# Recycling technologies

for filter dust and other residues in the steel industry

Thermal Recovery in

- Waelz Kiln
- Sinter Belt
- Rotary Hearth Furnace
- Shaft Furnace

EIRICH

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# Recycling technologies for filter dust and other residues

**The steel industry is adopting innovative ways of recycling dusts and residues, aiming for zero waste. Correct mixing and preparation of these difficult materials is essential for efficient plant operation, and the use of Eirich mixers is well established in this field.**

As environmental legislation has tightened, the steel industry, as with other industries, is subject to an increasing pressure to improve the environmental compatibility of their production. As a result, measures are implemented to particularly reduce energy consumption, emissions and residues. For this reason, several methods have been developed and brought up to production level over recent years that allow steel works residues to be reconditioned or directly fed back into the steelmaking cycle. The economic efficiency of these processes is based on:

- Reducing the emissions
- Saving on dumping costs
- Recovering the reusable materials such as Fe and Zn that are part of the residues

In this paper, various processes will be presented for recycling residues back to the production process. As examples, some existing plants are described where the residues are charged to a sintering belt (HKM), a rotary kiln (BUS), a multiple hearth furnace (Primorec) or a shaft furnace (TKS). The residues usually come as fine filter dusts or as sludges. For recycling, most processing methods require the residues to be transformed into a shape that allows dust-free handling.
There are several preparation processes in use to achieve this purpose:

- Agglomarating
- Pelletising (build-up granulating)
- Briquetting
- Pressing into blocks or bricks

Which technique is best suited depends on the process used for recycling the residues back to the production line. For all these processes, mixing is crucially important. The mixing systems used often must operationally manage several processing steps at a time, namely:

- Mixing
- Moistening/moisture distribution/moisture removal
- Dispersing
- Compacting
- (Pre-) granulating
- Reacting
- Cooling

The mixing system that has proved to be very efficient for these tasks is the Counterflow Intensive Mixer, often simply referred to in the industry as the Eirich mixer. Particularly challenging for mixers are the often extremely unpleasant mechanical, physical and chemical properties of the treated raw materials.

They are sometimes:

- Abrasive (sinter dusts, coke)
- Corrosive (containing chloride)
- Pyrophoric (fine Fe powder)
- Reactive (quicklime)
- Extremely sticky with a propensity to material caking

| Typical residues | Frequently used binders |
|---|---|
| Sinter plant dust | Quicklime |
| BF top gas dust | Dead lime |
| Cast shop dust | Limestone powder |
| EAF dust | Dolomite |
| BOF dust | Cement |
| BF sludge | Bentonite |
| Steel mill sludge | Return sand |
| Mill scale sludge | Cellulose |
| | Molasses |
| | Water |

Table: Typical treated residues and frequently used binding agents

Over recent years, zinc has become increasingly important in the steelmaking cycle. As more and more galvanised surfaces are used, there is an increasing amount of zinc returning to steel plants for remelting. Two methods will be described for preparing zinc-containing residues for external processing, or recovering zinc as oxide.

**Pelletising of BOF dust**

At the Voest Alpine Stahl steel works in Linz, Austria, the dusts contained in the off-gas from the converter are separated in the cooler and the downstream electric filter. The coarse dusts from the cooler and the fine dusts poor in zinc from the electric filter are heated in a rotary kiln and hot briquetted in a continuous process. The briquettes are then directly fed back to the converter. The dusts rich in zinc from the electric filter are prepared in a special pelletising system for further processing **(see Fig. 2.1).**

The problems with these dusts are their pyrophoric properties due to their high iron and quicklime contents, and the high temperatures (150°C) at which they have to be handled. To counteract an iron reaction the system is inerted with nitrogen. For dissipating the reaction enthalpy of lime slaking and other heat sources, the mixer is also used as an evaporative cooler.

