Production of Recycled Products from Coal Ash Using a Plasma Enhanced Melter™

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ABSTRACT:

Integrated Environmental Technologies, LLC, (IET) has developed the technology to recycle coal ash into valuable resources using the Plasma Enhance Melter™ (PEM™) for treating and vitrifying the ash. Coal ash, containing primarily inorganic residues can be converted into glass in the high temperature, plasma environment of the PEM™. By suitably modifying the glass matrix, the molten glass can be used for the production of glass based products. The PEM™ uses a DC plasma to gasify any residual carbon and melt the ash.

Products produced include high quality grit blasting media, low density aggregate, roofing tiles, brick and block. The recycle concept uses the coarse fraction of the crushed glass for grit blasting media and the fine fraction for forming the low density, foam glass products. While the glass density is normally in the range of 2.5 to 2.8 g/cm^3, the density of the foam glass tiles and brick can be adjusted to between 0.4 to 1.0 g/cm^3 depending upon the material strength required. This paper discusses some of the key considerations relative to this recycle concept.

INTRODUCTION

The Plasma Enhance Melter™ (PEM™) has been developed by IET to provide an environmentally friendly method for processing waste and to recover by-product materials where practical. The technology has the ability to process nearly any waste and recycle virtually all of the effluent streams. Regulations such as the RCRA "derived from rule"[i] and the presence of radioactive materials in the glass necessitate exceptions to the recycling concept. The PEM™ has been applied commercially to waste applications including medical, hazardous, and nuclear waste streams. In addition, the technology has been applied in the laboratory to other waste application such as the gasification of coal and the recycle of coal ash to produce glass products and eliminate any risks of leaching contaminants into groundwater. This paper focuses on the coal ash recycle portion of the IET efforts.

DESCRIPTION OF THE TECHNOLOGY

The PEM™ is a DC plasma-based chemical reactor where waste materials are gasified or melted. At the high temperatures associated with the plasma, organic materials are reacted with steam to produce carbon monoxide and hydrogen – a syngas. The syngas is processed through a gas cleaning train and used to power a generator. A schematic of the PEM™ process vessel is shown in Figure 1. A simplified process flow diagram for a PEM™ system is shown in Figure 2.

The PEM™ can be used to process solid or liquid wastes with suitable feed preparation. For coal ash, little preparation is required as it is already a relatively small sized material that can be augered directly into the PEM™. If the ash contains substantial moisture, a gas dryer unit operation before the melter could used to removel excess water. The dryer can be heated using syngas from the PEM™ or from the generator exhaust waste heat recovery depending upon the moisture content. Recycled products are manufactured in subsequent operations as conceptually illustrated in Figure 3. IET has developed a special formulation for a grit blasting media called E-Grit™ that has properties similar to garnet. Major attributes of E-Grit™

