THE 'ENVIROPLAS' PROCESS FOR THE TREATMENT OF STEEL-PLANT DUSTS

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MINTEK
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OF STEEL-PLANT DUSTS

by

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1 INTRODUCTION

During steelmaking in electric-arc furnaces (EAF) 10 to 15 kg dust is generated per ton of steel product. This EAF dust is usually collected as a fine dust in a bag filter or as a sludge in a scrubber system. Traditionally EAF dust has been stockpiled or dumped on landfill sites. However, the use of galvanized scrap for EAF steelmaking has increased rapidly in recent years, resulting in a rise of the zinc, lead, and cadmium levels in EAF dust. In many countries the dumping of EAF dust is now regarded as presenting an environmental hazard because toxic metals may be leached into drinking water supplies, and dumping is allowed only on approved sites. In the United States EAF dust is listed by the Environmental Protection Agency (EPA) as hazardous waste under the Resources Conservation and Recovery Act (RCRA). Recent EPA regulations require EAF dust to be treated thermally or chemically to remove or stabilize the leachable toxic metals before dumping. The EPA has specified that dusts with a zinc content of 15 per cent or more will have to be treated in a High Temperature Metal Recovery (HTMR) process.

EAF dust is a mixture of very fine particles (average particle size of around 1 μm), consisting of various metal oxides. Its main mineralogical constituents are hematite, magnetite, zinc ferrite (ZnFe₂O₄), and zincite (ZnO). EAF dusts from the production of carbon steel tend to be rich in zinc and lead, and contains typically 35 per cent iron, 25 per cent zinc, and 5 per cent lead (in the form of metal oxides). Dusts from alloy steelmaking operations, such as those using argon-oxygen-decarburization (AOD) blowing vessels, contain significant amounts of chromium and nickel. These dusts contain typically 30 per cent iron, 3 per cent zinc, 0.5 per cent lead, 12 per cent chromium, and 5 per cent nickel.

The yearly quantities of EAF dust produced in Western Europe and the United States are both about 500 000 tons, and some 75 per cent falls into the high-zinc (more than 15 per cent zinc) category. The volume of alloy-steel dusts produced worldwide is much smaller than that of EAF dusts; the annual production in Western Europe is about 50 000 tons. At present around one half of the EAF dust produced in Western Europe and the United States is being treated in a number of industrial processes. Many of these processes have been reviewed recently¹. EAF dusts and dusts from alloy-steel operations cannot be recycled direct to the EAF because of their fine particle size, and their high contents of zinc, lead, halides and alkalis which would create operating problems. Thermal processing technologies that have and are being developed for the treatment of EAF dust fall into two broad categories: fuel-based processes, and electrically-based processes. The Enviroplas process developed at Mintek belongs to the latter category. All these thermal processes are based on the reduction of selected metal oxides in the dust (e.g. ZnO, Cr₂O₃, NiO) with a carbonaceous reducing agent at high temperatures (above 1200°C). In the case of EAF dust, zinc and lead oxides are reduced to
their respective metals, volatilized and then either reoxidized to a mixed oxide or collected as metals in a condenser. During the thermal treatment of alloy-steel dust, a ferro-alloy rich in chromium and nickel is tapped from the furnace. In both cases (EAF dust and alloy-steel dust treatment) metal values are recovered (e.g. zinc, chromium, and nickel), and inert slags are produced that are suitable for landfill disposal or applications such as road building and cement additive.

The Enviroplas process is a plasma-arc furnace operation that can treat EAF dust and alloy-steel dust, or a mixture of both. A non-toxic slag is produced together with either a zinc and lead oxide mix and/or an alloy containing chromium and nickel. The Enviroplas process is at present being developed further to recover metallic zinc directly in a lead splash condenser connected behind the plasma-arc furnace.

