

# Still no simple solution to processing EAF dust

For the past 22 years the steel industry in the USA has attempted to process EAF dust in an environmentally friendly way, but generally without success. The question remains why this lack of success and why did older technology provide better results than new processes?

By **Larry M Southwick\***

IN THE USA, processing of electric arc furnace dust has been regulated since 1988. Although several facilities were in compliance at the beginning of this period, the regulations were structured to encourage investment in new metals' recovery technologies and to avoid landfilling. In the past 22 years, virtually every new process has failed. Those that were successful either used old technology or were built by the original processor, Horsehead. This article will explain how such an unusually high failure rate occurred. The review is limited to US facilities because of the unique business and regulatory conditions there, and the dust processing industry has had to succeed on the basis of economics. The primary remaining process is the Waelz kiln, with which the industry started.

Why an almost unbroken string of failures with the new processes? Why did the old established process win out even given the regulatory preferences for the new processes? Reasons include finances, regulations, competition, inadequate planning and technical factors. In the early years many new processes were preferred by regulators, but who almost always demonstrated poor technical judgment.

Financial factors included difficulties in funding, a changing business environment and inadequate resources for proper development or to handle difficult startups. Regulatory issues included changes limiting entry and byproduct regulations. Competition factors included existing competitors, ignorance of steel company requirements and misjudging market conditions. Project planning was incomplete, overly optimistic and did not allow enough time for resolving operational problems. Each country had their own regulations, some focused on penalties and liabilities for infractions (the US) and others were similarly restricted as to practices, but innovation was easier (as in Europe and Asia).

However, most failures were rooted in inadequate attention to technical details and poorly conducted development, testing, design and startup. A modicum of success during superfi-



**FASTMET plant at Kobe Steel's Kakogawa Works to treat steelmaking dusts**

cial testing of the primary concept was automatically assumed to lead to financial success with commercial facilities. Science and economics were seemingly expected to meekly and dutifully conform to environmental goals. In short, the failures were mostly 'man-made'.

## Same problems

Such development problems are not new. As was noted more than 100 years ago under the heading 'Adoption of a New Process' in the 11 March, 1905 issue of the *Daily Mining Record* (Denver, Colorado):

'When new metallurgical processes are introduced on a commercial scale, it is important all the details be worked out by the inventor before making an expensive installation; but this, unfortunately, is not always done. In such an event, the company's plant becomes a school for experiment, not only for the perfection of the chemistry of the process, but also for evolution of a satisfactory and economical means to apply it.

Often, the estimated expense runs far in excess of the amount believed to be sufficient, and for this reason ample funds should be available, or all that that has been done may be lost.

Sometimes it occurs that after a plant has been installed its defects are realised, and it is seen that had a different course been pursued, success might have resulted; but the funds are exhausted and the process is condemned, when a more fortunate application of the ideas

might have brought success. In some instances the chemistry of a new process has been fully settled, but the details of the mechanical portion have not been given sufficient consideration. The engineer engaged to review the proposed installation fails to dis-

cover this important fact until too late.'

In short either:

- the development programme was cut short;
- design and installation were faulty;
- startup and operations (and available funds) could not overcome the first two; and
- examples of prior art were not properly noted or evaluated.

Usually, prior art proved to be negative examples of the technology - proof rather than the process or equipment application would not work.

Complicating the issues with EAF dust were bureaucrats defining the science used to determine hazardous waste definitions, characterisations, treatment and legal liability. Consequently, in-depth generation of test results and their analysis, investigation of anomalies and operating limits or potential bottlenecks, and hands-on familiarity with equipment were considered unnecessary.

Buying into the pseudo-science and bureaucratic basis of many regulations could reflect a

mindset incompatible with scientific methods. Also missing were aspects such as thorough execution, engineering and metallurgical skills, acuity and integrity, actual equipment behaviour and financial reality. Unfortunately, university training also seemed to encourage these attitudes. Such deficiencies can be remedied by developers and designers having actual operating experience. Sadly, many of the attempts with dust treating technologies involved companies with little

commercial experience in processing plants.

