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Review of Westinghouse AP1000 LLW Management Program

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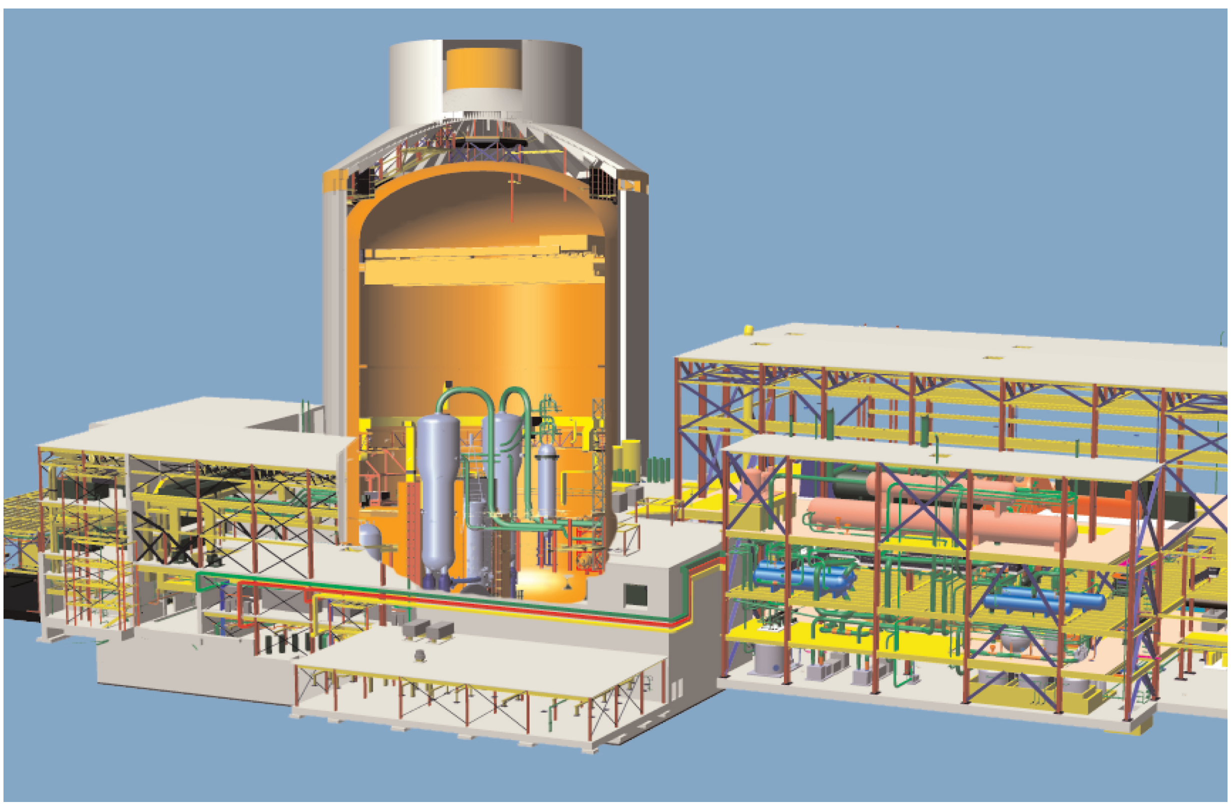

Review of Westinghouse AP1000 LLW Management Program

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Final Report, November 2003

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REPORT SUMMARY

Significant operational cost and waste volume reduction savings opportunities exist, based upon current low level waste (LLW) treatment technology gains, for future operators of the AP1000 reactors. This report is a summary of a review of the AP1000 Radioactive Waste Management Program as defined in the EPRI Utility Requirements Document (URD) and the AP1000 Design Control Document (DCD).

Background

In the late 1980's and early 1990's, EPRI developed a Utility Requirements Document (URD) for the Advanced Light Water Reactor (ALWR). Since that time, the industry has made substantial strides in terms of LLW minimization strategies, volume reduction technologies, and waste disposal alternatives. In 2001-2002, EPRI performed a preliminary review of the URD to identify whether it still embraced the most advanced approach to LLW management (TR-1003434).

Additional review of the AP1000 clearly indicated that the program could benefit further from the most recent advances in waste related technologies and management strategies. As discussed in this report, significant opportunities exist for enhancing many of the design aspects of the AP1000 to garner additional benefits related to cost efficiency, liquid processing operations, generated and disposed solid waste volumes, activity management, and personnel exposure.

Objectives

- To identify and quantify opportunities for significant improvements in cost and performance related to the next generation of light water reactors, without impacting the ongoing regulatory approval process.
- To determine if the documents warrant a more detailed review and what the potential benefit of that review might be to utilities.

Approach

EPRI tapped the expertise of several industry experts and a panel of senior utility LLW professionals to review the subject data and develop this report. That unique and deep-seated knowledge base identified opportunities for enhancing the performance and cost efficiency of the next generation of reactors, while maintaining the industry's high standards for public safety and environmental stewardship.

Results

EPRI developed this document primarily for managers of the ALWR URD, AP1000 design engineers, and utilities considering new reactors or pursuing license extension of existing reactors. The EPRI approach for Advanced Light Water Reactor (ALWR) LLW management discussed in this report can result in very significant cost savings and disposal volume reductions. Those savings will be compounded when life of plant and cost escalation are considered. The EPRI approach will result in an annual performance improvement (disposal volume reduction) of approximately 1800 ft^3, and an annual cost savings of $0.74 million. Based on a 60-year plant operating cycle, these performance and cost savings benefits rise to 110,000 ft^3 and $45 million. Implementing the EPRI recommendations and approaches in this report will reduce the number of stored waste containers by at least an order of magnitude, making life-of-plant storage an even more practical option. Most importantly, this eliminates any dependency on LLW disposal facilities, making it economically feasible to store all operational waste until decommissioning.

EPRI Perspective

EPRI's URD for the ALWR was produced in the late 1980's and early 1990's. Since that time, the commercial nuclear industry has made substantial advances in terms of minimizing LLW generation, processing liquid and solid waste, and implementing more efficient packaging and volume reduction technologies. The cumulative effect of these advances is a dramatic reduction in disposed waste volumes and lower operating costs. The technological advances and lessons learned need to be captured both in the URD and in the design and operational considerations for all ALWRs. The AP1000 is the ALWR design that has progressed furthest in NRC's current on-going certification activities. Therefore, this report compares the DCD for the AP1000 ALWR to the most advanced approaches presently employed in the commercial US nuclear industry. The intent is that this information will form the basis for design improvements in the AP1000 and other ALWRs, as well as contributing to future revisions of the EPRI URD.

Keywords

Low level waste
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Volume reduction
License extension

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Background

In the late 1980s and early 1990s, EPRI developed a Utility Requirements Document (URD) for the Advanced Light Water Reactor (ALWR). Since that time, the industry has made substantial strides in terms of low level waste (LLW) minimization strategies, volume reduction technologies, and waste disposal alternatives. In 2001, a preliminary review of the URD was performed to identify whether it still embraced the most advanced approach to LLW management.

As an extension of the URD review effort, a cursory review also was performed for the AP600 advanced reactor design and its associated USNRC Final Safety Evaluation. It was determined that the AP600 LLW management considerations were very consistent with the URD. Unfortunately, both documents were significantly dated in terms of both LLW technology considerations and the flexibility required to adapt to changing technologies and LLW management strategies. It had also been recognized by the reactor vendor that the AP600 may not be a cost effective competitor in the U.S. domestic power generation market, leading to the larger, advanced AP1000 design. This change necessitated a refocusing of the project to a more comprehensive EPRI review of the AP1000 LLW management program and the associated Design Control Document (DCD).

The AP1000 review clearly indicated that, while that design had moved to a level well beyond that of the AP600 and the URD, it can benefit further from the most recent advances in waste related technologies and management strategies. As discussed in this report, significant opportunities exist for enhancing many of the design aspects of the AP1000 to garner additional benefits related to cost efficiency, liquid processing operations, generated and disposed solid waste volumes, activity management, and personnel exposure.

Objectives

EPRI tapped the expertise of several industry experts and a panel of senior utility LLW professionals (hereafter referred to as the “ALWR LLW committee” or the “committee”) to review the subject data and develop this report. Their primary objective was to identify and quantify where applicable, opportunities for significant improvements in the AP1000 DCD related to:

- Construction and other capital costs
- Operating and Maintenance (O&M) costs
- Operating environmental impact
  - Released liquid effluent radioactivity
  - Generated solid waste volume
  - Disposed solid waste volume
- Personnel exposure
- Staff resource requirements

A secondary objective was to determine if a more detailed evaluation of the URD and AP1000 documents was warranted and what the potential benefit to utilities would be. Thus, this review focused not only on individual considerations offering substantial benefit, but also those that would collectively offer opportunities to improve an advanced reactor's design and operating excellence.

Finally, as part of the analysis process, improvement opportunities were assessed for their applicability to currently operating units that have been approved for, or are pursuing, license renewal.

Path Forward

As a result of a variety of factors including improvements to processing technologies, changes to the regulatory climate and environmental management, and a significant industry experience database, this review process resulted in the identification of numerous opportunities to enhance the existing reactor design. In many cases the improvements were specific to the AP1000 design, but the majority are also applicable to the more global EPRI URD for any ALWR.

Recommendations specific to the Westinghouse design were evaluated over an extended period of time by a team comprised of Westinghouse advanced reactor design representatives, EPRI LLW management, and advanced reactor design staff members, and EPRI contractors. The Westinghouse organization has committed to a very aggressive schedule for submittal and approval for its AP1000 design. That schedule is currently driven by a combination of an acceptable political climate, a business case, regulatory processes, and industry interest. Some of the recommendations were readily accepted by Westinghouse for inclusion in this version of the AP1000 design document; however several of the identified opportunities—although acknowledged as having merit—would result in an unacceptable delay to the submittal schedule.

The ALWR LLW committee agrees that the majority of items can be resolved as part of post-DCD design detail and documentation. Additionally, the ALWR LLW committee members are appreciative of the Westinghouse scheduling constraints and desire to avoid any adverse impact to that schedule. However, the *committee strongly believes that several of the issues are sufficiently important to the success of specific process's that they should be reconsidered for inclusion in the DCD and should not be deferred for future disposition. This position includes design considerations as well as several high-impact administrative corrections and clarifications.*

In an effort to expedite resolution and avoid any potential for delaying submittal and approval of the DCD, the ALWR LLW committee is proposing parallel action paths:

1. Those considerations which are critical to the basic functional design of the AP1000 will be captured in a Utility Position Paper (UPP) co-authored by the utility and EPRI members of the existing ALWR LLW committee. That document will clearly state the significant considerations and proposed options, and will request resolution during a joint meeting of the ALWR LLW committee and the Westinghouse design team. Simple administrative clarifications and corrections can be resolved in this same review. The agreed upon results should be documented in either the DCD or the URD.

2. Those enhancements that are not resolved via option 1 above, but are designated as applicable to other advanced reactor designs, will be earmarked for incorporation into the EPRI URD document either as direct changes to the document or as a “living” addendum to that document. It is anticipated that the addendum will be generated as a template for capturing future enhancements to the URD.

The current status of each design consideration identified-to-date is captured in the subsequent chapters of this document under the heading “Current Status” and includes initial responses from Westinghouse and/or the ALWR LLW committee’s position and proposed course of action.

Report Organization

The first few chapters of this report present a variety of design-specific recommendations, comments, and questions related to the AP1000 DCD, which collectively could result in significant cost savings and enhanced performance efficiencies. Several issues clearly illustrate the potential benefit that would be derived from a more detailed evaluation of the documents. The later chapters analyze and summarize the current AP1000 radwaste generation and disposal volumes and costs, which are then compared to alternative approaches reflecting the current industry best performers. This comparison suggests the potential cost and performance benefits obtainable through implementing the recommendations in this report. The following offers a brief discussion of each chapter:

- Chapter 2 is related to the design and/or operation of the balance of plant systems that impact liquid or solid waste characteristics, volumes, or processing.
- Chapter 3 is a summary of in-plant liquid radwaste (LRW) opportunities.
- Chapter 4 captures those considerations related to solid waste handling, packaging, staging and storing, and disposition.
- Chapters 5 through 9 capture waste related cost and volume benefits associated with bringing the design standard in-line with current industry performance.
- Chapter 10 summarizes the potential benefits from Sections 5 through 9.
- Chapter 11 discusses issues and opportunities related to life-of-plant storage.
- Appendices A–D contain a waste summary table and disposition figure from the AP1000 DCD, a methodology that can be applied to escalating the benefits summarized in this document, and a list of reference documents used during this project.

2
BALANCE OF PLANT DESIGN CONSIDERATIONS

The design, maintenance, chemistry controls, and operating strategies for radioactive and select non-radioactive plant systems can play a significant role related to the volumes and characteristics of generated liquid and solid wastes. The specific factors impacting wastes are numerous and can be categorized by system and plant evolution, and a detailed review of the EPRI URD using this approach is planned for 2003. However, during this initial review of the AP1000, several opportunities were identified that have the potential to improve the overall plant performance relative to effluent activity, off-site exposure, and waste volumes and characteristics. These opportunities are offered for consideration in this chapter.

Within the AP1000 DCD, the following sections were reviewed relative to Balance of Plant considerations:

- Section 3, *Reactor Coolant System and Reactor Non-Safety Aux Systems.*
- Section 8, *Plant Cooling Water Systems.*
- Section 9, *Site Support Systems.*

As is the case throughout this report, it is also apparent that a more detailed review of the DCD will likely yield a significant number of additional opportunities to benefit from recent industry experience.

1. Area Radiation Monitoring System

Installation of remote radiation monitoring for all demineralizers and high activity (e.g., RCS) filters would facilitate accurate predictions related to activity, waste classification, and activity removal efficiencies. Easily retrieved detectors would permit calibration, repair, or replacement with minimal personnel exposure. The best industry performers are currently augmenting their as-built radiation monitoring systems with temporary systems, creating an undue burden related to safety evaluations, installation, maintenance, and removal. In an ALWR such as the AP1000, installed remote radiation monitoring capabilities for radwaste processing components would be a valuable addition to the basic plant design.

Current Status

The Westinghouse AP1000 DCD will not be revised to address this issue. It will be incorporated into the URD update.

