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# Project Summary

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# Recycling of Electric Arc Furnace Dust: Jorgensen Steel Facility

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**The Ek Glassification™* process was evaluated under the Waste Reduction Innovative Technology Evaluation (WRITE) Program, a formal program established by the United States Environmental Protection Agency (EPA) to accelerate the development of new and innovative technologies used to recycle or reduce waste and pollution. The process has potential to effectively reduce hazardous waste generated in the steel-making industry (K061-listed waste, defined as "emission control dust/ sludge from the primary production of steel in electric furnaces," 40 CFR 261.32) by recycling Electric Arc Furnace (EAF) dust and converting it into usable products.**

**An economic assessment was made of applying this process to a plant producing approximately 21,000 tons of product/yr. These estimates indicate that a profitable operation is possible. Products range from $2/ton (Portland cement materials) to $650/ton (glass ceramics/ architectual tile feedstocks).**

**Air emissions and process wastewater were not analyzed for this test. For full scale applications these may need to be investigated under actual operating conditions.**

***This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

## Introduction

The steel-making industry produces a large amount of Electric Arc Furnace (EAF) dust as part of normal production. A glass technology called Ek Glassification™ (hereafter called "the Process") has been developed by Roger B. Ek and Associates, Inc. (hereafter called "the Developer") to recycle this listed waste (K061) and convert it, along with other byproducts of the steel-making industry (i.e., spent steel slags, spent refractories, mill scale, and grinding swarf), into marketable commodities that are defined as nonleachable by Toxicity Characteristic Leaching Procedure (TCLP) protocols. These products may include colored glass and glass-ceramics; ceramic glazes, colorants, and fillers; roofing granules and sand-blasting grit; and materials for Portland cement production.

For this project, a portable pilot-scale process furnace was utilized (see Figure 1). Natural gas burners were used to heat the furnace to its operating temperature of approximately 2,500˚F. The furnace was also equipped with molybdenum metal electrodes for partial or complete electric heating. The use of natural gas results in volatilized metal emissions whose levels are regulated. Electrical resistance heating using electrodes is the preferred method of supplying heat to the furnace once the glass has become molten. This is because of better heat transfer between the electrodes and the melt and because no additional volume of pollutants are gen-

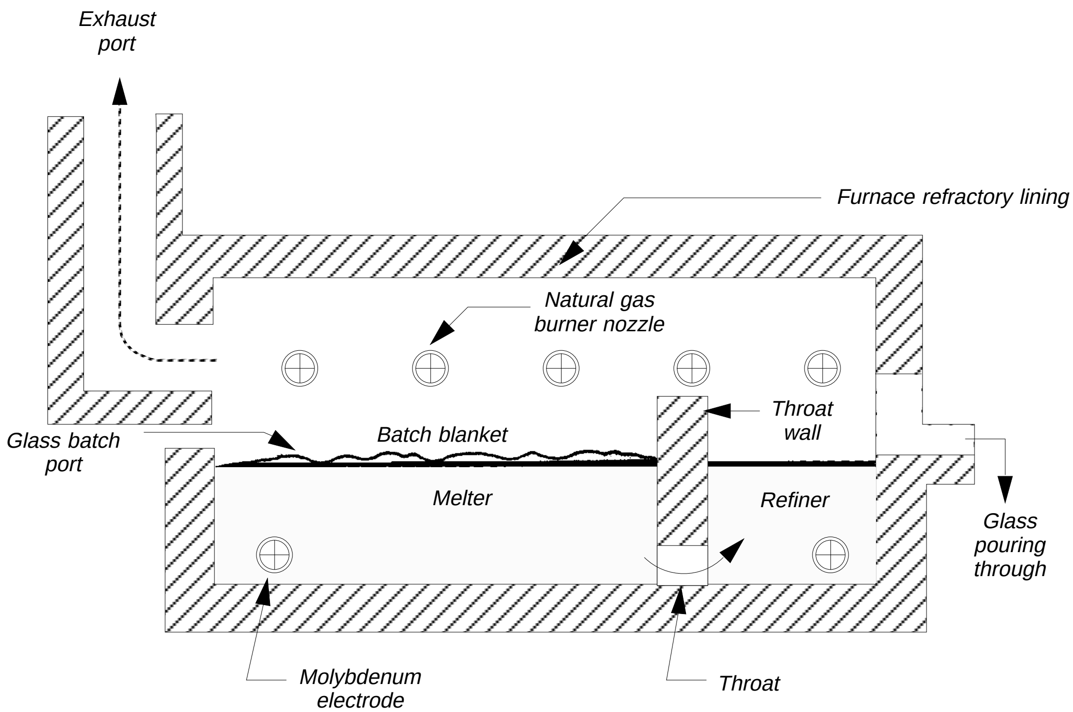


***Figure 1.*** *Ek Glassification™ test furnace for EAF dust.*

erated by the addition of air and fuel and the associated products of combustion that may sweep volatile metals out of the exhaust port. Additionally, the heating takes place below an insulating blanket of cool feed material that retains/recondenses volatile metals.