The following review covers commercial-sized examples of dust treatment projects. A few successes are noted, but most have not been commercially viable.

The primary technology areas explored here

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## Abbreviations

RHF - Rotary Hearth Furnace  
EPA - Environmental Protection Agency  
HTMR - High Temperature Metals Recovery  
SAF - Submerged Arc Furnace  
CZO - Crude Zinc-Oxide  
DRI - Direct Reduced Iron

## Environment

are glassification, hydrometallurgy and pyrometallurgy. The full presentation at the August 2009 MetSoc meeting in Sudbury, Ontario, Canada provides extensive details on these plants and others around the world. The criteria for success here emphasises commercial viability, which helps focus and complete the analysis.

### Classification

Two plants glassifying dust were built in the early 1990s: Inorganic Recycling (Nucor, Hickman, AK) and Glassification International (Oregon Steel, Portland, OR). In general they produced an abrasive frit. The former used a typical glass furnace, which did not provide the mixing required to complete the chemistry and thoroughly fix lead in the feed materials (primarily dust and sand). The latter used induction heated crucibles, which also did not provide good mixing. Both suffered from the sensitive chemistry of glassification and variable dust compositions. The second also contaminated a frit user's site and personnel.

A recent example is International Melting and Manufacturing (La Porte, IN). This started up in 2008, using a new furnace design with improved mixing. However, there has been little information published on this plant so its success remains unknown. It would still have to deal with variable dust chemistry, as well as plant design and startup issues. Another example, Richland Molded Brick (Mansfield, OH), operated successfully making architectural bricks from the dust. But its normal brick was highly profitable, so they stopped processing dust.

### Hydrometallurgy

Much of the zinc in EAF dust is tied up as ferrites,  $\text{Fe}_2\text{O}_3$ ,  $\text{ZnO}$ . Ferrites do not break down with normal solvents, so an initial reduction roast is common practice. Unfortunately, most hydromet technology developers did not do sufficient homework to learn this. Metals Recycling, using ammonium chloride as a solvent and precipitating high purity zinc oxide fell into this trap, their first plant at Nucor - Darlington, SC failing. Their second plant at Florida Steel, Jackson, TN added a rotary hearth furnace (RHF) to deal with ferrites, but then the back end zinc oxide purification and precipitation step did not perform as required. Its shortcomings had been hidden by the lack of a roaster.

Ezinex, also using ammonium chloride, used electrowinning to recover zinc metal. Their plant in Italy benefited from a dust apparently low in ferrites (because it was collected in a wet scrubber, not a hot system), so recovery rates were good. Initial plans to build in the US included furnace pretreatment, but financing failed. Initial plans in Spain by Zincex for a sulphuric acid leach followed by solvent extraction did not include a furnace, nor did plans using the same technology begun by ZincOx for Ohio in the US. Current ZincOx plans for the US plant, now with an RHF, have collapsed since delays caused their partner to sell the dust supply contracts to a major competitor. They have however purchased the idled RHF at Rouge Steel in Michigan, which will provide a platform for future plans.

A couple of pressurised hydrochloric acid processes (which will break down the ferrites),

Terra Gaia and Cashman/American Metals Recovery, have been unable to attract full scale financing. The problems are the cost to pressurise a relatively low value dust up to operating conditions, the purity of precipitated oxide or the complications in electrowinning zinc metal. Insufficient financing has not allowed adequate development of these steps, though it has also prevented premature construction of speculative facilities.

### Pyrometallurgy

The primary successful process is the Waelz kiln, commercialised 80 years ago to process zinc oxide ores. In the USA Horsehead Industries (three plants and one under construction), Zinc Nacional (ZN, in Mexico) and Steel Dust Recycling (now owned by ZN) use this technology. The initial Environmental Protection Agency (EPA) regulations emphasised high temperature metals recovery (HTMR) technologies, but asked for new processes to be developed.