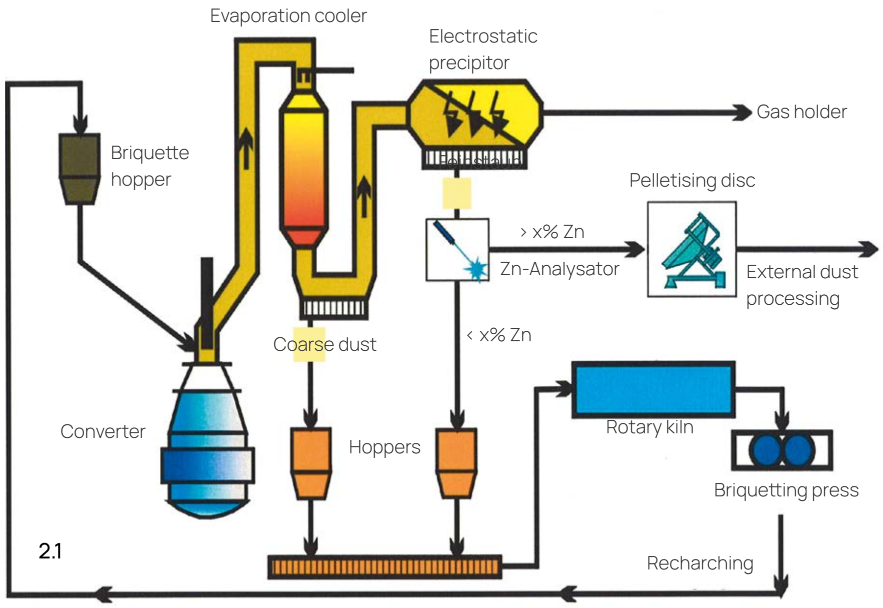



Fig. 2.1: Recycling of residual BOF dusts at Voest Alpine Stahl in Linz, Austria

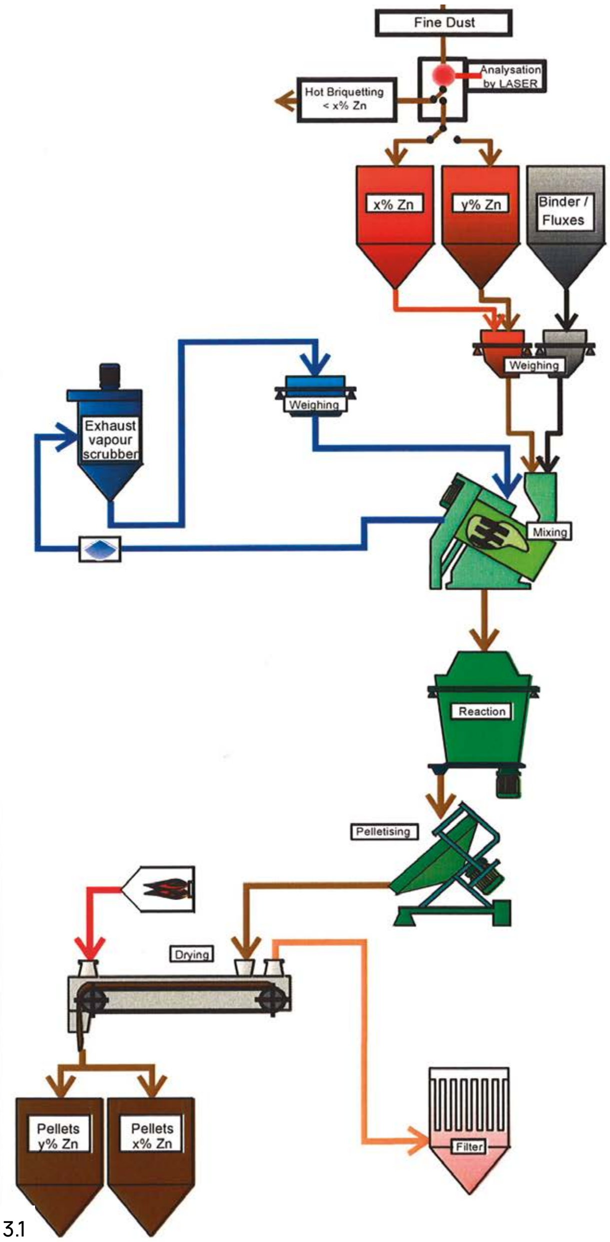
A modified table feeder is installed as a reactor between the mixer, operating in batch mode, and the disk pelletiser, operating in continuous mode. It serves both as a buffer organ between batch and continuous operating mode, and also provides the necessary holding time for the lime slaking reaction to almost fully complete **(see Fig.3.1)**.

