The Role of Advanced Polymer Solidification in a Comprehensive Plan for Handling, Storing and Disposing of Class B & C Resins and Filters

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Abstract

A bill seen as the best -- if not last -- hope of keeping the Barnwell disposal site open to non-Atlantic Compact generators was defeated in March 2007 by a vote of 16-0. Sponsored by South Carolina State Representative Billy Witherspoon, the bill would have rescinded the 2000 pact that prohibited all states except South Carolina, Connecticut and New Jersey from sending radioactive waste to Barnwell after June 2008.

The defeat of the bill seems to ensure that, as of July 1, 2008 non-Atlantic Compact members will be cut off from the current disposal pathway for Class B & C wastes. At operating power plants, these wastes consist mostly of ion exchange resins used to purify reactor coolant and spent fuel pools. A small volume of Class B & C filters is also generated. Without access to a disposal site, plants will have a problem disposing of these wastes.

In the past, on-site waste storage was considered short-term storage and, as such, was subject to minimal review by the Nuclear Regulatory Commission (NRC). However, with no date certain for opening a new burial facility, generators will be faced with storing Class B & C wastes for an extended period. In recognition of the challenges this will present, the Nuclear Energy Institute (NEI), working with the NRC, and with input from 30 utility-associated individuals, has submitted to the NRC for review and endorsement a draft Electric Power Research Institute (EPRI) report entitled, "Guidelines for Operating an Interim On-Site Low-Level Radioactive Waste Storage Facility." This report presents Guidelines developed for use by Part 50 and 52 licensees to provide a "consistent approach to implementing an operational program for safe interim storage of low-level radioactive waste at a commercial nuclear plant site."

This paper looks at how the Advanced Polymer Solidification (APS™) process developed and applied by Diversified Technologies Services Inc. (DTS) can be an integral part of a power plant's approach to safe interim storage of Class B & C resins and filters. By producing a safe, non-dispersible 10 CFR61 Branch Technical compliant Stable Class B & C waste form, APS™ reduces waste handling and personnel exposure, and protects the public and the environment against radioisotope releases during routine transport and handling.

Introduction

Currently, Class B & C resins generated during clean up of reactor coolant and spent fuel pools are readily disposed of -- though at significant cost. These resins can be buried in High Integrity Containers (HIC) in a concrete vault at Barnwell, or sent to an off-site processor such as Studsvik for volume reduction (VR) via a thermal process. The resulting residue is commingled with that from other generators, and then buried at Barnwell.

With the closure of the Barnwell facility to generators outside of the Atlantic Compact, an alternative means of handling and processing such wastes is needed. This interim storage of low-level waste at generator sites presents several waste handling, packaging and waste form issues that are addressed in the NEI draft EPRI Report, "Guidelines for Operating an Interim On-Site Low-Level Radioactive Waste Storage Facility" dated February 12, 2008.

Advanced Polymer Solidification (APS™) is a viable method of generating Stable Class B & C resins and filters for on-site storage pending the opening of a Class B & C disposal facility. A key advantage of APS™ is that it renders an end product that is compliant with USNRC 10 CFR 61.56(b) Branch Technical Position (BTP) Stable Class B & C waste form, as suggested by Section 5.1 "General Guidance on Waste Form" of the draft report.

Typical of a Stable Class B&C waste form, the APS™ product is inert, non-dispersible, non-flammable and non-toxic; all characteristics desirable for waste destined for interim low-level waste storage.

The APS™ Process

Before looking at the favorable impact of the APS™ product on stewardship of a low-level storage facility, it is helpful to have a broad understanding of the process.

The APS™ process involves a chemical formulation similar to that described in NRC-approved Topical Report DTI-VERI-100-NP-A: "Vinyl Ester Resin In Situ Solidification Process for Low-Level Radioactive Waste, Rev 1." APS™ uses the same in situ solidification process, but a different proprietary modified polymer formulation, referred to as the Advanced Polymer (AP). The AP formulation, like the Vinyl Ester Styrene (VES) binder, results in a rock hard, stable monolith. This AP formulation has been approved by the Conference of Radiation Control Program Directors (CRCPD) for generation of Stable Class B & C wastes.