2 THEORETICAL CONSIDERATIONS

The thermal processes for the treatment of steel-plant dusts are based on the carbothermic reduction, at high temperatures, of selected metal oxides present in the dusts. The main objectives are to produce an innocuous disposable slag and to recover valuable metals at minimal operating costs. In thermal processing of typical EAF dusts (i.e. high-zinc, carbon-steel dusts) the addition of carbonaceous reducing agent is designed to reduce the zinc and lead oxides in the dusts while minimizing the reduction of iron oxides. The advantage of this selective reduction is that carbon and energy are saved and that less CO is generated. A smaller gas handling system is required and less feed carry-over is expected at lower gas evolution rates. However, in order to attain a CO-to-CO$_2$ ratio in the gas phase that is high enough to prevent excessive back reaction of CO$_2$ with zinc vapour, some reduction to metallic iron is necessary when zinc condensing is practised.

Ideal equilibrium calculations, based on the minimization of the free energy of a multi-component and multi-phase system, were performed using the Mintek Pyrosim$^2$ computer program, to simulate the smelting of steel-plant dusts. The simulations were conducted at a fixed temperature of 1500°C and at a pressure of 1 atm. Temperatures of around 1500°C are generally employed in industrial furnaces for the smelting of steel-plant dusts. A temperature of about 1500°C is necessary to drive the reduction reactions rapidly towards completion. At much higher temperatures the energy requirement of the process is raised significantly and undesirable side reactions, such as the vaporization of magnesium, manganese and silicon, are enhanced. The increase in refractory erosion and the rise in slag fluidity (ease of tapping) when the operating temperature is increased have also to be considered in the selection of the operating temperature.
The results of the thermodynamic simulations for a typical high-zinc EAF dust are shown in Figures 1 to 4. Most of the zinc is removed from the slag and very little iron is theoretically produced at a carbon addition of 75 kg per ton of EAF dust (Figures 1 and 2). The extracted zinc passes into the gas phase which contains about 50 per cent zinc, 30 per cent CO and 5 per cent CO₂ (CO-to-CO₂ volume ratio of about 10). When the carbon addition is raised from 75 to 150 kg per ton of EAF dust, the theoretical energy requirement increases from about 0.8 to 1.1 MWh per ton of EAF dust, while the CO-to-CO₂ volume ratio in the gas increases from approximately 10 to 1000 (Figure 3). This rise in carbon addition also results in a drop in the FeO content of the slag from about 60 to less than 1 per cent and an increase in the amount of metal product from 16 to 310 kg per ton of EAF dust feed (Figure 4). When zinc is condensed from the gas phase, the temperature of the gas needs to be decreased rapidly to below 500°C in order to minimize the reoxidation of zinc by CO₂. Equilibrium curves given in Figure 5 show the temperatures at which reoxidation starts for different CO-to-CO₂ volume ratios and different partial pressures of zinc in the gas stream. For example at a CO-to-CO₂ volume of 10 and a partial pressure of zinc in the gas of 0.3 atm, the back reaction between zinc and CO₂, under equilibrium conditions, occurs at temperatures below 1000°C. In practice it is possible to achieve satisfactory zinc recoveries at CO-to-CO₂ volume ratios in the off-gas of around 10, by using rapid quenching in a zinc or lead splash condenser.

When a typical alloy-steel dust is smelted at 1500°C, a carbon addition of 170 kg per ton of dust is required to extract most of the chromium (Figure 6). Ideal equilibrium simulations also predict a theoretical energy requirement of about 1.1 MWh per ton of dust, which is significantly higher than the energy required to smelt high-zinc EAF dust (about 0.8 MWh/t). Also the level of CO in the off-gas and its CO-to-CO₂ ratio is much higher when alloy-steel dust is treated, because the iron oxide in the dust has to be reduced as well to achieve satisfactory recoveries of chromium to the metal. The low zinc content of typical alloy-steel dust does not warrant the condensation of zinc from the off-gas of the furnace.

