SPENT RESIN INCINERATION:
SHOULD RADIOACTIVITY PRECLUDE IT?

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ABSTRACT

The application of advanced volume reduction (VR) by incineration to spent resins and other power plant wet solid wastes has not become fully evident. The economic advantages of incineration of wet solid waste have been overshadowed by concerns with licensing and operation, and the resultant VR product. The objective of this paper is to provide an industry-wide perspective of the wet solid wastes generated by nuclear power plants, and to address possible VR limitations based on concentrating the radioactivity.

INTRODUCTION

Based on analysis of the most current data available on waste source data and resin incineration testing, we believe that resin incineration can prove to be a viable option for volume reduction (VR) of low activity spent resins. Equipment selection and reliability is a major concern when considering ALARA for onsite occupational dose accumulation and environmental assessment. Gilbert/Commonwealth has developed extensive experience in the areas of radwaste source data and radwaste incineration by completing a number of research studies and designs in these areas for the U.S. Department of Energy, the Electric Power Research Institute, and several utilities.

Data describing average quantities and radioisotopic characteristics of various forms of wet solid waste have recently been compiled for operating plants within the nuclear industry. These data are an important point of reference for considering the feasibility of advanced VR systems including the use of incinerators to destroy spent resins. The compilation of industry-wide data provides both users and suppliers with a reference point for examination of process applicability for various utility needs. By use of a source term data base (Reference 1), and test results on incineration of simulated resin slurry (Reference 2), we can estimate the effects of concentrating the radioactivity in utility-generated wet solid waste.

Reducing the volume of wet solid waste by incineration results in concentrating the specific activity of the ash product and in the potential for radioactive contaminants to escape the incinerator containment. The increased activity of the ash raises questions concerning the suitability of incineration when considering inplant materials handling operations, transportation, and burial. The use of a combustion process raises the question of maintaining off-gas effluent releases below the plant's technical specifications and Federal or local limits.

To evaluate these concerns, a number of scenarios have been addressed and are discussed in this paper.

This evaluation shows that none of these resin incineration concerns precludes its use at operating nuclear power stations. In fact, the most formidable concern appears to be onsite handling of the higher dose rates which result from the concentrated activity in the ash product. The lack of worldwide incinerator experience from the processing of wet solid waste limits our ability to predict the degree of this concern. However, there is every reason to believe that the typical operating nuclear plant could satisfactorily deal with this higher activity as long as adequate attention to ALARA is given to the design and installation of the incinerator and ash handling capability.

Resin Source Data

The four scenarios employed to evaluate resin incineration include source term data from the following categories:

- Freshwater BWRs.
- Saltwater BWRs.
- Freshwater PWRs.
- Saltwater PWRs.

Industry averages for annual spent resin volumes and specific activities taken from the work performed for EPRI are utilized, along with vendor test data concerning mass reduction factors, to develop annual production rates of VR product ash. The test data on mass reduction indicates a broad spectrum of results, primarily dependent on the type of resin utilized at operating plants (e.g. the anion to cation ratio). Accordingly, the results in Tables I and II describe an 'average' as well as a 'highest' ash product volume. These were based on the 'average' and 'worst' case resin mixes documented in the data base of Reference 2. The predicted variations in product specific activity for the different resin mixes are listed in Tables I and II.

TABLE I

PREDICTED BWR ASH PRODUCT

		BWR Freshwater	BWR Saltwater
Resin Volume as Shipped		1250 ft^3	4400
Specific Activity		0.38 Ci/ft^3	0.38 Ci/ft^3
Curie Content		475 Ci	1648 Ci
Resin Mass		42,125 lb	148,280 lb
Average Mass of Ash		20,060 lb (9.11×10^6g)	70.609 lb (3.21×10^7g)
Highest Mass of Ash		35,104 lb (1.59×10^7g)	128,939 lb (5.85×10^7g)
Average Volume of Ash		247 ft^3	870 ft^3
Highest Volume of Ash		433 ft^3	1590 ft^3
Average Specific Activity		1.92 Ci/ft^3 (52.1 μCi/g)	1.92 Ci/ft^3 (52.1 μCi/g)
Lowest Specific Activity		1.10 Ci/ft^3 (30.0 μCi/g)	1.05 Ci/ft^3 (28.6 μCi/g)
Curies in 50 ft^3 Liner, Unsolidified	Average	96 Ci/liner	96 Ci/liner
	Lowest	55 Ci/liner	53 Ci/liner
Curies in Solidified Drum	Average	11.8 Ci/drum	11.8 Ci/drum
	Lowest	6.76 Ci/drum	6.4 Ci/drum

