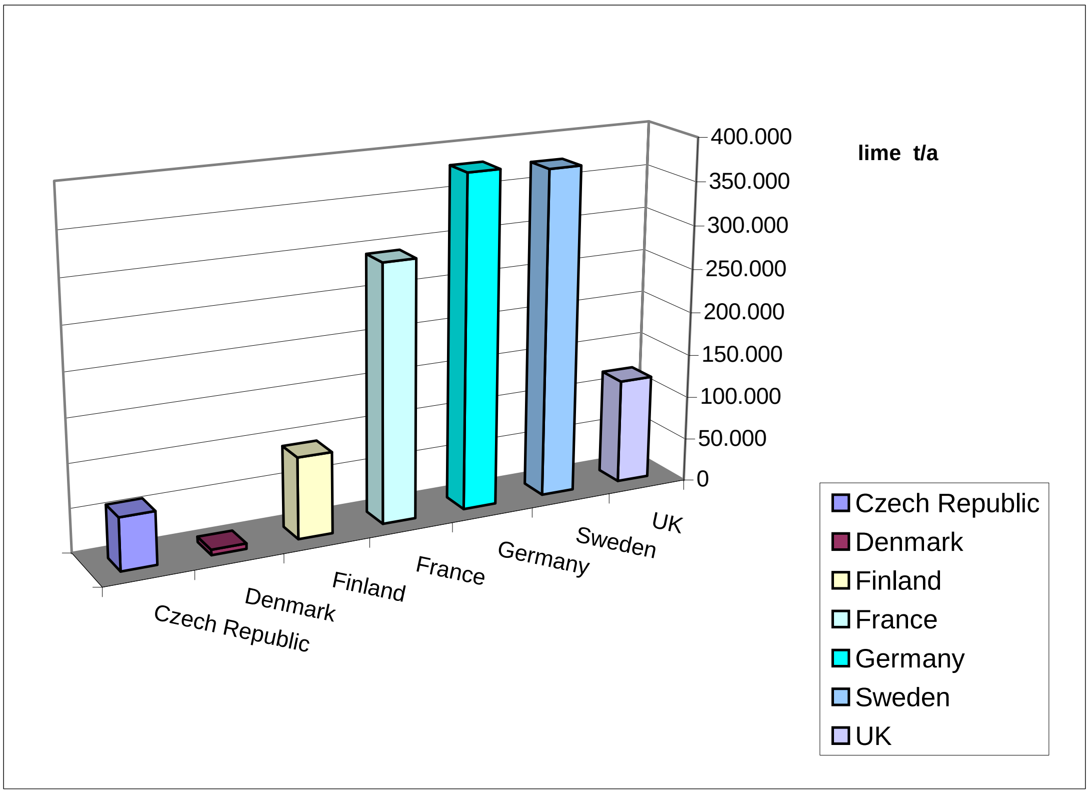

Fig. 1: Amount of lime produced with alternative fuels in different countries

Lime manufacturing requires a substantial input of energy, thus making fuel the largest element of production costs. The use of alternative fuels also enables the lime producer to reduce the consumption of fossil fuels and contributes to the economic viability of the lime sector in Europe. Their importance to the lime industry has grown in recent years with the drastic increase in the cost of fossil fuels. By using alternative fuels the lime industry usefully recovers energy from these materials and makes a significant contribution reducing societies waste problem.

Co-Incineration Technology

Lime manufacturing is not fundamentally changed when alternative fuels are used. Lime kilns can be operated with very different substitution rates: from low levels (alternative fuels then supply only a small percentage of the total energy) up to full substitution.

Type of kilns used for co-incineration

Co-incineration can be carried out in rotary kilns (RK), annular shaft kilns (ASK), Parallel Flow Regenerative kilns (PFRK) or other shaft kilns (OSK). Fig. 2 shows the number and type of kilns burning alternative fuels in the different European countries.