3 EXISTING TECHNOLOGY

Although a large number of thermal processes for the treatment of steel-plant dusts have been developed to the pilot-plant stage, only a few technologies have found industrial application. The relatively high costs of the existing dust treatment processes, and the technical and legal problems experienced by certain of these processes have urged steel producers to still consider alternative methods. In the United states the EPA has instituted regulations whereby disposal on landfill sites is no longer permitted. This ban on landfilling which was scheduled to take effect in August 1988, has already been postponed three times. The reason for the extensions of the deadline is to allow time for the development of the best demonstrated
available technology (BDAT) to treat steel-plant dusts and simultaneously recover most of their valuable metal contents. The major existing technologies for the treatment of EAF and alloy-steel dusts, employed in Western Europe and the United States are described below.

3.1 Western Europe

3.1.1 The Waelz kiln process

The Waelz kiln process is basically the only process used in Western Europe for the treatment of high-zinc EAF dust. A secondary oxidic dust is produced, rich in zinc oxide, which is further processed in a conventional Imperial Smelting Furnace (ISF), where metallic zinc is recovered in a lead splash condenser. The Waelz kiln technology is operated and marketed by Berzelius Umwelt-Service (BUS), formed in 1987 by Metallgesellschaft to develop the recycling of wastes from the metallurgical industry other than scrap, in particular dusts and sludges. BUS treats a total of 120,000 t/a of EAF dusts in Duisburg and at the Aser plant near Bilbao. The Aser plant is jointly owned by Indumetal, Metalquimica del Nervion, and BUS (30 per cent). EAF dusts from steelworks in northern Italy are processed in a Waelz kiln operated by Nuova Samim SpA at Ponte Nossa, near Bergamo. BUS has entered into a joint venture with Metaleurop to start a Waelz kiln operation at Noyelles-Godault, northern France. This operation is planned to come on line during early 1993. BUS is at present also exploring the market for their technology in the United Kingdom. The total capacity of the three existing plants in Western Europe is about 180,000 t/a of EAF dust. The Waelz kiln process is also operated in the United States and Japan. Currently 14 kilns are reported to process EAF dust in Western Europe (3 kilns, 180,000 t/a capacity), the United States (7 kilns, 450,000 t/a capacity), and Japan (4 kilns, 200,000 t/a capacity).

The Waelz kilns are operated much the same way worldwide. Pelletized EAF dust is mixed with a reducing agent, such as coke breeze, and fed into the gas-fired rotary kiln. Zinc, lead and cadmium oxides are carbothermically reduced, volatilized, and subsequently reoxidized in the freeboard of the kiln. Halide and alkali compounds are also volatilized, and iron oxides are partially reduced. The reoxidized metal vapours leave the kiln in the form of a flue dust which is collected in a baghouse. This dust is called Waelz oxide and has a typical zinc content of 55 per cent. The slag product which contains some metallic iron meets the EPA Toxicity Characteristic Leaching Procedure (TCLP) test, and can be dumped safely or used as road fill. The Waelz oxide is hot briquetted and the briquettes are further processed in an Imperial Smelting Furnace (ISF) to recover metallic zinc and lead. At present there are 5 ISF plants in Western Europe. They are located in Duisburg, Bristol, Noyelles-Godault (France), Porto Vesme (Italy), and Titov Veles (Yugoslavia).
3.1.2 The Plasmadust process

The Plasmadust process was developed by SKF and has been operated in Landskrona, Sweden, since 1984. The company established for the operation of this process is called Scandust. In 1989 BUS obtained 25 per cent of Scandust's shares while the remainder is owned by SKF. The process was originally developed and built for the treatment of high-zinc EAF dusts. In 1988 the installation was converted to process alloy-steel dusts. The plant has a processing capacity of about 40 000 t of alloy-steel dusts per annum.

The Plasmadust process is carried out in a coke-filled shaft furnace equipped with three 6 MW plasma generators. The d.c. non-transferred plasma devices are mounted onto the tuyeres of the shaft. Alloy-steel dust, pulverized coal and fluxes are injected via the tuyeres together with the superheated plasma gas. Temperatures of around 2500°C are reached in the cavity (raceway) formed in front of each tuyere. The high temperature and low oxygen partial pressure in the furnace makes it possible to readily reduce iron and chromium oxides, which is not the case for fuel-air based processes such as the Waelz kiln process. Hot metal containing iron, chromium and nickel, and a non-hazardous slag are tapped at the lower part of the furnace. The dusts generated by the process itself contain about 20 per cent zinc oxide and are further processed in a Waelz kiln.

