

PAUL WURTH'S COMMITMENT TO ENVIRONMENTAL AND ENERGY SAVING TECHNOLOGIES FOR THE IRON AND STEEL INDUSTRY¹

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Abstract

In the ironmaking industry Paul Wurth is very well known with its particular equipment essential for modern blast furnace operation and since almost 10 years also as a main plant builder of complete blast furnace plants. Beyond this engagement, Paul Wurth together with its subsidiary in Germany, Paul Wurth Umwelttechnik GmbH, has developed equipment and processes related to the iron and steel industry which contribute to a clean and sustainable operation of different plants in integrated steel works. The report shows examples of gas cleaning facilities in blast furnace, in steel and in sinter plants. Furthermore, the paper shows Paul Wurth's commitment to energy saving and recovery activities within the iron and steel industry as well as residue treatment.

Key words: Environmental technology; Energy recovery; Gas cleaning; EFA[®] process; Recycling of residues.

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1 INTRODUCTION

Paul Wurth is a Luxembourg based engineering company which serves the industry for more than 140 years. The company started as a boiler maker, in the steel structure fabrication and in the beginning of the 1950th more and more in the Iron and Steel industry. Today Paul Wurth is a well known and well recognized plant builder for blast furnaces and other related equipment in the iron and steel industry. Today's expectations towards an engineering company are not limited to its core business and core knowledge regarding production facilities like a blast furnace plant but include also profound knowledge and know-how about environmental protection for these kinds of plants. Already since a long time it is no more possible the built up a new plant without taking into consideration its effects to the ambient environment. Therefore, Paul Wurth has developed a numerous amount of processes for the iron and steel industry to ensure a proper, save, and environmental friendly production of sinter and hot metal within an integrated steel plant. With our technologies we have to make sure that the chimneys do not anymore look like shown in Figure 1. This report will give some examples on how Paul Wurth s.a. and its subsidiary company Paul Wurth Umwelttechnik GmbH have developed and successfully implemented technologies to protect the environment, to recover energy, and last but not least to recover and recycle valuable residues.



Figure 1. Smoking chimney in a former steel plant.

2 ENVIRONMENTAL TECHNOLOGIES

Paul Wurth Umwelttechnik GmbH, based in Essen/Germany is working now since more than thirteen years in the field of environmental technologies. Even though in most of the cases any kind of environmental technology is only a cost driver and does not contribute to any improvement (by quality) or to any kind of maximization of the product as such, the industry is forced by law to implement these technologies to protect the environment. This phenomenon is spreading around the world even into those countries which, ten years ago, would not even had thought about any installation in this regard. Thanks to more knowledge about the general health of the population and also driven forward by the “green movement” the attitude towards

environmental technology has changed. In the following sections some examples of PAUL WURTH's engagement in technologies, helping to keep the environment around industrial installation cleaner, are shown.

2.1 Filter Technologies – Dry Gas Cleaning

PW Umwelttechnik GmbH has developed and successfully implemented dedusting facilities for steel plants (EAF and BOF shops), blast furnace, and sinter plants. The filtering capacity varies between 250,000 and 1.5 Mio.m³/h (STP). The solutions are tailored made based on latest technologies, fully automated, and integrated into the operational it-system of the plant. An example for a larger dedusting system is a bag filter plant, operated at the new electric arc furnace of Peiner Träger, a company of the Salzgitter Group. The dedusting plant which is shown in Figure 2 is not only a filter plant but also a cooling plant in order to cool down the very hot off-gas from the EAF operation. The plant is designed to clean the process off-gas as well as the surrounding atmosphere around the electric arc furnace (secondary dedusting). The final dust content at the chimney of the dedusting facility is lower than 2 mg/m³ (STP).



Figure 2. Dedusting plant for Peiner Träger with piping and canopy suction point.

A similar technology is a filter plant for a secondary dedusting of a BOF converter in the steel shop. In 2008 Paul Wurth received an order for the engineering and supply of a secondary dedusting plant for ArcelorMittal Temirtau, Kazakhstan. All three existing converters will be equipped with Paul Wurth primary and secondary dedusting facilities. The total suction volume of the secondary dedusting plant is 1.2 Mio. m³/h (STP). Figure 3 shows in 3D schematically the new installations which are now under construction. The installations will be done consecutively for each of the three converters one by one. The final dust limit of < 20 mg/m³ (STP) must be fulfilled.