The binder and the curing agents are combined in a mix tank, and the viscosity adjusted to permit optimum flow through the waste media, The mix tank is then pressurized, and the AP allowed to flow into the freeboard of a container (steel or plastic) filled with dewatered waste media. Figure 1 illustrates a typical solidification setup.

When the AP has formed a cap on top of the waste media, the same AOD pump used in the initial gross dewatering is activated, and a combination of gravity and vacuum draws the AP down through the waste media. The advancing polymer, which is hydrophobic, drives any remaining interstitial water from the media as it flows down through the container, filling voids between the beads and grains. When polymer is present in the sight glass, the solidification process is complete and the polymer is then allowed to cure over 24 hours, forming a liquid-free,

hard, free-standing monolith inside the container. This process enables virtually 100% waste loading, since the polymer binder fills only the voids within the waste media.

Upon completion of the solidification, the transfer hose is disposed of as clean waste and the vacuum hose as DAW. The catch drum ensures that no polymer migrates to the air operated diaphragm pump (AOD), eliminating the need to chemically clean or dispose of the pump. If any polymer is collected in the Catch Drum, it is allowed to cure and the puck is dumped out of the drum and disposed as DAW. No cleaning solvents or other chemicals are used in the APS™ process other than the binder components. Once the container is solidified, it can be moved to interim storage until a Class B & C disposal site is available.

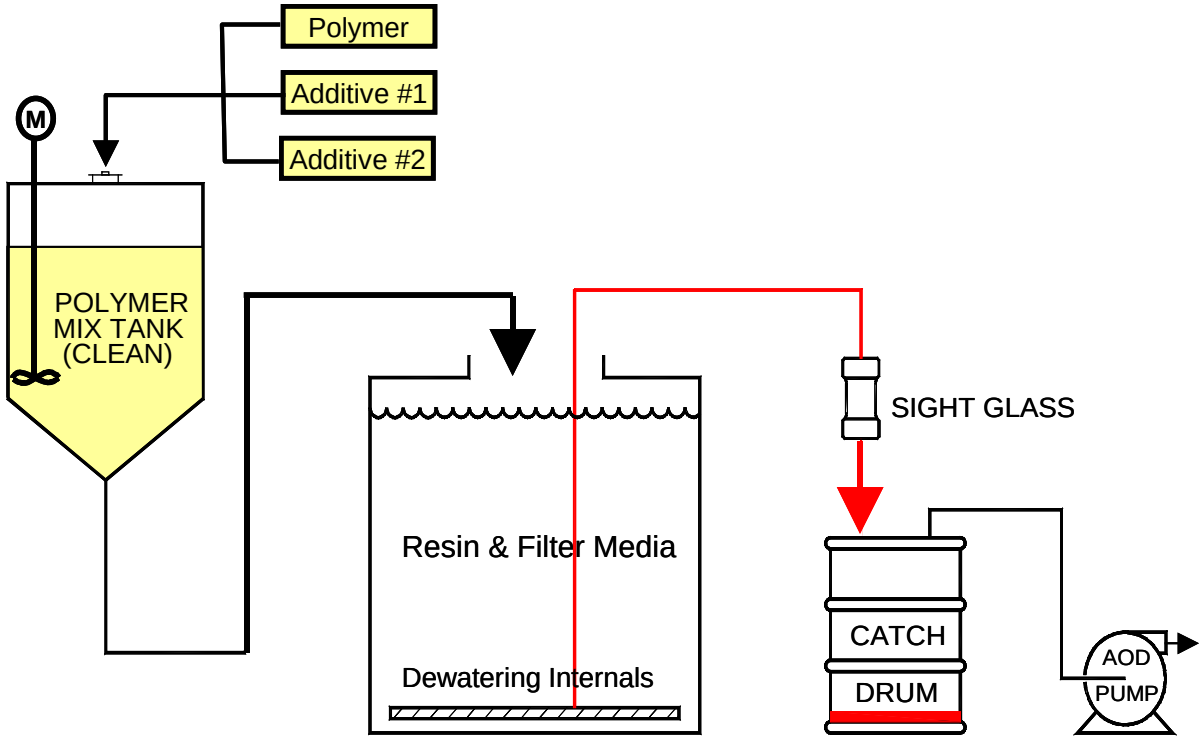

Figure 1

APS™ Simplified Process Flow Diagram

Figure 2 shows a solidified resin liner with encapsulated filters. The ENCAP™ process with VES was the subject of the last Topical Report approved by the NRC. This process permits encapsulation of filters, tools and other large-scale objects in the resin monolith produced by the in situ solidification process. Filters are dropped randomly into a liner that has been equipped with a perforated metal cage. The cage ensures that filters (and other objects) cannot contact the container wall. When the cage is full of filters, the liner is sluiced full of resin, and solidification proceeds in the normal manner.