TABLE II

PREDICTED PWR ASH PRODUCT

		PWR Freshwater	PWR Saltwater
Resin Volume as Shipped		600 ft^3	1800 ft^3
Specific Activity		.85 Ci/ft^3	.85 Ci/ft^3
Curie Content		510 Ci	1530 Ci
Resin Mass		20,220 lb	60,660 lb
Average Mass of Ash		9629 lb (4.37×10^6g)	28,885 lb (1.31×10^7g)
Highest Mass of Ash		16,850 lb (7.65×10^6g)	52,747 lb (2.39×10^7g)
Average Volume of Ash		118.7 ft^3	356.2 ft^3
Highest Volume of Ash		207.8 ft^3	650.4 ft^3
Average Specific Activity		4.29 Ci/ft^3 (117 μCi/g)	4.29 Ci/ft^3 (117 μCi/g)
Lowest Specific Activity		2.45 Ci/ft^3 (66.7 μCi/g)	2.35 Ci/ft^3 (64.0 μCi/g)
Curies in 50 ft^3 liner, Unsolidified	Average	215 Ci/liner	215 Ci/liner
	Lowest	123 Ci/liner	118 Ci/liner
Curies in Solidified Drum	Average	26.5 Ci/drum	26.5 Ci/drum
	Lowest	15.1 Ci/drum	14.5 Ci/drum

Transportation of Product Ash

The specific activities are listed with respect to two viable packaging options:

- A 50 cubic foot high integrity container (HIC).

- A drum of ash product solidified in DOW binder (500 pounds of ash per drum).

Comparison of the predicted end product waste form to current transportation classifications for LLW in 49CFR173 was made. The results suggest that all ash product from spent resin incineration can be categorized as greater than Type A and low specific activity (LSA). Although categorized as Type A, a Type B cask would be required to reduce the radiation levels to shippable levels unless credit can be taken for shielding inside the shipping cask.

In-Plant Material Handling

The in-plant limitations of occupational exposure appear to be the most important limitations on the process. State-of-the-art resin incineration equipment designs include remote manual and automatic functions for the components located in the high radiation areas which will prevail. However, the likely higher exposure from periodic hands-on maintenance due to the increase in the number of high radiation areas, has the potential to detract from the benefits of VR. Although these dose rates can be reduced by system decontamination prior to maintenance, the external dose rates on equipment and the significantly higher dose rates in disposal containers may provide a practical limitation for spent resin incineration.

Burial of Product Ash

Consideration of burial site requirements for concentrations of various radionuclides in ash does not preclude the viability of spent resin incineration. In some circumstances the concentrating effect may pose an area of concern with respect to changing the burial site classifications for the end product. The waste classification per 10CFR61 could be increased due to one or more individual radionuclides in the ash. The most current industry-wide data concerning plant average isotopic distributions for PWR and BWR resins (Reference 1) were examined with respect to concentrating effect in ash.

The data suggested that a single isotope, Cesium-137, would exceed the 10CFR61, Table 2, Column 1 limit for incineration of such resins resulting in Class B waste disposal criteria. Note that the PWR and BWR isotopic sources utilized for this analysis do not include contributions from additional sources required by 10CFR61. Such additional sources as technecium and iron, if present, may also require the ash product be reclassified as Class B waste. In the same manner, if a plant has experienced increasing transuranic activities in spent resins, the resultant incinerator ash product may contain levels above the 100 nCi/g limit.

Off-Gas Treatment for Resin Incineration

Off-gas systems for radwaste incinerators incorporate provisions for treatment, filtration, sampling, and discharge of the products of combustion. Combinations of wet and/or dry methods are provided in operating radwaste incinerators to provide the needed total system decontamination factor (DF) (i.e. ratio of input activity to output activity) to meet effluent release requirements. Operating radwaste incinerators currently employ various combinations of off-gas components (mostly dry due to reduced maintenance) in order to provide system design DF's on the order of 10^6 and 10^7. These DF's have been shown to be quite adequate for low level dry waste incineration and should be equally satisfactory for spent resins realizing that a wet off-gas component is necessary for spent resin chemical effluents. A number of off-gas components can be aligned in series to provide a total system efficiency capable of limiting the off-gas discharges to well below the maximum allowable limits.