The dusts are reluctant to blend with water, but require a large amount of water to be added. Therefore, for wetting an Eirich mixer is used, as shown in **Fig. 3.2** The amount of water to be added is automatically calculated by the process control system based on several measured values.

It is basically composed of the following fractions:

- Stoichiometric water for CaO slaking
- Water for dissipating the reaction heat
- Water for cooling the hot dusts
- Water for dissipating the mechanical energy of the high-performance mixer
- Water for moistening the dusts for pelletisation

The evaporation of water causes large quantities of dustloaded vapours to form inside the mixing reactor, the reactor and the disk pelletiser. They are separated in a scrubber and recycled. Water addition to the mixer is performed by feeding dirty water directly from the scrubber. This way the water is run in a closed cycle without any emissions into the environment, and any water consumed in the process is added as fresh water to the scrubber. As the moist, limecontaining dusts are extremely sticky, the mixer is equipped with a fully automatic cleaning system.
After leaving the disk pelletiser the moist pellets are dried on a belt drier until they can be stored in silos without problem. The pellets obtained have a high mechanical strength, remain stable even in a humid atmosphere, and can be transported over long distances.




3.1

Fig. 3.1: Pelletising system for BOF dusts

**BUS Waelz kiln process**
In 1992, BUS Zinkrecycling Freiberg GmbH built a modern ecologically compatible zinc recycling plant on a former steel mill site in Freiberg, Germany, in the Saxonia industrial zone. It uses a rotary kiln system to transform zinc-containing industrial residues into rolled oxide under ecologically compatible and resource sustaining conditions.

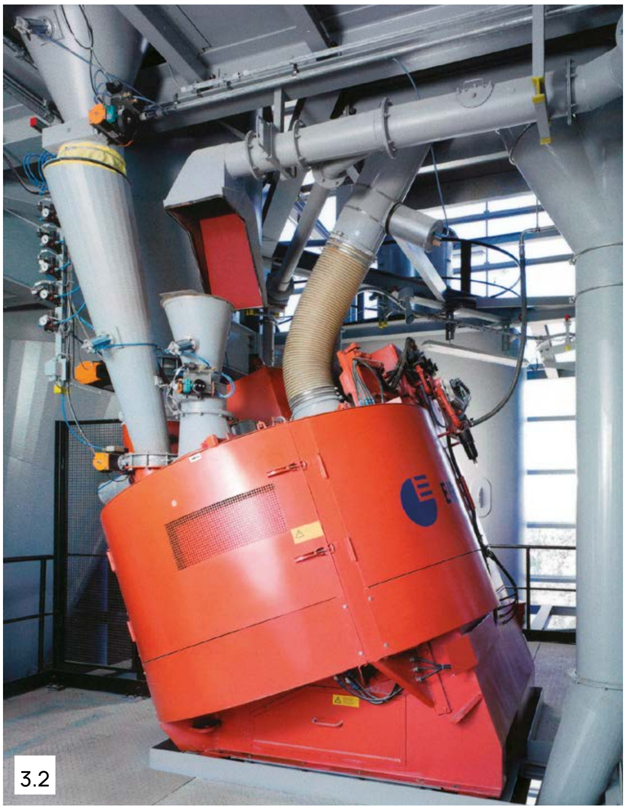


Fig. 3.2 Eirich mixer 1,500l batch volume

In zinc mills the rolled oxide is transformed back into metallic zinc. For the rotary kiln, or Waelz kiln process, the following raw materials can be used:

- Filter dusts from electric steel mills
- Steel mill sludges
- Waste pellets from steel mills
- Coke, moist
- Coke, dry (petrol coke, anthracite coke)
- Flue gas desulphurisation-gypsum, moist
- Gypsum, ground and dry
- Quicklime
- Hydrated lime

The steel mill dusts are usually delivered by silo trucks and then stored in large volume silos. Compact, moist material and pre-pelletised steel mill dusts are received in an enclosed store.