Typically, the void space in a liner of filters is 70% to 80%. By filling the void space with spent resin, nominally 100% waste loading efficiency is achieved. This greater loading efficiency reduces the number of liners required and provides a pathway for disposal of Class B & C filters.

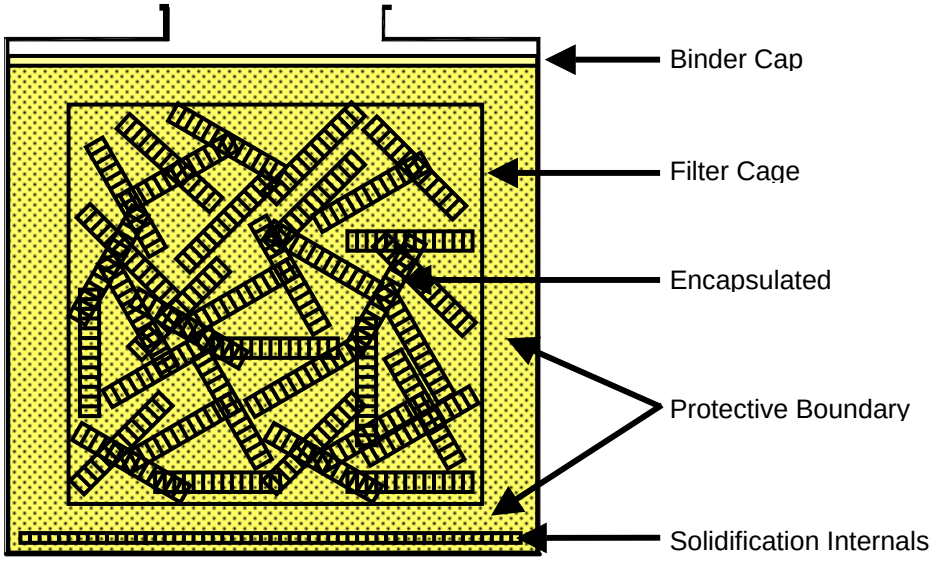

Figure 2

APS™ Monolith with Encapsulated Filters

NEI Operating Guidelines for Interim Storage Facilities

With the closure of the Barnwell site to generators outside the Atlantic Compact, generators will be forced to plan for on-site storage of Class B & C wastes for an indeterminate period. In recognition of this reality, NEI has submitted to the NRC, for review and endorsement, a draft EPRI report addressing guidelines for operation of interim storage facilities for low-level waste.

It therefore seems appropriate and useful to review how the APS™ Stable Class B & C waste form can help waste generators to comply with the recommended guidelines for a safe, effective storage facility. In the items below, excerpts from the draft report (shown in ***bold italic*** print, and sometimes paraphrased) are followed by relevant discussion of the APS™.

2 GUIDANCE ON STORAGE FACILITY START-UP EVALUATION

This Guideline focuses on operating an interim LLW storage facility (as opposed to designing and constructing one).

2.1 Licensing Safety Analysis Report, and Other Regulatory Requirements for Start-up

2.1.1 Previous USNRC Guidance Replaced or Deleted

- ***10 CFR Part 50.59 evaluations are normally required when new LLW storage facilities are constructed and when certain changes are made in existing facilities (such as increases in stored waste volumes and activities beyond those previously evaluated).***

The inert, non-flammable, non-combustible waste form produced by the APS™ process does not require repackaging, re-dewatering or reprocessing. This may reduce the scope of issues to be addressed in a 50.59 evaluation of the storage facility, if required.

2.2 Practical Storage Facility Start-up Evaluations

2.2.1 Start-up Review of Physical Facility Design Features

- ***Prior to start-up (of the storage facility), ensure that procedures have been (1) written, (2) approved by management and (3) are available to storage facility workers for the following (partial list):***
  - ***Periodic testing of fire and smoke detectors***
  - ***Continuously manned monitoring and response to fire, smoke...***

The non-flammable, non-combustible nature of the APS™ waste form and steel container may reduce or eliminate, the need for installing (and maintaining, testing and monitoring) fire and smoke detection systems. This is particularly applicable to storage systems installed on a pad or other structure external to the plant's physical facility.