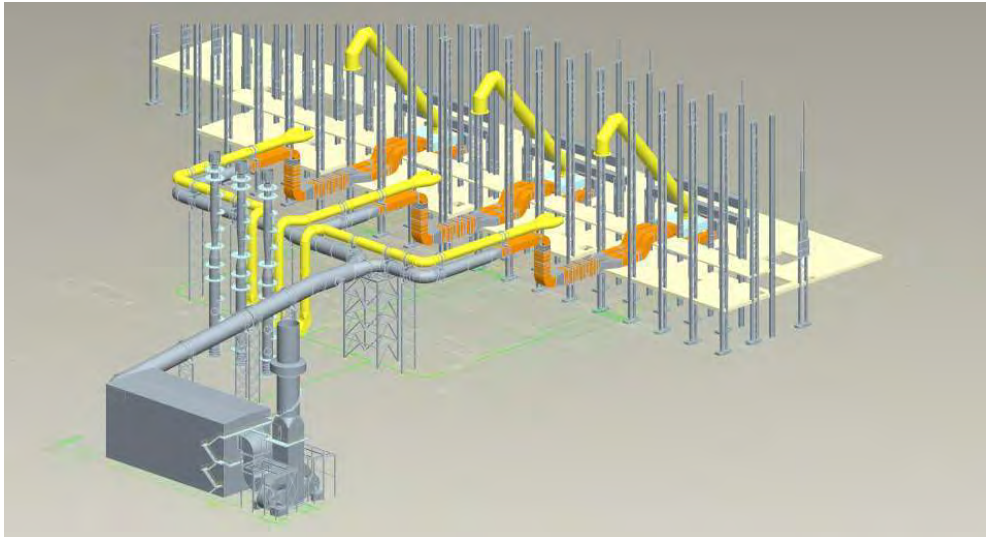


Figure 3. 3D-scheme of the Temirtau secondary dedusting facility.

Another important development was the so-called EFA[®] process. Up to now, there are three installations based on this technology in operation, two at the Dillinger Hütte in Dillingen/Germany and one at Salzgitter Flachstahl GmbH (Salzgitter Group) Salzgitter/Germany. All three plants are of different sizes from approx. 500,000 m³/h up to 900,000 m³/h (STP). The purpose of the plants is to reduce the dust, the sulfur content (and other acid components), and the dioxin/furan level of the sinter plant's off-gas. By means of hydrated lime and lignite coke (char coal) as additives injected into a special purpose absorber just in front of a bag filter in a defined mode, the sinter plant off-gas will be conditioned in temperature and cleaned to the required level. Figure 4 shows the general flow sheet of such an EFA[®] plant.

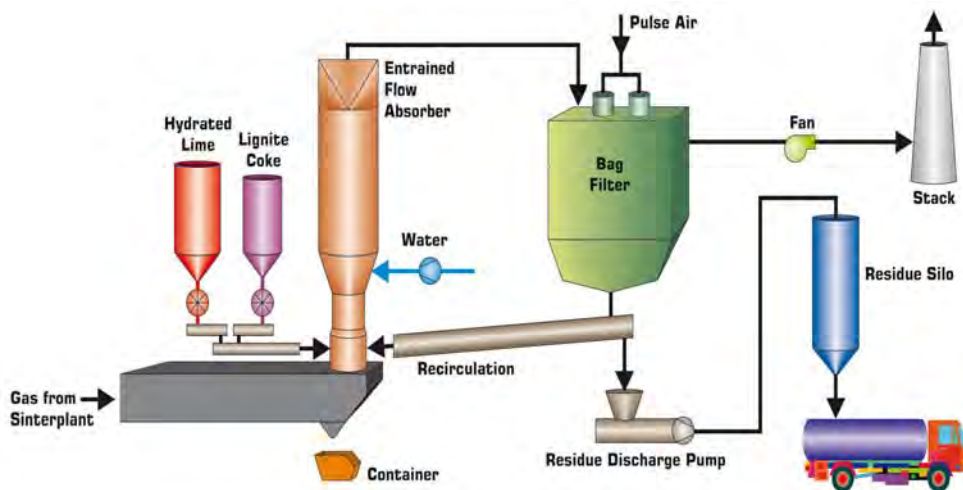


Figure 4. The general flow sheet of an EFA[®] plant.

