OPERATION RESULTS OF THE NEW WASTE GAS TREATMENT FACILITY AT ROGESA'S NO. 2 SINTERPLANT – THE EFA® PROCESS[1]

Walter Hartig[2]
Dany Labar[3]
Franz Reufer[4]

Abstract

Environmental protection is an important aspect at sintering since many years. Due to more stringent requirements from the authorities, the extended cleaning of the waste gas of sinterplants has become necessary. A new sinterplant waste gas treatment facility has been developed at full scale which is in operation since middle of 2006. First operational results of the commissioning phase and results of the improvement phase until full operation in conjunction with the ROGESA sinterplants shall be given. The process developed by PAUL WURTH will be described and specific consumption figures will be highlighted. The EFA® technology (Entrained Flow Absorber technology/process) will become state-of-the-art of sinterplant desulphurization, dedusting, and dedioxination in order to fulfill the strict environmental rules in many countries all over the world.

Key words: Sinterplant; Waste gas cleaning; EFA® process; Entrained flow absorber.

---

[1] *Technical contribution to the 39th International Meeting on Ironmaking and 10th International Symposium on Iron Ore, November 22 – 26, 2009, Ouro Preto, MG, Brazil.*

[2] *General Manager Ironmaking, Dillinger Hüttenwerke, Dillingen, Germany*

[3] *Director Engineering, Dillinger Hüttenwerke, Dillingen, Germany*

[4] *Managing Director, Paul Wurth Umwelttechnik GmbH, Essen, Germany*

1 INTRODUCTION

The process routes for steel making (Figure 1) are mainly distinguished by raw material input: Based on iron ore and sintering or pelletizing through the blast furnace to produce hot metal, direct or melting reduction and through the electric arc furnace route with mainly scrap and DRI.

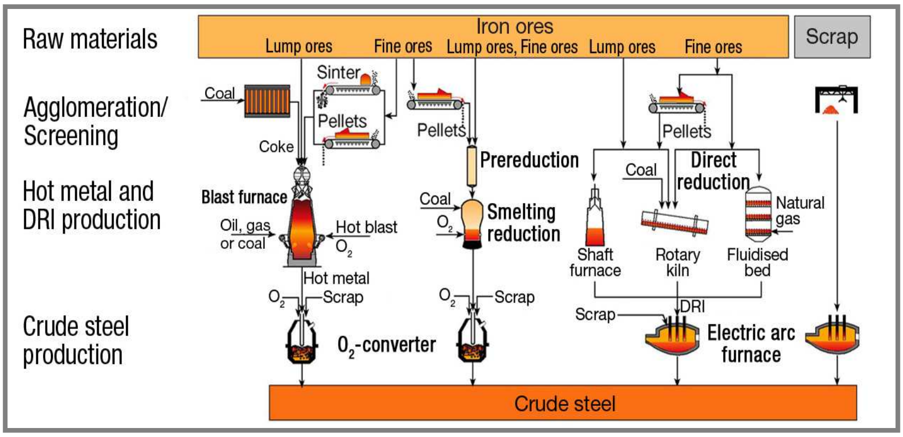
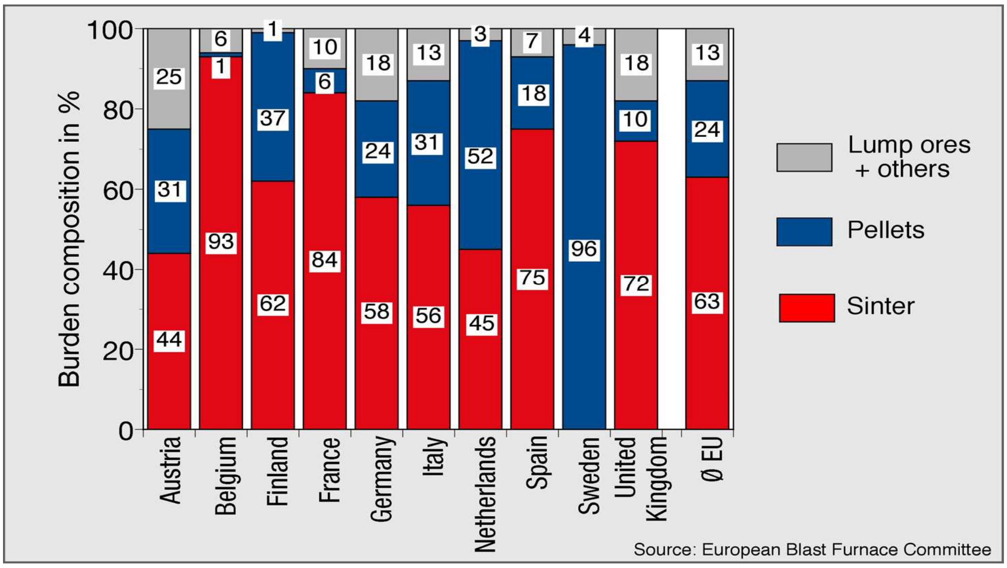


Figure 1: Steel making routes.