2.2.3 Dry LLW and Solidified LLW Storage

- ***Controls should be in place to segregate and minimize the generation of dry LLW to lessen the impact on waste storage.***

- ***Ensure that the following design objectives and criteria have been addressed for <u>solidified waste storage</u> containers and facilities:***
  - ***Although solidified waste storage structures are not required to meet seismic criteria, protection should be afforded to ensure the radioactivity is contained safely in a seismic event.***

2.2.4 Wet LLW Storage

- ***Ensure that the following design objectives and criteria have been addressed for <u>wet waste storage</u> containers and facilities:***
  - ***Shall comply with seismic criteria as defined by USNRC Standard Plan, Section 11.2***
  - ***Shall have foundations and walls designed to contain liquid inventory***
  - ***Shall have containers to withstand the corrosive nature of wet waste***
  - ***Shall have curbs, elevated thresholds, floor drains and sumps that assume failure of all tanks and containers***
  - ***Shall have provisions to monitor liquid levels or check for free-standing water in wet resins***
  - ***Shall verify potential release pathways of radionuclides are controlled and monitored***

With waste stored as solidified Stable Class B & C, the need for a seismically qualified storage facility is eliminated, as are most or all of the requirements for storage of wet wastes, including dewatered resin. Evaluation and assessment of the ability to contain the solidified waste in the event of a seismic event is likely to be straightforward, since there is no credible means of dispersal or leakage of the waste (as may occur with dry ash type products or wet resin media). As a result a facility for APS™ waste form storage will be smaller in size, simpler in design and less costly to construct and maintain than storage for wet LLW.

5 GUIDANCE ON WASTE FORMS FOR EXTENDED STORAGE

5.1 General Guidance on Waste Form

- ***Where possible, waste should be processed before storage, packaged in a form ready for transport and disposal at the end of the storage period in accordance with the requirements of 49 CFR part 170-189 and 10 CFR Part 61 respectively.***

The APS™ product is a waste form ready for transport and disposal at the end of the storage period. The product complies with the referenced CFRs, including the Branch Technical Position (BTP) 10 CFR61.56 (b) Branch Technical Position on waste forms for a Stable Class B & C. This waste form and the process used to produce it are approved by the NRC through its Topical Report program, as well as by the CRCPD, who took over waste form review after the NRC ended its Topical Report program in the early 1990s.

By comparison, dewatered resins will not be ready for transport and storage. They will need, at a minimum, to be re-dewatered before shipping and disposal. The NEI Guidelines cite a test conducted by a nuclear plant where retrieving dewatered resin from storage and re-dewatering it in preparation for shipping took approximately one week of labor and 420 mRm per liner of personnel exposure. This empirical experience certainly supports processing the waste to a Stable waste form before it is placed in the on-site storage facility.

- ***Some waste forms are not appropriate for long-term storage.***

- Raw (untreated, unprocessed) radioactive waste or unpackaged radioactive materials should not be placed in LLW storage facility.

Processing resins (and other bead and granular media), and encapsulating filters with the APS™ in situ process prior to storage ensures that raw, untreated or unprocessed waste is not placed in the LLW storage facility.

- ***The packaged material should not cause fires through spontaneous chemical reactions or retained heat.***

The APS™ product is rock-hard, inert and non-flammable, and will not support combustion. Unlike poly containers, the steel storage liner for the APS™ product does not add to the fire load of the facility.

- ***All wet LLW in interim storage will require additional reprocessing before shipment offsite.***

Dewatered resin (a wet waste) must be re-dewatered if stored for more than 90 days before shipping. Processing or packaging may be required to achieve a Stable waste form or other waste form meeting the waste acceptance criteria of the disposal site. This results in additional waste handling, exposure and expense.

Because the rock-hard monolith of Stabilized Class B & C waste is not wet waste, no further processing will be required.