2. Steam Generator Blowdown System

The DCD specifies that this liquid stream is treated using an "electrodeionization process" that incorporates ion exchange media (Reference 10.4.8.2.4). The application of this technology in the commercial nuclear industry has not previously been evaluated by EPRI. Additional information would be valuable to the COL (common licensee) for analyzing processing options, projecting secondary waste generation, and planning for waste packaging, volume reduction, and disposal options. In the event that this ion exchange media becomes contaminated as a result of a primary-to-secondary leak, it is not clear how the resin would be removed and dispositioned. The DCD suggests that the resin is removed and contained as part of the electrodeionization stack (i.e., both the stack and the resin are removed simultaneously as a package). This could result in additional, unnecessary packaging and disposal costs. Additional information and clarification is needed to understand this resin removal and replacement process.

Current Status

This process has been briefly researched, and its use is becoming widely accepted in the non-nuclear power industry and the U.S. Navy's nuclear propulsion program. EPRI and Westinghouse agrees that this does not warrant a change to the AP1000 DCD and can be addressed as part of a future design option package.

It will be included as appropriate in the URD update.

3. Chemical and Volume Control System (CVCS)

a. The AP1000 DCD refers to the installation of two mixed bed and one cation bed CVCS ion exchangers, accompanied by a post-filter, located inside the containment structure (Reference 9.3.6.2.1.1). The DCD is based on all media components providing service for a full fuel cycle. This approach does not allow for chemistry or operational perturbations that may prematurely deplete or foul the processing media. Containment entries at power may pose significant exposure and personnel safety hazards. This configuration requires further clarification with regard to the design objective and operating strategy.

b. Similarly, the CVCS purification loop design does not appear to account for shutdown crud burst cleanup management. Installing a dedicated demineralizer for controlling shutdown activity–which can be isolated for in-situ decay until it requires reload prior to subsequent outages–is a very cost-effective strategy that should be incorporated into the purification loop design. The natural reduction in activity prior to commingling with lower activity media in the spent resin tank will result in significant transportation and disposal curie surcharge savings, resulting in a very short return on the additional demineralizer investment.

Current Status

Generally, Westinghouse's response indicated that the CVCS design as documented in the DCD provides capability superior to current operating plants. With reduced cobalt, crud will be reduced, so crud burst concerns are minimized, and filter replacement under power will not be required. In the event an operator wants more flexibility with respect to CVCS ion exchange media during shutdown operations, consideration could be given to additional ion exchange beds within the existing CVCS envelop. Of course, time for radioactive decay can be accomplished in the spent resin storage tank. As such, Westinghouse does not believe changes to the CVCS equipment inside containment will be justified, although these can be considered in later design phases. The Westinghouse AP1000 DCD will not be revised to address these issues.

The ALWR LLW committee's position is that industry experience with both filtration and ion exchange media clearly and repeatedly demonstrates that their life expectancy cannot be accurately predicted in all cases. This important issue should not be deferred as a post-DCD design detail package.

This open item will be included in the Utility Position Paper (UPP) and the URD update.

4. System's Liquid Waste Management

a. Draining any component or system should be incorporated into the plant design rather than relying on floor drains or sumps for waste liquid collection. Allocating space and permanent piping would permit temporary supplemental water management for the capture and recycle of chemically treated, non radioactive wastes, outage waste, and special project surge wastes.

b. Specific chemical controls (with the exception of primary Lithium and Boron) are not referenced in the DCD; however, some passages refer to their use (e.g., corrosion inhibitors, pH controls). Similar to currently operating units, the design constraints imposed by the AP1000 DCD require the use of strategies for draining, diluting, or disposing of chemically treated liquids that are detrimental to liquid radwaste influent quality. Careful selection, control and **planned-by-design** disposition will minimize the chemical impact on processing media and waste generation.

Current Status

Westinghouse responded that component drains have been designed to prevent cross-contamination and keep "like with like" - e.g., component cooling water drains to non-radioactive drains, and reactor coolant generally drains to radwaste. Westinghouse also responded that proposed EPRI modifications could be considered during more detailed design phases.

The ALWR LLW committee's position is that this issue will be included in the URD update.

5. Data Management

The AP1000 document does not specifically address data controls and management related to LRW processing. The use of an integrated data capture system that can track, trend and archive system performance, coupled with remote audio and visual monitoring, would provide the tools necessary to monitor and assess system performance with a high degree of accuracy and with minimal staff requirements. EPRI's proven Waste Logic Suite PC based programs would provide excellent platforms for live data capture, tracking, trending, and for evaluating process performance.

Further, remote audio, video, and radiation monitoring systems have proven to enhance the capabilities of plant operating programs. This technology would allow operation of the system from a primary control room, with minimal field interaction required. The use of this strategy also permits real time process evaluation to ensure that optimal performance is maintained. It also would facilitate automated report generation to meet local, state, and federal reporting requirements. Individual elements of this strategy are successfully being used by numerous nuclear stations. The effect of combining all of these technologies would result in a staff reduction when compared to current industry allocations.

Current Status

Westinghouse believes their current data system will capture the appropriate information.

The ALWR LLW committee's position is that this is an important issue that directly impacts regulatory compliance, solid and liquid effluents, program performance, cost, and staffing requirements. Additionally, as a result of the historical lack of industry understanding of its importance and impact, presenting a limited program to a licensee as an additional cost option minimizes the potential for success with that endeavor. Further discussion and analysis of this critical program performance and cost tool is warranted.

This issue will be addressed in the UPP and the URD update.

3
LIQUID RADWASTE IN-PLANT PROCESSING

Significant advances in liquid processing related technologies have been made over the past decade. The use of advanced technologies such as membrane based purification and automated coagulant injection systems to reduce or eliminate liquid release volumes and activity, have gained considerable momentum in recent years in both PWR and BWR stations. Additionally, EPRI continues to research technologies that are not currently applied to nuclear plants and to evaluate newly developed processing options. With that in mind, an advanced reactor design should consider incorporating the following concepts to ensure it is at least current with available technology at startup.

Within the AP1000 DCD, the following sections were reviewed relative to liquid radwaste in-plant processing considerations:

- Section 3, *Reactor Coolant System and Reactor Non-Safety Aux Systems.*
- Section 8, *Plant Cooling Water Systems.*
- Section 9, *Site Support Systems*.

1. Liquid Waste Recycle

Minimizing any form of effluent waste (liquid, solid, gas) reduces a reactor's overall environmental impact, and in turn helps minimize the impact those effluents have on the siting process, operational success, and scope and depth of decommissioning activities. Therefore, the plant tank capacity, piping and components, and operational strategies should be designed ***to facilitate*** (but not dictate)100% radioactive *liquid* recycle. This option should be made available to the COL (common licensee) who would base their decision regarding recycle, release, or a combination of each on such items as:

- Cooling and dilution volume, along with off site dose modeling
- Decommissioning goals
- Cost-benefit analysis

This strategy can be accomplished using one or a combination of proven advanced membrane systems or high quality evaporative/concentrating processes (e.g. HPD). Additionally, should the plant elect to use enriched boron as a primary system moderator recovering waste liquid would represent a significant economical benefit. Finally, the current ALWR design improvements for balance of plant components should help to ensure that the liquid radwaste streams are low volume, low activity, and contain minimal concentrations of organic and inorganic impurities. The combined benefit of these considerations provide a solid foundation for recycling all radioactive waste liquids generated from normal plant operations.

Current Status

The Westinghouse design is based on 100% release, but they are not adverse to recycle. Their analysis assumes 2.5 primary system volumes to LRW per cycle to maintain acceptable tritium concentrations in the primary system.

The ALWR LLW committee's position is that the DCD should include a by-design ***option*** for 100% recycle, thus allowing for zero to 100% recycle. Increasingly stringent effluent oversight and effluent impact litigation has made recycle an integral LRW program strategy for many utilities.

Further discussion and analysis of this design issue is warranted. It will be addressed in the UPP and the URD update.

2. LRW System

The LRW system should be designed with maximum flexibility related to influent and effluent waste capacity, routing during sluicing operations, and waste segregation. This allows the unit operator to process each waste stream using the most cost-effective strategy:

a. Tankage should designed to permit segregation of liquid volumes into at least four (4) categories:

   1) High activity, high purity

   2) Low activity, low purity

   3) Chemically challenged

   4) Clean—monitored release within release restrictions and without processing

b. The volume of the LRW Waste Holdup Tanks (WHUT) and Monitor Tanks (MT) for the AP1000 should be increased (Reference Table 11.2-2, Sheets 6 & 7 of 7). The design is based on the design input, but experience suggests the need to consider process delays related to large influent volumes (unplanned surge volumes), process media performance issues, or MT release delays for a host of reasons.

c. The LRW system design configuration should also include a smaller volume (~2,000 gallon) membrane system feed tank for use with membrane processing. That tank would require at least two influent lines (input from the WHUT/Effluent Holdup Tanks and input from membrane reject/brine), a liquid effluent line to feed the membrane component, and a bottom concentrates discharge line to a waste shipping containers or a mobile on-site concentrates processing system.

d. MT volume should match or exceed WHUT volume. Industry experience with small volume MTs has clearly demonstrated the benefit of larger tankage in terms of preventing slowing or stopping processing during release evolutions.

e. Include at least one separate effluent tank for collecting non-processed wastes for monitored release without processing. This would permit sampling and monitored release of innocuous wastes such as ground, cooling, or fire protection liquids without challenging the processing media.

Current Status

The Westinghouse AP1000 DCD will not be revised to address this issue.

The ALWR LLW committee's position is that further discussion and analysis of this ***very*** important design issue is warranted. It will be addressed in the UPP and the URD update.

3. Flexible Piping and Hoses

The use of flexible piping and hoses is not currently approved for permanent installations [Reference NRC Regulatory Guide 1.143, Rev. 2, November 2001] although their use is approved in that application per ANSI Standard 40.37. The AP1000 design includes extensive reference to the use of mobile processing for liquid wastes. In order to more readily adapt a variety of skid mounted or free-standing mobile components, the use of **permanently** installed flex hoses the industry would benefit by including this in the regulatory approval process for the AP1000 design.

Current Status

Both EPRI and Westinghouse are in agreement that the Westinghouse DCD is not the correct forum for resolving this issue, and that it will be pursued using other appropriate avenues. However, the need for this design consideration will be included in the URD update.

4. LRW and Effluent Holdup Tank

The LRW and Effluent Holdup Tank designs for the AP1000 generally refer to horizontal cylinders or free standing cylinders with manual cleaning considered (Reference 11.2.2.3.3). Industry experience with these designs and cleaning strategy combined with the low fluid flow across the tank bottom, has repeatedly shown that sludge accumulation is an issue with serious exposure, cost and corrosion consequences. The use of upright cylinders with conical bottoms to preclude sludge accumulation is a proven concept and should be considered for both tank and sump design. Using this method to reduce the accumulation of sludge in tank and sump bottoms would reduce the associated cleaning labor, exposure and waste disposal costs, and reduce the potential for concentrating chemical impurities that leads to localized corrosion and weld failure.

Current Status

The Westinghouse AP1000 DCD current tank design is "fixed." The Westinghouse AP1000 DCD will not be revised to include address this issue.

The ALWR LLW committee's position is that this will be addressed in the URD update.

5. LRW Processing

Several special LRW processing needs were identified as part of the review process. They are based both on the document and on industry operating experience.

a. Several non-LRW tanks may require purification during the plant life. Contingencies for that evolution should be designed into their system configuration to preclude commingling those liquid streams with normal LRW streams. Examples include the PCCAWST (passive containment cooling ancillary water storage tank), the reactor core makeup tanks (2 each), and the IRWST (in-containment refueling water storage tank).

b. Consider the installation of separate filter and demineralizer systems for refueling cavity water processing and for spent fuel pool "projects" (e.g., silica removal, cleanout projects, ultrasonic fuel cleaning, spent fuel cask loading/rinsing). Alternatively, connections should be included to facilitate the installation of flexible pool hose which can be routed to project areas of the spent fuel pool or the reactor cavity. This important feature would preclude the requirement for portable underwater systems and temporary filter housings.

c. Resin vessel sluice, spent resin tank transfers, and the associated waste container decant can create severe challenges to processing media, as well as to radiation exposure and hot spot reduction programs. The AP1000 design relies on resin pumps for transferring resin. Industry experience with resin pumps has shown that the destruction of media during that process due to the mechanical stresses imparted by the pump, create fines that foul dewatering laterals in waste containers and settle out in low flow crud traps. The use of air/nitrogen pressurization with adequate sluice water volume is a more effective method of media transfer. Additionally, by-design capture of transfer and decant liquid in spent media tanks and containers, minimization of piping runs and crud traps, and adequate shield designs will minimize the impact of these wastes on processing media.

Current Status

Item a): Based on Westinghouse clarification of the specific design considerations, the ALWR LLW committee agrees that this is no longer an issue.

Item b): Westinghouse believes that adequate purification provisions for the refueling cavity and spent fuel pit exist. These will be better documented during future design phases, and more detailed modifications can be considered at that time.

The ALWR LLW committee will review those designs as they are made available.

Item c): The recommended improvements related to spent resin handling issues will not be included in the Westinghouse AP1000 DCD.

The ALWR LLW committee's position is that further discussion and analysis of the spent resin handling issue is warranted. Modification after the fact will require significant piping and control changes. This will be addressed in the UPP and the URD update.

6. Secondary Resin

For the AP1000, secondary resin includes condensate polishing resin and steam generator blowdown resin. The AP1000 documentation specifies that there is no expected radioactive resin from condensate polishers or steam generator blowdown during most operating cycles. However, the document indicates that, in the event of primary to secondary leakage, the volume of secondary resin could become substantial. (Note: Steam Generator Blowdown Resin is also addressed in Chapter 2, subparagraph 2, as part of the Balance of Plant system operations.)

It is recommended that some discussion be included in the DCD as to why no secondary resin will be generated during normal plant operation. For example, it may be that the resin is being generated but is assumed to be clean (non-radioactive). It should be noted that even clean resin has a very significant cost profile for purchase and for disposition. It is further recommended that some discussion be included in the DCD with respect to the volume of secondary resin being generated from both sources as a result of primary to secondary leakage.

Current Status

Westinghouse indicated they are not taking any action on this issue.

The ALWR LLW committee's position is that it should be addressed in the URD update.

7. Chemical Waste

The AP1000 documentation specifies "chemical" wastes of 350 ft^3/year (~2,600 gal/year) with a shipping/disposal volume of only 20 ft^3/year following compaction. The liquid component of this waste stream is generated from collection of chemistry sampling and analytical procedures. The relationship between the volume generated, shipped, and disposed is not clarified in the document. The documentation refers to the small volume generated, and mobile or off-site processing for the liquid. Accordingly, chemical waste was not reviewed for inclusion in this document, but will be included in a future, liquid radwaste impact review.