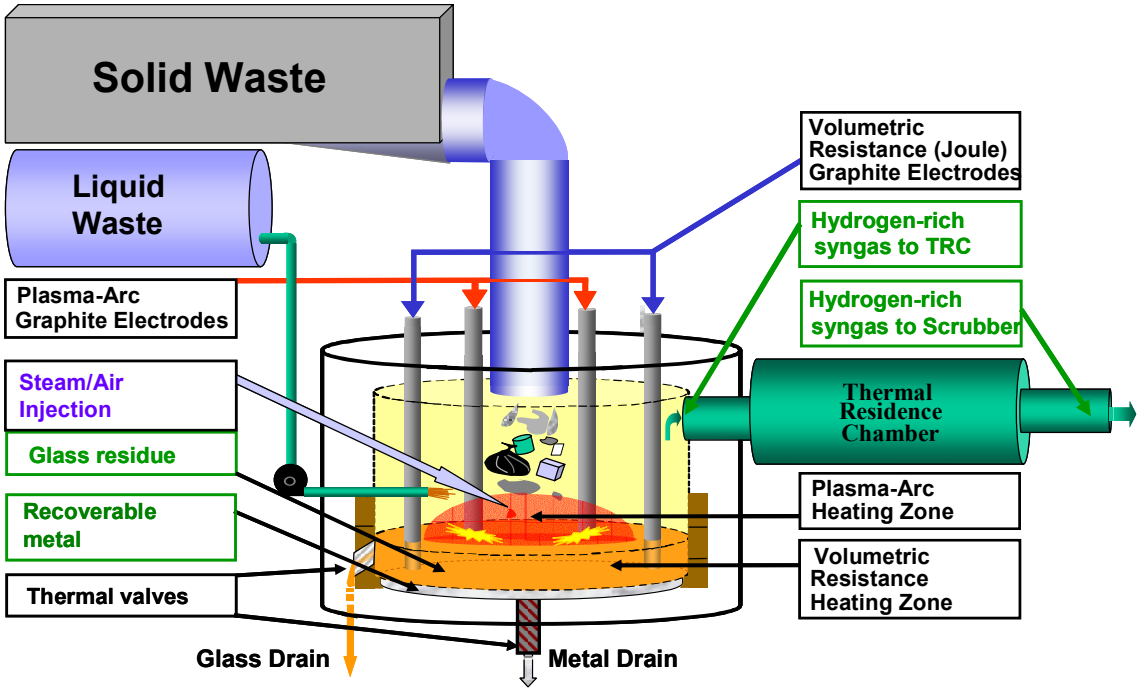

Figure 1. PEM™ Process Vessel Schematic Arrangement

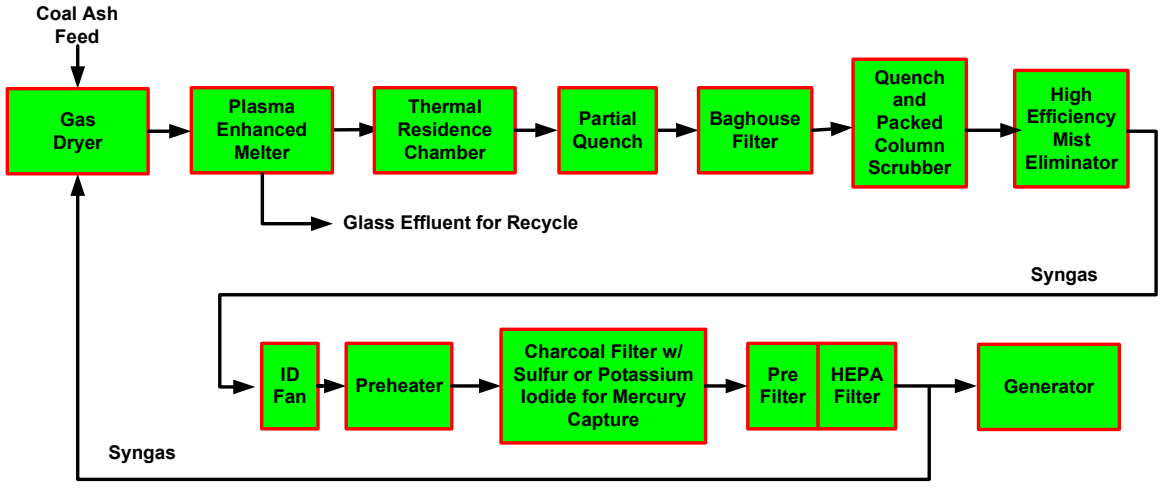

Figure 2. Simplified Process Flow Diagram for a Coal Ash Processing PEM™

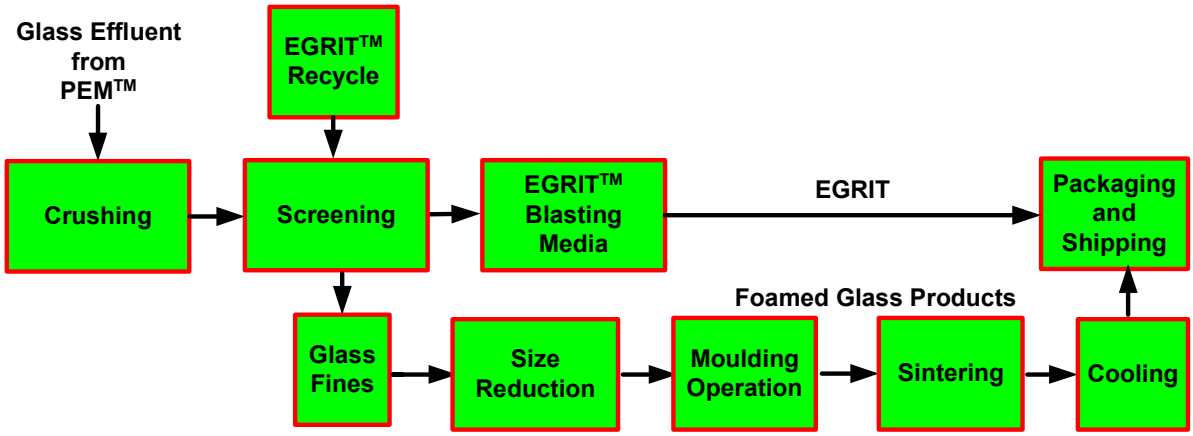

Figure 3. Simplified Process Flow Diagram for Recycled Glass Product Production of E-Grit™ and Other Foamed Glass Products

are provided in Table 1. To achieve the proper composition for the E-Grit™, appropriate additives are fed to the PEM™ along with the coal ash. Although the E-Grit™ composition is not critical, due to the variability in coal ash, some reasonable knowledge of the ash composition is needed to assure the quality of the final product. The same applies to foamed glass products.

Inherent in the crushing process is the generation of a fines fraction too small to be useful in grit blasting applications. This fines fraction can either be returned to the melter or, as shown in Figure 3, can be used in subsequent products. The glass fines are further size reduced and mixed with suitable additives, placed in moulds, and sintered into a low density, foamed glass product such as a brick, block, or roofing tile. Laboratory samples of such products are shown in Figure 4 along with a piece of uncrushed glass from the PEM™.

Table 1. EGRIT Physical Characteristics	
Color:	Dark gray to dark green depending on particle size range
Hardness:	Mohs 6-7
Particle Shape:	90% blocky or pyramidal
Odor:	None
Free Silica:	Fully vitrified with no detectable free silica
Recyclable:	Yes, product can be reused and when cutting is sufficiently slowed, it can be remelted and new material produced
Glass Density:	2.6 g/cm^3 or 163 lb/ft^3

ENVIRONMENTAL ADVANTAGES

Unless the coal ash is recycled, the fate of coal ash is disposal. In the disposal environment, trace metals in the ash can leach into groundwater. In contrast, when the ash is converted into glass products, any heavy metals are tied up in a leach resistant glass matrix. TCLP testing of glass containing concentrations of regulated heavy metals has always shown that the leaching characteristics are well below the regulatory limits of RCRA (40CRF268.48). While coal ash is not regulated as a hazardous material, the stabilization of the trace metals renders the recycled products very stable to leaching of trace contaminants. This is particularly important for recycle applications.