3.2 United States

3.2.1 Waelz kiln and Flame Reactor processes

Horsehead Resources Development Company (HRD) is the principal company in the United States for the treatment of EAF dusts. HRD's history goes back to St. Joe Minerals Corporation, but its present ownership is 45 per cent Horsehead, 45 per cent BUS and 10 per cent public. HRD has completed two new Waelz kiln plants over the last four years and now operates 7 kilns at 3 sites; Palmerton PA, Calumet IL, and Rockwood TN. The annual EAF dust processing capacity of the 7 kilns is 450 000 t. The Waelz kiln operation is similar to that practised by BUS in Europe (described in the previous section) but with one difference in that limestone is added as a flux instead of silica sand.

HRD also operates a Flame Reactor demonstration plant for the treatment of EAF dust in Monaca PA. In 1991 HRD signed an agreement with North Star Steel to install and run a Flame Reactor facility with a capacity of 30 000 t of EAF dust per annum in Beaumont TX. The demonstration plant consists of a water-cooled vertical cylinder divided into a combustion and a smelting stage. In the first stage, carbon monoxide reducing gas is produced by partial combustion of natural gas with oxygen-enriched air. This first step is carried out in a cyclone burner at the top of the reactor. The hot reducing flame (flame
temperature in excess of 2000°C) travels vertically downward to the second stage where EAF dust is pneumatically injected. The reactor has an internal diameter of 0.6 m and a height of 3 m. The average retention time in the reactor is about 0.5 seconds and feed rates of 1 to 2 t of EAF dust per hour are achieved. Metal oxides of zinc, lead and cadmium are reduced and the metals are volatilized at the temperature of the reactor (average temperature of about 1600°C). The off-gas leaving the reactor is post-combusted, the metal vapours are reoxidized and a crude zinc oxide is collected in a bag filter. Molten slag is continuously tapped from the reactor and is sold or disposed of. HRD claim that there is little to choose between their Flame Reactor and Waelz kiln technologies. Most of the zinc oxide product of HRD is further processed to zinc metal at their electrothermic zinc plant in Monaca PA.

3.2.2 Other thermal processes

The Inmetco process has been operating since 1978 in Elwood City PA, using alloy-steel dusts and other oxidic wastes from the steel industry. In 1990, Inmetco processed over 55 000 t of oxidic wastes and recovered about 20 000 t of remelt alloy. The process consists of three steps, i.e. first pelletizing of the waste materials with coal fines, then reduction of the pellets in a rotary hearth furnace (RHF), and finally production of liquid metal in a submerged-arc furnace. Green pellets are fed directly into the gas-fired RHF which is operated at a temperature of about 1250°C. Zinc, lead and cadmium are evaporated, reoxidized and collected in a bag filter. The highly metallized pellets leaving the RHF are transferred hot into a submerged-arc furnace where molten metal, containing iron, chromium and nickel is tapped and cast into pigs which are recycled by stainless steel producers. The non-hazardous slag is dumped or used for road fill.