Current Status

Westinghouse believes that radioactive chemical waste generation is anticipated to be minimal; i.e., limited to that generated by laboratory titration procedures. The DCD values incorporate conservative use of aging ANS standards. Detailed (non-licensing) radwaste documentation will clarify these waste levels.

The ALWR LLW committee's position is that this section of the DCD is not clear. However, the committee agrees with Westinghouse that this level of detail does not need to be included in the DCD, and it can be addressed as part of a post-DCD design detail or option package.

Accordingly, it will be addressed in the URD update.

4
WASTE REMOVAL AND DISPOSITIONING CONSIDERATIONS

Over the past decade, LLW minimization approaches, in-plant recycling activities, volume reduction technologies, and disposal options have dramatically reshaped the landscape of LLW management economics. The AP1000 DCD incorporates advanced thinking and represents a substantial leap forward from the AP600 design and from the EPRI URD in terms of waste management flexibility. However, the DCD can further its potential for maximizing cost efficiencies and performance in some areas. Additionally, the document as written raises some questions or suggests a need for clarification in other areas.

Section 11.4 of the DCD describes the solid waste management program. It addresses the dispositioning and disposal methods and options for all wet and dry solid wastes, including on site processing, off site processing, and temporary storage.

This chapter provides a comprehensive review of Section 11.4 of the DCD. It offers several important recommendations ranging from simple—but important—administrative changes to significant system modifications and options. It also identifies areas which are in need of further clarification in order to assess the waste quantity projections in Table 11.4-1. Each recommendation is carefully referenced to assist the reader in understanding the question, comment or suggestion.

Within the AP1000 DCD, the following sections were reviewed relative to waste removal and dispositioning considerations:

- Section 1, *Introduction and General Description of the Plant.*
- Section 10, *Steam and Power Conversion System.*
- Section 11, *Radioactive Waste Management.*

1. Fuel Cycle Identification

Table 11.4-1 is based on a plant which has chosen an 18-month fuel cycle. It is suggested that this be included in the title or at least in the notes. If included in the notes, it should be mentioned that a 24-month fuel cycle should result in lower annual waste quantities and associated costs. (Reference paragraph 11.4.2.1.)

Current Status

Westinghouse is taking no action relative to this item. The ALWR LLW committee's position is that this is a simple, minor administrative clarification which should be resolved by Westinghouse as part of the DCD.

It will also be considered for inclusion in the URD update.

2. Shipping Volumes versus Disposal Volumes

Section 11.4 and Table 11.4-1 refer to "shipping volumes." These are actually disposal volumes (i.e., shipped for disposal). If the waste was shipped to an off site vendor, most of the "shipped" values in Table 11.4-1 would not apply. Consideration should be given to listing these as "disposal volumes;" in Table 11.4-1, the applicable column headers might be changed to "Expected Disposed Solid" and "Maximum Disposed Solid."

Current Status

Westinghouse responded that "Shipping volume" in Table 11.4-1 is the volume as it is shipped off-site. This notation has been used for both AP600 and AP1000 without NRC issues.

The ALWR LLW committee's position is that this is a simple, minor administrative clarification which should be resolved by Westinghouse as part of the DCD. Further discussion and analysis of this issue is warranted.

It will be considered for inclusion in the URD update.

3. Description of Primary Resin

Table 11.4-1 identifies one of its waste types as "Primary Resins (includes spent resins and wet activated carbon)." This description needs some clarification for us. It may be better to use the term "primary plant resins" as opposed to secondary polishing resin and SGBD resin. Today, the better plants are tracking on a vessel-by-vessel basis the resin loaded into each demineralizer according to the expected waste classification, vessel resin volume, type of media (e.g., cation, anion, mixed), and expected replacement frequency. This data is used to project long range waste management strategies, container needs, disposal site allocation requirements, and storage needs, as well as developing alternative in-plant processing options. It is strongly recommended that such a table be developed and included in Section 11.4 of the DCD with a referenced link to or notation on Table 11.4-1 (e.g., a footnote for Primary Resin) referring the user to Table 11.4-x).

Current Status

Westinghouse responded that such detailed information is not required by NRC and therefore is not appropriate for the DCD. This level of detail will be published in non-licensing material during more detailed design phases.

The ALWR LLW committee agrees with Westinghouse that this level of detail is not required for the DCD, however, the information is required to evaluate the projected design processes' performance and cost. Further discussion and analysis of this issue is warranted. It will be considered for inclusion in the URD update.

4. Waste Processing System Flow Diagram (Waste Flow Path and Options)

Figure 11.4-1 (page 11.4-35) of the DCD provides substantial flexibility for the dispositioning of DAW. However, additional flexibility could be added for wet solid wastes (resin, filters). Consideration should also be given to allow all waste to go directly to an off site processor or directly to a disposal site. Therefore, consideration should be given to the following options to Figure 11.4-1:

a. A bypass with a deionized water flush capability should be considered to allow spent ion exchange resin to bypass the spent resin tanks and go directly to a HIC or liner in the spent resin container fill station at the west end of the rail car bay of the auxiliary building. The container and fill station are discussed in paragraph 11.4.2.1; the bypass is not discussed, and the bypass is not shown in Figure 11.4-1.

b. A flowpath should also be considered to allow for direct disposal of resin *AND* for direct shipment to an off site processor. This flowpath should come from both the spent resin tank *AND* from the bypass line discussed above. (This option includes two source points and two end points.)

c. Both high activity filters and moderate activity filters should allow for direct disposal of filters *AND* for direct shipment to an off site processor. This flowpath should begin after the filters are transferred to storage drums or casks.

d. HVAC filters, DAW in yellow bags, and clean trash in green bags are all shown with an option to be placed into sealand containers and shipped to an off site processor. An additional option should be added to allow for direct disposal from the sealand container.

Current Status

Westinghouse believes that all of the above items can be accommodated by the current system design. In general, these are not fixed by the licensing process and can be developed in more detailed design phases.

The ALWR LLW committee believes that this appears to be a simple and appropriate administrative fix which should be included in the DCD. As it currently exists, it does not correctly reflect the existing written discussions in Section 11.4 for waste dispositioning. Relying on a future document to correct inconsistencies provides opportunities for confusion and error.

It will be considered for inclusion in the URD update.

5. Clean RCA Waste

a. Paragraph 11.4.2.3.3 makes reference to the management and disposition of clean waste generated within the radiological control area (RCA). Figure 11.4-1 also indicates dispositioning options for clean waste. Because this waste is not "radwaste," it is not addressed in Table 11.4-1 and is not otherwise quantified. This has a significant cost impact and should somehow be projected. Typically, a PWR generates a clean waste volume equal to the annual DAW volume. It is not clear how this could be captured in the DCD, but a discussion of typical generation volumes should be included.

b. Paragraph 11.4.2.3.3 also states that clean waste will be monitored using a "mobile radiation monitoring and sorting system." The following additional information is recommended for this system:

   1) Why is it a "mobile system?" Is this a containerized system intended to be operated in the mobile systems facility (which would suffer from background radiation levels)? Or does "mobile" actually mean "portable," as in some type of cart-mounted monitoring system?

   2) Where will this mobile system be located? As pointed out above, this system needs to consider background radiation levels from resin processing, filter compaction, resin storage in HIC, and waste stored in the waste accumulation room, packaged waste storage room, and sealand container.

   3) Clean waste radiation monitoring equipment should be considered as part of the mobile or off site processing services. At the present time, off site clean waste monitoring is the most cost effective option available for the majority of commercial nuclear plants. For the ALWR, eliminating installed clean waste monitoring equipment will also minimize capital construction costs. The majority of plants now utilize off site servicing for this waste stream.

Current Status

Westinghouse responded that this would be addressed in future detailed designs.

The ALWR LLW committee's position is that the DCD sets forth at least a functional design for plant operation and support systems. The above considerations raise reasonable questions as to whether those support systems are really functional. Therefore, such a determination should be made now, and if they are not functional, then a resolution should be implemented before final submittal and approval of the DCD. Further review and discussion of this issue is warranted.

Clean waste monitoring and management will be addressed URD update. As discussed further in paragraph 4.16, questions remain as to whether the current design for the Mobile Systems Facility will meet its intended functions as stated in the DCD. Accordingly, the Mobile Systems Facility design, and the scope and heavy reliance on mobile processing systems—including clean waste monitoring and sorting—will be addressed in the UPP.

6. Resin Sampling

A single resin sampling device is provided. It is able to collect a representative sample of the spent resin either during spent resin recirculation or during spent resin waste container filling operations. As discussed above, it is important to have the ability to bypass the spent resin tanks and pump resin directly into a HIC. Therefore, a resin sampling capability is also needed for this bypass option. It is not clear that the current resin sampler is located so as to provide this sampling capability. If that is the case, an alternative solution or location is needed. (Reference paragraph 11.4.2.2.5 and Table 11.4-10.)

Consideration also should be given to including a resin sampler and radiation detector on each demineralizer. The savings in waste classification, volume reduction, and disposal costs would result in a very short term return on investment when included as part of the original plant design and construction.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee agrees with Westinghouse that this level of detail does not need to be included in the DCD. However, further discussion and analysis of this issue is warranted, and it should at least be considered for inclusion as part of a post-DCD design detail or option package.

It will also be addressed in the URD update. Because it is a design *option*, it should be considered as part of the utility detailed purchase design, yet it need not be a formal COL item.

7. Data Projections for Table 11.4-1

Consideration should be given to including a table which identifies the VR efficiencies used to derive the data for each waste type and process in Table 11.4-1. This table also should include the container used for each DCD analysis, along with the internal and external container volumes assumed. A note at the bottom of the table should restate the comment in paragraph 11.4.1.3 that, “The solid waste management system does not require source-specific waste containers.” The note might also specify that the containers listed in this table are typical examples only and are included only to demonstrate calculations.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee agrees with Westinghouse that this level of detail does not need to be included in the DCD. However, further discussion and analysis of this issue is warranted, and it should at least be considered for inclusion as part of a post-DCD design detail package.

It will be addressed in the URD update.

8. Segregation by Waste Class

The importance of segregating Class A solid waste (resin, media and filters) from Class BC is a critical consideration from an end product handling aspect, transportation impact, storage impact, disposal impact and availability, and overall program costs. Substantial benefits can be derived by utilizing some or all of the following options:

a. Provide a capability to collect 10 CFR 61 samples from each ion exchange vessel prior to sluicing the media to a storage tank or waste container.

b. Include a pathway to permit sluicing any ion exchange vessel directly to a shipping container (i.e., bypassing the spent resin tanks). This is especially beneficial for vessels loaded with carbon or zeolite media due to the complex nature of sluicing these media and the VR options available for their treatment.

c. Allow routing of any ion exchange vessel to either of the two resin storage tanks or the HIC in the container fill station in the rail car bay.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee agrees with Westinghouse that this level of detail does not need to be included in the DCD. However, further discussion and analysis of this issue is warranted, and it should at least be considered for inclusion as part of a post-DCD design detail or option package.

It will be addressed in the URD update.

9. Spent Resin Waste Container Fill Station

Paragraph 11.4.2.1 (page 11.4-4) states that resin is sluiced from the spent resin tanks into two 158 ft^3 HICs for offsite transport. This raises a few questions:

a. The next paragraph on the same page states that there is only one HIC in the rail car bay. Which is correct?

b. Since at least some of this resin is Class BC resin and high activity, it is likely that a Type B shipping package will be needed. That will limit the container size to an 8-120 HIC (and 90 ft^3 internal net waste volume). Since the DCD indicates that all resin will be mixed—thereby making all resin Class BC—the data in Table 11.4-1 should be revised to reflect this limitation.

c. At the present time, the most economical approach to managing Class A resin is to (1) segregate it from Class BC resin, and (2) use a 21-300 HIC. This will reduce annual container costs, shipping costs, disposal costs, labor, and dose. Therefore, the spent resin waste container fill station in the rail car bay of the auxiliary building should be designed to accommodate a 21-300 HIC (270 ft^3 internal net waste volume).

(Note that a 21-300 HIC will accept 100% of the resin from either of the spent resin tanks, allowing one tank to be designated for Class A resin and the other for Class BC resin. It is recommended that this concept be included in the DCD as an option and as the recommended approach.)

Current Status

Westinghouse will investigate the use of larger HICs; these can be accommodated within the general building design but might require design modifications within the buildings (e.g., wall heights, jib crane lifts).

More segregation of resins (i.e., having multiple HICs available for filling with different resins) will also be investigated. Westinghouse believes this can be accommodated by use of local shielding in the rail bay and / or radwaste building storage areas.

The ALWR LLW committee's position is that item a) identifies an error in the DCD which should be corrected prior to the final submittal. Item b) raises a serious concern over the commingling of Class A and Class BC wastes at a time when some utilities can no longer dispose of Class BC waste due to disposal site restrictions, and the majority of nuclear plants are facing interim storage of Class BC waste by mid-2008. Accordingly, segregation of waste by disposal classification—which is the primary mechanism for reducing Class BC storage and disposal volumes—must be addressed at some point prior to construction of any ALWR. The Westinghouse DCD should at least ensure that this option remains open. The ALWR LLW committee supports Westinghouse's continuing investigation of item c) as an appropriate response.

The error identified in item a) should be corrected in the existing DCD before final submission. Further discussion and analysis of item b) is warranted and will be addressed in the UPP and URD update.

10. Resin and Filter Replacement Frequency

Paragraph 11.4.2.1 (beginning on page 11.4-4) identifies the replacement frequency for resin and filters. The listed frequencies do not give consideration to resin bed depletion nor optimal filter replacement criteria (e.g., maximum dose rate). Consider the following:

- All ion exchange resin beds are disposed and replaced *every refueling cycle*. This is typically necessary only in the event of significant fuel failure resulting in significant cesium buildup in the primary system. Even then, it only applies to selected resin beds. Aside from a fuel failure situation, running all resin beds to exhaustion could increase the useful bed life by 50% or more, which translates to a 50% reduction in resin generation, disposal, and replacement costs. However, the AP1000 design configuration has CVCS demineralizers located inside containment and therefore may preclude mid-cycle change-outs, requiring replacement each cycle. Additionally, loading a clean mixed bed prior to shutdown for crud burst cleanup is a common industry practice. The AP1000 resin management strategy should be re-considered and addressed in the DCD and be reflected in Table 11.4-1, columns 2 and 3.