In 2007 1,69 billion tonnes of crude steel have been produced in total of which approx. 65 % were produced through the blast furnace and BOF converter route.
The importance of sinter for the hot metal production and subsequently also for the crude steel production can be shown with the development of the world production figures. The significant increase of the crude steel production was achieved by an increased amount of hot metal. It is well known that the availability of scrap is very limited. The world's iron ore production raised from 950 Mio. tonnes in 2000 up to 1360 Mio. tonnes in 2005. Based on the iron ore deposits, more and more fine ores and concentrates are produced which need to be agglomerated for the blast furnace operation. Accordingly, sinter and pellet production increased over the recent years.



Source: European Blast Furnace Committee

Figure 2: Burden composition.

Figure 2 shows as a snap-shot the burden composition of blast furnace works in Europe in 2007. With the exception of one country, Sweden, all blast furnace plants use a significant amount of sinter in the burden for an economic and high quality hot metal production.

2 ROGESA's SINTERPLANTS

During the last twenty years there have been no new sinterplants commissioned in Europe, therefore, most of the operated sinterplants are already relatively old and their environmental equipment is from plant to plant different. However, only few companies in the iron and steel world are able to give-up the sintering process because of the insufficient supply of pellets. The environmental problems of the sinterplants can be solved to the necessary extent.

Table 1: ROGESA's Sinterplants

		Strand No. 2	Strand No. 3
Year of construction		1961	1981
Last modernization		1997	2006
Suction area	m²	180	258
Depression	mbar	100	140
Waste gas temp.	°C	140	140
Bed height	mm	500	510
Ignition gas		mixed gas (cal. value 5,2 MJ/m³ STP)	
Dedusting		horizontal electrostatic precipitators	
Productivity	t/(m²24h)	29 – 32	36 – 41

At the site of ROGESA which is a joint venture of two steelmaking companies: AG der Dillinger Hüttenwerke and Saarstahl AG, two sinter strands (No. 2 and No. 3) are operated. Table 1 shows the technical data of the two sinter strands. The total sintering capacity amounts to 5 Mt/a where strand No. 2 has a suction area of 180 m² and strand No. 3 of 258 m². As there are different depressions of 100 mbar respectively 140 mbar, the productivity differs from 29 – 32 t/m² 24h at No. 2 strand to 36 – 41 t/m² 24h at strand No. 3.

Figure 3 shows the task which had to be fulfilled with the new Paul Wurth Entrained Flow Absorber (EFA®) process: The simultaneous removal of dust, SO2, HCl, HF, and dioxins. Another important topic also for the decision towards the PW technology was the flexibility of the plant regarding the optimization of the reaction temperatures and consequently to minimize the consumables. As a result a cost optimized operation of the plant by fulfilling all necessary emission limits could be established.

- Construction of a plant for simultaneous cleaning of
  - dust
  - SO_2/HCl/HF and
  - Dioxins
- Plant has to be flexible according to
  - Adjustment to optimum reaction temperature
  - Minimizing of consumables and therefore
  - cost of operation
- Future oriented safe technology