The Tetronic plasma-arc process was developed in the late 1970s by Tetronics Research and Development (TRD) in the UK and was demonstrated during 1987/88 for the smelting of EAF dust in a collaborative effort of Bethlehem Steel Corporation, Bethlehem PA, and TRD. The demonstration trials were funded by the Centre for Metal Production (CMP), Pittsburgh PA, and 22 US steel producers. The process was subsequently市场营销 by International Mill Service (IMS) and in 1989 two commercial plants were installed in the US. The first one at Florida Steel, Jackson TN, with a capacity of 6000 t/a of EAF dust was later upgraded to 9000 t/a. The second installation at Nucor-Yamato Steel, Blytheville AR, has a capacity of 12 000 t/a. EAF dust and coke fines are fed through ports located in the roof of the cylindrical d.c. plasma-arc furnace. Electrical energy is supplied via a central graphite electrode. The zinc, lead and cadmium oxides contained in the EAF dusts are selectively reduced and vaporized, and a non-hazardous slag, rich in iron oxide is periodically tapped from the furnace. Gases are continuously withdrawn from the furnace and most of the metal vapours are condensed and captured in an ISP zinc splash condenser.
The Elkem process\textsuperscript{7} for the treatment of EAF dusts is based on the use of the Elkem multi-purpose furnace (EMPF) in combination with an ISP zinc splash condenser. The EMPF is an air-tight, three-phase furnace, equipped with a thermal oil-cooling system to achieve a frozen slag lining. Elkem a/s markets its EMPF technology through Elkem Technology. To date one EMPF has been built at Laclede Steel, Alton IL. The furnace has a rating of 10 MW and a designed capacity of 40 000 t/a of EAF dusts. Construction started in 1989 and was completed in the third quarter of 1991. The process is scheduled to reach full operational status and capacity in mid 1992. The Elkem process is similar to the Tetronics process described in the previous section. The main differences are that a three-phase slag-resistance furnace is used instead of a d.c. open-arc furnace, and that briquettes are employed instead of unagglomerated feed.

4 ENVIROPLAS PROCESS

4.1 Process Description

The Enviroplas process was developed at Mintek for the smelting of solid wastes from the metallurgical industry, especially zinc oxide containing slags and dusts. The production of environmentally acceptable, non-toxic slags and the recovery of zinc and other valuable metals from these waste materials has been studied since 1987, using d.c. transferred plasma-arc technology. The development of this technology was started at Mintek in 1979 for the smelting of ferrochromium and has been successfully implemented at a scale of 40 MVA by Middelburg Steel and Alloys. To date a total of about 100 tons of lead blast furnace slags and steel-plant dusts have been processed at the Mintek pilot plant. The plasma-arc pilot-plant equipment includes four furnaces which are operated at power levels between 20 kW and 1 MW. The equipment has been described in detail elsewhere\textsuperscript{8}. A schematic diagram of the 1 MW pilot plant is shown in Figure 7. The 1 MW facility consists essentially of a d.c. power supply, a feed system, the plasma-arc furnace, a gas cleaning system, and instrumentation for control and data logging. The water-cooled furnace is operated with a single graphite electrode as the cathode and the molten bath as the anode. The return electrode consists of several steel rods, built into the hearth refractories and connected at their lower ends to a steel plate which is further linked to the anode cable. The feed is supplied to the furnace at a controlled rate, through the central hole in the electrode or via feed ports in the roof of the furnace. Molten slag and metal are intermittently tapped and gases are continuously withdrawn from the furnace. The off-gas system is designed to ensure complete combustion of carbon monoxide and metallic vapours produced in the furnace. Combustion air is drawn in at the off-gas port of the furnace and at the bottom of the combustion chamber.
4.2 Testwork

4.3 Advantages of the Enviroplas Process

At present the dominant technology, worldwide, for the treatment of EAF dust is the Waelz kiln process, while the main technologies employed in Western Europe and the United States for alloy-steel dusts are the Plasmadust and Inmetco processes. The Waelz kiln, Plasmadust and Inmetco processes are well established, and they achieve the desired results. However, the installations are large and capital intensive, and because their processing capacities are between 40 000 and 80 000 t/a of steel-plant dusts, they have to rely on dusts from several mini-mills (a typical mini-mill produces about 5000 t/a of EAF dust).

Over the last few years new thermal processes for the treatment of steel-plant dusts have been developed. They are targeted at smaller processing capacities of 5000 to 40 000 t/a of dusts, and at the direct production of metallic zinc from zinc-bearing EAF dusts. The Tetronic, Elkem and Enviroplas processes fall into this category of new developments. As compared to the Elkem process the Enviroplas process has the inherent advantages of a d.c. plasma-arc furnace over an a.c. slag-resistance furnace. They include the following: reduced electrode consumption, symmetrical heat distribution and a high degree of operational control. The graphite electrode is not in contact with the molten slag or metal and hence accurate carbon addition to the process is possible. The plasma-arc furnace generates most of its heat between the tip of the electrode and the molten bath and its power is not limited by the electrical conductivity of the slag. No fluxes are required to stay within the constraints of sufficient slag resistance.