Those that were, and subsequent efforts, have led to failures, except in one case. Non-HTMR processes that the EPA directives flushed out have already been discussed.

The single continuing success with new processes was the flame reactor developed by Horsehead and installed at North Star Steel in Beaumont, TX. It fumes heavy metals, burning them to the oxides and produces an iron slag. While its economics may not be as compelling as Horsehead's Waelz kiln operations, it fits their markets and helps compete with ZN.

Another of the new plants, by Zia Industries (Caldwell, TX), uses a two-diameter rotary kiln. Operation was not satisfactory until petroleum coke was tried as a reductant. But by then a competitor had won away their clients. Philip Environmental also built a rotary kiln plant in Hamilton, Ontario, Canada which operated satisfactorily but was too small to be commercial. A tandem two-kiln plant was planned for Cardiff, Wales, UK but this was not a workable concept (oxidising kiln followed by reduction) and after a technical review was not built.

Three plants have used a plasma furnace - two with Tetronics (Nucor - Blytheville, AR, and Florida Steel - Jackson, TN), and the other at Plasmex, Houston. These suffered because they fumed zinc directly into splash condensers for metal recovery. Such operations were known to be problematic because of chlorides and feed dusts arriving with the zinc fumes, fogs and mists. Also, splash condensers are notoriously inefficient, usually requiring two or more in series. These negative examples were inadequately reviewed by design engineers and metallurgists. These furnaces also had serious slag bath containment problems and the DC plasmas were difficult to control.

Two proposed plants, Oxide Recycle at Lone Star Steel, Texas and Philip at Hamilton, ON with the Zinc Iron Plasma Process, were to use the plasma cupola manufactured by Westinghouse. In both cases any zinc fumed would have been condensed and collected within the cupola and recycled back down the shaft. The result was the formation of 'scaffolds' of agglomerated feed, condensed zinc, sticky zinc oxide and a unit

plugged, much like an iron blast furnace with a zinc feed. These projects were halted prior to construction.

There are ways to deal with the zinc condensation problem. These include feeding low-zinc dust (less than 2%), using large feed briquettes (as the Imperial Smelting process, and even larger ones of EAF dust in the OxiCup process in Germany), high top temperatures to keep the fumes above zinc condensation temperature (again, used by ISP), and providing gas withdrawal ducts to remove zinc fumes prior to condensation (as was tried in zinc industry retorts 100 years ago). Without these modifications, cupola or blast furnaces will not operate with EAF dust. Applying these changes unfortunately results in expensive operations. A new blast furnace outside the US is in the process of re-proving these axioms.

An Elkem submerged arc furnace (SAF) was built at Laclede Steel in Alton, IL. The plant had several problems (splash condenser, furnace cooling panel failures and burnout) and was taken over by Laclede and modified. Eliminating the splash condenser resulted in formation of high-quality crude zinc-oxide (CZO), but eventually there was a furnace failure and fire, terminating operation.

The pig iron - zinc oxide process, fuming CZO and making iron in a circular induction furnace, is trying to establish operability at their plant at Nucor in Blytheville, AK. Little information has come out of this operation, now almost two years old, so its success or lack of is unknown - though the dearth of information is a bad sign. Pilot plant operations noted 'refractory problems' and, based on the other examples cited herein, must surely be the case with the full scale plant. Induction furnaces are successfully applied to melting metal (as in casting or galvanizing operations), but these are relatively quiet baths compared to the cyclone of splashing and bubbling with dust fuming.

### Dust process

A rotary hearth plant built by AllMet at Nucor, Blytheville, AR, made a CZO and a highly metallised (~90%) direct reduced iron. The collected oxide was to be re-fumed in an electric furnace and zinc metal collected in a splash condenser. Feed was to be EAF dust and other mill iron wastes. Unfortunately, the feed and rotary hearth operation was trouble-prone, DRI was of poor quality and not highly metallised, collecting fumed CZO incurred operating problems, and the splash condenser was never operated. Poor development and design, inadequate startup staff and an unworkable concept were to blame.