Figure 3. Tasks for the New Plant

3 LEGISLATIONAL ASPECTS

Since sinter strand No. 2 has been commissioned in 1961 and sinter strand No. 3 in 1981, the existing gas cleaning systems are no more capable to fulfill the actual emission limits of the new German clean air act (TA – Luft 2002). The local environmental authorities did consequently claim for the renewal of the gas cleaning systems in order to respect the new legislation within a deadline until july 2006 for strand No. 3 and october 2008 for strand No. 2. The emission limits of the sinter waste gas have been continually and strictly tightened for the recent years.
Dust emissions must be lower than 50 mg/m³ (STP) by using the electrostatic precipitator (ESP) as final dedusting stage. However, by using another technology, the dust content of the waste gas must remain below 20 mg/Nm³. The emissions of heavy metals vary between 0,05 to 1 mg/m³ (STP) depending on their classification. Concerning acid gas components, HF must be below 3 mg/m³ (STP), HCl below 30 mg/m³ (STP) and SOx below 500 mg/m³ (STP), The NOx must be lower than 400 mg/m³ (STP). The volatile organic compounds (VOC) measured as total carbon content have to be below 75 mg/m³ (STP). Finally, the limit of dioxins and furans (PCDD/F) is 0,4 ng/m³ (STP), however, the final target is to reach an emission value lower than 0,1 ng/m³ (STP). Until now, the main problems for the sinterplant operators concern emissions of dust, heavy metals, SOx and dioxins, whilst the NOx limit of 400 mg/m³ (STP) can be achieved by optimizing sinter raw materials and solid fuels. For this reason and with regard to the fact that with some improvements of the existing installations the new limits could never be respected with certainty, a new gas cleaning plant at Rogesa was planned.

4 THE PROCESS

Basis for the planning was a general specification of the raw gas, the sinterplant's offgas: The plant had to be designed for 600.000 m³/h (STP) wet at a temperature of 190 °C with the following pollutants:

Dust	95 mg/m³ (STP) dry
SO2	900 mg/m³ (STP) dry
HCl	19 mg/m³ (STP) dry
HF	3 mg/m³ (STP) dry
PCDD/F	3 ng/ m³ (STP) dry

Rogesa has chosen the Paul Wurth EFA® technology as a so-called end-of-pipe-solution. Together with the existing electrostatic precipitator which had to be kept in operation the Entrained Flow Absorber technology was finally deemed as best and optimum solution for ROGESA's sinterplants due to its best effectivity and flexibility in the future.

The Paul Wurth-Process has been selected because of the following reasons:

- Low investment costs,
- Low operating cost (after 12 years the operating cost will exceed the investment cost!),
- Dry addition of the substances, consequently no risc for sticking,
- High flexibility in the temperature range, consequently no risc for condensation,
- High potential of desulphurisation at low temperatures,
- Low maintenance costs because of less mechanical parts,
- References in powerplants.

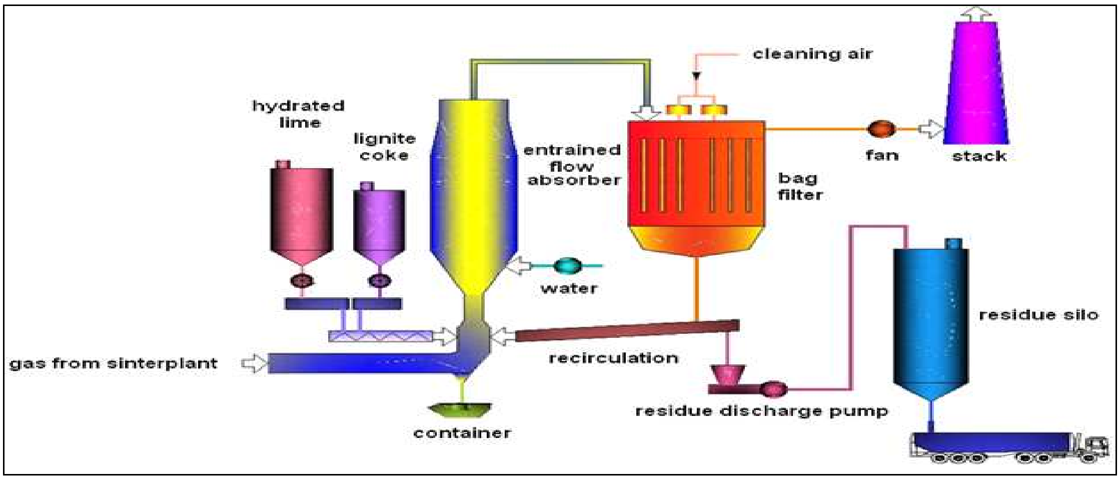


Figure 4. The process flow sheet.