For improving the raw material properties, a mixing and pelletising system was installed in 1997, which resulted in the furnace output increasing by 20%. The different residues are matched according to their zinc content and mixed and moistened homogeneously with reducing or binding agents. The heart of the pelletising system is an Intensive Mixer operating in batch mode with a continuously operating pelletising drum mounted downstream. The slightly inclined rotary kiln No.1 is 43 m long with a diameter of 3.6 m rotating approximately once every minute. The batch travels slowly through the furnace while being dried and heated by the furnace gas travelling in the opposite direction. In the reaction zone, the contained metal oxides are reduced at a temperature of 1,200°C, at which zinc and lead vaporise. The process air causes the metals to re-oxidise and they pass with the crude gas into the gas purification system. The rolled oxide is separated in flat tube coolers and product filters, from where it is conveyed to silos for intermediate storage. The slag leaving the furnace can be used for land filling or building roads. The patented Waelz kiln process (SDHL) uses the reaction enthalpy of iron oxidation inside the rotary kiln.

This drastically reduces the energy consumption (gas and coke) and the production of rolled oxide improves by an additional 30%. This technology produces no waste water and the CO2 emissions are 40% lower than the standard process without iron oxidation energy use.

For this reason, BUS Zinkrecycling Freiberg won the 1999 Environment Award for the energetic optimisation of a rotary kiln system, and in 2000 the Innovation Award for the SDHL process for the recovery of secondary raw materials, both prizes administered by the Free State of Saxony.
The successful operation of the plant led, in 2002, to the commissioning of a second Waelz kiln measuring 50m **(see Fig. 4.1)**.

Because the need for roadbuilding slag is not relevant at this time, the process functions with finer agglomerates which proves favourable in terms of furnace output. This is why no pelletising drum was installed. For mixing and agglomerating they opted again for Eirich equipment with the proven Intensive Mixer. In system No.2, however, it is operated in continuous mode. In **Fig. 4.2** the mixing tower can be seen still open, while being assembled. The BUS Group meanwhile operates several such plants at sites in Germany, Switzerland and France. The Taiwanese steel industry is also going a similar way.

Fig. 4.1: Waelz kiln 2 at BUS Zinkrecycling in Freiberg, Germany

Fig. 4.2: Assembly of the continuously operating agglomeration system

In Tai Chung the Taiwan Steel Union Co Ltd (TSU) operates a joint venture for processing 50,000t/ yr of zinc-containing residues from the whole Taiwanese steel industry **(see Fig. 4.3)**. As zinc dust production has risen by almost 50%, ValoRes GmbH in Düsseldorf was commissioned to develop measures for increasing the capacity. The rotary kiln output can essentially be improved by better preparation of the feedstock materials. For this reason, an Eirich mixing system was installed in spring 2004 for agglomerating the dusts and sludges with coke and binder.

Fig. 4.3: Rotary kiln system at Taiwan Steel Union in Tai Chung, Taiwan

**Recycling of residues in a sinter plant**

The Hüttenwerke Krupp Mannesmann (HKM) steel works demonstrated, when concluding a research contract on sinter production with the technical university RWTH Aachen and the research institute SGA Liebenburg, that:

- Iron-containing materials can be recycled via the sintering belt
- The metallurgical quality of pig iron is not impaired, provided that the formula of the recirculating material is identical with the original sintering mix

The objective was to reduce dumping costs and recover the iron contained in the recirculated material. The recycling of dusts, however, deteriorates the permeability of the sinter and increases the dust load in the crude gas. The aim, therefore, was to avoid these effects by agglomerating the recycled dusts. In 1997, HKM installed a pilot system for the recycling of dusts in agglomerated form. The results obtained were so convincing that the pilot system was kept operating for several years, and in 2001 an order was placed for an industrial scale system.

Extensive tests were conducted using different mixers to study the properties of the agglomerates, as well as the suitability of different systems for heavy duty in a steel mill (wear, material caking). HKM compiled a comprehensive assessment catalogue and particularly tested an Eirich Counterflow Intensive Mixer in comparison with a single-shaft tube-type mixer with cutter heads. The studies indicated that the Eirich mixer performed better in practically all criteria.

**The most important and pronounced features were:**

- Granulate quality
- Controlled particle size distribution
- Water absorption/moistening
- Dissolving of lumps
- Permanent self-cleaning
- Wear

In 2002, HKM put the new production system into operation **(see Fig. 5.1)**.