The process is very efficient and reliable. Due to the special design, the dust including the hydrated lime and lignite coke is re-circulated to such an extent that the set points for SO₂, dust and dioxin/furan are reached. For SO₂, HCl, HF and dust there are online measurements installed which are the basis for the automation system. Dioxin/furan concentrations cannot be measured online. The amount of lignite coke to be charge into the system is based on particular dioxin/furan measurements by an iterative mode. Measurement → lignite coke adjustment → next

measurement until the emission limit of 0.1 ng/m³ (STP) for dioxins/furans is reached. The results of the 2nd EFA[®] plant in Dillingen are given in Table 1. All three plants fulfill the very stringent emission limits of the German TA-Luft, and even better for future challenges.

Table 1. Results of the 2nd EFA[®] plant in Dillingen

	Guarantee load case (clean gas)	Actual load data (average values)
Flow rate m ³ /h (STP) dry	740,000	710,000
Flow rate m ³ /h (STP) wet	810,000	760,000
Temperature outlet °C	100	100
Dust mg/m ³ (STP) dry	< 10	< 5
SO ₂ mg/m ³ (STP) dry	< 500	< 350
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
Ca(OH) ₂ /SO ₂ (stoichiometric factor)	1.6	1.1 - 1.2

In 2007, PW Umwelttechnik installed a filter plant with a heat transformer for a so-called flame scarfing plant (Figure 5). The purpose of the scarfing plant is to prepare slabs for the rolling process. Surface impurities and fissures are removed in a particular way that the slabs practically loose approx. 5% of its initial weight. The treatment is applied on both sides of the slab. As a result of this treatment the surface quality can be increased significantly which increases the quality of the hot rolled heavy plates. The fumes and exhaust vapors generated during the operation of the flame scarfing plant are aspirated by a bag filter with a heat transfer system in front, also installed at the Dillinger Hütte/Dillingen, Germany. The total amount of off-gas is approx. 300,000 m³/h (STP), the final dust content is below 5 mg/m³ (STP).



Figure 5. Heat transformer (front, middle-left) and the bag filter including chimney in the back of the picture, at the Dillinger Hütte, Dillingen Germany

It is important to note that any kind of a bag filter plant is basically always linked to a particular process of which the bag filter is only a part of the system. The ability of process engineering as part of the solution of environmental problems is one the strength of PAUL WURTH Umwelttechnik. These examples show solutions in conjunction with a bag filter as the main filtering equipment. The portfolio of PW is also covering gas cleaning systems and plants which are based on dry/wet gas

cleaning. In the following chapters some more details about wet gas cleaning are reported.

2.2 Dry and Wet Gas Cleaning Systems in an Integrated Steel Mill

A modern gas cleaning plant of a blast furnace is separated into a dry and a wet gas cleaning section. In the dry gas cleaning a major amount of the dust carried over with the process gas flow is collected up to 85% - 90% in a cyclone, either a tangential or an axial one. Paul Wurth promotes the axial cyclone as it allows an easier and simpler supporting structure for the downcomer, a gas main which connects the blast furnace with the gas cleaning plant. Figure 6 shows the typical arrangement of a blast furnace, an axial cyclone, and an annular gap scrubber. The recovered dust from the axial cyclone being operated in the sinter plant is finally recycled to the blast furnace and contributes to the saving of valuable raw materials. Paul Wurth has executed meanwhile ten axial cyclones distributed all over the world.



Figure 6. BF gas cleaning plant (axial cyclone, AG scrubber, mist eliminator of BF2, Tianjin, PR of China).

Since the first days of the company wet gas cleaning of blast furnace gas was one of the main products. With the so-called annular gap scrubber (AGS) technology the blast furnace gas is not only cleaned for further processing, but the blast furnace gas pressure is also controlled by this equipment. In this sense the AGS technology is different from the filter technologies based on a bag filter system. An annular gap scrubber is part of the blast furnace process and as such important for the pressure control. Blast furnace operation at elevated top pressures up to 3.5 bar absolute is today's basis for the maximized production of hot metal. Even small blast furnaces are today equipped with annular gap scrubber technology in order to maximize production. The advantage of an AGS is that two basically different operational steps, the cleaning of the blast furnace gas and the pressure control of the furnace, can be done in one step. The dust content of the blast furnace gas is reduced to maximum 5 mg/m³ (STP), the amount of free water droplets in the cleaned BF gas is limited to 5 g/m³ (STP). The dust collected in the wet gas cleaning plant is separated from the water by means of a clarifier. The de-watered sludge has to be deposited as it

contains undesirable elements, which cannot be recycled to the blast furnace (e.g. zinc).

