DEVELOPMENT OF PROCESS SYSTEMS

FOR RADIOACTIVE INCINERATOR ASH

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ABSTRACT

This paper summarizes the results of a pilot program performed to quantify the macroscopic properties of incinerator ash, identify appropriate ash collection and handling systems designed to interface with an extruder-based asphalt solidification system, and quantify volume reduction factors and other important characteristics of incinerator ash encapsulated in asphalt.

INTRODUCTION

Expectations of rapid increases in waste disposal costs have caused utilities to consider volume reduction alternatives for dry active wastes (DAW), e.g. contaminated clothing, plastics, blotter paper, wood, etc. This waste form accounts for an appreciable and growing fraction of the total amount of waste produced by the nuclear power industry. In particular, incineration of burnable DAW has received a great deal of attention for its potential to reduce DAW volumes by an order of magnitude or more beyond conventional compaction processes.

Unlike the combustible feed stock to the incinerator, the "solid" product of combustion, ash, is an extremely dispersible waste form and may not be allowed to be packaged without first being encapsulated in a binder. For this reason, the reliable transfer, feeding and encapsulation of radioactive incinerator ash is a highly important subject which has received limited attention in the literature (Ref. 1).

ASH CHARACTERIZATION

The physical properties of two different ash types were determined in this program and were used as a basis for selecting hardware for use in an ash handling system. Both ash products were produced with controlled air incinerators.

Ash A was obtained from an industrial incinerator in which non-radioactive waste products, consisting primarily of scrap wood, paper products, assorted plastics and other miscellaneous combustibles, were burned. This facility made no attempt to segregate noncombustibles such as scrap metal from their combustible trash.

This ash was a gray-white material which contained a substantial fraction of metal scrap and other noncombustibles. It was screened prior to testing to remove all large anomalous particles. In actual practice, large pieces of metal will be eliminated from incineration feeds by procedural control and X-ray of waste packages. Large particles resulting from combustion, i.e. clinkers, will either be retained on incinerator grates or will be crushed in clinker grinding equipment to prevent clogging of handling systems.

Ash B was obtained from Battelle Pacific Northwest Laboratories and was prepared as part of an NRC-sponsored program (Ref. 2) to investigate ash properties. This ash was prepared by burning a carefully prepared mixture of materials intended to simulate DAW plus ion exchange resins contaminated with corrosion products from the feed water cycle of a typical power plant. Ash B was a black ash which had been screened to remove large clinkers.

Each of the ash types was exposed to a series of conventional tests to evaluate various physical properties which are relevant to defining storage and flow characteristics of material when discharged from a bin. A list of the tests performed for both ash types is shown on Table I.

Results of these tests predicted that even though the physical appearance and bulk density of both ash types were quite dissimilar, the materials would behave similarly in handling systems. Both ashes were compressible to a degree which predicted non free-flowing behavior, resulting in a tendency to bridge in bulk storage bins. The "angle of repose", "angle of fall", and "angle of shear" measurements indicated that, while both materials do not flow well, neither do they exhibit an unusually high degree of cohesion which would make particles interlock to form clumps, etc. "Angle of slide" and "dynamic chute angle" measurements revealed that internal surfaces of non-agitated/vibrated bins and gravity chutes should be steep-sloped to ensure that the material will flow without leaving a significant residue.

In addition to the foregoing tests, samples of both ash types were exposed to air at high relative humidity to determine if the materials were hydroscopic. Measured moisture contents were low enough to indicate no propensity to absorb moisture which could have a significant effect on handling characteristics.

TABLE I

PHYSICAL CHARACTERISTICS EVALUATED
FOR EACH ASH TYPE

Apparent Bulk Density
Tap-Pac Density
Compressibility
Angle of Repose
Angle of Fall
Angle of Shear
Angle of Slide
Dynamic Chute Angle
Stickiness
Hydroscopicity

ASH COLLECTION/HANDLING SYSTEMS

The results of the aforementioned flow property tests were used to select "candidate" ash bin and feeder types for actual testing. Since the feed systems were to be used for handling radioactive ash in conjunction with an extruder-based asphalt solidification system, the following general performance criteria were established for the bins and feed devices. The ideal bulk accumulation/feed system has the following characteristics:

1. It is a static system with no or few moving parts;
2. It discharges reliably for a wide range of ash properties, i.e., material does not bind, bridge, etc.;
3. Its contents are completely isolated from the room in which it is located to eliminate airborne contamination due to dusting. Likewise it has few gasketed joints which are potential sources for leakage and contamination;
4. It can be completely emptied;
5. It can be easily decontaminated.