### Stainless no comparison

This plant is just one example from many which have based their plans on the financially successful operation of the Inmetco stainless steel dust plant at Elmwood City, PA. That plant sends dust pelletised with reductant and a binder to a RHF; CZO is fumed off and sent to Horsehead and DRI goes to a SAF. In the SAF ferro-nickel and ferro-chrome are produced. Unfortunately, other developers missed the financial factors that Inmetco is able to charge five times or more for processing and its ferroalloy products bring five times what iron would bring and the iron is also being sold. Inmetco's SAF operates at 1450°C, 150-200°C cooler with ferroalloys than when making iron. So Inmetco still makes money,

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though its DRI quality is poor, resulting in considerable carbon boil. The SAF, while high maintenance, is not as bad as when making iron from poor DRI since it operates at lower temperatures.

Carbon steel dust cannot produce the same financials, whether making iron or not.

Interestingly, RHF technology has found wide application in Japan (and Korea plans to build units) to manufacture DRI from iron and steel waste oxides. Developers include Demag (RedSmelt), Maumee and Kobe (FASTMET), as well as improvements based on units operated by Nippon Steel. Feeds include up to 10-20% EAF dust.

However, economics, regulations, operating philosophies and disposal options differ in Japan from the US, so comparisons are difficult.

Five FASTMET plants are currently operating in Japan. The first to be built was at Kobe Steel Kakogawa works and can treat 14kt of dusts a year and the remaining four each have capacities of 190kt/y. Kobe Steel's development work on Fastmet led to the ITmk3 Process. The world's first commercial ITmk3 plant which began production in January in Hoyt Lakes, Minnesota in a joint venture between Steel Dynamics and Kobe Steel. While ITmk3 is a higher temperature process than Fastmet, forming iron nuggets rather than DRI, it uses most of the same mechanical design and operational features.

The commercial plant should provide addi-

tional operating data on the ITmk3 Process under US conditions. ITmk3 does not process EAF dust, using iron ore instead, but that is

not critical. What is critical is the unit's economics, energy requirements, product quality, yields and raw material consumption, as well as the mechanical design and operating features under US operating philosophies.

#### Homework

Established technology (Waelz kilns) succeeds as do some established zinc companies. None of

the new process developers and the EPA did their homework, they did not have sufficient industry experience to determine the viability of their technology, they did not allow a long and extensive enough development programme to resolve operational and design issues and that the new plants did not make sufficient allowance for startup problems and delays.

Why would such amateurs:

- plan to enter a complex and demanding market they are not familiar with;
- propose a technology about which they do not completely understand;
- build and begin operation without adequate preparation via testing and without sufficient staffing to deal with startup problems;
- have such complete disasters; and

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- be so completely clueless about their failures that they still try to build other similar plants, other developers choose the same processing concepts, and financial firms continue to support such questionable concepts?

One possible reason is that regulations for landfilling encouraged the steel industry to support new technology, even those with no hope of success. Following the initial string of failures in the mid 1990s, the EPA allowed relief from the processing monopoly, which their regulations and technology designs had induced.

Yet the root problem appears to be a developer's conviction that the environmental benefit from their technology trumps metallurgical science and good engineering. Even

stranger, a study published by the Swedish research organisation Mefos in 2000 determined that recycling of EAF dust was less environmentally friendly than landfilling.

In the US, for a period up until the last three years, landfilling held its own on an economic basis as well as provided a simple option to monopoly. Now, economics has begun to favour processing, which has become virtually the sole disposal method of choice. It means EPA's 22-year-goal of ending

landfilling of EAF dust is nearing realisation but it is not through their own contribution or on the part of their science and technology 'expertise'. n