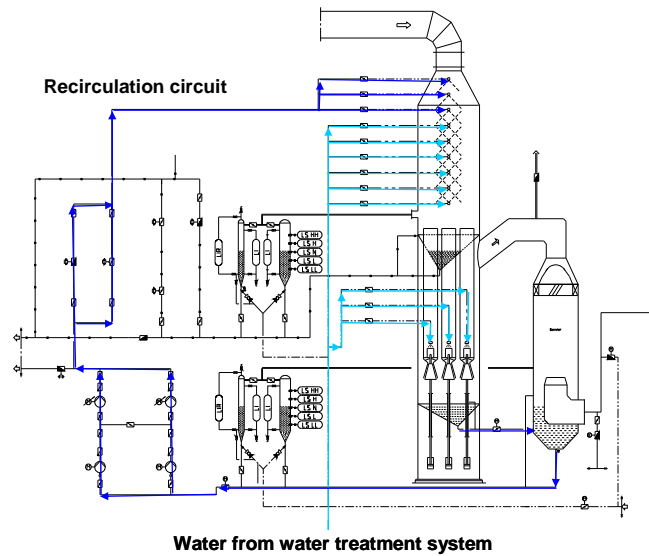


Figure 7. Schematic description of an AG scrubber.

Annular gap scrubbers are executed with one or three annular gap elements depending on the size of the blast furnace. Figure 7 shows a typical schematic arrangement of an AGS with gas and water circuits, Figure 8 a photo of the scrubber at ThyssenKrupp's new BF 8 in Duisburg-Hamborn, Germany. The BF gas volume is max. 400,000 m³/h (STP) and the BF top pressure is 2.6 bar absolute.



Figure 8. BF Gas scrubber at ThyssenKrupp's BF No.8.

The wet scrubbing technology on the basis of annular gap elements is not only state-of-the-art for blast furnace plants, but also applicable for basic oxygen furnace plants (BOF converter). In this case, the converter gas, which is generated by oxygen blowing, is cleaned. The dust particles are removed from the gas flow significantly below dust concentrations of 50 mg/m³ (STP). The difference to blast furnace gas cleaning is that the BOF gas is not continuously produced, only during the blowing period. The pressure drop necessary for the gas cleaning is generated by a fan which sucks the gas through the scrubber and demister. The converter gas is a high calorific gas and is normally stored in a gas holder for further processing or for

heating purposes inside the steel mill. A typical scheme of a BOF converter primary gas cleaning is shown in Fig. 9. The arrangement shows a plant which is installed at BOF shop 1 at ArcelorMittal Gent/Belgium. Three further installations (for three converters) are actually under construction at the ArcelorMittal Temirtau works in Kazakhstan.

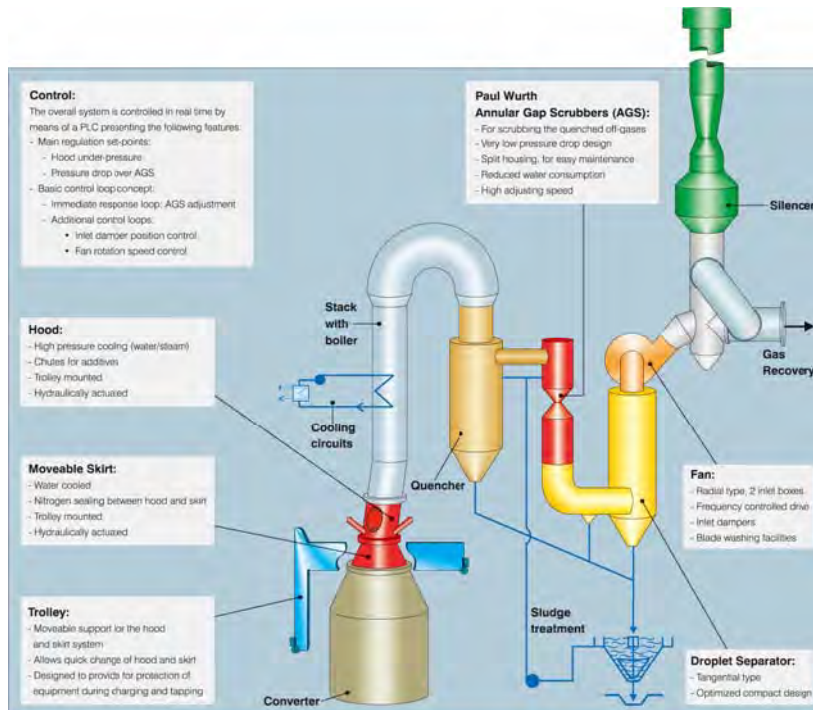


Figure 9. Schematic description of a BOF primary dedusting facility.