- All wet filters are replaced every refueling cycle. Primary filters at most nuclear plants are replaced on activity/dose rate correlations, which are typically based on the limiting long-lived nuclides. Also, many filters are replaced on a much greater frequency than once per fuel cycle due to filter material degradation considerations. Current filter replacement practices should be reviewed, evaluated, and additional discussion provided in the DCD to support the filter replacement frequency.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee's position is that spent filter and ion exchange media are the most expensive waste forms routinely generated at light water reactors. Accordingly, the dispositioning options should be optimized and addressed in some detail. The committee agrees with Westinghouse that this level of detail does not need to be included in the DCD. However, further discussion and analysis of this issue is warranted, and it should at least be considered for inclusion as part of a post-DCD design detail package.

It will be addressed in the URD update.

11. Filter Sampling for Waste Characterization

Paragraph 11.4.2.3.2 of the DCD states that a filter sample is obtained "through a port in the transfer cask." Consideration should be given to having a remote capability for obtaining swipes of either the filter housing or the actual filter without the need for obtaining an actual filter sample. This is especially important for primary filters, which, with currently used filter technology, require metal jackets to preclude failure. This makes obtaining samples a very difficult task even with filter ports on the transfer cask—not impossible, just very difficult and dose intensive.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee's position is that this is an important ALARA consideration which should not be overlooked. The committee agrees with Westinghouse that this level of detail does not need to be included in the DCD. However, further discussion and analysis of this issue is warranted, and it should at least be considered for inclusion as part of a post-DCD design detail or option package.

It will be addressed in the URD update.

12. Draining Liquid from Spent Filters

Paragraph 11.4.2.3.2 also states that excess water from filters can be drained from the filter storage tubes into a floor drain in the waste accumulation room. This type of approach ALWAYS leads to contamination events from hose failures, highly contaminated floor drains, etc. An alternative and better approach would be to allow the filters to drain in the filter housing for 8 hours or more as necessary prior to removal.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee's position is that the approach provided in the DCD will not likely be used and that utilities will universally use an alternative approach. However, the Westinghouse approach is plausible and need not be changed. Instead, this recommendation will be addressed in the URD update.

13. Volume Reduction of Spent Filters

Both low activity and moderate activity filters are placed in drums and then supercompacted. If stabilization is required, they may be placed in a HIC or encapsulated in drums using a mobile system. The dispositioning approach for high activity filters is not addressed. (Reference paragraph 11.4.2.3.2.) This raises the following questions:

a. How will high activity, Class BC filters be packaged and processed?

b. Filter construction materials should be specified by application, to ensure maximum VR is attainable. Examples include 100% incinerable for low activity applications, and no metal components for high activity applications to permit advanced VR processes.

c. An option needs to be defined for all filter waste to be shipped to an off site processor.

d. Drum compaction VR ratios are specified in the DCD as 3.6:1 (paragraph 11.4.2.1, page 11.4-3). However, Table 11.4-1 suggests only a 2:1 VR (from 52 ft^3 generated to 26 ft^3 shipped/disposed). Also, filter encapsulation results in a net increase in volume. Some discussion should be provided to explain what is happening with spent filter waste sufficiently to reproduce the stated shipping volumes.

e. For filters collected in a HIC, where will the HIC be located? Is there room for a separate Class A HIC and a Class BC HIC? Where will the packaged filter HIC be stored while awaiting characterization, decay and shipment? Where will the next filter HIC be staged while waiting for the first one to be shipped?

f. High activity filters that cannot be volume reduced should be packaged in a HIC which is specifically sized for the applicable filters. Within such a container, the filters should be packaged in an upright array to minimize void space and to facilitate overfill where practical. This is not currently a common practice, as it requires extensive advance planning. Such advance planning which matches filter quantities and sizes to the internal configuration of the disposal container can easily be accommodated for a new reactor. One plant which has implemented this approach is Crystal River, which may serve as an example design.

Current Status

More detailed filter handling procedures will be developed during later design phases and included in design documentation (i.e., not in licensing documentation since this has not been required by NRC). This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee agrees with Westinghouse that, for most of the items above, this level of detail does not need to be included in the DCD. However, several elements of the spent filter handling process would impact the design for filter housings, overhead clearance, and structural access/through-passage. Further discussion and analysis of each of the above considerations are warranted, and they should at least be considered for inclusion as part of a post-DCD design detail or option package.

The above items will be addressed in the URD update. In addition, due to the large number of issues identified in items 10 through 13, the UPP will address filter waste management as a collective area of focus.

14. Maximum Filter Waste Generation

The *maximum* generation volume of filters in Table 11.4-1, column 4, of the DCD is projected at 9.4 ft^3, or approximately 18 filters per fuel cycle. This volume is less than the normally *expected* generation volume for both installed and portable filter system (e.g., cavity drain filtration, SFP and cavity underwater filtration, & LRW processing) wastes. This seems unusually low and should either be corrected or further explained in the DCD.

Current Status

These values were corrected by Westinghouse in the existing AP1000 DCD.

The ALWR LLW committee will work with Westinghouse to review the final estimates prior to dispositioning this item. This item will also be captured in the URD update.

15. Storage for Accumulated and Packaged Wet Solid Waste

No storage space is provided for packaged spent resin or for filters packaged in a HIC, although the DCD specifies a 90-day post-packaging storage period. The DCD indicates that the packaged waste storage room is for DAW and for filters in process shields. Large, high activity packages, such as HIC, are not likely to move in and out of the processed waste storage room, and they would represent a substantial personnel dose impact if they were stored in that room. (Reference paragraph 11.4.2.1; Tables 11.4-4 and 11.4-5; and Figure 1.2-22.)

Resin is normally removed from spent resin tanks as part of a campaign involving several HICs over only a few days or weeks. If both resin tanks were filled with a mixture of Class A and Class BC resin (550 ft^3 total), at least six 8-120 HIC would be required. Yet the fill station can handle only one HIC. It is unclear where the other five HIC will be stored during the resin transfer campaign. Also, these HIC must be stored for sampling and characterization, decay, shipping cask availability, off site processor availability, and accumulation for off site processing campaigns. The current AP1000 design should incorporate these capabilities, which will impact plant operations, staffing requirements, and personnel exposure.

Consideration should be given to providing a packaged waste storage facility for high activity waste in HIC ranging in size from 8-120 to 21-300 (A typical design might be similar to that used at Callaway NPP; however, it will require better HIC and crane access.) Based on the calculations included in the storage section of this report, space will be needed for at least seven of each of these two cask sizes.

Current Status

Westinghouse responded that the accumulation and handling of wet solid wastes will be developed in more detail during more detailed design phases, and EPRI/Utility input will be welcome.

The ALWR LLW committee's position remains that the existing design does not accommodate adequate accumulation and storage space to operate the plant in the most economical manner. The committee agrees with Westinghouse that this could be accommodated outside of the DCD by providing such space as part of further design options and considerations.

Because this is an important operational area which impacts O&M costs, this should not be overlooked. Further discussion and analysis of this important issue is warranted and will be addressed in the URD update. It will also be considered for inclusion in the UPP as part of the discussion on the Mobile Systems Facility, which provides for some limited waste storage.

16. Mobile Systems Facility

The following comments and questions are offered on general arrangement of the Mobile Systems Facility:

a. The total storage capacity of the "packaged waste storage room" is 3900 ft^3 (10'Dx30'Lx13'H). This storage space is for DAW, mixed waste, and chemical waste; it is not for packaged spent resin or filters. Although the dimensions of the room suggest 3900 ft^3, the actual usable storage space is less, as variations in package shapes and sizes would reduce this storage volume. More importantly, the dimension of the room includes the shielded accessway, which is approximately 10'x4'x13'H, or 520 ft^3. Accordingly, the usable storage space is probably closer to 3000 ft^3.

b. The actual dimensions for the accessway to the packaged waste storage room were not specified, but a reasonable approximation indicates a maximum container width of 4'. This may be too narrow for even a B-25 box to maneuver through, and it would have to go in end first—which means a fork lift or a pallet jack could not move the box. It also means that the box would not fit through the 4' door opening (i.e., either the accessway or the door needs to be *at least* 6').

In addition, mixed liquid waste and chemical waste is stored on a four-drum containment pallet—which could probably *not* go through a 4' accessway due to the narrow passage width and the absence of turning clearance. This same challenge would exist for palletized drums. As a minimum, this accessway limits the type of packages which could be moved into the packaged waste storage room, and this should be reviewed to ensure flexibility. Given these physical access restrictions, it is not likely that the room would be used for its intended purpose.

(Note: If it is intended that waste be moved in and out of the packaged waste storage room using the overhead crane, this is not addressed in the DCD. If it is intended that the crane be used, overhead clearance requirements would likely reduce the storage capacity of the room. Moreover, the drawing provided in Figure 1.2-22 (Section 1 of the DCD) suggests double doors at the entrance to the packaged waste storage room; the door header would eliminate the ability to move a container through the passageway with a crane, and raising further questions about the overhead clearance, maximum package height, skyshine, etc.)

c. There is a "waste accumulation room" adjacent to the "packaged waste storage room." Although the purpose of this room is briefly referred to in the DCD (paragraph 11.4.2.3.2), it appears that this room is used to accumulate waste pending volume reduction processing and for storing empty waste containers. It is also used for storing filter waste in process shields, for storage of mixed waste and chemical waste, and for storage of DAW. In addition, it is likely that this room is intended to sort waste by the expected volume reduction method and for recovery of reusable items. Clearly this is a very busy room with many activities and varying dose rates, all of which compete for space and shielding.

The dimensions of the room were not stated, but they can be reasonably approximated from the known dimensions of the packaged waste storage room as being 20'x30'x13'H, or 7800 ft^3. The intended purpose of this room should be discussed in section 11.4.2.1 and in greater detail.

Note that the doorway to the room appears in the drawing to be 4'. It needs to be at least 6'. In addition, the drawing provided in Figure 1.2-22 (Section 1 of the DCD) suggests double doors at the entrance to the waste accumulation room. The door header would eliminate the ability to move a container through the passageway with a crane, and raising further questions about the overhead clearance, maximum package height, skyshine, etc.

d. The most common approach to managing DAW in U.S. commercial nuclear plants is to accumulate waste in sealand containers, which is included in the waste flowpath as an option (Figure 11.4-1). Ideally, space would be provided for four side-by-side 20' long sealand containers for the accumulation of segregated waste: 2 for DAW, 1 for metal, and 1 for clean RCA trash. None of these sealand containers could fit into the waste accumulation room. Paragraph 11.4.2.4.2 states that the mobile systems facility has a designated laydown area for a sealand (cargo) container, which can be handled by the facility crane. Consideration should be given to additional containers.

e. A review of the general plant arrangement drawing (site plan Figure 1.2-2) indicates that vehicles moving in and out of the mobile systems facility may have difficulty in turning around. If the trailer is backed into the facility (which would be the expected approach), it would need to back in from the plant entrance past many buildings and possible obstructions for up to 100 yards, including a 90 degree turn. A similar design challenge currently exists at a few of the operating plants and seriously impacts the ability to use their LLW storage and processing facilities. Consideration should be given to incorporating either a large turn-around area or, more practical, a second plant entrance in direct line with the front of the mobile systems facility.

f. Given the overall space requirements identified herein for packaged waste storage, waste accumulation, mobile waste processing equipment, three to four sealand containers, and storage for 14 to 15 resin and filter HIC, the mobile systems facility appears to be rather small to meet cost efficient operational requirements. This will most certainly result in an increase in radiation exposures and labor/staffing requirements. (Note that each additional person added to the plant staff results in an increased life-of-plant operating cost of $4 million.)

Current Status

Westinghouse responded that more detailed discussion of the number of waste storage containers will be considered in later design phases. Westinghouse believes the AP1000 represents a cost-optimized waste accumulation area, but this is open item from the ALWR LLW committee.

The committee's position is that sufficient, detailed concerns are set forth above to question the operational functionality of the Mobile Systems Facility as it currently exists in the DCD. Westinghouse has suggested that a "more detailed discussion of the number of waste storage containers" is an appropriate resolution, yet it will not adequately address the numerous and varied concerns over this facility's functions and capabilities. Clearly this is a key facility integral to the AP1000 design; accordingly, as a minimum, its general arrangement, area dimensions, waste capacities, accessway dimensions, and crane clearances should be adequate, accurate, and included in the final DCD submission so as to demonstrate that the facility meets the minimum design functional intent.

Further discussion and analysis of this issue is warranted and will be included in the UPP and URD update.

17. Liquid Chemical Wastes and Oily Wastes

The AP1000 documentation specifies "chemical" wastes of 350 ft^3/year (~2,600 gal/year) with a shipping/disposal volume of only 20 ft^3/year following compaction. If liquid chemical wastes are "reduced in volume" from 350 ft^3 to 20 ft^3/year, then some discussion is needed as to how this is accomplished. (Reference paragraph 11.4.2.1.) Similarly, oily wastes (contaminated oil, grease, oily rags, etc.) are not addressed in the DCD.

Current Status

Similar to 3-7, Westinghouse responded that radioactive chemical waste generation is anticipated to be minimal; i.e., that generated by laboratory titration procedures. The DCD values incorporate conservative use of aging ANS standards. Detailed (non-licensing) radwaste documentation will clarify these waste levels.

The ALWR LLW committee's position is that this section of the DCD remains elusive and incomplete. However, the committee agrees with Westinghouse that this level of detail does not need to be included in the DCD, and it can be addressed as part of a post-DCD design detail or option package.

Accordingly, it will be addressed in the URD update.

18. Mixed Waste and Chemical Waste Containment Pallet

A single four-drum containment pallet is provided for accumulation of mixed liquid waste and chemical waste (after VR). This is a very limited capability and leads to the following questions:

a. Where is the chemical waste stored prior to volume reduction?

b. Where is the chemical waste volume reduction facility or equipment?

c. Where is contaminated oil accumulated?

d. If three mixed liquid waste drums and three chemical waste drums are generated annually, then a four-drum pallet falls short of the annual needs. Moreover, shipping a single drum of chemical waste at a time is prohibitively expensive, suggesting a need to accumulate many waste drums. (Note that few nuclear plants are required to disposition their mixed or chemical waste on an annual basis.) A chemical waste storage facility is needed which meets the EPA/RCRA requirements, and it does not appear that any such provisions are made in the waste accumulation room of the mobile systems facility for such storage.

Current Status

Westinghouse responded that more detailed development of mixed waste handling is necessary and will be provided in more detailed design phases. This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee's position remains that the existing design does not accommodate adequate accumulation and storage space for mixed waste and chemical wastes, including contaminated waste oil. The committee agrees with Westinghouse that this could be accommodated outside of the DCD by providing such space as part of further design options and considerations. However, it is an important operational area which should not be overlooked and will be addressed in the UPP and URD update.