In addition, since sand has been outlawed in grit blasting operations in many states, the availability of a silica-free, low-cost material offers societal benefits compared to the disposal option. If the recycled E-Grit™ made from coal ash reduces mining impacts required for

generating other alternate materials, then it offers further environmental advantages. IET has produced E-Grit™ for evaluation by both grit users and manufacturers and hopes to be producing the material within the next year in commercial quantities.

ECONOMIC CONSIDERATIONS

Key to any recycle activity is the cost of recycling compared to the cost of alternatives. If disposal of a waste stream is the lowest cost option, that option establishes the maximum price for the recycle applications – i.e., the avoided cost. Regulatory requirements that dictate the disposal requirements directly affect the cost. For recycling of coal ash, since disposal is the current practice for most of the coal bottom ash generated, the recycle concepts in this paper must be feasible at the avoided cost of disposal or less plus the selling price of the product. For a 50 ton per day PEM™ system, the estimated cost of processing is about $160 per ton.

Figure 4. Glass Recycle Products from the PEM™ System

Glass Aggregate

The least expensive recycle product to produce is construction aggregate by crushing the glass to a suitable size. However, since natural aggregate is available in most areas for $10 to $15 per cubic yard, this product value will not support very much of the processing cost.

E-Grit™ Blasting Material

E-Grit™ is the next lowest cost material to produce. IET is working with a grit manufacturer and other users to determine a value for the E-Grit™. Its value depends on its overall effectiveness as a blasting medium compared to other higher quality materials on the market such a garnet and alumina. These evaluations are underway.