3 ENERGY SAVING AND RECOVERY

3.1 General Considerations

For every modern plant energy saving and recovery are a big topic and vital for an economic blast furnace operation. This topic will lead to the reduction of operating cost, the reduction of combustion emission in general, the reduction of CO₂-emission and to excellent and progressive technologies as such. The evaluating of new technologies will always be done by evaluating the energy demand. Therefore, Paul Wurth is handling energy saving and recovery as a main item, not only in case of general technologies and plants in the Paul Wurth portfolio but also as a stand alone item for energy saving and recovery in a blast furnace plant. Generally, every Paul Wurth plant is optimized in view of energy consumption.

For energy recovery it is fundamentally important to define the purpose and application of the recovered energy. For every blast furnace plant, e.g. depending on the global location of the plant, one has to define the aim and the form of energy to handle with. Thermodynamic laws show the efficiency of energy recovery and the limits and obtainable energy output by conversion of heat into other forms of energy.

The blast furnace plant and the auxiliary plants are consuming and emitting a huge amount of energy. As per BAT-paper the total energy consumption per ton crude steel (rolled) of modern plants is about 18 GJ/t crude steel, 2010 (23 GJ/t, 1980; 30 GJ/t, 1960). The most efficient energy saving is to avoid energy losses by making each process as much efficient as possible.

The conversion of energy (esp. heat energy) is always associated with energy losses. Furthermore, the temperature level of the heat energy to be converted is one major factor of the efficiency.

There are three possibilities for energy using/conversion:

- direct heat transfer by replacement of sources at lower temperatures e.g. by mixing;
- indirect heat transfer via heat exchanger;
- conversion of heat energy into mechanical or electrical power.

The most efficient way of heat energy conversion/usage is the direct heat transfer. Some potential at a blast furnace plant is to use hot air e.g. coming from the sinter cooler (see below), dry slag granulation (see below) directly as cold blast air for the hot stoves or e.g. as preheated air for combustion or e.g. for drying purposes. The direct heat transfer does not generate any energy losses except the transportation, whereas the indirect heat transfer additionally will be affected by the efficiency of the heat exchanger. The indirect heat transfer can be used to preheat air for combustion, e.g. heat recovery at hot stoves (see below) or e.g. steam generating for the steam network etc.

The conversion of heat energy into electrical or mechanical energy has a significant lower efficiency as heat transferring. The generation of steam or organic fluids to operate a steam turbine or ORC (organic rankine cycle) turbine do have efficiencies which are not much higher than 20%. Additionally, one major problem is the non continuous energy supply due to the batch processes of the blast furnace plants. Slightly higher efficiencies (up to 30%) for conversion of heat energy into electrical or mechanical energy are reachable with the well applied TRT-technology for blast furnace gas.

3.2 TRT-System (Top Gas Energy Recovery Turbine)

TRT systems are well known and applied at many BF plants. Until now, Paul Wurth equipped 17 blast furnaces with TRT systems. The latest installed TRT was at ThyssenKrupp Steel Europe, Hamborn, blast furnace 8. Figure 10 shows a picture of the ThyssenKrupp turbine. The turbine is located downstream the cyclone, scrubber and demister. With a flow rate of 400,000 m³/h (STP), a inlet temperature of 55°C and inlet pressure of 1.5 bar(g) the electrical power output is approx. 9.5 MW. The annual saving can be accumulated to 4.1 Mio. € (8,600 h/year operation, 5 cent/kWh).



Figure 10. TRT at ThyssenKrupp Steel, Duisburg, Hamborn, BF8.

3.3 Hot Gas Filtration

Paul Wurth Umwelttechnik developed a Hot Gas Filtration (HGF) system which is able to clean the BF-gas without scrubber and demister (Figure 11). This system has advantages compared to wet systems as e.g. no water handling and treatment, less pressure losses (30 mbar instead of 300 mbar) and dry dust handling instead of sludge. One main advantage is the higher energy output in comparison to the wet system. Because of the avoidance of heat losses by water treatment of the BF-Gas, the higher temperature and higher pressure after hot gas filtration the energy output of the turbine can be increased by app. 20% compared to the wet gas treatment with scrubber and demister. Paul Wurth is operating a test/pilot plant at Dillinger Hütte, BF 4. The hot gas filtration can also be adapted to other applications like sinter cooler gas cleaning.