19. Isotopic Data Tables

Tables 11.4-2 and 11.4-3 provide *influent* isotopic data; Tables 11.4-4 and 11.4-5 provide *shipped* (disposed) isotopic data after a specified number of days decay. This differentiation should be clarified as follows:

a. Paragraph 11.4.2.1, page 11.4-3, states that Tables 11.4-2 and 11.4-3 provide the "estimated expected isotopic curie content of the primary spent resin and filter cartridge wastes to be processed…" However, the title of the two tables indicates that the data is the "Expected Annual Curie Content of Primary Influents." It is not clear from the discussion at which point this curie data applies:

- When transferred to the spent resin tank?
- When transferred to a HIC or a filter process shield?
- When actually processed via dewatering, encapsulation, etc.?

b. With respect to the above discussion, when does the decay clock begin running for Tables 11.4-4 and 11.4-5?

c. Tables 11.4-4 and 11.4-5 should be clearly labeled with the number of days decay, which are 90 days and 30 days respectively.

d. It is not clear why Tables 11.4-4 and 11.4-5 have two different decay periods. Table 11.4-5 is based on a 30-day decay period for the maximum generation rate, but that does not seem to justify a shorter decay period. It is suggested that both use the same decay period, and preferably both be 90 days to recognize a combination of decay in the spent resin tanks and decay in HIC.

Current Status

This will not be addressed in the Westinghouse AP1000 DCD.

The ALWR LLW committee's position is that the above concerns are largely administrative clarifications and corrections which should be added to the DCD.

Further discussion and analysis of this issue is warranted. It will be addressed in the UPP and URD update.

5 WASTE QUANTITIES AND COST ANALYSES

It is sometimes difficult to quantify the cost savings and performance benefits of individual system modifications and alternative approaches to LLW management. All of the recommendations in this report are based on extensive LLW cost and performance analyses using data from almost every commercial nuclear plant in the U.S. Such analyses were accomplished using EPRI's Waste Logic suite of software programs. The recommendations herein represent the optimum approaches employed by those plants which have the lowest LLW program costs and lowest disposal volumes for each waste type.

Chapters 6 through 10 quantify, in terms of LLW program cost and performance, the current AP1000 approach as detailed in Section 11 of the DCD and as summarized in Table 11.4-1. The LLW quantities and associated costs for the DCD are compared to the optimum approach which EPRI currently recommends during LLW assessments to members of its Nuclear Business Group and which are implemented by the top performing plants for each waste type. The results suggest annual cost savings of $0.74 million, and a 60-year cost savings of roughly $45 million. These cost savings benefits are accompanied by a substantial reduction in disposed waste volumes (i.e., improved performance). ***The magnitude of the cost and performance benefits derived from the updated waste generation values provides ample justification for implementing the recommended design enhancements.***

The following global assumptions apply to all cost and performance analyses in Chapters 6 through 10.

Global Assumptions for Quantifying Waste Volumes and Costs

1. All program improvement considerations, recommendations, and analyses were selected so as *not* to impact the regulatory approval process.

2. The AP1000 design is consistent with the EPRI advanced design standard "good neighbor policy:" ***All liquid waste effluent releases will meet or exceed the current best performers***.

3. Cost and volume reduction values for the AP1000 were quantified based on the waste generation and shipping (disposal) volumes identified in Table 11.4-1 of the DCD. Some data points do not reflect typical industry values (e.g., unusual processing efficiencies or waste generation volumes); these items are identified, discussed herein, and adjusted accordingly.

4. All cradle-to-grave (CTG) cost profiles assume the continuous availability of a disposal site for the entire plant life. Interim on site storage considerations and life-of-plant storage options are addressed separately in Chapter 11.

5. It is assumed that disposal fee structures similar to existing disposal sites will be applied.

6. It is assumed that the existing, commonly used volume reduction processes, or equivalent, will continue to be available throughout the entire plant life.

7. Only proven technologies and approaches were considered. In this case, a "proven technology" is one which has been demonstrated to EPRI member utilities to be an effective process with readily reproducible results.

8. The impact of balance-of-plant system design, operation, and chemistry controls can dramatically affect radwaste generation and characteristics and will be included in the next review phase of this project. Balance of plant considerations are discussed in Chapter 2.

9. Unless specifically addressed herein, it is assumed that the AP1000 design meets the performance capabilities of the top tier (top 10%) of existing commercial nuclear plants. Accordingly, all proposed EPRI performance values and recommended approaches are based on these top tier plants, *as defined for each waste type* rather than being based on overall plant operating performance.

10. This reports examines LLW technologies and performance, as they exist in 2002. It is recognized that LLW technological advancements are not frozen in time but will, instead, continue to evolve and improve. Such future advancements will be addressed at the appropriate time and in appropriate documentation, including the EPRI URD.

11. The determination of escalation factors for waste burial/dispositioning costs, including all assumptions, is discussed in Appendix C. Those escalation factors are based on the only known factors for LLW burial and dispositioning, which are set forth in NUREG-1307 for estimating decommissioning costs. Fluctuations in waste burial costs and dispositioning costs have been inconsistent and generally unpredictable over the sixteen year period captured in NUREG-1307. The uncertainties inherent in the escalation factors contained in NUREG-1307 make them unreliable when projected 60 years into the future.

    For this reason escalation was not included in any of the cost analyses in this report. The 60-year cost and cost savings projections are presented in year 2003 dollars. However, because there is no other long range escalation factor data available at the present time, the escalation factor tables in Appendix C are included in this report to be applied independently by any reader who has need of such a projection. Table C-1 should be used for interim and life-of-plant storage; Table C-2 should be used when waste is shipped annually (i.e., without extended storage).

12. The volume reduction ratios and cradle-to-grave (CTG) costs listed in Table 5-1 are used in all related calculations in this report. They were derived from industry LLW cost analyses performed using EPRI's Waste Logic software over the past ten years and adjusted to 2002 typical processing and disposal fees. Note that all costs in Table 5-1 are in $\$/ft^3$ *generated* and not $\$/ft^3$ disposed. These costs are arrived at by dividing the total of all related costs by the number of ft^3 generated.

Table 5-1
Volume Reduction and Cradle-To-Grave Costs for Individual Waste Types

Waste Type	Processing Technology	VR Ratio (1)	$/Ft^3 Generated	Top Tier CTG $/Ft^3 Gen
Class A Resin	Direct Disposal	1:1.14	$350-500	$375
	Steam Reforming	7:1	$350-$450	$400
Class BC Resin	Direct Disposal	1:1.34	$650-2200	$950
	Steam Reforming	7:1	$700-$1800	$950
Class A Filters	Direct Disposal	1:4	$1200-$1800	$1,500
	Drum Supercompaction	5:1	$275-450	$325
	Filter Shear	1:1 (2)	$500-800	$700
Class BC Filters	Direct Disposal	1:4	$2500-4700	$3,000
	Filter Shear	1:1	$500-700	$600
DAW	Best Way Processing	20:1	30-40	$35
	Drum Supercompaction	3:1	$70-110	$85
	Box Supercompaction	5:1	$50-70	$60
	Bulk Supercompaction	7:1	$30-45	$40
Mixed Solid Waste	Microencapsulation	1:2	$1700-2700	$2,200
Mixed Liquid Waste	Burn for Recovery	100:1	$1500-2500	$2,000
Chemical Waste	Not defined in DCD	17.5:1		

(1) VR Ratio is Generation: Disposal volume. If Disposal volume is higher than Generation volume, then additional waste or void space is generated during packaging or processing.

(2) VR ratios for filter shear are challenging to understand. Most plants package 16 to 35 ft^3 of unsheared filter waste in an 8-120 HIC, with the better performers achieving 30 ft^3. Filter shears typically result in four times as much filter waste in a HIC. Although the final disposal package includes some void space, the VR efficiency factor is 1:1 (120 ft^3 of filter waste packaged into a 120 ft^3 container).

(3) All proposed EPRI performance values and recommended approaches are based on these top tier (top 10% of) plants, *as defined for each waste type* rather than being based on overall plant operating performance.

(4) As used throughout this document, "CTG" refers to all costs and activities from initial procurement to final disposition, including waste generation, containers, transport, characterization, volume reduction (conditioning), storage, and final disposal.

6
PRIMARY FILTER WASTE

Background

Table 11.4-1 of the AP1000 DCD defines “Primary Filter” waste to include “high activity and low activity cartridges.” This definition suggests that Class A and Class BC filters will not be segregated, thereby relegating all such filters to a single generic classification of Class BC waste. This approach has a significant adverse impact on cradle-to-grave (CTG) costs, applied volume reduction technologies, and disposed waste volumes.

This chapter quantifies the annual and 60-year CTG cost and performance values for LLW burial and dispositioning of filter wastes. It quantifies both the assumed AP1000 approach and the recommended EPRI advanced approach (i.e., the approach used by the top tier U.S. commercial nuclear plants). These analyses are supported by three data tables:

- Table 6-1 quantifies the current AP1000 approach based on the data in Chapter 11 of the DCD and top tier industry CTG costs.
- Table 6-2 quantifies the advanced approach suggested by EPRI’s ALWR LLW Committee.
- Table 6-3 summarizes the net cost savings and performance (disposal volume reduction) benefits of implementing EPRI’s advanced approach.

The assumptions used in these analyses precede the applicable tables.

Assumptions for Table 6-1: Filter Waste Analyses for Assumed AP1000 DCD Approach

1. The DCD assumes no segregation of Class A and Class BC filter waste, which is reflected in Table 6-1 with 100% of the filter waste recorded as a single waste type, Class BC.

2. Table 11.4-1 of the DCD indicates an annual filter waste generation volume of 52 ft^3, which is the value used in Table 6-1.

   The DCD also specifies that all filter waste will be collected in 55-gallon drums and then compacted so as to achieve a 2:1 VR. Compaction of commingled Primary Filter waste would involve too much radiation exposure and would likely produce a significant quantity of Greater Than Class C waste. For the purposes of the analyses in Table 6-1, it is assumed that all commingled filter waste is disposed as Class BC and is packaged into a 8-120 HIC. It is anticipated that the commingled filter waste will be shipped in a Type B shipping cask, thereby limiting the HIC size to an 8-120.

3. As indicated in Table 5-1, top tier industry values for waste packaging for commingled filter waste (direct disposal) indicate a reverse packaging VR of 1:4 (e.g., 30 ft^3 of filter waste in a 120 ft^3 HIC). Assuming that the AP1000 generates 52 ft^3/year of commingled filter waste as reported in Table 11.4-1 of the DCD, the annual disposal volume would be 208 ft^3 instead of the 26 ft^3 reported. The value of 208 ft^3 was used for the analyses in Table 6-1.

4. A CTG cost of \$3000/ft^3 of generated waste was used for the AP1000 cost analyses in Table 6-1. This is based on the top tier CTG cost value in Table 5-1 for direct disposal of Class BC filters using a reverse packaging ratio of 1:4.

Table 6-1
Primary Filter Profile: *Current* Assumed AP1000 LLW Approach

	Annual	60-yr Plant Life
Generation Volume (Ft^3)	Class ABC = 52	Class ABC = 3,120
Disposal Volume (Ft^3)	Class BC = 208	Class BC = 12,480
Key VR Method	Direct Packaging in 8-120 HIC	Same
Typical Cradle-To-Grave Cost (\$/Ft^3 generated)	Class BC = 3,000	Same (unescalated value)
Total Cost (\$)	Class ABC = 0.16 M	Class ABC = 9.36 M

Assumptions for Table 6-2: Filter Waste Analyses for EPRI Advanced Approach

1. The better performing PWR stations are generating one filter HIC every two fuel cycles (3 years). Assuming 30 ft^3 of filter waste in an 8-120 HIC, this translates to a generation volume of only 10 ft^3/year for a single-unit plant. Note that this includes both high activity Class A (i.e., >200 mR/hr) and all Class BC filters. Regardless of how efficient the plant is at reducing filter waste, the quantity of filters generated is highly dependent upon the limiting long-lived nuclide for Class BC waste. That nuclide generally determines when to replace high activity primary filters. In an effort to be conservative, the volume of filter waste used in these analyses is, therefore, doubled to 20 ft^3 annually.

2. As discussed previously, it is assumed that the DCD approach does not include segregation of Class A and Class BC filter waste. The EPRI advanced approach (consistent with the top tier industry performers) assumes reasonable segregation efforts so as to achieve at least a 60:40 split between Class A and Class BC filter waste (12 ft^3 of Class A filters; 8 ft^3 of Class BC filters). These values are applied in Table 6-2.

3. EPRI's advanced approach would segregate Class A filter waste into 55-gallon drums, hold for decay as needed to meet supercompaction dose rate acceptance criteria, then

supercompact the drummed waste. This may achieve a VR of 7:1; for the purposes of this analysis, a conservative VR of 4:1 was used for Class A filters, producing a disposal volume of 12 ÷ 4, or 3 ft^3 annually.

Segregated Class BC waste would be volume reduced using a filter shear or equivalent VR method capable of increasing the packaged volume of filter waste in a HIC by at least a factor of 4 (i.e., significantly minimizes waste container void space). The 8 ft^3 generated will result in a unprocessed disposal volume of 32 ft^3. Employing a filter shear will cut that disposal volume by a factor of four to only 8 ft^3/year.

Accordingly, the disposal volumes used in Table 6-2 are: Class A = 3; Class BC = 8.

4. The most expensive component of the CTG cost profile for high activity filter waste is the container void space and resulting packaging inefficiencies. A typical high integrity container of Class BC filter waste will cost between $60,000 and $120,000 just to dispose, and most of this is void space. When the entire cradle-to-grave cost is applied against the net waste inside the waste container, CTG costs range from $300 to $4700/$ft^3$ of generated waste, depending on the packaging inefficiencies (void space), volume reduction ratio of the applied VR technology, activity and dose rate of the filters, and the waste Class of the disposal package.

   The AP1000 design provides for direct disposal of filter waste without VR, so a direct disposal CTG cost value of $3000/$ft^3$ was used for the AP1000 analysis. For the EPRI advanced approach in Table 6-2—which involves a combination of filter segregation by waste Class, supercompaction of low activity filters, and the use of a filter shear or equivalent VR technology for high activity filters—a value of $325 was used for Class A filters being supercompacted and $700/$ft^3$ for Class BC filters.