The main difference between the Tetronics and Enviroplas plasma-arc systems lies in the charging practice. In the Enviroplas process, the feed is supplied to the furnace via the central hole of the graphite electrode, while in the Tetronics process feed ports located in the roof are employed. Feeding through the hollow graphite electrode offers the advantage that the fine steel-plant dust is rapidly absorbed into the molten slag. The vapour products, zinc and lead, leaving the furnace do not move through feed materials falling down from feed ports in the roof, thus minimizing contamination and elutriation or carry-over of feed. The charge is delivered directly into the high-temperature reaction zone under the electrode. Consequently, heat transfer to drive the endothermic reactions is very efficient and high reaction rates can be achieved. On the other hand, the supply of cold feed through the hollow electrode permits the control and suppression of the temperature in the arc attachment area, which is necessary to limit the vaporization of unwanted species.
5 COMMERCIAL CONSIDERATIONS

The selection of a treatment process for steel-plant dust should be based on site conditions such as local environmental regulations, current transport and disposal costs, local electricity and fuel costs, dust volume and chemical composition of the dust. For example, a 2 MW on-site plasma-arc furnace could be the most cost effective solution for the processing of around 10 000 t/a of EAF dust. Treatment and landfilling charges per ton of EAF dust, to be paid by steelworks, currently range from R200 to R300 in Western Europe and in the United States fees of over R500 have been reported. On-site treatment of EAF dust containing more than 15 per cent zinc is believed to be economic when metallic zinc is produced directly from the dust, using a condenser with a satisfactory zinc recovery of greater than 80 per cent. Upgrading of the dust to a high-zinc dust (50 to 60 per cent zinc), and selling this dust to a zinc producer or reducing it once again to form metallic zinc is usually prohibitive for the economic on-site processing of this low grade material.

A preliminary economic analysis of the Enviroplas process was conducted to provide an estimate of costs and credits involved. A throughput of 18 000 t/a EAF dust was selected as the basis for the cost estimate. The following assumptions were made:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Assumption</th>
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</thead>
<tbody>
<tr>
<td>Zinc content of dust</td>
<td>20%</td>
</tr>
<tr>
<td>Thermal efficiency of furnace</td>
<td>70%</td>
</tr>
<tr>
<td>Zinc condensing efficiency</td>
<td>90%</td>
</tr>
<tr>
<td>Operating availability</td>
<td>85% (7446 h/a)</td>
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<tr>
<td>Zinc, market price</td>
<td>R4000/t</td>
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<td>Electricity, unit cost</td>
<td>R95/MWh</td>
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<td>Electrode, unit cost</td>
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<tr>
<td>Electrode consumption</td>
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<tr>
<td>Metallurgical coke, unit price</td>
<td>R230/t</td>
</tr>
</tbody>
</table>

The theoretical energy requirement for the selective reduction (reduction of the zinc and lead oxides and minimal reduction of iron oxide) of EAF dust containing 20 per cent zinc is about 0,8 MWh per ton dust. The furnace needs to be operated at a power level of 3 MW with a feed rate of about 2,5 t of dust per hour. The estimated outside diameter and overall height of the furnace are 3,5 m and 3,8 m respectively. The capital costs for an on-site plant to treat 18 000 t/a of EAF dust were calculated at Rm 12. The main items involved in this cost figure were the plasma-arc furnace, a lead splash condenser and bag filter, a feed system, product handling equipment, buildings, utilities and instrumentation. It is emphasized here that to date only pilot-plant work on the 500 kW level has been carried out at Mintek, in which zinc vapours have been combusted to a zinc-oxide fume and collected in a bag filter, i.e. the lead splash condenser part of the Enviroplas process to recover metallic zinc directly, needs still to be demonstrated.