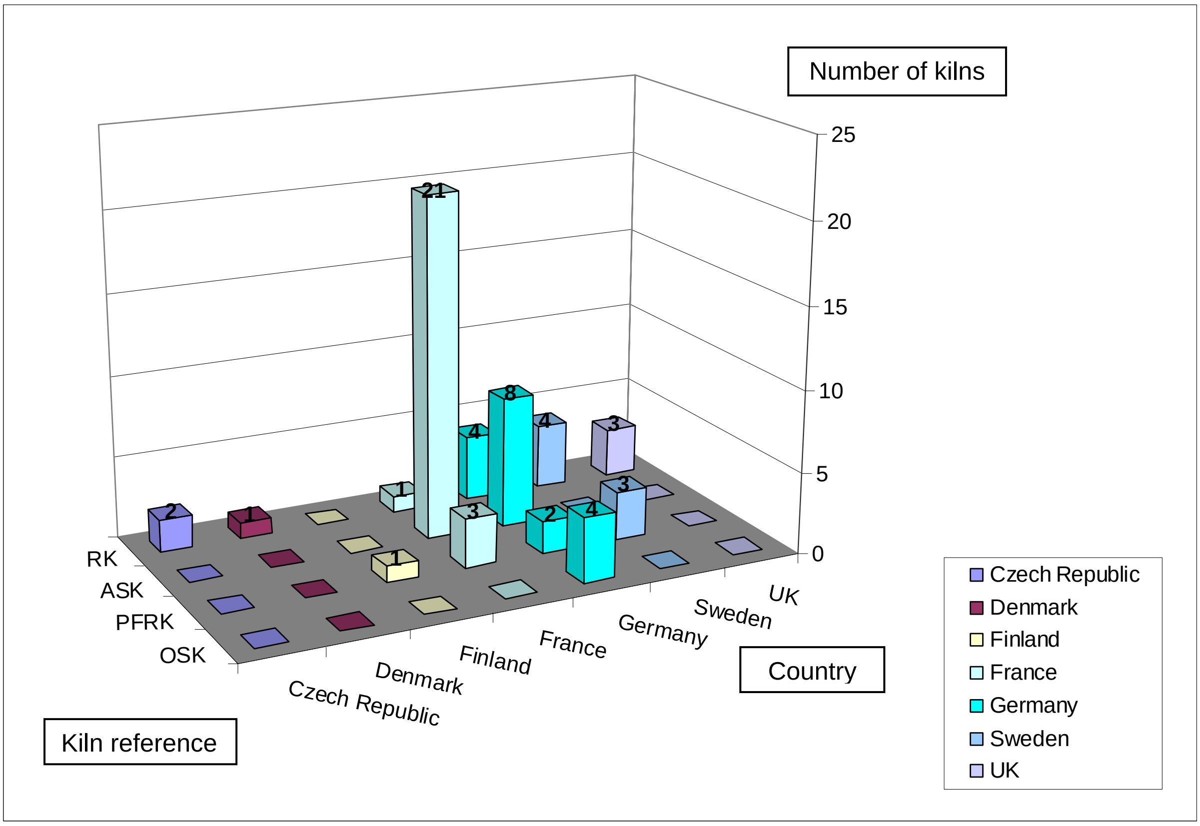

Fig. 2: Distribution of lime kilns co-incinerating alternative fuels in different countries

The selection of the kiln type is driven by the quality requirements of the customers and by the existing available production capacities.

With the exception of PFR kilns, all of the above-mentioned types of kiln must be equipped with special burners designed either for gaseous fuels or for liquid fuels. In rotary kilns, burners for solid fuels can also be used (s. fig.3 and 4.)