5.2 Guidance for Minimizing Fire Hazards

- ***Any remaining waste package that may represent a fire hazard will need to be stored in fire-protected areas with appropriate fire suppression equipment or systems.***

The non-flammable, non-combustible APS™ product does not add to the fire load of the storage facility. This eliminates the need for fire suppression equipment or systems for that area of the facility where the steel liners are stored, thus reducing facility costs and costs of surveillance and maintenance of the fire suppression system.

5.3 Guidance for Minimizing Gas Generation

- ***Gas generation from organic materials in waste containers can also lead to container breach and potentially flammable explosive conditions.***
- ***To minimize the number of potential problems, the waste form gas generation rates from radiolysis, biodegradation or chemical reaction should be evaluated with respect to container breach and the creation of flammable/explosive conditions.***

While the APS™ process effectively isolates the waste and inhibits or halts biological or chemical activity; some hydrogen may be produced by radiolysis. However, since the waste has already been processed to a Stable waste form, it is not necessary to reopen the container (as must be done to re-dewater wet resin). A flammable/explosive condition cannot be created because oxygen is not introduced to the liner.

<u>Source Controls</u>

To minimize the potential for gas generation in LLR, suitable source controls should be instituted. Examples of source control include:

- ***contain and separate oils, grease, solvents and similar hydrocarbons, high detergent content (especially phosphorus-based) aqueous wastes.***

Oily and greasy waste entrapped on resin or filtration media are effectively contained in the polymer monolith. The polymer process is approved for wastes containing up to 10% petroleum based oils, greases and solvents. The polymer is missile with petroleum products and will incorporate them into the matrix, thus rendering them non-combustible and fully contained.

Other Considerations

- ***Oxidizers (i.e. chlorine, chlorite, peroxides) must not be used without full consideration given the potential reactions with the waste forms, container, seals and gaskets.***

Plant chemical control programs are the first line of defense against inclusion of these agents. However, since the APS™ final solidified product is inert, any oxidizers that have accumulated on anion resin or other media will be effectively isolated from the environment. Thus, oxygen cannot reach the oxidizers to support chemical reactions, heat generation or combustion.

5.4. Other Regulations and Regulatory Guidance on Waste Form

USNRC regulation 10 CFR 61.56 provides the basis for regulating waste forms for disposal, which has applicability to waste storage. In addition, statements in the USNRC Branch Technical Position further expand the USNRC's position on waste forms. The key USNRC requirements for all disposed waste form---and which have applicability to stored waste forms---are as follows:

5.4.1 10 CFR 61.56

- ***Liquid waste must be solidified or packaged in sufficient absorbent material….***

While the APS™ process is applicable to solidification of bead and granular media, as well as encapsulation of filters and other large-scale objects, a companion process can solidify liquids into a rock-hard monolith that complies with Stable Class B & C waste form requirements. This eliminates the need for addition of absorbent material.

- ***Waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.***

The APS™ product is physically stable and chemically inert. Thus it is not capable of detonation or explosion, and has no reaction with water.

- ***Waste must not contain, or be capable of generating toxic gases, vapors or fumes harmful to persons "transporting, handling, or disposing of the waste."***

The cured polymer components do not generate toxic gases, vapors or fumes. Most importantly, the APS™ protects individuals handling the waste from gases, vapors and fumes since there is no need to open the container for inspection or for re-dewatering.

- ***Waste must not be pryophoric. Pyrophoric materials contained in waste shall be treated, prepared and packaged to be non-flammable.***

Pyrophoric waste, when stabilized with the APS™ process, becomes non-flammable and will not support combustion. Uranium chips and zirconium and hafnium swarf material that has been solidified APS™ will pass the 2000^{o}F torch test and be self-extinguishing. The polymer matrix deprives the pyrophoric material of the oxygen necessary for combustion.

10 CFR 61 has additional requirements for Class B & C wastes. These wastes must be able to maintain structural stability to inhibit slumping, collapse or other failure of the disposal trench that could lead to radionuclide migration. Regulations stipule a period of 300 years as a minimum time for Class B or C waste must maintain its integrity. The additional requirements for these higher-level wastes are as follows.