The following raw materials are processed:

- BF top gas dust, very fine, moist
- Dusts from room de-dusting, coarse, abrasive (sinter plant dusts from cooling, crushing and screening)
- Cast shop dusts, dry, fine
- Binders (lime, cement, etc)
- Water

The materials are automatically stored, conveyed, batched, weighed and fed to the batch mixer.

5.1

Fig. 5.1: Agglomeration system (blue) at Hüttenwerke Krupp Mannesmann in Duisburg, Germany

The extremely sticky agglomerates from the mixer are emptied into a box feeder that discharges them continuously onto the belt that feeds the sintering system. After a prolonged commissioning stage during which the equipment components and binding systems were optimised, there are now extensive operating results available that can be summarised as follows:

- The agglomeration of dusts improves the permeability of the sintering mix, which leads to an increased output
- The dust content of the crude gas in the sintering system is lowered
- Copper-containing micro-particles in the dust from room de-dusting are bonded in the agglomerates, thus lowering the copper content in the offgas and its catalytic effect on dioxin formation.

Fig. 5.2: Primus process

**The Primus process**
In 2003, having been successfully tested in a pilot system, the first production plant using the Primus system **(see Fig. 5.2)** was put into operation. For this plant the PRIMOREC S. A. company was founded by Paul Wurth, ProfilArbed (ARCELOR GROUP) and SNCI.
The plant on the ProfilArbed site in Differdange not only provides a Primus multiple hearth furnace as the heart of the system, but also an electric melting furnace that transforms the pre-reduced iron into pig iron. In addition, the plant is equipped with an already tested off-gas conditioning system that guarantees minimum emissions.

The Primus process, as shown in **Fig. 6.1**, is an innovative solution for:

- Production of sponge iron (DRI) or pig iron from iron ore powder in an ecologically compatible process. It can, therefore, be considered as a miniature blast furnace
- Recycling of residues from the iron and steel production with the objective of recovering iron and zinc, as well as other non-ferrous metals

This new process is based on multiple-hearth furnace technology for direct reduction and is suited for processing low-grade coal. The plant in Differdange was conceived for the recycling of all residues from the Luxembourg steel industry, including dust from electric arc furnaces and oil-containing mill scale sludge. Other dusts and sludges from blast furnaces and steel mills can also, of course, be processed.

The different residues and binders are batched, weighed and processed in an Eirich mixer. By measuring the moisture content of the previously homogenised raw materials inside the mixer, varying moisture contents of the basic materials can be directly compensated in the mixing process. Downstream of the mixer there is a drum pelletiser with a relatively long holding time. Inside it the pellets are built up for the furnace, before they are continuously fed to a drier.

The multiple hearth furnace is a simple, compact and reliable unit and consists of several decks (hearths) arranged vertically one on top of another. On each level, mixing arms are in action, driven by a rotating, cooled axial column. The raw materials are charged, together with coal from the top and descend through the furnace from the top to the bottom. The mixing arms cause them to move, alternating from the outside inward on one level and, on the one below, back again from the centre to the wall. The air is introduced from the sides and leaves the furnace at the top. The residues are dried and reduced inside the furnace.