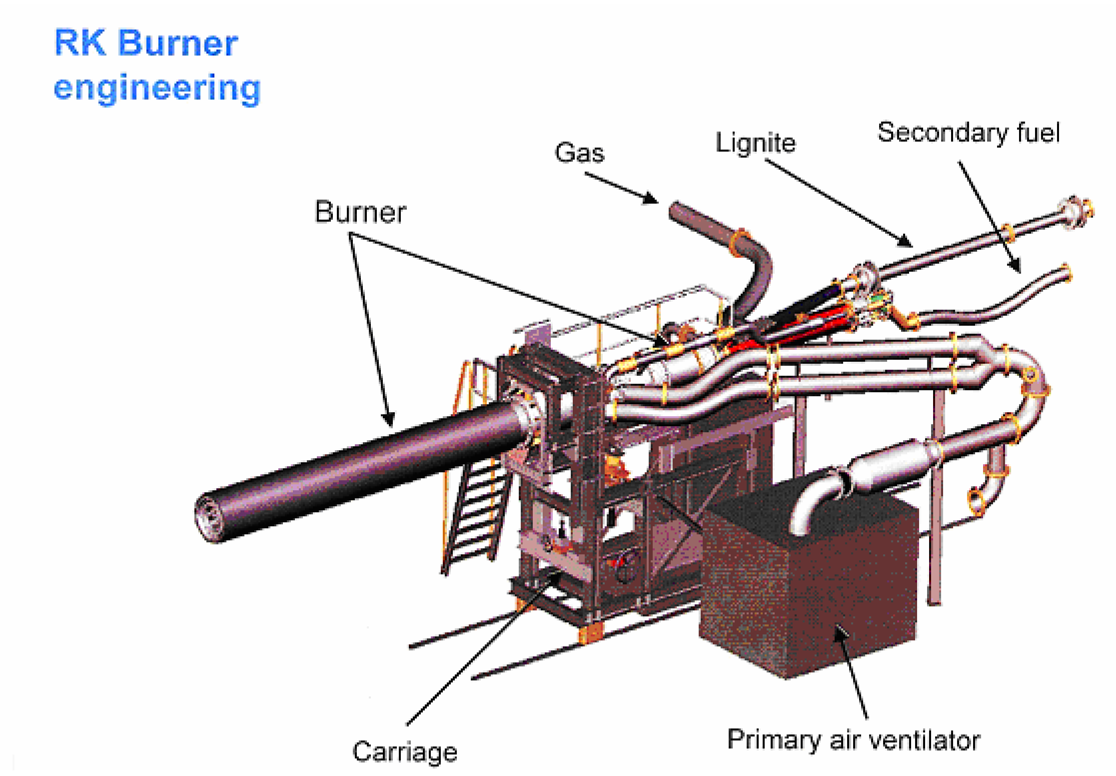

Fig. 3: Overview of a the burning system of a rotary kiln designed for burning several types of fuels (gas, lignite, alternative liquid and solid fuels)

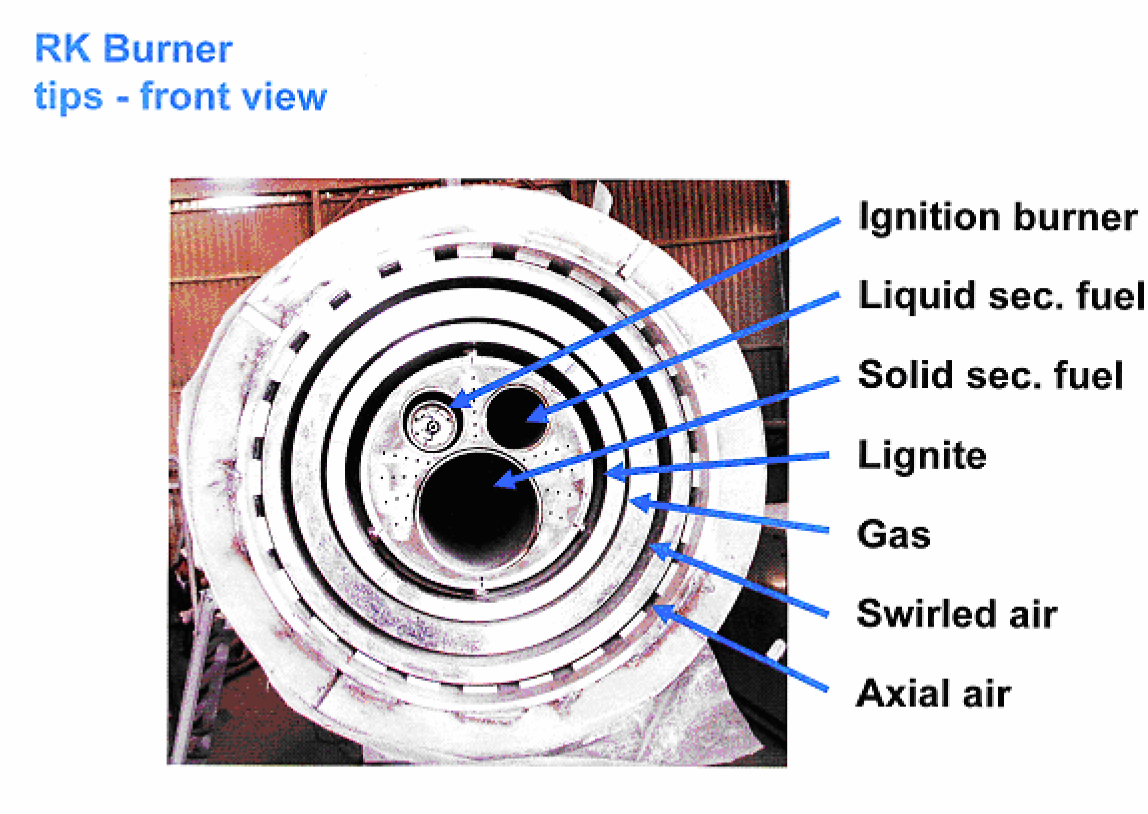

Fig. 4: Detailed view of the front of the burner

PFR kilns are equipped with lances specifically designed for the combustion of gaseous, liquid and solid fuels.