Particulate Cleanup

Particulate cleanup is required for spent resin incineration systems due to the likelihood of carry-over of particulate from the environment of the combustion chamber. The particulate may contain non-combustibles and unburned carbon including radioactive and non-radioactive material. Particulate release standards are controlled by EPA and state requirements for non-radioactive particulate. Since resin incinerators would most probably require off-gas polishing filters (HEPA/carbon) to ensure radiological environmental requirements are maintained, non-radioactive particulate emission criteria can quite clearly be satisfied.

Contaminated particulate can be filtered out of the off-gas flow from the combustion chamber before off-gas discharge. Operating radwaste incinerators (for processing of DAW) currently utilize dry (particulate) filters such as mechanical separators, high temperature ceramic filters, fabric filters, fiberglass (roughing) filters, and HEPA filters. Particulate carry-over varies in different designs depending upon the air to fuel mixing environment in the combustion chamber, different densities of half-burned resins in the combustion, and temperature at the filter. DF's for deposited radionuclides have been demonstrated at 3×10^4 for cobalt and 5×10^3 for cesium for individual filter elements. DF's for gaseous isotopes such as iodine are not applicable to dry particulate filter elements.

Gaseous Activity

If any gaseous radioactive effluent, such as radioactive iodine, is evident in the resin waste, it can be removed by either wet scrubbing or carbon adsorbers.

The wet scrubbing process can remove gaseous activity by applying a liquor spray into the off-gas such that gaseous activity is adsorbed into the liquor droplets. Scrubbing equipment which have been utilized for radioactive service includes spray towers, venturi scrubbers, and packed towers.

Beside removal of gaseous radioactive effluents, wet scrubbers provide for removal of entrained particulate, removal of organic and toxic vapors (SO_x) and heat removal. The scrub liquor, therefore, requires pH neutralization due to vapor removal, and processing as radioactive liquid due to adsorption of contaminants. Wet scrubbing system DF's for iodine have been estimated at 10^2.

Carbon adsorbers can also be utilized to remove gaseous radioactive effluents such as iodine if any is present. These adsorbers are generally utilized as polishing filters because of their sensitivity to organic vapors and particulate. A specific DF for a carbon adsorber, as with HEPA polishing filters, is highly dependent upon the volume of adsorber exposed to the off-gas flow.

Chemical Waste Problems

Combustion of spent resins involves the evolution of several effluents due to the chemical constituents in these resins. For example, sulfur oxides are generated in the off-gas from combustion of cation exchange resin. This effluent can be controlled through liquid off-gas scrubbing by absorption into the scrub liquor requiring caustic addition to the scrub liquor. Alternate methods for sulfur oxide capture include injection of caustic into the feed or directly into the combustion chamber. Treatment of toxic gases is important to minimize corrosion and pitting in the off-gas components, rapid depletion (i.e. poisoning) of the carbon adsorbers, and release of toxic effluents. Similar concerns also exist for combustion products resulting from halogenated resins (Cl^-, F^-), and to a lesser extent, from carbonates.

Environmental release requirements for combustion products do not necessarily mandate the use of wet scrubbing since typically sized spent resin incinerators cannot generate large quantities of environmental pollutants. However, removal of sulfur oxides is most important to prolong the effectiveness of carbon adsorbers.

Since wet scrubbing is important for carbon adsorber operation to avoid early depletion of available exchange sites in the media, and to minimize corrosion of off-gas components, the use of a wet scrubber for incinerator systems which will process spent resins is considered important to minimize long-term maintenance due to erosion and corrosion.

Nitrogen oxides can be generated in the off-gas stream if complete combustion does not take place. These oxides are also generated from the combustion of anion exchange resins. Sufficiently high operating temperatures in an incinerator afterburning section are normally adequate to provide for low emissions.

Conclusion

From the data available, the authors believe that low activity spent resins generated at nuclear power plants can be adequately processed by incineration. Average spent resin activity is several orders of magnitude higher than that for DAW currently being processed by incineration. Increasing the off-gas system DF by a factor of 10^3 or more appears to be a viable method to comply with effluent release requirements. Consideration of the concentrated activities in the ash product show that this product can be safely and satisfactorily handled.

References

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