The principle of the PW Entrained Flow Absorber technology is highlighted in Figure 4 which shows a simplified process flow sheet. The key part of the process is the Entrained Flow Absorber (EFA®). Inside the EFA® a fluidized bed of recirculated material mixed with fresh additives establishes ideal conditions for the evaporation of the injected water and the removal of the pollutants. Measurements have shown, that more than 90 % removal takes place inside the EFA® and less than 10 % at the filter bags. The EFA® itself is a rather simple construction consisting of an inlet pipe, the so called nozzle, where the gas is accelerated, a diffuser and a cylindrical pipe. There are no internal built in components inside the EFA®. At the upper end of the diffuser one spill back nozzle is located, injecting the water cross wise to the gas/solid flow. Due to the well known excellent mixing conditions in the fluidized bed, the solid particles keep absolutely dry even at high water flow rates. A small layer of water vapor at the surface of the solid particles is responsible for the enhancement of the chemical reactions taking place inside the EFA®.

Another main technology part of the process is the bag filter which can be seen almost in the center of Figure 5. The fabric filter or bag filter technology was initially designed only for dedusting and is widely used in power plants and incineration industry. In the last years, the latest development enhances the fabric filter capability of de-dioxin and de-SOx, based on the adsorption of dioxins with activated lignite coke and the desulphurisation reaction of SOx with hydrated lime $Ca(OH)_2$. Typical features of the modern fabric filter technology are the following:

- A filter system consisting of a large number of bags arranged vertically in several chambers for dedusting,
- the addition of the activated lignite for adsorption of dioxins and heavy metals,
- addition of hydrated lime $Ca(OH)_2$ for the desulphurisation, and
- the particle recirculation inside the system to build up a layer at the surface of the bags to improve the dedusting efficiency and to increase the utilisation efficiency of the sorbents.

The desulphurisation efficiency of $Ca(OH)_2$ depends mainly on the gas temperature, moisture content and retention time of the sorbent inside the filter system.

After being pre-cleaned in the existing electrostatic precipitator (ESP) and downstream the main blower, the waste gas enters the new plant flowing into the Entrained Flow Absorber. In the nozzle of the lower part of the absorber the gas is accelerated and the addition of the fresh additives of hydrated lime $Ca(OH)_2$ and lignite char is taking place. At the same time the recirculated material coming out of the bag filters is added. The additives and the recirculated material react with the gaseous components.

For the temperature control there is an injection of high pressurized water at 35 bar which evaporates and accelerates the reaction of the acidic components like SO_2. There is no agglomeration of the dust and the temperature can be always kept above the dewpoint.

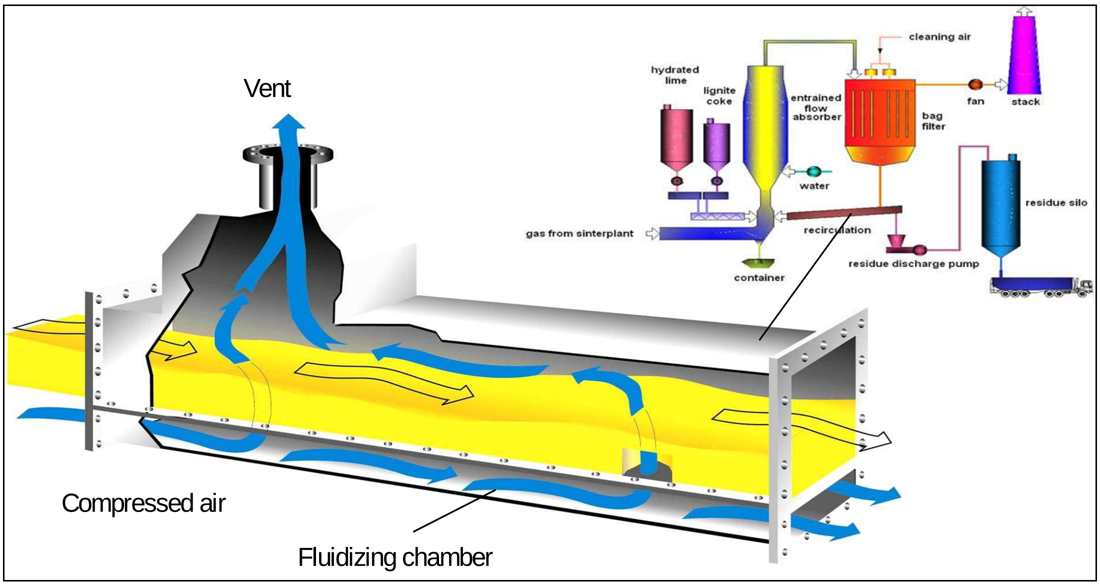


Figure 5. Fluid slide.