Blasting grit effectiveness is measured indirectly by such factors such as reusability (number of cycles before the material must be disposed), surface cleaning rate (this parameter effects the labor cost which usually dominates over all other costs), dusting (effects worker effectiveness and safety), and disposal issues. Some users ascribe value to materials that can be recycled as it reduces disposal cost and potential liability. A recent government contract award for Black Beauty as published in the Commerce Business Daily was at a price of $91 per ton. Black Beauty is a material made from coal slag directly with no chemical modification. More premium materials such as garnet and alumina are priced at $230 to $300/ton in large quantities. Consequently, if E-Grit™'s performance can be established to be similar to garnet and alumina, then it can be priced comparable to the premium products. However, unlike the other materials, it can be recycled as an alternative to disposal.

Brick, Block, and Roofing Tile

The more advanced building materials such as the brick and block shown in Figure 4, will command even higher values than the grit blasting media. Roofing tile, another product under development but not shown in Figure 4, is a major high value product used in residential and commercial construction. However, these

products must be produced in very large quantities to get the unit costs of production down to a level where they will favorably compete with current products. Consequently, the classic Catch 22 situation exists. The cost of a capital facility to produce large quantities of tiles or brick at low cost is very large. Thus, until there is a well developed demand, such an investment is unlikely. Until there are lots of products available for samples and construction demonstrations, the demand cannot be developed.

PERFORMANCE ADVANTAGES OF LOW DENSITY FOAM GLASS PRODUCTS

The primary performance advantage of the IET developed foam glass construction products will be in the weight savings. For example clay roofing tiles made by a major US manufacturer have a roof loading of between 8 to 9.9 lbs/ft^2 for standard clay products and 5.8 lb/ft^2 installed for lightweight clay products. Cement based tiles have weights in the range of 7 to 9.8 lb/ft^2 installed. Using a 10% weight adder to account for the weight of the overlap area[1], the IET low density flat glass tiles would range between 2 to 2.9 lb/ft^2 for 0.5 inch thickness. Feasibility tests are underway to assess the strength of 1 inch thick material having a density of 0.4 g/cm3. This would have comparable surface loading as the more complex shapes would weigh more but the weight advantage over other products is still clear. This comparison data is summarized in Table 2 along with retail prices where available.

Table 2. Weight and Cost[1] of Roofing Materials

Product	Manufacturer	Weight (lb/ft^2)	Retail Cost Range ($/ft^2)
No. 1 Heavy Cedar Shakes	Multiple	3	$1.80
Composition Shingle (40 year)	Owens Corning	3.0	$0.67
Cement Tile – Std Weight	Bartile	9.8	$0.87 to $1.1
Cement Tile -Ultralight	Bartile	6.95	$1.12 to $1.37
Light Weight Clay Tile	US Tile	5.8	$2.25 and up
Standard Clay Tile	US Tile	8.0 to 9.9	$2.25 and up
Foamed Glass Tile[2]	IET	2.0 to 2.9	TBD

1. Cost is approximate as some materials require special pieces for gable, edges, etc. which increase effective cost.
2. Optimum density and thickness have not yet been determined.

One of the factors besides design, color, and esthetic considerations affecting the choice of roofing materials is fire protection. This is where the concrete, clay, and IET glass materials excel as they consist of entirely inorganic materials. Another parameter that can be compared between materials is the thermal conductivity. While data are not available for all materials, with the lower density of the IET foam glass, a substantial advantage is expected here as well. With low thermal conductivity, the heating of the roofing materials below the tiles and the subsequent heating of the attic space will be reduced having a beneficial effect on the air conditioning load for the building.

Light weight brick and block materials may have application advantages in remodeling construction applications where the building structural design might not support convention higher density materials. Furthermore, in areas of the country where winters are severe, the added insulation value of low density bricks could prove attractive.

[1] Adds 10% extra weight to account for the required overlap area.

CONCLUSIONS

IET has developed the basic technology to process ash waste materials into useable products. Current efforts continue to evaluate options for large scale, economic manufacturing of the construction products. Performance data such as thermal conductivity, moisture absorption and mechanical strength are also being acquired. The cost of recycled goods is the cost of production minus the disposal cost alternative. With sufficient product value, coal ash recycle may be economically feasible. Large scale production is required to get production costs to be competitive with existing materials. If roofing tile can be made cost effectively using the IET foamed glass process, then the large weight savings associated with the low density product will offer a substantial advantage compared to other concrete and clay based tiles available today. The insulating value of low density brick may add additional value to the foamed glass brick compared to traditional clay materials.

REFERENCES

[i] 40CFR268 derived from rule.