Table 6-2
Primary Filter Profile: AP1000 *Advanced* Approach

	Annual	**60-yr Plant Life**
Generation Volume (Ft^3)	Class A = 12 Class BC = 8	Class A = 720 Class BC = 480
Disposal Volume (Ft^3)	Class A = 3 Class BC = 8	Class A = 180 Class BC = 480
Key VR Method	Class A = Supercomp Class BC = Filter Shear	Same
Typical Cradle-To-Grave Cost ($/$Ft^3$ generated)	Class A = 325 Class BC = 700	Same (unescalated value)
Total Cost ($)	Class A = 0.00 M Class BC = 0.01 M **Total = 0.01 M**	Class A = 0.23 M Class BC = 0.34 M **Total = 0.57 M**

Cost and Performance Benefits Summary

Table 6-3
Primary Filter Profile: Cost and Performance Benefits

	AP1000 Documentation Approach	**EPRI Advanced Approach**	**Delta (Benefits)**
Annual			
Generation Volume (Ft^3)	52	20	**32**
Disposal Volume (Ft^3)	208	11	**197**
O&M Cost ($)	0.16 M	0.01 M	**0.15 M**
60-yr Plant Life			
Generation Volume (Ft^3)	3120	1200	**1,920**
Disposal Volume (Ft^3)	12,480	660	**11,820**
O&M Cost ($)	9.36 M	0.57 M	**8.79 M**

7
PRIMARY RESIN

Background

Table 11.4-1 of the AP1000 DCD defines “Primary Resins” waste as including “spent resins and wet activated carbon.” This implies that all primary resin is commingled for disposal as Class BC waste.

This chapter quantifies the annual and 60-year CTG cost and performance values for burial and dispositioning of resin. It quantifies both the AP1000 approach and the recommended EPRI advanced approach (i.e., the approach used by the top tier U.S. commercial nuclear plants). These analyses are supported by three data tables:

- Table 7-1 quantifies the current AP1000 approach based on the data in Chapter 11 of the DCD and top tier industry CTG costs.
- Table 7-2 quantifies the advanced approach suggested by EPRI’s ALWR LLW Committee.
- Table 7-3 summarizes the net cost savings and performance (disposal volume reduction) benefits of implementing EPRI’s advanced approach.

The assumptions used in these analyses precede the applicable tables.

Assumptions for Table 7-1: Primary Resin Analyses for Assumed AP1000 DCD Approach

1. The DCD estimates that the AP1000 will generate 400 ft^3 of primary resin each year. There is no clear definition in the DCD for “primary resin,” so it is assumed to mean everything other than secondary resin (i.e., everything other than steam generator blowdown resin and condensate polisher resin).

2. The 400 ft^3 of primary resin is packaged into HICs, producing a shipping/disposal volume of 510 ft^3. This suggests a reverse efficiency of 1:1.27. This is inconsistent with industry data, which indicates an average reverse packaging efficiency for commingled primary resin at – 1:1.34, increasing the annual shipping/disposal volume to 535 ft^3. This is the corrected value used in Table 7-1, and it should be reflected in the DCD.

   (The *maximum* generation volume listed in Column 5 of Table 11.4-1 would also increase to 2278 ft^3/year, although *maximum* values are not included in the analyses in this report. This should be reflected in the DCD.)

3. The DCD proposes to use a size 158 HIC for collection and shipping of primary resin. It is highly probable that such waste will need to be shipped in a Type B shipping cask, which limits the container size to an 8-120 HIC (net waste = 90 ft^3).

4. The DCD appears not to provide for segregation of Class A and Class BC resin, which is reflected in Table 7-1 with 100% of the filter waste recorded as a single waste type, Class BC.

5. A CTG cost of $950/ft3 of generated waste was used for Class BC resin in the AP1000 cost analyses in Table 7-1. This is based on the top tier CTG cost value in Table 5-1 for dewatering and direct disposal of Class BC resin using a reverse packaging ratio of 1:1.34.

Table 7-1
Primary Resin Profile: Current Assumed AP1000 LLW Approach

	Annual	**60-yr Plant Life**
Generation Volume (Ft^3)	Class ABC = 400	Class ABC = 24,000
Disposal Volume (Ft^3)	Class BC = 535	Class BC = 32,100
Key VR Method	Dewater; Direct Disposal	Same
Typical Cradle-To-Grave Cost ($/$Ft^3$ generated)	Class BC = 950	Same (unescalated value)
Total Cost ($)	Class ABC = 0.38 M	Class ABC = 22.80 M

Assumptions for Table 7-2: Primary Resin Analyses for EPRI Advanced Approach

1. Large single-unit PWRs generate between 90 and 180 ft^3 annually (and sometimes less). For the purposes of this report, a conservative mid-range value of 140 ft^3/year was assumed.

2. EPRI's advanced approach centers around segregation of Class A and Class BC resin. It is conservatively assumed that 50% of the resin generated will actually be Class A; 50% or less will be Class BC. This translates to 70 ft^3/year each of Class A and Class BC resin, which are the resin generation quantities used in Table 7-2.

3. Under the EPRI approach, all resin is assumed to be shipped in a HIC and shipped either for steam reforming or to a similarly aggressive process (e.g., glassification, incineration). Steam reforming offers a typical VR ranging from around 6:1 to 30:1, which is highly dependent upon sludge loading. For large PWRs, a conservative average VR of 7:1 applies to both Class A and Class BC resin, which is the value used for the resin analyses in Table 7-2. (It also is a typical VR for glassification and incineration of resin, but those processes only apply to low activity Class A resin.)

Table 7-2
Primary Resin Profile: AP1000 *Advanced* Approach

	Annual	**60-yr Plant Life**
Generation Volume (Ft^3)	Class A = 70 Class BC = 70	Class A = 4200 Class BC = 4200
Disposal Volume (Ft^3)	Class A = 10 Class BC = 10	Class A = 600 Class BC = 600
Key VR Method	Segregation plus steam reforming or better	Same
Typical Cradle-To-Grave Cost ($/$Ft^3$ generated)	Class A = 320 Class BC = 950	Same (unescalated value)
Total Cost ($)	Class A = 0.02 M Class BC = 0.07 M **Total = 0.09 M**	Class A = 1.34 M Class BC = 3.99 M **Total = 5.33 M**

Cost and Performance Benefits Summary

Table 7-3
Primary Resin Profile: Cost and Performance Benefits

	AP1000 Documentation Approach	**EPRI Advanced Approach**	**Delta (Benefits)**
Annual			
Generation Volume (Ft^3)	400	140	**260**
Disposal Volume (Ft^3)	535	20	**515**
O&M Cost ($)	0.38 M	0.09 M	**0.27 M**
60-yr Plant Life			
Generation Volume (Ft^3)	24,000	8400	**15,600**
Disposal Volume (Ft^3)	32,100	1200	**30,900**
O&M Cost ($)	22.80 M	5.33 M	**17.47 M**

8
DRY ACTIVE WASTE

Background

The DCD divides DAW (other than mixed waste and filter waste) into two categories: compactable and non-compactable. The design then provides for all compactable waste to be processed using a mobile compaction system. Mobile compaction systems have, in the past, proven not to be cost competitive with other approaches, including off site processes.

The EPRI advanced approach would rely on a variety of less expensive VR approaches, including off site supercompaction, incineration, dissolution, and metal melt. This would bring the AP1000 stated performance into line with current commercial U.S. industry standards demonstrated by the top tier plants, which currently are around 20:1 (95% across-the-board VR).

This chapter quantifies the annual and 60-year CTG cost and performance values for burial and dispositioning of DAW. It quantifies both the assumed AP1000 approach and the recommended EPRI advanced approach (i.e., the approach used by the top tier commercial nuclear plants). These analyses are supported by three data tables:

- Table 8-1 quantifies the current assumed AP1000 approach based on the data in Chapter 11 of the DCD and top tier industry CTG costs.
- Table 8-2 quantifies the advanced approach suggested by EPRI's ALWR LLW Committee.
- Table 8-3 summarizes the net cost savings and performance (disposal volume reduction) benefits of implementing EPRI's advanced approach.

The assumptions used in these analyses precede the applicable tables.

Assumptions for Table 8-1: DAW Analyses for Assumed AP1000 DCD Approach

1. The DCD projects DAW generation at approximately 5000 ft^3/year. This is reasonable for a large single-unit reactor, although some are performing at values well below that projection.

2. The DCD assumes that all noncompactable waste is compacted using a mobile compactor. Typical VR as indicated by the data in Table 11.4-1 of the DCD is only 3.6:1.

3. Based on Table 5-1, the typical as-generated CTG cost for mobile drum supercompaction is \$85/ft^3. This is the value used in Table 8-1.

Table 8-1
DAW Management Profile: *Current* Assumed AP1000 LLW Approach

	Annual	60-yr Plant Life
Generation Volume (Ft^3)	5,000	300,000
Disposal Volume (Ft^3)	1,383	82,980
Key VR Method	Mobile Compaction	Same
Typical Cradle-To-Grave Cost ($\$/Ft^3$ generated)	85	Same (unescalated value)
Total Cost ($)	0.43 M	25.50 M

Assumptions for Table 8-2: DAW Analyses for EPRI Advanced Approach

EPRI's advanced approach relies on a wide range of aggressive VR technologies, such as incineration, metal melt, metal decon/survey, supercompaction, dissolution, etc. As indicated in Table 5-1, applying these technologies is already allowing commercial nuclear facilities to achieve an across-the-board VR of 20:1 and with a typical as-generated CTG cost of $\$35/ft^3$.

Table 8-2
DAW Management Profile: AP1000 *Advanced* Approach

	Annual	60-yr Plant Life
Generation Volume (Ft^3)	5,000	300,000
Disposal Volume (Ft^3)	250	15,000
Key VR Method	Incineration, GIC, metal melt	Incineration, GIC, metal melt
Typical Cradle-To-Grave Cost ($\$/Ft^3$ generated)	35	Same (unescalated value)
Total Cost ($)	0.18 M	10.50 M

Cost and Performance Benefits Summary

Table 8-3
DAW Management Profile: Cost and Performance Benefits

	ALWR Documentation Approach	EPRI Advanced Approach	Delta (Benefits)
Annual			
Generation Volume (Ft^3)	5,000	5,000	**0**
Disposal Volume (Ft^3)	1,383	250	**1,133**
O&M Cost ($)	0.43 M	0.18 M	**0.25 M**
60-yr Plant Life			
Generation Volume (Ft^3)	300,000	300,000	**0**
Disposal Volume (Ft^3)	82,980	15,000	**67,980**
O&M Cost ($)	25.50 M	10.50 M	**15.50 M**

9
MIXED WASTES

Background

It is rare for any commercial U.S. nuclear plant to generate any solid mixed waste today, and certainly not a drum each year. The AP1000 DCD specifies an average of one 55-gallon drum of mixed solid waste per year. The top tier plants generate one drum of mixed solid waste every ten years.

The AP1000 documentation specifies mixed liquid waste generation volumes of 15 ft^3/year. This waste is collected in a 55-gallon drum, which also becomes mixed waste; thereby increasing the total net annual generation to 17 ft^3.

The source of this significant volume of mixed waste is not clear in the documentation. Following EPRI guidelines for mixed waste management, a typical commercial nuclear plant has advanced its mixed waste minimization program so as to generate only one drum of mixed liquid waste every few years; many plants do not generate any mixed waste at all. If the AP1000 implements the EPRI guidelines, it can be reasonably assumed that only one drum of mixed liquid waste is generated every three years on average (as is consistent with the top tier plants).

This chapter quantifies the annual and 60-year CTG cost and performance values for burial and dispositioning of mixed solid waste and mixed liquid waste. It quantifies both the AP1000 approach and the recommended EPRI advanced approach (i.e., the approach used by the top tier U.S. commercial nuclear plants). These analyses are supported by three data tables:

- Table 9-1 quantifies the current AP1000 approach based on the data in Chapter 11 of the DCD and top tier industry CTG costs.
- Table 9-2 quantifies the advanced approach suggested by EPRI's ALWR LLW Committee.
- Table 9-3 summarizes the net cost savings and performance (disposal volume reduction) benefits of implementing EPRI's advanced approach.

The assumptions used in these analyses precede the applicable tables.

Assumptions for Table 9-1: Mixed Waste Analyses for AP1000 DCD Approach

1. The DCD projects 5 ft^3 of solid mixed waste to be generated annually at an AP1000 reactor. This waste is placed in a 55-gallon drum, which also becomes mixed waste, thereby increasing the total net annual generation to 7.5 ft^3. This quantity is used in Table 9-1 for mixed solid waste generation.

2. All mixed solid waste is collected in a 55-gallon drum and shipped to a vendor site without further VR (i.e., assumes the processor only performs conversion). Reverse VR efficiencies—which are typical for Mixed Solid Waste VR processing—should be incorporated in the DCD analyses for Table 11.4-1.

   Typically, conversion of mixed solid waste to LLW doubles the volume of waste due to the stabilization media. This affects the performance in terms of disposed waste volume. Thus, the disposal volume for mixed solid waste in Table 9-1 is increased to 15 ft^3.

3. As indicated in Table 5-1, the cost of dispositioning mixed solid waste is approximately $2,000/ft3 plus double the CTG cost (double the generation volume) for direct disposal of DAW, or a total of $2,200/ft3. This is the value used in Table 9-1 for mixed solid waste.

4. The DCD projects mixed liquid waste generation at 15 ft^3/year and specifies a shipping volume of 17 ft^3 annually. These volume numbers need to reflect the entire drum volume which is considered mixed waste regardless of the volume of the contents. Accordingly, if three drums of mixed liquid waste are generated each year, then the annual generation volume is 3 x 7.5, or 22.5 ft^3. This is the value used in Table 9-1 for mixed liquid waste, and it suggests an adjustment is needed in Table 11.4-1 of the DCD.

5. All mixed liquid waste is collected in a 55-gallon drum and shipped to a vendor for processing; yet there is no value provided for VR processing efficiencies. Typically, mixed liquid waste is processed using a "burn for heat recovery" (incineration) process, with the container being processed by incineration (if plastic) or metal melt. This effectively produces a 100% VR process and a zero ft^3 disposal volume. This is the value used by in Table 9-1.