From the hopper of the bag filter the material is recirculated to the reactor by means of fluidized troughs, so called “Fluide Slides” shown in Figure 5. Only a small part of the solids is taken out of the system by a residue discharge pump and transported to the residue silo. The cleaned waste gas is sucked into the newly erected stack by two fans. The stack of 6 m diameter has a height of 115 m with an inside encasement or shell of stainless steel.

For removal of acidic gas components like SO_3, SO_2, HCl and HF hydrated lime $Ca(OH)_2$ is used as alkaline compound.

The following reactions take place:

$$SO_3 + Ca(OH)_2 \longrightarrow CaSO_4 \bullet \tfrac{1}{2} H_2O + \tfrac{1}{2} H_2O$$

$$SO_2 + Ca(OH)_2 \longrightarrow CaSO_3 \bullet \tfrac{1}{2} H_2O + \tfrac{1}{2} H_2O$$

$$SO_2 + \tfrac{1}{2} O_2 + Ca(OH)_2 \longrightarrow CaSO_4 \bullet \tfrac{1}{2} H_2O + \tfrac{1}{2} H_2O$$

$$2\ HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2\ H_2O$$

$$2\ HF + Ca(OH)_2 \longrightarrow CaF_2 + 2\ H_2O$$

Figure 6. Main chemical reactions.

In Figure 6 the main chemical reactions for the removal of acidic gas components like SO_2, SO_3, HCl and HF with the hydrated lime $Ca(OH)_2$ as alkaline compound are shown.

One important aspect of the process is the consumption of the additives and the amount of residues. They are strongly influencing the operating costs. Figure 7 shows the required quantity of additives in order to surely fulfill the actual legislational and guaranteed limits of less than 500 mg/m³ (STP) of SO_2 and 0,1 ng/m³ (STP)of Dioxins/Furans.

The recirculation of the sorbens and the reaction products is one major advantage of the process. This process feature allows to limit and to optimize the required consumables to a minimum. Based on calculations it is expected to consume about 300 kg/h of hydrated lime and approx. 30 kg/h of activated lignite. The expected quantiy of residues amounts to 600 kg/h which has to be deposited underground so far at ROGESA until another solution for the waste disposal is found. However, the optimization process is under progress.

The control of the process as a whole is managed by three closed control circuits:

1. Control of the fluidized bed pressure loss in the absorber in order to keep the specific amount of recirculated material (up to 1 kg/m³ (STP)) constant at changing gas flow rates.
2. Control of the waste gas temperature at the outlet of the absorber by the amount of water injection.
3. Control of SO_2 in the clean gas by the added amount of fresh hydrated lime. The addition of the acivated lignite is made in a fixed relation to hydrated lime $Ca(OH)_2$.

$SO_2 < 500$ mg/m³ (STP)

hydrated lime powder, $Ca(OH)_2$: < 300 kg/h

95 % $Ca(OH)_2$, spec. surface > 18 m²/g, granulometry 99 % < 90 µm

PCDD/F < 0,1 ng/m³ (STP)

lignite coke, C: < 30 kg/h

minimum quality: ground activated lignite coke, spec. surface approx. 300 m²/g, granulometry 100 % < 125 µm, 63 % < 32 µm, d50 = 24 µm

---

Residues: < 600 kg/h

Figure 7. Quantity of additives.

5 OPERATIONAL RESULTS

The start of the site activities was in April 2005. Figure 8 shows a virtual overview of the new plant with the essential components like silos for the additives, the two Entrained Flow Absorbers, the bag filters and the blowers (on the backside of the view). The arrangement is very compact in order to minimize the necessary area for the erection. The chimney is designed for two plants and is located in such a way that the second plant can easily be connected.