The glass batch, consisting of the mixture of glass forming ingredients, EAF dust and other steel mill waste products, forms an insulating blanket on the surface of the melted glass in the melter section of the furnace. As the level of melted glass rises in the melter, the molten product flows into the refiner section through a port in the throat wall. The melted glass can then be ladled out or allowed to exit via the pouring trough. For this test, both ladling and pouring were utilized, the latter enhanced by elevating the feed end of the furnace. Glass was dispensed either into molds to form castable products or into a granulator (water quench) to form granular products. Once ladling or pouring was complete, the furnace was refilled with glass batch and the process was repeated.

## Procedure

The goal of this project was to evaluate the effectiveness of the Process in generating a nonleachable product from K061-listed waste. Testing was performed at the Earle M. Jorgensen Steel Co. (EMJ), from July 8 to 10, 1991. Three glass recipes were designed for use at EMJ, identified as Glass I, II and III. The EPA test program focused on recipe II.

Due to the scope of the effort, the EPA work was restricted to the collection of two duplicate samples from each of the solid products for the Glass II recipe (granular and castable). A split of each sample was also taken and given to the Developer. These samples were subjected to TCLP and analyzed for the eight RCRA metals plus zinc, since the leachability characteristic of the metals in the final product is the critical parameter that determines if the product meets treatment standards for K061-listed wastes. The samples analyzed as part of the EPA program were compared with the analyses of split samples taken for the Developer. The complementary sampling and analysis conducted by EPA was to compare the Developer's analytical results for (TCLP) with that of an independent laboratory and to obtain a "snap-shot" of the process in operation at the facility. Sampling of the stack gas for metals emissions was not implemented during these tests.

Stack gas sampling data were gathered by Horizon Engineering during earlier, independent tests of the system conducted at Oregon Steel Mills, Inc. (OSM). These data, however, were not suitable for projecting full scale performance at EMJ or for generalizing about regulatory compliance issues for other applications of this technology. Process quench water generated during the granulation procedure was also not characterized during this test.

The Developer's sampling program consisted of the sampling and analysis of all three glass recipes and included the batch feed, the glass products (castable and granular), and other manufactured products made from the glass produced during the tests. These products included glass ceramic, tile glaze, and three varieties of brick glaze. Process monitoring was conducted throughout the tests by the Developer.

Representatives of EMJ supplied samples of feed materials for all of the tests. The EAF dust sample was taken directly from the baghouse hopper.

Chemical analysis was performed on the feed materials to serve as a basis for mixing the three recipes. The feed materials used for the production of the glass included EAF dust, spent steel slags, spent refractories, bricks, mill scale, and grinding swarf.

All feed materials, with the exception the EAF dust, spent slag, and grinding swarf, required crushing and screening to reduce particle size to minus 10 mesh (U.S. sieve standard).

The crushed and screened materials were placed in steel drums and plastic pails, labeled, and covered. Weighing was performed on a 3 $ft^2$ platform scale with a capacity of 5,000 lb.

Each ingredient for the 260-lb batch was weighed in a 5-gal plastic pail and added to a paddle mixer equipped with plow blades intended for dry mixing of refractory castables. The blender was covered and sealed to eliminate fugitive dust emissions. Blending was carried out for at least one minute in accordance with blender manufacturer's recommendations, followed by visual inspection for homogeneity. To avoid contamination of the blender with EAF dust, the dust componentwas hand-blended into the batch just prior to loading into the furnace.

The furnace was charged with a steel shovel. At the start of charging, particulate emissions were very noticeable in the furnace stack. However, once the glass batch covered the molten glass surface to a depth of about one inch, the visible emissions diminished rapidly.

The furnace was located in the steel-melting area of the EMJ plant so that fugitive emissions could be collected with the steel plant's dust collection system and routed to the baghouse.

Gas burners were used to bring the furnace up to operating temperature (2,400 to 2,500˚F). This operation required approximately 12 hr. Once the operating temperature was reached, the glass batch was added. Approximately 1-1/2 hr were required to load one batch. At the completion of loading the batch, electrode tests were conducted intermittently. The electric heating system utilized two commercial-sized, 1-1/4-in. diameter molybdenum electrodes. The testing used natural gas as the primary melt energy. The purpose of the electric melting tests was to establish melt conductivity, measure the amperage flow at constant voltage and select glass temperature isothermal conditions. These data were used to determine the specifications for transformer equipment (especially the operating voltage range) to be used in full-scale operations. The electrodes also provided heat to maintain the furnace temperature between 2,400 and 2,500˚F. Each batch produced about 250 to 300 lb of molten product. Approximately 30 min were required to ladle the glass into moulds. At the end of the day, the furnace temperature was dropped slightly and maintained between 2,200 and 2,300˚F during the night.

The Glass II recipe was sampled and analyzed as part of the EPA testing activities. This recipe was used to prepare glaze, iron silicate for Portland cement production and sandblasting grit. For the castable product, the glass was poured into a 6-in. diameter disc mold to a depth of approximately 2 in. and allowed to cool into a solid monolith. For the granular product, the molten glass was quenched with water as it was poured into a storage vessel. Quenching of the molten glass produced a granular material known as "frit."