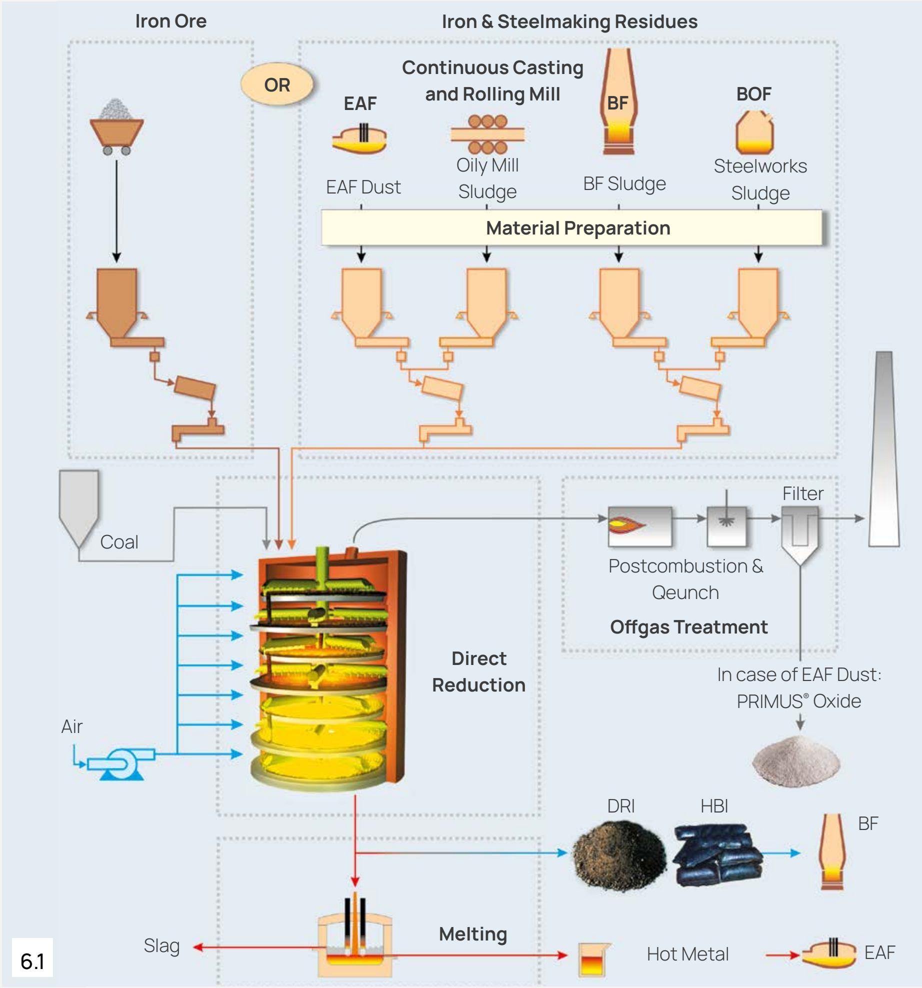



Fig. 6.1: Primus process

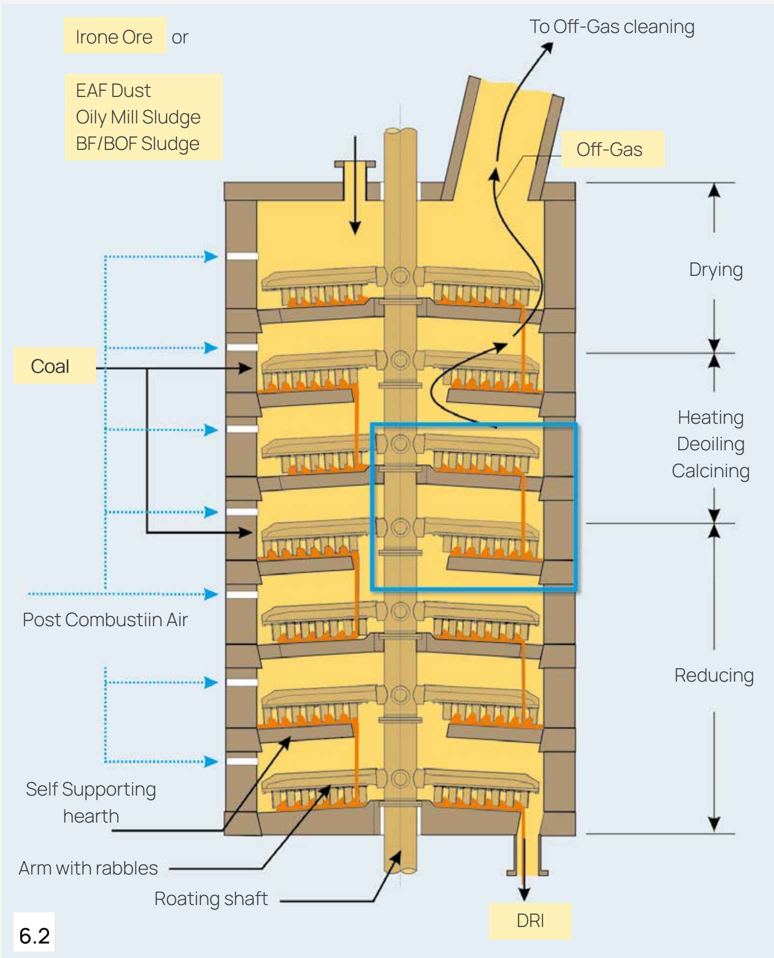



Fig. 6.2: Functioning principle of a multiple hearth furnace

As can be seen from **Figure 6.2**, they go through several process steps from drying at approximately 100°C, de-oiling at approximately 400°C and reduction at approximately 1,100°C. Inside the material bed a reducing atmosphere prevails, whereas the conditions in the gas flow are oxidising. This causes the zinc to re-oxidise in the gas flow, so that it can be separated in the off-gas cleaning filter as the so called Primus oxide. The hot sponge iron is discharged at the furnace bottom and continuously charged to the Primus melting furnace. The specially developed three-phase electric arc furnace continuously produces pig iron and slag. The inert slag is comparable to blast furnace slag and can be used, for instance, for road building.

## The OxyCup process

In summer 2004, a new plant for the OxyCup process was started at the Thyssen Krupp Stahl (TKS) steel works in Duisburg, Germany. TKS operates three sinter plants, four furnaces and two steel works and, by using this new technology, it is possible to process residues from all these plants and recover the contained iron. Küttner is responsible for overall planning and implementation, and also supplied the heart of the system – the shaft furnace **(see Fig. 7.1)** . Prior to TKS's decision to erect a new plant, it had been success-fully operating a pilot system for several years based on a modified cupola furnace, together with its partners Hüttenwerke Krupp Mannesmann (HKM), Küttner, Berzelius Umwelt Service (BUS) and Messer Griesheim. The main idea behind this process is the manufacture of bricks out of iron and carbon containing residues that are reduced in the furnace to DRI and melted into pig iron in one step. It also allows zinc-bearing dusts to be processed, that cannot be recycled to the normal production line. This 'zero waste' concept is shown in **Fig. 7.2**.