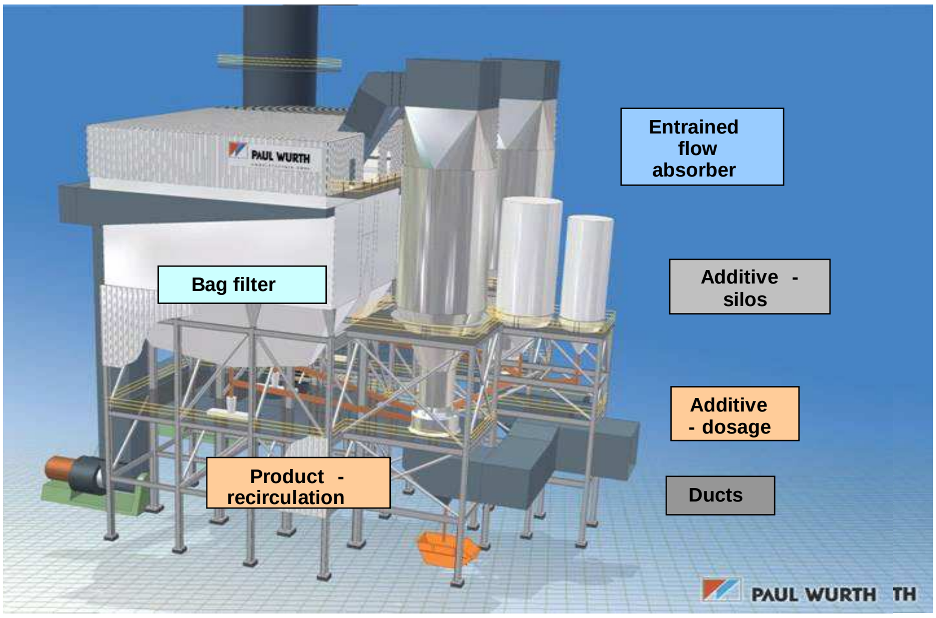


Figure 8. Virtual plant view.

After the solution of different problems with the quantity of the gas volume entering the plant, the bag filter material, and the parameter adjustment of the closed control circuits in conjunction with the automation system the following results of the emissions in the clean gas are achieved (Table 2):

Table 2. Operational results

	Guarantee load case (clean gas)	Actual load data (average values)
Flow rate m^3/h (STP) dry	540.000	430.000
Flow rate m^3/h (STP) wet	600.000	480.000
Temperature outlet ℃	120	110
Dust mg/m^3 (STP) dry	< 10	< 5
SO_2 mg/m^3 (STP) dry	< 500	480
HCl mg/m^3 (STP) dry	< 10	< 10
HF mg/m^3 (STP) dry	< 1	< 1
PCDD/F ng/m^3 (STP) dry	< 0,1	< 0,1
SO_2 removal %	45	47
$Ca(OH)_2/SO_2$ (stoichiometric factor)	1,6	1,1

The optimization is under progress, but the operational results are very promising in particular regarding the consumables. Any improvement resp. any minimization of the amount of consumables means direct savings in the operating cost. The basic process principle, the recirculation, is one of the important steps to minimize the operating cost and to reduce the amount of consumables to its minimum by maximizing the rate of reaction. The value of the stochiometric relationship as defined in Table 2 is an extraordinary achievement of the optimization progress. It finally leads to significant savings under two aspects: the procurement of hydrated lime plus lignite coke and the landfill of the reaction products.

Based on modifications of sinter strand No. 3 to improve the sinter production there were operational situations mainly during the start-up after a stoppage of the empty strand when an amount of far more than 700.000 m^3/h (STP)sinter offgas was produced. In this case the waste gas cleaning plant was found to be to small. In order to cope with this situation ROGESA decided to connect sinter strand No. 2 to the EFA® plant.

Two pictures show the new PAUL WURTH gas cleaninig facility at ROGESA's sinter strand. The first picture (Figure 9) does not look anymore virtual but very real as a side view of the plant. The main buildings and plant equipment can be seen. The space in front of the plant is forseen for the second gas cleaning plant for sinter strand No. 3.

Figure 9. Plant view.

6 SUMMARY AND OUTLOOK

Sinter plants are an important facility in the production chain of ironmaking. They are not only producing sinter as ironbearing burden for the blast furnace, but also recycle a lot of valuable secondary materials to avoid their landfilling.

However, the environmental legislation has been continually and strictly tightened by the environmental authorities concerning the emissions of pollutants in the waste gas. The option ROGESA has chosen to face this liability was a so called „end-of-pipe“ solution with retaining of the existing electrostatic precipitator and the addition of an injection process with a so called Entrained Flow Absorber operating with hydrated lime and activated lignite coke. The bag filter increases the dioxin adsorption and removes the dust. With this installation ROGESA’s sinter strand is at the top of the environmental development for waste gas, sinterplant off-gas cleaning. The order for second EFA® plant at sinter strand No. 3 is placed, and the EFA® plant will be in operation in the middle of 2010. This technology has become a milestone in sinterplant desuphurization, dedusting and dedioxination.