Table 9-1
Mixed Waste Profile: *Current* AP1000 LLW Approach

	Annual	**60-yr Plant Life**
Generation Volume (Ft^3)	Mixed Solid Waste = 7.5 Mixed Liquid Waste = 22.5	Mixed Solid Waste = 450 Mixed Liquid Waste = 1,350
Disposal Volume (Ft^3)	Mixed Solid Waste = 15 Mixed Liquid Waste = 0	Mixed Solid Waste = 900 Mixed Liquid Waste = 0
Key VR Method	None Specified	Same
Typical Cradle-To-Grave Cost ($/$Ft^3$ ***shipped***)	Mixed Solid Waste = 2,200 Mixed Liquid Waste = 2,000	Same (unescalated value)
Total Cost ($)	Mixed Solid Waste = 0.02 M Mixed Liquid Waste = 0.05 M Total Annual Cost = 0.07 M	Mixed Solid Waste = 0.99 M Mixed Liquid Waste = 2.70 M Total Annual Cost = 3.60 M

Assumptions for Table 9-2: Mixed Waste Analyses for EPRI Advanced Approach

1. Due in large measure to the efforts of the U.S. commercial nuclear industry in developing and implementing mixed waste minimization and management guidelines, a typical U.S. nuclear plant generates no solid mixed waste at all, although on rare occasions, something unexpected occurs to produce a tiny quantity. For this reason, it is assumed that the actual mixed solid waste generation rate for an ALWR which implements and follows EPRI mixed waste guidelines will be one drum every ten years, or 0.75 ft^3/year. This is the value specified in Table 9-2.

2. As discussed for Table 9-1, mixed solid waste is typically stabilized for disposal by encapsulation, producing a 1:2 reverse VR efficiency (i.e., for every one drum generated, two drums are disposed). Accordingly, Table 9-2 specifies a disposal volume of 1.5 ft^3 annually.

3. The generation rate for mixed solid waste is so low that it is normally shipped to a waste processor and disposal facility as a single drum shipment. For mixed solid wastes, mixed waste processors charge minimum handling fees per shipment of around $70,000, all of which is then applied against the single drum in the shipment. This creates a very large cost profile of approximately $10,000/ft3 for mixed solid waste.

4. Recent and pending regulatory changes will reduce that cost dramatically by allowing for greater accumulation prior to shipment. It is therefore anticipated that mixed solid waste CTG costs will stabilize in the next few years at around $2,200/ft3 generated. This is based on the current cost of mixed liquid waste plus a $200/ft3 adjustment for burial of the encapsulated waste. (Note that $200/ft3 generated in this case translates to a $100/ft3 disposal fee due to the 2:1 volume increase during processing.) The CTG cost used in Table 9-2 for mixed solid waste is $2,200/ft3.

5. The typical waste generation volume of mixed liquid waste for a top tier plant is between zero and one-third of a drum annually. For this reason, the EPRI values in Table 9-2 assume 2.5 ft3 (one-third drum) each year.

6. Mixed liquid waste is expected to be incinerated with a 100% VR. Thus, the disposal volume of mixed liquid waste specified in Table 9-2 is zero.

7. Mixed liquid waste is among the most expensive waste types in the U.S., averaging around $2,000/container in CTG costs. Most of this cost is due to TCLP analyses required for every container, as well as for shipping costs applied against relatively small volumes of waste per shipment. This is the CTG cost used in Table 9-2 for mixed liquid waste.

Table 9-2
Mixed Waste Profile: EPRI *Advanced* Approach

	Annual	60-yr Plant Life
Generation Volume (Ft^3)	Mixed Solid Waste = 0.75 Mixed Liquid Waste = 2.5	Mixed Solid Waste = 45 Mixed Liquid Waste = 150
Disposal Volume (Ft^3)	Mixed Solid Waste = 1.5 Mixed Liquid Waste = 0	Mixed Solid Waste = 90 Mixed Liquid Waste = 0
Key VR Method	Mixed Solid Waste = Microencapsulation Mixed Liquid Waste = Burn for Heat Recovery	Same
Typical Cradle-To-Grave Cost ($/$Ft^3$ ***shipped***)	Mixed Solid Waste = 2,200 Mixed Liquid Waste = 2,000	Same (unescalated value)
Total Cost ($)	Mixed Solid Waste = 0.00 M Mixed Liquid Waste = 0.00 M Total Annual Cost = 0.01 M	Mixed Solid Waste = 0.10 M Mixed Liquid Waste = 0.30 M Total Annual Cost = 0.40 M

Cost and Performance Benefits Summary

Table 9-3
Mixed Waste Profile: Cost and Performance Benefits

	ALWR Documentation Approach	EPRI Advanced Approach	Delta (Benefits)
Annual			
Generation Volume (Ft^3)	30	3	**27**
Disposal Volume (Ft^3)	15	2	**13**
O&M Cost ($)	0.07 M	0.00 M	**0.07 M**
60-yr Plant Life			
Generation Volume (Ft^3)	1,800	195	**1,605**
Disposal Volume (Ft^3)	900	90	**810**
O&M Cost ($)	3.60 M	0.40 M	**3.20 M**

10
SUMMARY OF WASTE REMOVAL AND DISPOSITIONING ANALYSES

Table 10-1 summarizes the volume reduction and cost savings benefits of implementing published EPRI guidelines and the waste management strategies and recommendations in this report. As summarized in Table 10-1, the EPRI approach will result in an annual performance improvement (disposal volume reduction) of approximately 1800 ft^3, and an annual cost savings of $0.74 million. Based on a 60 year plant operating cycle, these performance and cost savings benefits rise to 110,000 ft^3 and $45 million.

It also must be noted that these cost savings benefit does not include labor/staff reduction benefits. Based on EPRI Waste Logic analyses, a *fully burdened* labor cost for a top-step radwaste technician is conservatively estimated at $75,000/year. Thus, the 60-year cost of a single worker is around $4 million. The changes recommended in this report and the corresponding reductions in waste volumes will likely reduce the size of the radwaste staff by at least 3 individuals, representing an additional cost savings benefit of $12 M.

Table 10-1
Summary of Volume Reduction and Cost Savings Benefits

Significant Item	Annual	60-yr Plant Life
Primary Filters	Disp VR: 197 ft^3 Cost Savings: $0.15 M	Disp VR: 11820 ft^3 Cost Savings: $8.79 M
Primary Resin	Disp VR: 515 ft^3 Cost Savings: $0.27 M	Disp VR: 30,900 ft^3 Cost Savings: $17.47 M
Compactable and non-compactable DAW	Disp VR: 1,133 ft^3 Cost Savings: $0.25 M	Disp VR: 67,980 ft^3 Cost Savings: $15.50 M
Mixed Waste	Disp VR: 13 ft^3 Cost Savings: $0.07 M	Disp VR: 810 ft^3 Cost Savings: $3.20 M
Total Benefits	Disp VR: 1,858 ft^3 Cost Savings: $0.74 M	Disp VR: 112,510 ft^3 Cost Savings: $44.96 M

Another important consideration of implementing the EPRI approach is the *option* of any given plant to eliminate the need for off site LLW disposal facilities during the normal 60-year operating cycle. Both the annual and 60-year waste generation volumes and stored waste volumes are so low that the plant can easily store these quantities on site in interim LLW storage facilities until decommissioning. This important option removes the plant from reliance on LLW disposal facilities as an operational impediment. It also allows the plant the flexibility to accumulate wastes in safe storage facilities during times of high processing and disposal prices, then ship when prices drop to more competitive levels. This is discussed in depth in the next chapter.

11
LIFE OF PLANT STORAGE OPTION

At some point during the 60-year operating life of an ALWR, it is possible that all LLW disposal facilities may close. Additionally, transportation security or other liability issues may have a significant impact on waste disposal. These issues could eliminate LLW disposal as an option for an unknown number of years, forcing nuclear plants into an interim on site storage mode. Therefore, all ALWR must be designed to:

1. Ensure that LLW generation will not become a liability sufficient to impact continued plant operation.

2. Ensure that waste packaging, handling, and storage facilities are capable of handling the most efficient waste packages and storage configurations.

It also must be recognized that some international members of EPRI's Nuclear Business Group may wish to build and operate an ALWR even though a national LLW disposal facility is not available in their country. It is not unusual for countries to license nuclear plants and include life-of-plant on site storage as a license stipulation. Accordingly, the design of the ALWR should ensure that life-of-plant (60-year) storage is feasible without the need to construct prohibitively large and expensive LLW storage facilities.

The as-built storage accumulation capacity of the AP1000 is not designed to serve as life-of-plant storage. However, the overall plant design and waste management options minimize waste generation sufficiently to make the cost of a life-of-plant storage option a reasonable expenditure if needed. Clearly this would also apply to any short duration, interim storage period.

Implementing the EPRI recommendations and approaches in this report will reduce the number of stored waste containers by at least an order of magnitude, making life-of-plant storage an even more practical option. Most importantly, this eliminates any dependency on LLW disposal facilities, making it economically feasible to store all operational waste until decommissioning.

Table 11-1 identifies the 60-year waste generation volumes and converts them to the total number of storage containers.

Table 11-1
Suggested Minimum Packaged Waste Accumulation Capacity

Waste Type	Accumulation Container & External Volume	Accumulation Period	Optimum Accumulation Capacity
Class A Resin	21-300 HIC 301 ft^3	7 container accumulation	2107 ft^3 (7 HIC)
Class BC Resin	8-120 HIC 120 ft^3	7 container accumulation	840 ft^3 (7 HIC)
Class BC Filters	8-120 HIC 120 ft^3	2 fuel cycle accumulation	120 ft^3 (1 HIC)
Secondary Resin	B-25 Boxes 96 ft^3	2 year accumulation	518 ft^3 (6 boxes)
DAW	B-25 Boxes 96 ft^3	2 year accumulation	10,464 ft^3 (109 boxes)
Chemical, Oil, and Mixed Waste Drums	Oil 6-Paks 45 ft^3	2 fuel cycle accumulation	135 ft^3 (3 Six-Paks)
Total Storage Capacity	—	—	Low Activity = 11,117 ft^3 High Activity = 3,067 ft^3

Assumptions for Life of Plant Storage

1. It is assumed that the plant design will be adjusted to allow the transfer of wet solid waste into 21-300 liners for Class A resin. This applies both in terms of available space and container movement in/out of the resin fill station. Since the current AP1000 design does not include long term storage facilities, this assumption also applies to any newly constructed storage facility.

   It may be possible to collect Class A wet solid waste in smaller containers, but this simply increases overall program costs and storage/disposal volumes. The dimensions for a 21-300 liner as used in these analyses are 80"Dx108"H; external volume of 301 ft^3; internal net waste volume of 270 ft^3.

2. It is assumed that the plant design for transferring Class BC wet solid waste can accommodate 8-120 liners, both in terms of available space and container movement in and out of the container fill station. This also applies to any newly constructed storage facility. The dimensions for an 8-120 liner as used in these analyses are 60"Dx73.5"H; external volume of 120.3 ft^3; internal net waste volume of 90 for resin and >100 ft^3 for sheared primary filters.

3. The storage facility can accommodate half-height ISO (HHISO) containers, which are approximately 8'Wx4'Hx20'L; external volume of 640 ft^3; internal net waste volume of 520 ft^3.

4. The DCD identifies a short term waste storage accumulation capacity of 3900 ft^3 (adjusted in Chapter 4 of this report to approximately 3000 ft^3). As discussed in Chapter 4, the referenced storage capacity is used as a surge capacity and a staging capacity, allowing space to store DAW while it is being characterized and while a sufficient quantity is accumulated to fill an entire waste shipment. It also provides storage space for a disruption in shipping of up to six months. It appears that the AP1000 DCD does not include *storage space for packaged resin or high activity filter waste*.

5. The optimum situation for short term waste storage accumulation for resin would accommodate a storage volume equal to the expected volume reduction times the capacity of the storage container. For example, this report assumes a VR equal to steam reforming or better for resin, which is also assumed herein to be a 7:1 VR ratio. If the selected resin VR technology achieves a 7:1 VR, then seven containers will be converted to one container. Therefore, the storage accumulation capacity for seven containers would be:

   If waste is collected in a 21-300 container:

   Class A = 7 containers * 301 ft^3 external container volume = 2107 ft^3

   If waste is collected in a 8-120 container:

   Class BC = 7 containers * 120 ft^3 external container volume = 840 ft^3

   Total Storage Accumulation Capacity Needed *for Resin* = 2947 ft^3

6. The above approach offers the most cost efficient means of managing resin waste. A similar approach can be used for other waste, although the storage accumulation capacity for other wastes is not necessarily VR dependent. For example, sufficient storage accumulation capacity should be provided to accommodate the waste generated during at least one full fuel cycle and, preferably, two fuel cycles. Table 11-1 suggests the optimum waste accumulation capacity for each waste type. Remember that this is unpackaged generation volume in waste collection/accumulation containers.

Although it is valuable to know the optimum waste accumulation capacity, it is equally important to project the long range storage capacity. Tables 11-2 and 11-3 compare the assumed existing AP1000 approach to the recommended EPRI advanced approach. As indicated, in the event that extended on site storage becomes necessary, the EPRI approach results in far fewer storage containers, which translates to a much smaller storage facility and substantial capital cost savings.

Table 11-2
Projected Numbers of Containers Stored Over Life of Plant: AP1000 Assumed Approach

	AP1000 Current Approach				
Waste Type	**60-Year Class A Storage Vol (Ft^3)**	**Class A Storage Container**	**60-Year Class BC Storage Vol (Ft^3)**	**Class BC Storage Container**	**Total Containers**
Primary Filters	(1)	N/A	12,480	8-120 HIC	416 (2)
Primary Resin	(1)	N/A	32,100	8-120 HIC	357 (3)
DAW	82,980	HHISO	N/A	N/A	160 (4)
Total	**82,980**		**44,580**		**933**

(1) Class A resin/filters are commingled and stored with Class BC Waste

(2) 12,480 ft^3 ÷ 30 ft^3/8-120 HIC = ***416*** HIC

(3) 32,100 ft^3 ÷ 90 ft^3/8-120 HIC = ***357*** HIC

(4) 82,980 ft^3 ÷ 520 ft^3/HHISO = ***160*** HHISO

Table 11-3
Projected Numbers of Containers Stored Over Life of Plant: EPRI Advanced Approach

	EPRI Advanced Approach				
Waste Type	**60-Year Class A Storage Vol (Ft^3)**	**Class A Storage Container**	**60-Year Class BC Storage Vol (Ft^3)**	**Class BC Storage Container**	**Total Containers**
Primary Filters	180	(1)	480	8-120 HIC	5 (2)
Primary Resin	600	21-300 HIC	600	8-120 HIC	9 (3)
DAW	15,000	HHISO	N/A	N/A	29 (4)
Total	**15,780**		**1,080**		**43**

(1) Class A filter waste is assumed to be compacted or sheared and stored as DAW.