5.4.2 USNRC Branch Technical Position (BTP)

- ***Waste shall be a solid form or in a container or structure that provides stability.***
- ***Waste shall not contain free-standing and corrosive liquids***
- ***Waste shall resist degradation caused by radiation effects***
- ***Waste shall be resistant to biodegradation***
- ***Waste shall remain stable under compressive loads of the burial environment***
- ***Waste shall remain stable if exposed to moisture or water after disposal***
- ***Waste shall be compatible with solidification media or container***

The above requirements are the hallmarks for determining Stable Class B & C compliant waste forms. The APS™ process and resulting waste form have been subjected to the full gamut of these tests, and it has been demonstrated that the waste form will meet each of these requirements to ensure stability in the burial environment for 300 years.

The VERI™ (in situ) and ENCAP™ processes with VES were submitted to the USNRC for review, and approval under its Topical Report program. The APS™ process for in situ solidification of resin and media has been tested by DOE Idaho to the NRC BTP waste form criteria, and approved by the E-5 Committee of the CRCPD as Stable. The ENCAP™ process using AP is expected to be approved by the CRCPD later in 2008.

Other Waste Handling and Disposal Considerations and Factors

While the NEI draft Guidelines dealt primarily with issues related to operating a low-level storage facility, there are many factors to consider in a comprehensive plan for handling, processing, storing, shipping and disposing of Class B&C waste beyond those linked to a storage facility. These issues are addressed below.

Transportation Footprint. The APS™ process, performed on-site at the plant, requires no Type B cask shipments (until a waste disposal facility opens). In contrast, off-site processing requires Type B cask shipments to transport raw resin to a processing facility, and more Type B shipments to return the treated waste to the plant for storage if not stored off-site.

While the frequency of transport accidents is low, any increase in cask trips will be accompanied by a similar increase in the potential for accidents involving the public. By eliminating Type B shipments until disposal time, the APS™ process reduces the nuclear waste transportation footprint, including the potential for injury and death, to near zero.

Waste Handling for Processing. Waste handling activities inherently entail the greatest risk of accidents resulting in personal injury or release of contamination to the environment. The more frequent and longer the duration of waste handling activities, the greater the odds of mishap. The simple 3-step (sluice, solidify, store) APS™ process reduces waste handling to a minimum.

Sending waste to an off-site processor increases the number of times that waste is handled. If sluicing is done in a process shield, the liner has to be moved to a shipping cask. The lid has to be secured, paperwork generated, and security support provided to send the shipment off-site. The return shipment of the thermal ash again requires the services of security as well as operations (to open the cask, attach to the liner for lifting, and move it into storage). The cask must then be surveyed, closed and shipped off-site.

The number of Type B shipments illustrates the contrast between APS™ and off-site thermal processing, We can assume that 500 cubic feet of Class B & C resin requires approximately five Type B cask shipments to the processor, and another for return of the ash to the plant. The APS™ process requires none.

Waste Handling for Disposal. The waste handling steps for APS™ stabilized resins are limited to removing the liner from storage and placing it in the shipping cask for transport to disposal.

By comparison, if resins are stored in the wet dewatered state, multiple handling steps will be required for retrieving, opening, inspecting, re-dewatering, repackaging or reprocessing and finally moving the waste to a shipping cask for shipment for offsite processing or disposal.

If filters are placed in a storage liner, removing them for processing or repackaging, if required, will also be dose and labor intensive.

Terrorist Threat. Long-term storage plans must include an assessment of a terrorist threat. The International Atomic Energy Agency states in its position paper, “The Long Term Storage of Radioactive Waste: Safety and Sustainability” (Vienna, 2003):

> “While nuclear material has traditionally attracted security precautions to prevent it falling into unauthorized possession, it is now recognized that nonfissile material must also be protected because of the possible threat of deliberate spreading of contamination by terrorists.”

While the likelihood of a terrorist event is small, proper waste form is the key to minimizing any possible impact. The rock-hard APS™ monolith directly mitigates the potential for deliberate spread of contamination. The large monolith is not subject to removal from site, and a scenario involving explosives (either placed adjacent to the waste package or delivered by projectile such as a rocket-propelled grenade) is likely to damage the liner and fracture the monolith into large discrete chunks. Dislodged pieces of the monolith will be intact, and will generate little (if any) airborne contamination. The chunks will be relatively easy to detect and recover.

Dewatered resin is more prone to loss of liquids and wide disbursement of material that is difficult to detect and challenging to retrieve. Though airborne contamination is likely to be limited, the widespread dispersion of resin fines and particulate contained in the bed will be troublesome.