The following table summarise the possibilities of using fossil and alternative fuels in the different types of kiln.

	Gas		Liquid fuels		Solid fuels (pulverised)		Solid fuels (lump)	
	Fossil	Alternative	Fossil	Alternative	Fossil	Alternative	Fossil	Alternative
RK	X	(*)	X	X	X	X	X	X
ASK	X	(*)	X	X	X	X	X	
PFR	X	(*)	X	X	X			
OSK	X	(*)	X	X			X	

Table 1: Use of fossil and alternative fuels in different types of kiln
(*) : alternative gaseous fuel are not available

Types of waste co-incinerated

Like any fuel switch, the specific physical properties of the alternative fuels have to be considered (e.g. physical state, net calorific value, chemical composition). The selection of the appropriate alternative fuels depends also on the desired product qualities and on the technical possibilities to inject them into the selected kiln. Their use is mainly limited by:

- the physical and chemical properties that do not always meet the relevant physical, chemical or process-specific requirements. Hence it is impossible to burn lumps of solid fuel in PFR kilns,
- the availability on the market,

The market availability is largely responsible for the observed differences in the type of alternative fuels co-incinerated in the different countries, as shown in the following table:

Type of alternative fuels	Liquid	Solid - pulverulent	Solid - lump
Czech Republic	X		X
Denmark		X	
Finland	X		
France	X	X	X
Germany	X	X	X
Sweden	X		X
United Kingdom	X		

Table 2. Type of alternative fuels co-incinerated in different countries

Liquid fuels include:

- Waste oil,
- Solvent and Liquid Derived Fuels,
- Animal fat.

They can be burned in Rotary Kilns, Annular Shaft Kilns, PFR kilns and other shaft kilns (OSK).

Solid fuels include:

- Solid Derived Fuels,
- Plastics (except PVC),
- Waste wood,
- Tyres,
- Bone meal.

When solid fuels are pulverised, they can be burned in all above-mentioned kilns. Small lumps of solid fuel can only be co-incinerated in rotary kilns or annular shaft kilns.

During co-incineration, neither solid nor liquid wastes are produced

Legal requirements to alternative fuels

The member states of the European Union subject the use of alternative fuels to rather different legal restrictions. Most of them have only imposed restrictions on a limited number of substances, if any at all. France, Germany and the UK have listed a lot of specifications and thresholds, which may even vary from region to region. In addition, for heavy metals, different thresholds with different totals are defined by the national or regional authorities, thus making any comparison of the standards very difficult.

Pre-Treatment Measures

Due to the specific product requirements and the nature of the production processes, alternative fuels need to have very precisely defined physical properties. Such fuels are not prepared in lime plants. Therefore, the fuel suppliers have to prepare on their production site fuels that can be burned in lime kilns without any additional treatment. The single exception concerns the filtering of liquid fuels, which prevents coarse particles from clogging the control valves or the burner.

Example for the handling of waste oil in a Shaft Kiln (OSK)

In order to convert a gas fired shaft kiln (OSK) into a waste oil fired shaft kiln, it was necessary to modify the burners and to build a dedicated infrastructure for the unloading and storage of the waste oil.

In this specific case the waste oil is delivered to the lime plant either by rail or by road (tank trucks). Two double wall storage tanks with a capacity of 100 m^3 each were erected. The waste oil is transferred from the wagons or from the trucks into the storage tanks which are located in a specially designed area to contain any spillage. Surface water (rainwater) is discharged to an oil separator. Since the filling area meets all relevant legal requirements, it is also used to wash and refuel all kinds of road and rail vehicles.

During the unloading of the wagons or tank trucks, the waste oil flows through a hosepipe connection and then through a steel pipe into a first pumping and filtering station. From there, it is pumped through underground double wall pipes into two 100 m^3 tanks. At a kiln output of 250 to 300 t_{lime} /d, this storage capacity is roughly equivalent to one week's consumption.