The following five volumetric feeder/bin combinations were tested:

1. Volumetric feeder with a double concentric auger feeder mechanism and a mechanically vibrated bin;
2. Volumetric feeder with a double concentric auger feeder mechanism and a nonvibrated large throat bin;
3. Volumetric live bin screw feeder with a single screw auger feeder and an offset-discharge live bin;
4. Volumetric live bottom bin screw feeder with a single screw auger feeder and a concentric discharge live bottom bin;
5. Twin screw feeder with a mechanically agitated/conditioned bin.

Bins

None of the bins tested exhibited all of the identified performance criteria. Reliable performance was obtained only from a live bottom bin and it is recommended that this design be selected for bulk accumulation of ash. Attention must be paid to proper selection and sealing of the flexible sleeve between the bin and the live bottom to minimize leakage potential.

Feeders

None of the feeders tested exhibited all of the desired performance criteria. Reliable performance was only achieved by the single and twin screw feeders with mechanical conditioning/agitating devices in the feeder throat. It was found, due to the variable bulk density of the ash, that gravimetric feeding is required to achieve the feed precision required by an extruder process.

ASPHALT ENCAPSULATED ASH PRODUCT CHARACTERISTICS

Using a pilot scale ash feed system similar to that identified in the aforementioned hardware selection program, both ash types were solidified in asphalt. Ash A was encapsulated in an asphalt binder by means of a Werner & Pfleiderer ZSK-53 twin-screw compounding extruder. Seven different waste-to-asphalt loadings (ratios) were examined, from 10 weight percent ash to 70 weight percent ash in 10% increments. Table II presents volume reduction factors and product bulk density data for each waste ash loading. The volume reduction factors reported are simply the ratio of the volume of the original ash to that of the asphalt encapsulated ash. For products with ash loadings in excess of ~ 35%, there is a net reduction in volume over that which would be occupied by an equivalent amount of ash. At a 70 wt% loading, the volume reduction factor is equal to 2.69. A 70% ash loading is judged to be the upper loading limit based on the fluidity of the product.

TABLE II

ASPHALT ENCAPSULATED ASH CHARACTERISTICS
VOLUME REDUCTION FACTORS AND BULK DENSITIES (ASH A)

Ash Loading (a)	Volume Reduction Factor (b)	Product Specific Gravity/Weight (----/lb/ft^3)
10/90	(0.23)	1.09/ 68.02
20/80	(0.49)	1.17/ 73.00
30/70	(0.82)	1.28/ 79.87
40/60	1.16	1.39/ 86.74
50/50	1.54	1.54/ 96.10
60/40	2.06	1.67/ 104.21
70/30	2.69	1.85/ 115.44

(a) Ratio of ash-to-asphalt by weight.
(b) Volume of ash/volume of product containing the same amount of ash.

Ash B was similarly encapsulated in asphalt for Battelle PNL as part of their NRC-sponsored program. Most of the Battelle ash was encapsulated at a prescribed 40 wt% ash loading. Some samples with higher loadings (up to 65% ash) were produced. Volume reduction factors, etc. were not calculated for Ash B; however, the consistency and physical appearance of products at equivalent ash loadings were virtually identical.

CONCLUSIONS

- Incinerator ash was found to exhibit a high degree of compressibility which can lead to bridging and hangup in static bins. The use of a live bottom bin is recommended to ensure reliable flow/discharge.
- Due to variable bulk density and compressibility, the use of gravimetric screw feeders is recommended for ash metering applications.
- Volume reduction factors for incinerator ash encapsulated in asphalt range from 1.5 to 2.7 for waste solids loadings in the range of 50 to 70 percent.

References

1. Development of Techniques for Radwaste Systems in CANDU Power Stations; W. T. Bourns, et al, Atomic Energy of Canada Research Company.
2. Incineration of a Typical LWR Combustible Waste and Analysis of the Resulting Ash; R. L. Treat et al, Battelle Pacific Northwest Laboratory for USNRC, Division of Health, Siting and Waste Management.