The materials to be processed are BOF dusts, sinter dusts, blast furnace sludge, mill scale sludge, and coke breeze. In a preparation system these are cooled, conveyed, batched and processed in a special Intensive Mixer by adding a binding agent to form a concrete-like body. This body is conveyed to a brick moulding line of the type used for paving stones. There the material is moulded into 110mm hexagonal bricks **(see Fig. 7.4)**. The bricks contain approximately 50% iron and after hardening for about three days, they can either be melted directly or kept in store for later use.

For the uniform distribution of residues and for the stability of the bricks the preparation process in the mixer is of crucial importance. The different sludges have to be disintegrated and mixed homogeneously with the fine grained dusts. After several extensive test series, TKS and Küttner decided to use rugged and low-wear Eirich Counterflow Intensive Mixers **(see Fig. 7.3)**, which not only disintegrate the sludges, but also accomplish correct dispersion of binder and moisture.

7.1

Fig. 7.1: Shaft furnance at ThyssenKrupp Stahl in Duisburg, Germany


7.3

Fig. 7.3: EIRICH mixer 3,000 litre batch volume

These two properties are prerequisites for optimal filling of the moulds in the press and for obtaining the required brick hardness.
Due to the high specific surface of the fine waste materials and high temperatures, the reaction velocity inside the furnace is very rapid. As all bricks are of the same size, there is a favourable proportion of cavities inside the shaft furnace that can be compared to a blast furnace. As the bricks descend they are reduced to DRI and then enter the melting zone. Hot metal and slag are tapped off continuously and separated. The zinc contained in the residues is volatilised and leaves the furnace with the top gas. The zinc-enriched filter sludge can be sold for zinc recovery.