From the tanks, the oil flows into a second pumping station, which is located in the immediate neighbourhood of the kiln. A feeding pump conveys the oil to another filter and to an electric heating system, which heats the oil up to 60 ÷ 80° C. These temperatures are necessary to decrease the viscosity of the oil thus improving its atomisation in the burner and its optimal combustion. Ascending pipes lead the heated oil to a dosing and measuring station, from where it is distributed to the individual burners. Within the burners, the fuel is mixed to air and both are directly injected into the kiln. No residue is produced during the combustion of the filtered oil.
Waste is only produced during the filtering process of the oil. The filters are washed, and any residue is collected in designated containers and safely disposed.

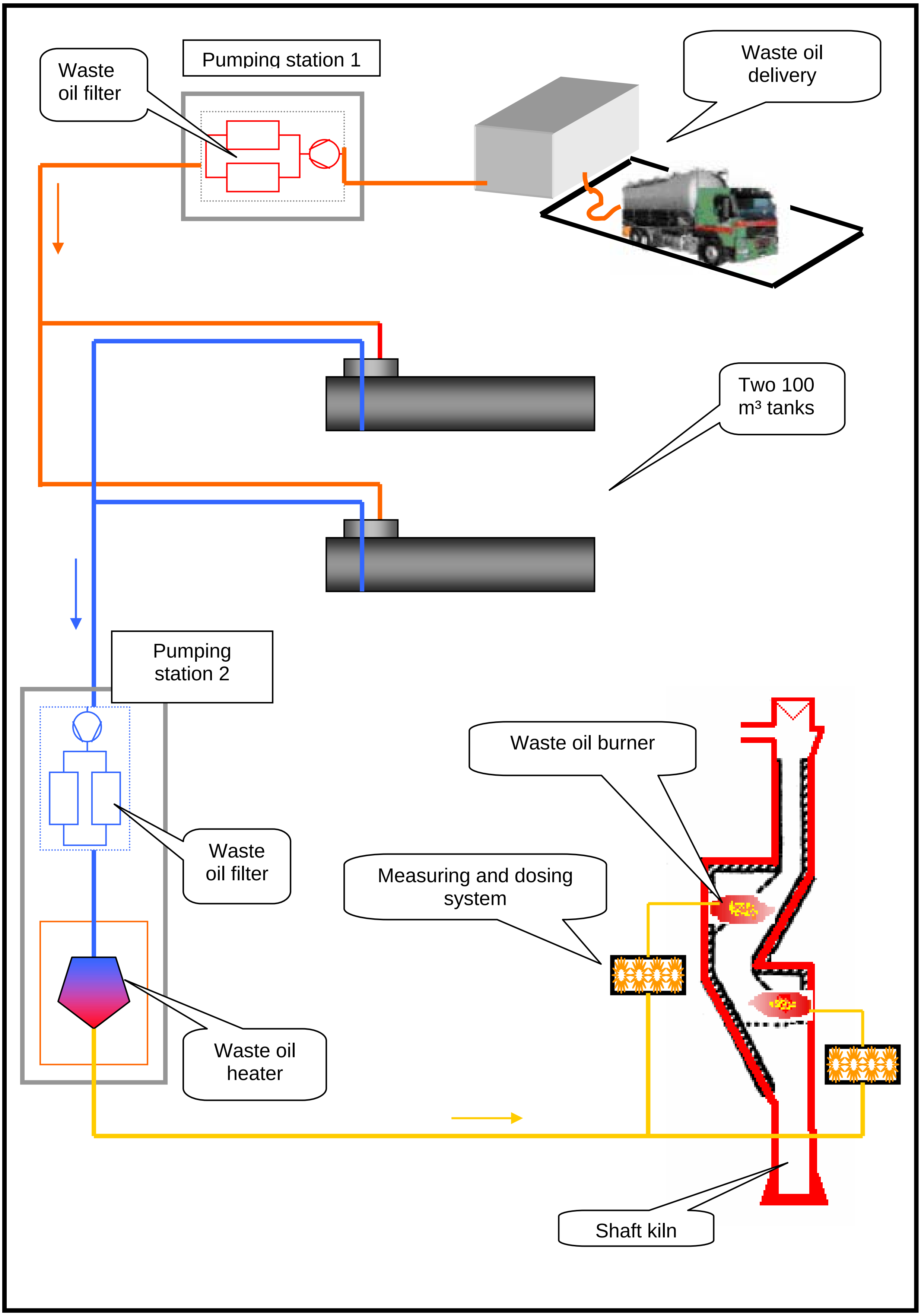

Fig. 5: Flow sheet of the waste oil from delivery to the shaft kiln (OSK)