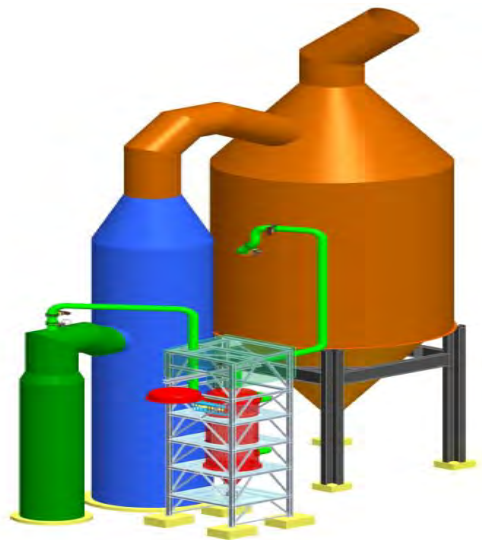


Figure 11. 3-D model of the pilot/test plant at Dillinger Hütte, Dillingen, BF4.

3.4 Dry Slag Granulation

Paul Wurth investigated and developed a new technology for dry slag granulation. By means of steel balls the slag will be rapidly cooled down to reach the valuable chemical/physical properties of slag for the cement industry. Afterwards, the slag will be cooled down with ambient air and easily separated from the steel balls. The ambient air will leave the cooler with temperatures up to 800°C. The quantity of heat will be at ~ 60 kWh/t_{HM} (HM=hot metal).

3.5 Heat Recovery for Stoves

Hot stoves will be fed with combustion air at ambient temperatures and combustion gas (BF gas) at net temperatures (~ 30°C by using of scrubber and wet-TRT system). After combustion the preferred dome temperature should be ~ 1,350°C. The waste gas will leave the hot stoves at a temperature of ~ 330°C and will be fed into the chimney. Depending on the calorific value of the BF gas it is necessary to add natural gas to reach the certain dome temperature. To avoid the use of natural gas and heat energy losses of the waste gas it becomes more and more usual to recover the heat energy of the waste gas by preheating the combustion air by means of heat exchanger. Paul Wurth prefers to apply a special kind of heat exchanger equipped

with heat pipes (Figure 12). This technology of Paul Wurth ensured the highest possible efficiency of indirect heat transfer. The heat pipe is a metallic pipe which is filled purely with one fluid. This fluid (e.g. water/vapor) has to have a certain vapor pressure to ensure that the liquid is evaporated at the hot side and condensate at the cold side. Half of the pipe is located in the hot part (waste gas side) and the other half in the cold side (combustion air).



Figure 12. Heat recovery at hot stoves with heat pipes heat exchanger.

3.6 Residue Treatment

Over the years Paul Wurth has gathered a vast experience in the treatment of steelmaking residues, through the installation of trial and industrial plants based on proprietary technologies, and the study of their application to a variety of metallurgical waste.

The Primus[®] technology, developed and delivered by Paul Wurth, is based on a multiple hearth furnace (MHF), used for pre-heating, calcining and pre-reducing the residues using high volatile coal, combined with a specially designed electric arc furnace (EAF) for smelting the charge from the MHF and fuming-off the zinc. It represents an innovative solution for recovering separately iron and zinc as added value materials from iron and steelmaking residues: zinc is recovered as zinc oxide, iron as pig iron and gangue materials as inert slag. The PRIMUS[®] process features recovery rates of zinc close to 100%, while complying with the most stringent environmental regulations.

The Primus[®] process has been industrially implemented first in 2003 in Luxembourg. The plant was built for recycling of 60,000 t/y of EAF dust and 15,000 t/y of rolling mill sludge. It includes a MHF (multiple hearth furnace) with 8 hearths of 7.7 m internal diameter and a 10 MW EAF (electric arc furnace) with 3.5 m internal diameter. Per t of input material it typically produces 0.25 t of pig iron, 0.35 t of secondary dust (zinc oxide concentrate) and 0.2 t of slag consuming an average 0.32 t of coal and 1.05 MWh of electricity.