Duplicate samples of both a castable product and a granular product were collected at the end of the day of testing. For the castable product, the solid monolith was fractured into small pieces (no greater than 1 in. in diameter) by placing the monolith of glass on a hard surface and striking the disk with a heavy object. Samples obtained were split for analysis by both EPA's laboratory (NET Pacific, Inc.) and the Developer's laboratory (Sound Analytical Services, Inc.) and placed in 1-L glass jars.

For the case of the granular product, the complete batch of product was manually homogenized using a drum and stainless steel trowel. Representative aliquots were then obtained from various random locations within the drum, split for analysis by the two laboratories, and placed into 1-L glass jars.

Process monitoring and furnace operating parameter data were gathered by the Developer. The primary granular, and a composite of the castable samples were subjected to the TCLP in accordance with SW-846 Method 1311 and subsequently analyzed for eight RCRA metals plus zinc.

## Results and Discussion

Samples analyzed by NET Pacific for EPA indicated low leachability characteristics for metals in the final products as shown in Table 1. The leachable metal content in both the castable and the granular samples was within the TCLP limits for all compounds for which they were analyzed. Barium, chromium, lead, and zinc were the only compounds detected in either of the EPA samples. Comparison of these data to those obtained by Sound Analytical Services, Inc. (see Table 1) produced similar results (for the granular product only) even though the Developer's laboratory could not achieve the same detection limits as the EPA laboratory.

TCLP analyses were performed on Glasses I and III by the Developer's laboratory. The results of these analyses indicated that the products are within the TCLP leaching maximums.

Stack gas sampling data were previously gathered during earlier tests at the Oregon Steel Mill (OSM). Although these data suggest acceptable air emissions, the data are of questionable quality because they do not satisfy EPA stack testing protocols and standards.

Cost estimates were performed for the OSM plant. A full-scale system producing 60 tons of glass/day, and operating 350

***Table 1.*** *TCLP Results and Comparison to Regulatory Limits for Samples from EMJ*

| *EPA HW No.*[1] | *Contaminant* | *EPA Castable Sample*[2] *(mg/L)* | *EPA Granular Sample*[2] *(mg/L)* | *Developer Granular Sample (mg/L)* | *Regulatory Level*[3] *(mg/L)* |
|---|---|---|---|---|---|
| D004 | Arsenic | <0.0025 | <0.0025 | <0.2 | 5.0 |
| D005 | Barium | 0.043 | 0.025 | <0.1 | 100.0 |
| D006 | Cadmium | <0.0035 | <0.0035 | <0.1 | 1.0 |
| D007 | Chromium | 0.050 | 0.13 | 0.1 | 5.0 |
| D008 | Lead | 0.067 | 0.120 | <0.1 | 5.0 |
| D009 | Mercury | <0.000086 | <0.000086 | <0.002 | 0.2 |
| D010 | Selenium | <0.001 | <0.001 | <0.3 | 1.0 |
| D011 | Silver | <0.0092 | <0.0092 | <0.1 | 5.0 |
| —— | Zinc | 0.95 | 0.60 | 0.6 | NR |

*1 Hazardous Waste Number*
*2 Average of duplicate samples*
*3 Regulatory levels taken from 40 CFR ch. 1 (7-1-90 Edition), Section 261.24, Table 1*
*NR Not Regulated*

days/yr would require an initial cost of $10,500,000 for design, construction and start up.

For a 10 yr period, the Process could produce a gross profit of $63,195,000 while avoiding $43,040,000 in disposal costs, for a total savings of $106 million, not including reduced liability benefits, and avoidance of administrative costs for permits and managing of hazardous waste under the old system.

The actual savings realized will depend on the types and amounts of products sold (at present market conditions, the lowest value products are cement additives at $2 to $6/ton. The highest value products, such as glass ceramics and architectural tiles sell from $175 to $650/ton.

## Conclusions

A number of conclusions may be drawn regarding the Process as a result of this study:

- The glass product types which were prepared by the Process and tested as part of this study resulted in relatively non-leachable glasses. For the metals of interest for K061 waste (calcium, chromium, and lead), these values were lower than those allowed under RCRA regulations for TCLP.

- The Process utilizes other (non-listed) foundry wastes to replace constituents that would be purchased as virgin additives for glass-making. Ideally this results in both a conservation of resources and recycling of both hazardous and non-hazardous wastes at the foundry.

- This project did not focus on investigating compliance issues in terms of air emissions and waste water generated during batch charging, melting, quenching and drying of the three glass products. It is believed that significant variation in emission species and concentrations are possible, due to the specific application and associated operational procedures.

Compliance issues should be evaluated on a case-by-case basis at least until full-scale data are accumulated to better identify the variability associated with applying this technology.

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***Ivars Licis** is the EPA Project Officer (see below).*
*The complete report, entitled "Recycling of Electric Arc Furnace Dust: Jorgensen Steel Facility," (Order No. PB95-167219; Cost: $19.50, subject to change) will be available only from:*
*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*
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