Fig. 6: Waste oil delivery and diesel tank filling station

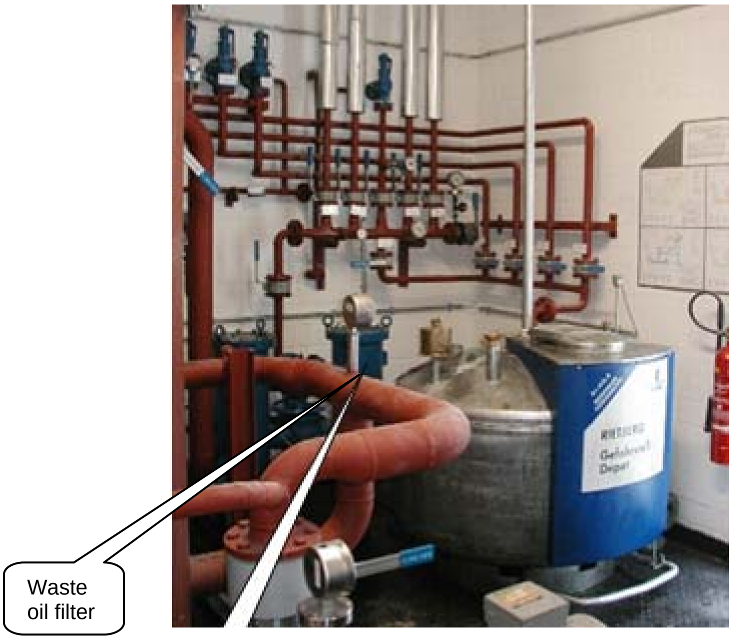

Fig. 7: Pumping station 2 with filter, and in the front, a waste container for the cleaning of the filter

Fig. 8: Measuring and dosing station with pneumatic valves

Example for the quality control of solid alternative fuels burned in RK's

In this example, the alternative fuels consist of solid refuse derived fuel (RDF) from selected wastes with low pollutant contents (mainly plastics) and well defined heating values. Their origin and waste classification according to the European Waste catalogue are exactly specified in the permit. The following table shows the type of waste that can be co-incinerated in these RK's:

Waste code	General description
02 01 04	Waste plastics (except packaging)
02 01 07	Waste from forestry
03 01 01	Waste bark and wood
03 01 05	Sawdust, shavings, cuttings, wood, particle board and veneer other than those mentioned in 03 01 04
03 03 02	Green liquor sludge (from recovery of cooking liquors)
03 03 07	Mechanically separated rejects from pulping of waste paper and cardboard
03 03 08	Wastes from sorting of paper and cardboard destined for recycling
04 02 09	Wastes from composite materials (impregnated textile, elastomer, plastomer
04 02 21	Wastes from unprocessed textile fibres
04 02 22	Wastes from processed textile fibres
07 02 13	Waste plastic
08 01 02	Waste paint and varnish except those mentioned in 08 01 11
08 02 01	Waste coating powders
09 01 07	Photographic film and paper containing silver or silver compounds
12 01 05	Plastic shavings and turnings
15 01 01 ÷ 03	Paper and cardboard, plastic, wooden packaging
15 01 05 ÷ 06	Composite and mixed packaging
15 02 03	Absorbents, filter materials, wiping cloths and protective clothing except those mentioned in 15 02 02
16 01 03	End-of-life tyres
17 02 01	Wood
17 02 03	Plastic
19 05 01	Non-composted fraction of municipal and similar wastes
19 12 01	Paper and cardboard
19 12 04	Plastic and rubber
19 12 07	Wood other than that mentioned in 19 02 06
19 12 08	Textiles
19 12 10	Combustible waste (Refuse derived fuel)

Table 3: List of wastes allowed to be co-incinerated

For each delivery, the fuel suppliers have to confirm that the ready for use fuels include only the wastes mentioned in Table 3.

For the quality control of these fuels, the alternative fuels are divided in four categories, which define the range of net heating values and the chemical composition.

The input of trace elements into the kiln is then regulated by using two statistical parameters (s. Table 4):

- The median value (= percentile 50%) also called "practical" value. It is based on the practical experience and takes into consideration the possible variations of the fuel composition,
- The maximal values (= percentile 100%).