- 10 -
The operating costs (capital recovery excluded) for a 18 000 t/a plant are estimated at R320 per ton of dust processed. The operating costs are based on pilot-plant test experience and thermodynamic simulations of the process. The major components are electricity and labour (6-man shift) at about 40 and 30 per cent of the operating costs respectively. Other operating costs include metallurgical coke, refractories, graphite electrodes, auxiliary power and maintenance. Credits were computed at R540 per ton of dust, indicating a gross profit of R220 per ton of dust treated. For the calculation of these credits, the zinc/lead product was given a value based on the current market price of zinc, reduced by 25 per cent to take the removal of troublesome impurities into account. It should be emphasized that the overall economics are extremely sensitive to the zinc content of the dust, the market value of zinc, electricity and labour costs, and plant capacity.

A similar economic evaluation on the treatment of a typical alloy-steel dust (containing 12 per cent chromium and 5 per cent nickel) indicated capital costs of around Rm10 for a 3 MW facility, capable of treating about 10 000 t/a of alloy-steel dust. Operating costs and credits were estimated at R470 and R1000 respectively per ton of dust, giving a gross profit of R530 per ton of dust treated. Standard ferro-alloy prices, discounted by 25 per cent, were used for the calculation of credits for the metal product. The assumed recoveries of chromium and nickel were 90 and 95 per cent respectively.

It appears from this preliminary cost analysis that the proposed plants for EAF dust and alloy-dust are profitable, even without considering the avoided disposal costs. However, the given cost figures should not be generalized but specific cost studies are required for individual steel companies to determine the profitability of an Enviroplas process for dust treatment. Discussions have already been initiated with several steel companies to analyse the technical and financial aspects of on-site dust treatment plants and larger-scale centralized facilities, serving a number of steelworks. A technical proposal, a budget price and a preliminary financial analysis are provided.

6 FURTHER TECHNICAL DEVELOPMENTS

Further technical developments of the Enviroplas process are required, particularly in the area of zinc condensing. Following detailed discussions with both the suppliers and users of zinc condensers, it became evident that the combination of a Mintek d.c. plasma-arc furnace and an ISP-type lead splash condenser should justify the further development of this new technology as a cost effective alternative to existing processes for the treatment of steel-plant dusts. Since dust carry-over to the condenser and kinetic phenomena such as the back reaction of zinc with CO\textsubscript{2} cannot be modelled accurately, it is necessary to conduct demonstration-scale testwork to prove the perceived benefits that can be attained by linking
two established unit operations. Mintek’s steel-plant dust program is at present focused on the design and installation of a demonstration-scale plant, including a lead splash condenser, to effect progress towards the refining of process economics and ultimately to achieve commercialization.

7 CONCLUSIONS

Steel-plant dusts are listed by the Environmental Protection Agency (EPA) as hazardous waste materials because they contain toxic constituents such as lead, cadmium and hexavalent chromium. A number of thermal processing technologies exist and new ones are being developed for the treatment of steel-plant dusts. In the Enviroplas process fine dusts are charged directly to a plasma-arc furnace via the central hole of a graphite electrode. Disposable slags are produced and at the same time valuable by-products, such as ferro-alloys containing chromium and nickel, and fumes high in zinc oxide are recovered. At present Mintek is developing the Enviroplas further to recover metallic zinc directly in a lead splash condenser and so to provide a cost-effective alternative process for the treatment of steel-plant dusts.

8 ACKNOWLEDGEMENT

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9 REFERENCES


Figure 1. Predicted mass and energy balance for high-zinc EAF dust

Figure 2. Predicted effect of carbon addition on zinc and iron extraction for high-zinc EAF dust
Figure 3. Predicted effect of carbon addition on energy requirement and gas composition for high-zinc EAF dust

Figure 4. Predicted effect of carbon addition on metal production and slag composition for high-zinc EAF dust
Figure 5. Temperature of back-reaction of zinc with \( \text{CO}_2 \) at different \( \text{CO}/\text{CO}_2 \) ratios and zinc partial pressures in the off-gas.

Figure 6. Predicted mass and energy balance for alloy-steel dust.
Figure 7. Schematic diagram of the Mintek 1 MW plasma-arc furnace