At Dragon Steel Corporation (DSC), Taichung works in Taiwan, Paul Wurth successfully started the new Primus[®] plant which will recycle fine material (dusts, sludges, etc.) from the existing Electric Arc Furnace shops and from future sintering,

blast furnace ironmaking and BOF steelmaking. In this frame, first hot metal has been successfully tapped from the plant's melting furnace on April 4th, 2009. Full production capacity was achieved in June 2009.

Fine materials like EAF or BOF dusts are designed to be mixed, pelletized and dried. Sludges from BF or BOF are composed to be charged directly without any pre-treatment. These feed materials are loaded together with high volatile coal into the multiple hearth furnace (MHF). The MHF consists of 8 self supporting refractory hearths. Its internal diameter is about 8 m. The pre-reduced material out of the MHF is then fed into the underneath located EAF smelter. This smelter has an internal diameter of 6 m. The power is rated to 30 MVA. In order to allow refractory repair without losing production a spare vessel is foreseen. The hot metal is poured into a pig casting machine.

The two furnaces are connected to a common off-gas treatment which consists of the following main components:

- Post combustion chamber;
- Quench;
- Filter for oxide recovery; and
- Adsorption filter for dioxin control including an active carbon injection (Figure 13).

Salable products are pig iron and Primus[®] oxide.

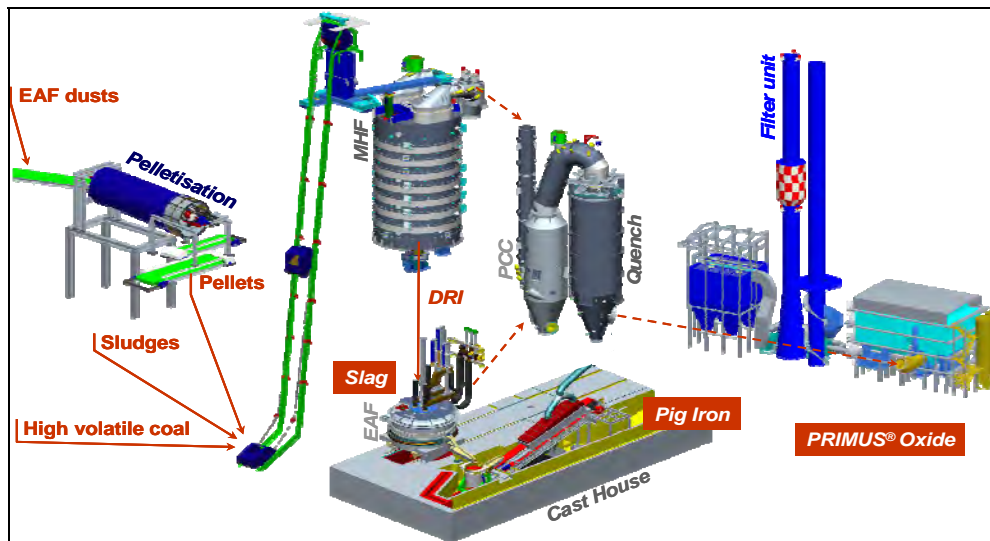


Figure 13. Principle flow sheet of PRIMUS[®] plant Dragon Steel.

At Dragon Steel, the Primus[®] plant (Figure 14) is designed for a nominal recycling capacity of 100,000 t/y (dry base) of fine material and will be operated with different feed mixes, ranging from 100% EAF dust to a high proportion of blast furnace residues.

Dust and sludge generated by integrated steel plants exclusively via the BF-BOF steelmaking route contain less zinc than the "poorest" mix processed by the described Primus[®] plant. For such cases, Paul Wurth is able to offer solutions employing a rotary hearth furnace (RHF) instead of the multiple hearth furnace.



Figure 14. Primus[®] plant at Dragon Steel.

4 CONCLUSION

These examples show the activities and products of Paul Wurth in the field of environmental technologies. Constant development and fulfillment of the stringent emission limitation prevailing in Europe and more and more also in other parts of world will lead into a better environment for human beings and animals. Industrialization does not necessarily mean “dirty chimneys”, which in former times was a sign of prosperity. The times have changed, and to the benefit of all of us, these stringent emission limitations lead to new processes and new equipment. Paul Wurth is dedicated to the iron and steel industry for a long time, however, today under new assumptions: mature and well established processes like the steel production through the conventional route can be operated with “clean chimneys”.