	Alternative fuel 1		Alternative fuel 2		Alternative fuel 3		Alternative fuel 4	
Pollutant	Median value (mg/kg)	Maximal value (mg/kg)	Median value (mg/kg)	Maximal value (mg/kg)	Median value (mg/kg)	Maximal value (mg/kg)	Median value (mg/kg	Maximal value (mg/kg)
Mercury Hg	0,4	1,0	0,4	1,0	0,4	1,0	0,6	1,2
Cadmium Cd	4,0	15,0	4,0	15,0	4,0	10,0	4,0	9,0
Thallium Tl	1,0	5,0	1,0	5,0	1,0	5,0	1,0	2,0
Arsenic As	5,0	10,0	5,0	10,0	5,0	15,0	5,0	13,0
Cobalt Co	5,0	10,0	5,0	10,0	5,0	10,0	6,0	12,0
Nickel Ni	20,0	100,0	20,0	100,0	20,0	100,0	25,0	50,0
Antimony Sb	40,0	100,0	40,0	100,0	25,0	60,0	25,0	60,0
Lead Pb	40,0	100,0	40,0	100,0	40,0	100,0	70,0	200,0
Chrome Cr	40,0	100,0	40,0	100,0	40,0	100,0	40,0	120,0
Copper Cu	100,0	250,0	90,0	250,0	90,0	500,0	120,0	300,0
Manganese Mn	50,0	100,0	50,0	100,0	50,0	100,0	50,0	100,0
Vanadium V	10,0	20,0	10,0	20,0	10,0	20,0	10,0	25,0
Tin Sn	15,0	50,0	15,0	50,0	15,0	75,0	30,0	70,0
Total chlorine.	7000,0	10000,0	7000,0	10000,0	7000,0	10000,0	7000,0	10000,0
Total Fluorine	250,0	500,0	250,0	500,0	250,0	1000,0	250,0	1000,0
Beryllium Be	0,5	5,0	0,5	5,0	0,5	5,0	0,5	2,0
Zinc	400,0	500,0	400,0	500,0	400,0	1000,0	400,0	1000,0
	w/w %	w/w %	w/w %	w/w %	w/w %	w/w %	w/w %	w/w %
Moisture	8,0	< 10,0	11,0	< 12,5	18,0	< 20,0	18,0	< 20,0
Ash content	6,0	< 7,0	8,0	< 9,0	11,0	< 15,0	11,0	< 15,0
Total sulphur.	0,3	< 0,5	0,3	< 0,5	0,2	< 0,3	0,2	< 0,3
PCB		< 3		< 1		< 1		< 1

Table 4: Median and maximal concentrations of trace elements for each type of alternative fuel

Furthermore the permit defines the permitted ranges for the net heating values of each fuel category:

Net heating value [MJ/kg]	Alternative fuel 1		Alternative fuel 2		Alternative fuel 3		Alternative fuel 4	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
	25	31	23	29	20	24	18	22

Table 5: Minimum and maximal net heating values for each type of alternative fuel

Sampling and analyses of the RDF fuels carried out by the fuel supplier

Each batch of 10 tons of alternative fuel is continuously sampled at the end of a belt conveyor. The material, is collected from a falling stream in a container that is as large as the belt conveyor. An **individual sample** of 2.5 litres is taken from the collected material.

This sample is then put into a sealed 10-litre bucket. That is tightly closed. It is shaken to allow the sample to be thoroughly mixed. The **water content** of the homogenized sample is measured in quick analyser.

The individual samples are collected in a vat, which is closed with a watertight lid. When 50 individual samples are collected, a representative mixed sample (so called "**500 t mixed sample**") is prepared. For this purpose, the vat is emptied into a concrete mixer. After the sample has been thoroughly mixed, two 10-litre samples are taken from the homogenized material. The remaining material is returned to the kilns.

An accredited chemical laboratory uses part of one of the **10-litre samples ("500 t mixed sample"**) to determine:

- the calorific value,
- the ash content,
- the water content,
- the total chlorine content
- the concentration of one of the heavy metals listed in the table 4.

The laboratory is required to keep a small part of the milled sample for at least half a year in an airtight blister pack. The second 10-litre sample is kept until the results of the full analysis according to the tables 4 and 5 have been carried out.

Once a charge has passed the mark of 1,000 t of alternative fuels, the chemical laboratory prepares a "**1000-ton mixed sample**" by mixing two 500-t samples. The 1000-ton mixed sample is divided in two portions. One is subjected to a full analysis (according to the tables 4 and 5). The other milled sample is kept in an airtight blister pack for at least half a year.

