Application of Microwave Solidification Technology to Radioactive Waste

RFP 5022
September 28, 1995

by
Michael Harris, Greg Sprenger, Bill Roushey, Greg Fenner and Ron Nieweg

KAISER • HILL
COMPANY
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
Application of Microwave Solidification Technology to Radioactive Waste

by

Michael Harris, Greg Sprenger, Bill Roushey, Greg Fenner and Ron Nieweg

Kaiser Hill Rocky Flats
P.O. Box 464
Golden, CO 80402-0464

ABSTRACT

The EPA has declared vitrification to be the Best Available Demonstrated Technology (BDAT) for High Level Radioactive Waste (40 CFR 268.42). Vitrification has been chosen as the method of choice for treating a number of radioactive residues and wastes in the DOE complex. Vitrification offers advantages of waste volume reduction, the ability to handle changing waste forms, and a stable, non leachable final waste form. Microwave heating is a superior method for vitrification of radioactive wastes. Advantages of microwave heating include: 1) direct waste heating, eliminates need for electrodes, refractories and other consumables; 2) "in-can" processing allows for treatment of the material in its final container; 3) a mechanically simple system where the microwaves are generated away from the treatment area and transmitted to the treatment applicator by a wave guide, thus minimizing worker exposure to radiation; 4) easier equipment maintenance; and 5) a high degree of public acceptance.

ADVANTAGES OF VITRIFICATION

There are several radioactive waste materials owned by DOE which will require processing to form stable, long lasting products which will be suitable for long term storage and/or disposal. Many of these materials are candidates for treatment by vitrification.

Vitrification is the process of converting materials into glass like substances. Basically the material to be vitrified is mixed with a silica source and other modifiers, if required, and heated to form a melt. The melt is cooled and the resulting vitrified material is in a glass or glass like form. The vitrified glass offers a number of advantages over other waste forms including: (EPA, 1992; Ritter, et.al., 1992; Bickford and Schumacher, 1995)

1) the waste glass produced is a very durable waste form with excellent mechanical and thermal stability,
2) the waste glass provides a large flexibility for incorporating a wide range of contaminants without a significant impact on the final quality of the glass,

3) vitrification can treat both inorganic and organic contaminants in varying amounts,

4) in many cases vitrification results in a volume reduction, thus reducing storage requirements and costs,

5) vitrification provides a well characterized waste form,

6) the vitrified material retains its essential release properties even if mechanically damaged

Many of the materials to be treated in the DOE complex are radioactive. With alpha-emitting materials the goal of waste treatment is to render small amounts of liquid or solid waste into small waste forms that are easy to handle and provide a high degree of contamination control. The waste glass produced by vitrification acts as a sealed source for these radioactive materials. One major advantage of vitrification is that it results in a reduction of the dispersibility of the radioactive constituents. (Bickford, 1994).

In addition, there are concerns over the potential for a criticality occurring while handling fissile materials. Here the advantage of vitrifying these materials is obvious. The formulation for the waste glass can be made to include neutron poisons such as $^{10}\text{B}$, thus eliminating the potential for a criticality. A glass containing a high concentration of neutron poisons could allow for higher loadings of Pu or other fissile materials which would result in a reduction of the overall volume to be stored. (Bickford, 1991).

Another significant advantage of vitrifying these materials is that there is often a large reduction in the volume of the final product, especially when compared to the cementation (stabilization) the current standard method for processing these materials.

The potential volume reduction is a result of a number of factors including: composition of the waste material, changes in density of the materials during processing, the addition of glass agents required for an acceptable product, vaporization of water and the combustion of organic material in the feed. Some waste materials may contain sufficient silica to form an acceptable vitrified product without the addition of other glass making agents. In these cases volume reductions can be upwards of 90 percent (EPA, 1992).

Jantzen, et. al. reported waste volume reduction results using surrogates for incinerator ash and incinerator blowdown wastes at Savannah River. Waste volume reduction of 96 and 97 percent (respectively) were reported when compared against the baseline cementation process.
ADVANTAGES OF MICROWAVE VITRIFICATION

There are a number of different technologies available for vitrifying wastes to form glass like materials. These include: Microwave heating, Joule heating, Plasma heating, resistance heating, induction heating, electric arc furnace, and rotary kiln incineration. Microwave heating offers several advantages compared to the others.

The main advantage to microwave heating is that the energy is delivered directly into the material to be melted and the resulting heat is produced directly in the mass of material being treated. This eliminates the need for electrodes, refractory liners and other ancillary equipment.

Heating rates can be higher than by conventional means, especially when the target material has a poor thermal conductivity. Furthermore, heat input can be stopped immediately even at the center of the target material whereas a time lag may occur when using conduction heating." (Morrell, et. al., 1986).