Thermal ash, because of it is highly dispersible nature, would present significant containment, detection and recapture problems. Any explosion that violates the integrity of the liner would release an airborne plume that could be carried by wind or ventilation systems. Contamination could be detected by smear, and would involve all surfaces in the path of the spreading plume. Decontamination inside of a building would be labor intensive and difficult. Outside, only a small fraction of the dispersed material is likely to be recovered.

Storage Dose Rates. The APS™ waste form reduces shielding requirements for long-term storage. The binding agent has a self-shielding effect (similar to water) that results in a dose reduction of approximately 30%. The lower dose rate reduces the thickness of the storage shielding required to comply with exterior dose levels.

Dewatered resin, without the benefit of polymer self-shielding, will require a shield wall about 30% thicker to attenuate external dose to the same level.

The concentrating effect of activity in the thermal ash may present a shielding challenge for on-site storage. If a 5:1 or 6:1 volume reduction of resins is achieved during thermal processing, the resulting ash is likely to have a dose rate 300% to 500% greater than the primary resin from which it was derived. The shield walls at some on-site storage facilities may be inadequate to provide sufficient attenuation. If on-site storage shields are used, heavier units may be needed, thus increasing the cost of procurement and transport.

Avoiding Legacy Waste. Both commercial and government nuclear facilities have subscribed to the policy that a waste form cannot be generated until a means of disposal has been identified. This policy serves to prevent the accumulation of legacy wastes – wastes that must be stored indefinitely pending development or identification of some means of treatment or packaging that will permit disposal.

The APS™ waste form is already a CRCPD-approved Stable Class B & C waste form that meets the requirements of the NRC 10 CFR 59(b) Branch Technical Position for waste forms.

Resin, in its dewatered state, is not stable and will have to be reprocessed or packaged to ensure compliance with waste acceptance criteria (WAC) of the current and future burial sites.
Ash residue is not stable and a means of repackaging or processing will have to be developed to convert it to a stable waste form.

Conclusion

Stable Class B & C waste forms generated with the APS™ process have multiple and key roles to play in a comprehensive plan for handling, storing and disposing of Class B & C resins and filters, as set forth in the NEI issued draft EPRI report "Guidelines for Operating an Interim On-Site Low-Level Radioactive Waste Storage Facility."

Key contributions of the APS™ waste form to waste handling, processing and plans for on-site storage of low-level waste include:

- Demonstrates high level of compliance with draft Guidelines
  - Waste form will not have to be reprocessed or repackaged
  - Waste form is inert, non-flammable, non-explosive, non-toxic
  - Complies with all requirements for a Stable Class B & C waste form, as recommended by Guidelines
  - Reduces fire protection requirements
  - Eliminates seismic requirements
  - Eliminates facility requirements for containment of liquids
- Protects the environment, the public, and plant personnel
  - Reduces transportation footprint
  - Reduces waste handling and related personnel exposure
  - Reduces impact of handling or transportation accidents or terrorist threat
- Avoids potential legacy wastes with unknown disposal paths
- Reduces external facility dose rate because of self-shielding
- Allows reduction of facility size by combining resin and filters in approved waste form
- Reduces negative impact of terrorist incidents
- Presents a known pathway for treatment and disposal of virtually all plant waste streams
- Avoids the curie concentrating effect of thermal treatment

References

1. Miller, C.C., Jensen, C.E., “Waste Solidification Experience with Vinyl Ester Styrene at Diablo Canyon Power Plant,” EPRI LLW Conference, Monterey, CA, 1993**.**

2. IAEA, “The Long Term Storage of Radioactive Waste: Safety and Sustainability, A Position Paper of International Experts,” Vienna, Austria 2003.

3. Miller, C.C., Jensen, C.E, et al., “Advanced Polymer Solidification (APS™) of Spent Ion Exchange Media and Activated Carbon” EPRI LLW Conference, Salt Lake City, UT, 2004**.**

4. Miller, C.C., Jensen, Werner C.E, et al., “In Situ Solidification and Encapsulation of Commercial Nuclear Power Plant, DOE and DOD wastes,” Waste Management Conference, Tucson, AZ 2007

5. NEI issued draft EPRI report “Guidelines for Operating an Interim On-Site Low-Level Radioactive Waste Storage Facility”, February 2008.