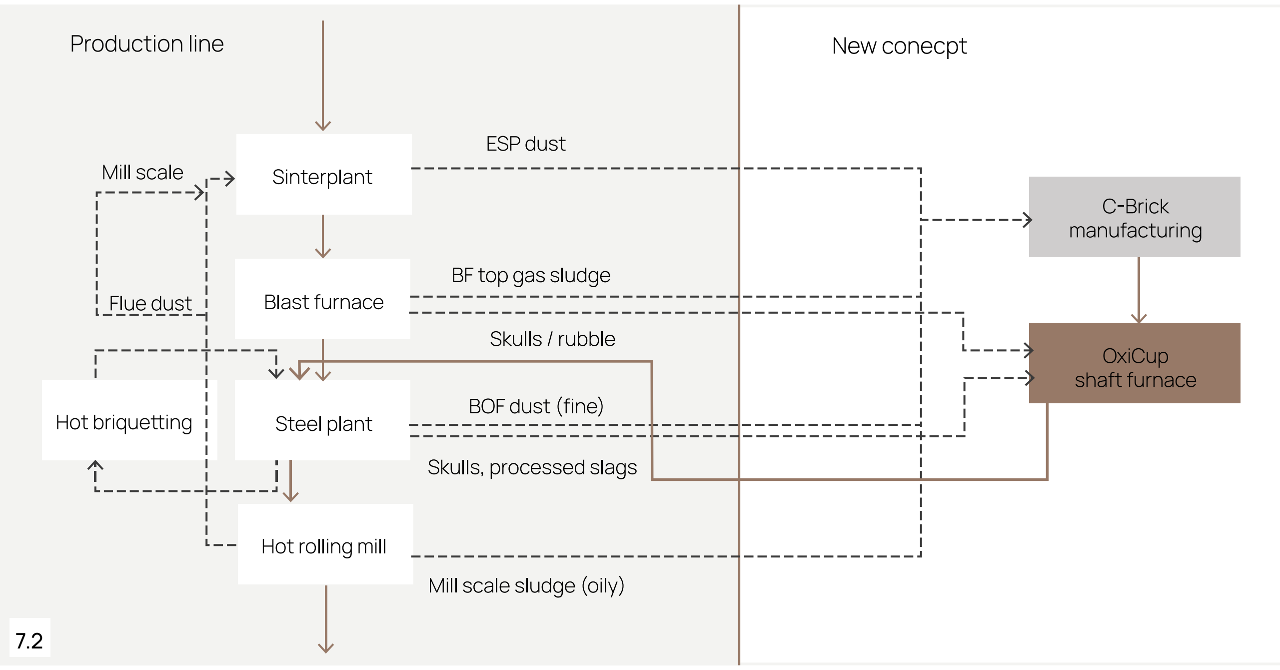



Fig. 7.2: Material recycling with the OxyCup process

The OxyCup process is very versatile and adaptable and, provided that the preparation system for brick moulding is flexible in design and layout, residual matter from a wide variety of origins and consistencies can be recycled. The overall strategy of this process is to keep the core components of the steel mill, ie, BF and BOF, free of any disturbing recycling materials, so maintaining high efficiency.

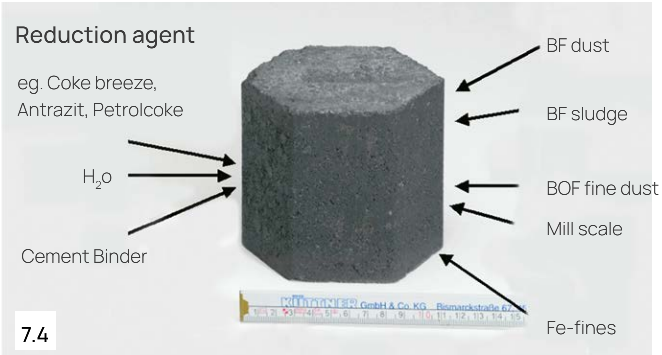



Fig. 7.4: Concrete brick with recycled materials

## Summary

The main residue recycling processes at some European steel works have been described. The common approach is not to dump 'waste' residues, but to recycle them into the production line. The dusts and sludges from sinter plants, blast furnaces, cast shops, BOF plants, and electric arc furnaces are prepared by adding binding and sometimes reducing agents so that the reusable substances contained in them can be recovered in thermal processes. Most of these residues are difficult to handle and have highly demanding mechanical, chemical and physical properties.
Adequate material preparation is an often underestimated step that decides to a large extent on how successful the process will be. At the core of a preparation task there is always a mixing process.

The Counterflow Intensive Mixer has proven its efficiency for all processes. It yields excellent mixing results and guarantees the necessary stabilities and other required properties of the intermediate product. Thanks to their working principle, the wearresistant and self-cleaning Eirich Mixers are very flexible to use and are therefore perfectly suited to coping with greatly varying properties in residues as opposed to the usual raw materials.

**Literature:**
Special report from the technical magazin „millennium steel", 5/2004 written by Jürgen Blatz
Maschinenfabrik Gustav Eirich GmbH & Co KG, Hardheim

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