In addition, since the melting takes place in the storage container the viscosity of the melt is not a controlling factor. This means that the waste loadings in the glass can be greater thereby reducing volume and storage requirements.

The microwave heating system can be easily adapted to treat varying volumes of waste and variety of waste forms can be treated. The equipment is inexpensive, it is easily obtained and easy to maintain.

The microwaves are generated away from the treatment area and conducted to the process area through a wave guide. This produces several advantages. First the workers exposure to radiation is reduced. Secondly, the major portion of the equipment is protected from exposure to radioactive materials and thus the potential for contamination is significantly reduced. This is especially important in terms of equipment maintenance and replacement. Often in radioactive surroundings only limited decontamination is possible. Thus minor contamination may lead to the disposal of the entire equipment assembly (Bickford, 1991).

Finally, microwave heating has been a well established technique for a number of years. Millions of ovens are in domestic use. This leads to a high degree of public acceptance of the heating technology (Morrell, et. al., 1986).

ROCKY FLATS MICROWAVE SYSTEM FOR TREATING RADIOACTIVE MATERIALS

A schematic of the microwave system used for treating radioactive materials is shown in Figure 1. This system can be used to treat materials on a batch or continuous basis.
Processing capabilities range from approximately 200 to 2000 grams per hour. The basic components include: a 6kW, 2450 MHz Cober microwave generator, waveguides, tuner, resonant cavity, glovebox, turntable, screw feeder and stand alone chiller. The generator has a variable output of 0 to 6 kW of microwave energy. The wave guide is separated from the glovebox with a 1/4 inch thick teflon window. (Fenner, et.al., 1995). Only the applicator chamber is located inside the glove box. All of the other equipment is located outside the glove box where it is easily accessible for maintenance. In addition, this arrangement minimizes the possibility of the equipment becoming radioactively contaminated.

The batch treatment process is composed of the following steps. The waste material to be vitrified is weighed and mixed with a suitable amount of glass forming materials. The mix is placed into a container (metal can, ceramic crucible, etc.) and the container is wrapped with fiber insulation to minimize heat losses during processing. The insulated container is placed in the applicator, the applicator chamber is closed and the microwave generator is turned on. The rate of heating is controlled by the amount of microwave energy produced. Slow heating can be accomplished with a low (0.2-0.5 kW) energy input. More rapid heating can be accomplished with higher energy inputs. After the required temperature is reached the waste is held at that temperature for a specified period of time to insure thorough heating and adequate reaction time. The material is then allowed to cool, after which it is ready for final disposition.

**PROCESSING RESULTS**

Work is continuing at Rocky Flats on the vitrification of Pu containing materials. Results to date have been promising. Petersen (1989) reported results for a bench scale study on mixed transuranic (TRU)/hazardous waste sludge. In this study volume reductions, densities and waste loadings of 72%, 2.17 g/cc and 60% respectively, were achieved. Fenner, et. al., (1995) reported on the results of treating a TRU precipitation sludge. Results showed that for sludge to frit ratios of 40/60 and 50/50, the TCLP analyses were acceptable and met Department of Transportation (DOT) requirements and waste acceptance criteria (WAC) for land disposal. Finally, Krikorian, et. al. (1993), in a study conducted for Rocky Flats reported on plutonium volatility under microwave melting conditions. Assuming an operating temperature of 1200 degrees Celsius and a Pu sludge/glass feed to contain 0.0003% $^{239}$PuO$_2$, the resulting partial pressure of PuO$_2$(OH)$_2$ above the melt was calculated to be 8.2 X 10$^{-14}$ atms.

Other researchers have conducted studies with various radioactive materials. Komatsu, et.al. (1990), report on tests using $^{137}$Cs, $^{60}$Co, and $^{54}$Mn added to a surrogate incinerator ash. The material was treated in a microwave melter with a 6kW output at 2450 MHz. The results of this test work showed that all of the $^{60}$Co and $^{54}$Mn were retained in the final waste product. A portion of the $^{137}$Cs was volatilized. The volatility of the $^{137}$Cs could be reduced by the addition of B$_2$O$_3$. 
REFERENCES


Morrell, et.al. (1986), report the results of decontaminating high level radioactive liquids by microwave vitrification and capturing the radioactive components in a glass block. They report decontamination factors for gross alpha and beta as $1.0 \times 10^5$ and $3.0 \times 10^5$, showing that better than 99.99 percent of the activity was retained in the vitrified glass.

CONCLUSIONS

Vitrification is the preferred method for processing radioactive wastes to form stable, durable, end products suitable for long-term storage and or disposal. Microwave heating offers a number of advantages over other heating methods including: remote processing, direct heating of the waste, lower worker exposure, easier equipment maintenance and a high degree of public acceptance.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
Figure 1: Schematic Diagram of Microwave Treatment System