Alternative fuels do comply with the requirements of the permit if the median values (percentile 50%) determined on the analysed samples do not exceed the "practical" values indicated in table 4. Should any "practical" value be exceeded, it is required to analyse all individual samples collected during a day in order to determine the concentrations of some critical parameters. The median values of these analyses are afterwards compared with the "practical" values. They shall not exceed the "practical" values. But should the maximal value nevertheless be exceedance, it must be checked if the exceedance is systematic or exceptional. The co-incineration of alternative fuels has then to be stopped until it is ensured that the quality of the fuels complies with the permit conditions.

Emission thresholds and emission monitoring

The emission limits and the requirement about continuous emission monitoring are specified in the Waste Incineration Directive 2000/76/EC (WID). The individual EU Member States have implemented this Directive through national legislation on their own.

The review of the existing permits granted to lime operations shows that the transposition of the WID into national law was subject to different interpretations Thus depending on the countries, permits for lime kilns were granted according to the special provisions:

- Either for cement kilns (annex II.1 of the WID),
- Or for combustion plants (annex II.2 of the WID),
- Or for industrial sectors not covered under II.1 and II.2

It follows that the emission limits, which are applicable for the lime plants, differ according to their classification in one of the three above mentioned categories (s. Table 6).

Parameter		Annex II.1	Annex II.2	Annex II.3
Reference value O_2	%	10	6	
Total particulates	mg/Nm^3	30	30 ÷ 50	
NO_x	mg/Nm^3	500 ÷ 800	200 ÷ 400	
SO_2	mg/Nm^3	≥ 50	200 ÷ 850	
HCl	mg/Nm^3	10		
HF	mg/Nm^3	1		
TOC	mg/Nm^3	≥ 10		
Hg	mg/Nm^3	0.05[1]	0.05	0.05
Cd + Tl	mg/Nm^3	0.05	0.05	0.05
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V	mg/Nm^3	0.5	0.5	
PCDD/PCDF	ng TE/Nm^3	0.1	0.1	0.1

Table 6: Summary of the emission thresholds applicable to lime plant according to the annexes of the WID

When alternative fuels are co-incinerated, the following emission parameters are usually continuously monitored. oxygen, dust and NO_x. In Denmark, France and the UK, the continuous emission monitoring is extended to substances like SO_2, HCl and TOC. A Continuous measurement of the mercury emissions is only required in Germany but significant technical difficulties have been experienced.

In order to interpret the data provide by the CEM's, it is necessary to know the flow of the flue gas, its temperature and its moisture. These parameters are usually not monitored continuously but derived from the operating conditions. This is possible as the mass flow and quality of the fuels are precisely known and the operators continuously record the process parameters of the lime kiln.

[1] The SO_2 and TOC thresholds can be increased by the authority providing that these emissions are not linked to the incineration of the wastes

Impact of alternative fuels on emissions

As explained in chapter 2.3, it is not possible to directly compare the emissions from lime kilns lime kilns using alternative fuels with those that do not since the emissions are also dependent on other parameters such as chemistry of the limestone and process conditions.

Hence from the measurements performed on kilns burning fossil and alternative fuels with similar chemical compositions, it is not possible to identify significant differences in the emission levels (e.g. on dust, NO_x, heavy metals, …).

Emission control techniques

The same dust abatement systems as those described in Chapter 2.4 are used when alternative fuels are co-incinerated. Techniques to abate the NO_x emissions in RK producing hardburned lime – independently from the type of fuel used – are discussed in the Chapter on “Emerging techniques“.

Impact of alternative fuels on the product quality

The impact assessment on the quality of the product is performed accordingly to the specifications of each client.

As sulphur from the fuels can be chemically absorbed by the lime, some (fossil and alternative) fuels with higher sulphur content are inappropriate for the production of lime for the steel and iron sectors. Indeed for both sectors, the sulphur content of the lime is a very important quality criteria. In order to prevent any quality issue, the production process is carefully controlled: the sulphur content in the lime is frequently monitored in order to ensure that the maximum sulphur content is not exceeded. Should any exceedance occur, the sulphur input is immediately decreased by limiting the sulphur input through the fuel.

When using bone meal, special attention has to be paid to the phosphorus content as very strict limits are set by some customers (e.g. steel and iron sector and water treatment) thus limiting the use of bone meal in lime manufacturing.

Alternative fuels used in the lime sector usually have such low concentrations of heavy metals that no adverse impact on the products is expected.