(2) 480 ft^3 ÷ 100 ft^3/8-120 HIC = ***5*** HIC

(3) 600 ft^3 ÷ 270 ft^3/21-300 HIC = 2 HIC; 600 ft^3 ÷ 90 ft^3/8-120 HIC = 7 HIC; total = ***9*** HIC

(4) 15,000 ft^3 ÷ 520 ft^3/HHISO = ***29*** HHISO

A
TABLE 11.4-1 FROM AP1000 DESIGN CONTROL DOCUMENT

Table A-1 is the original version of Table 11.4-1 in the DCD. Table A-2 is the EPRI projection based on implementing the recommendations in this report.

Table A-1
AP1000 Current Version of DCD Table 11.4-1

AP1000 Current - Estimated Solid Radwaste Volumes				
Source	**Expected Generation (ft^3/yr)**	**Expected Shipped Solid (ft^3/yr)**	**Maximum Generation (ft^3/yr)**	**Maximum Shipped Solid (ft^3/yr)**
Wet Wastes				
Primary Resins (includes spent resins and wet activated carbon)	400[(2)]	510	1700[(4)]	2160
Chemical	350	20	700	40
Mixed Liquid	15	17	30	34
Condensate Polishing Resin[(1)]	0	0	206[(5)]	259
Steam Generator Blowdown[(1)(6)] Material (Resin and Membrane)	0	0	540[(5)]	680
Wet Waste Subtotals	**765**	**547**	**3176**	**3173**
Dry Wastes				
Compactible Dry Waste	4750	1010	7260	1550
Non-Compactible Solid Waste	234	373	567	910
Mixed Solid	5	7.5	10	15
Primary Filters (includes high activity and low activity cartridges)	52[(3)]	26	9.4[(3)]	69
Dry Waste Subtotals	**4994**	**1417**	**7846**	**2544**
Total Wet & Dry Wastes	**5759**	**1964**	**11020**	**5717**

Notes:
1. Radioactive Secondary resins and membranes result from primary to secondary systems leakage (e.g., SG tube leak).
2. Estimated activity basis is ANSI 18.1 source terms in reactor coolant.
3. Estimated activity basis is breakdown and transfer of 10% of resin from upstream ion exchangers.
4. Reactor coolant source terms corresponding to 0.25% fuel defects.
5. Estimated activity basis from Table 11.1-5, 11.1-7 and 11.1-8 and a typical 30 day process run time, once per refueling cycle.
6. Estimated volume and activity used for conservatism. Resin and membrane will be removed with the electrodeionization units and not stored as wet waste. See subsection 10.4.8.

Table 11.4-1 from AP1000 Design Control Document

Table A-2
EPRI Projections (Proposed Revision to DCD Table 11.4-1)

EPRI Projections - Estimated Solid Radwaste Volumes				
Source	**Expected Generation (ft^3/yr)**	**Expected Shipped (Disposed) Solid (ft^3/yr)**	**Maximum Generation (ft^3/yr)**	**Maximum Shipped Solid (ft^3/yr)**
Wet Wastes				
Primary Resins (includes spent resins and wet activated carbon)	Class A = 70 Class BC = 70	Class A = 10 Class BC = 10	Not Analyzed	Not Analyzed
Chemical	350	20 - Requires Clarification	Not Analyzed	Not Analyzed
Mixed Liquid	2.5	0	Not Analyzed	Not Analyzed
Condensate Polishing Resin[(1)]	0	0	Requires Clarification	Requires Clarification
Steam Generator Blowdown[(1)(2)] Material (Resin and Membrane)	0	0	Requires Clarification	Requires Clarification
Wet Waste Subtotals	**492.5**	**40**		
Dry Wastes				
Compactable Dry Waste	5000	250	Not Analyzed	Not Analyzed
Non- Compactable Solid Waste			Not Analyzed	Not Analyzed
Mixed Solid	0.75	1.5	Not Analyzed	Not Analyzed
Primary Filters (includes high activity and low activity cartridges)	Class A = 12 Class BC = 8	Class A = 3 Class BC = 8	Not Analyzed	Not Analyzed
Dry Waste Subtotals	**5020.75**	**262.5**		
Total Wet & Dry Wastes	**5513.25**	**302.5**	Requires Clarification	Requires Clarification

Notes:

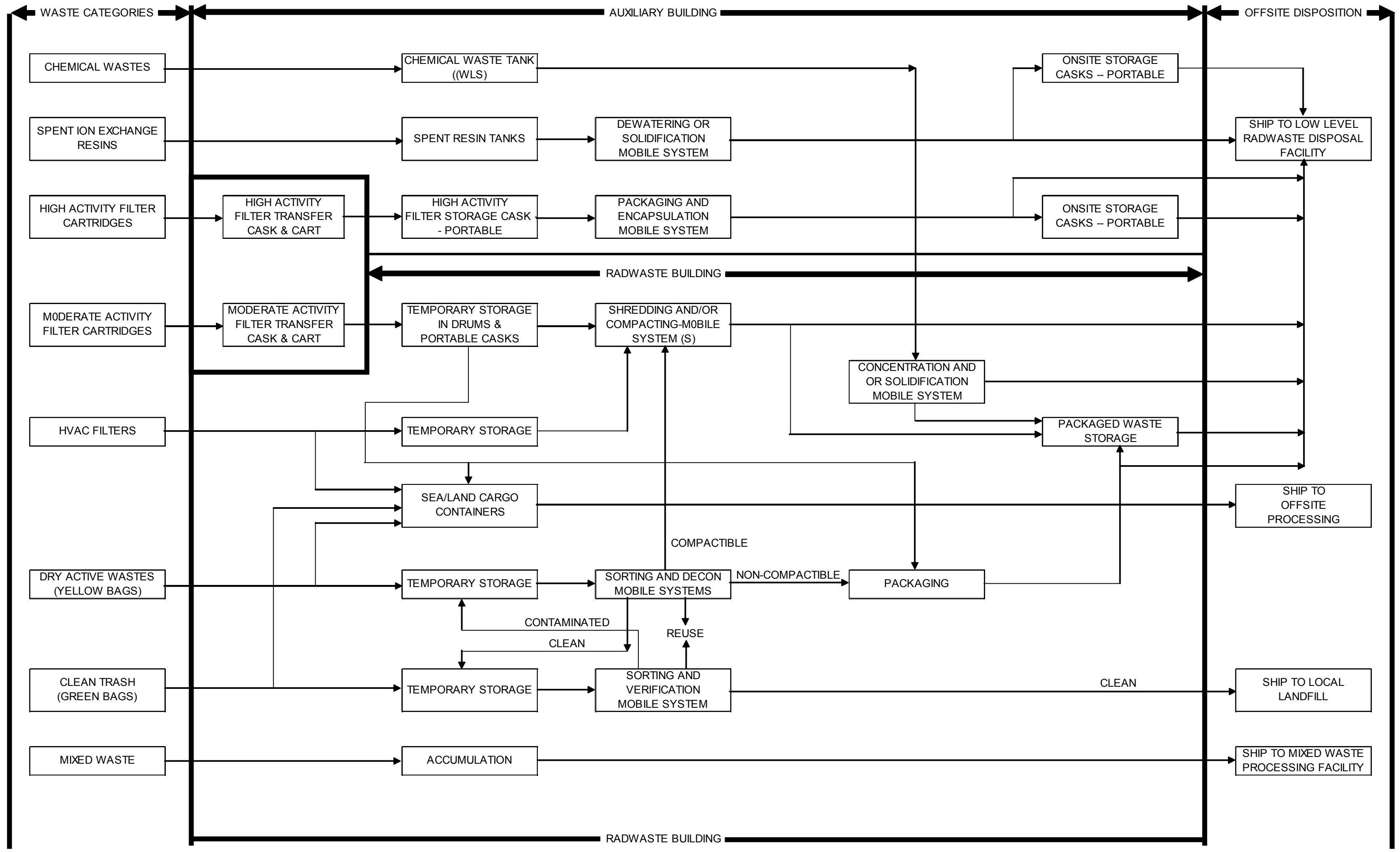
1. Radioactive Secondary resins and membranes result from primary to secondary systems leakage (e.g., SG tube leak).
2. Estimated volume and activity used for conservatism. Resin and membrane will be removed with the electrodeionization units and not stored as wet waste.

General Assumptions:

1. Estimated activity basis is ANSI 18.1 source terms in reactor coolant.
2. Estimated activity basis is breakdown and transfer of 10% of resin from upstream ion exchangers.
3. Reactor coolant source terms corresponding to 0.25% fuel defects.
4. Estimated activity basis from Table 11.1-5, 11.1-7 and 11.1-8 and a typical 30 day process run time, once per refueling cycle.
5. See subsection 10.4.8.

B
FIGURE 11.4-1 FROM AP1000 DESIGN CONTROL DOCUMENT

Figure 11.4-1 from AP1000 Design Control Document



C DETERMINATION OF ESCALATION FACTORS

Escalation factors are always subject to broad debate, yet they are important to include for the 60-year life of the AP1000. In an effort to minimize debate, escalation factors were based on the calculations and interpolations of the escalation values set forth in Section 2 and Table 2.1 of NRC NUREG 1307, Revision 10, *Report on Waste Burial Charges: Changes in Decommissioning Waste Disposal Costs at Low-Level Radioactive Waste Burial Facilities*.

Escalation factors for labor and energy costs are obtained from a nationwide Employment Cost Index and a Production Price Index, respectively. There is no such nationwide index for LLW burial/dispositioning costs, so they must be derived from historical costs for existing LLW disposal facilities.

In NUREG 1307, escalation factors are based on a combination of labor cost adjustments + energy cost adjustments + burial/dispositioning cost adjustments. All cost analyses in this report exclude labor and energy costs, thereby leaving only the burial/dispositioning cost adjustment. Consistent with NUREG-1307, this is accomplished by dividing the current year (2002) burial/dispositioning cost by the 1986 cost. This result is specified in Table 2.1 of NUREG-1307 for Hanford and for Barnwell, including separate escalation values for "direct disposal" and "direct disposal with vendors" (i.e., off site volume reduction prior to disposal). The NRC obtains these costs by contacting the various vendors and disposal facilities.

Because there are no other published national indices for LLW burial/dispositioning escalation factors, the values used in NUREG-1307 serve as the starting point for developing a 60-year table of escalation factors. The data in Table C-1 below is extracted from Table 2.1 of NUREG 1307. The values represent the amount of escalation in burial/dispositioning costs for LLW from 1986 to 2002 (sixteen years escalation).

Table C-1
LLW Burial/Dispositioning *Escalation Factors* from 1986 to 2002

Disposal Site	Reactor Type	Direct Disposal	Direct Disposal with Vendors
Hanford	PWR	3.634	5.748
Hanford	BWR	14.549	15.571
Barnwell (Atlantic Compact)	PWR	17.922	9.273
Barnwell (Atlantic Compact)	BWR	15.988	8.626
Barnwell (Non-Atlantic Compact)	PWR	18.732	9.467
Barnwell (Non-Atlantic Compact)	BWR	16.705	8.860

It is not likely that either of the above disposal facilities will be operational in 60 years. Also, Envirocare disposal is not included in the Table because (1) they did not have a full Class A license in 1986, and (2) they do not currently accept Class B or Class C wastes. Therefore, it is necessary to calculate average escalation factors based on Table C-1 and then assume that those derived factors will apply to any future disposal facility.

Base Escalation Factors for Direct Disposal (No Vendor VR)

- Escalation factors for PWRs range from 3.634 to 18.732, with no significant variation due to waste from within a compact versus waste from outside a compact. The average escalation factor for the sixteen year historical period is 11.183, or 0.699 per year.
- Escalation factors for BWRs range from 14.549 to 16.705. The average escalation factor for the sixteen year historical period is 15.627, or 0.977 per year.

Base Escalation Factors for Direct Disposal With Vendor VR

- Escalation factors for PWRs range from 5.784 to 9.467. The average escalation factor for the sixteen year historical period is 7.626, or 0.477 per year.
- Escalation factors for BWRs range from 8.860 to 15.571. The average escalation factor for the sixteen year historical period is 12.216, or 0.763 per year.

The above information is used to generate a simplified, straight-line escalation factor table, which is shown below as Table C-2.

Table C-2
Straight-Line Escalation Factors for LLW Burial/Dispositioning

	Direct Disposal (Without Off Site VR)		Direct Disposal (With Off Site VR)	
Period (Years)	**PWR**	**BWR**	**PWR**	**BWR**
NUREG-1307 16-year Average	11.183	15.627	7.626	12.216
1	0.699	0.977	0.477	0.763
2	1.398	1.953	0.953	1.527
3	2.097	2.930	1.430	2.290
4	2.796	3.907	1.906	3.054
5	3.495	4.883	2.383	3.817
10	6.989	9.767	4.766	7.635
15	10.484	14.650	7.149	11.452
20	13.979	19.534	9.532	15.269
25	17.473	24.417	11.915	19.087
30	20.968	29.301	14.298	22.904
35	24.463	34.184	16.681	26.721
40	27.958	39.068	19.064	30.539
45	31.452	43.951	21.447	34.356
50	34.947	48.834	23.830	38.173
55	38.442	53.718	26.213	41.991
60	41.936	58.601	28.596	45.808

The *straight-line escalation factors* in Table C-2 have limited application. For example, the table can be used to estimate waste dispositioning costs 25 years in the future. Similarly, if the waste is already generated and held in temporary storage for a 25-year time period, then the 25-year dispositioning cost from Table C-2 will apply to 100% of the waste. Thus, the data in Table C-2 can be used for performing cost analyses for life-of-plant storage.

However, if the waste *not* stored but is, instead, disposed each year, then the cumulative operating cost will be less over the same 25-year period. In other words, waste disposed this year or next year will cost less than if it is held in storage for 25 years and then disposed. Accordingly, for the same volume of waste generated annually, the cumulative annual disposal cost is determined as a function of the average escalation factor for the entire period.

This is illustrated by assuming that a given waste package from a PWR currently costs $10 for VR and disposal. One year from now it will cost $10*(1+0.477) = $14.77; two years from now it will cost $10*(1+0.953) = $19.53; two years from now it will cost $10*(1+1.430) = $24.30.

The cumulative cost for all three years is 58.60 for all three packages, or $19.53/year. This represents a *cumulative escalation factor* of 0.953. However, if all three packages were held in temporary storage and then shipped in year three, the burial/dispositioning cost would be $72.90, which reflects the *straight-line escalation factor* of 1.430 shown in Table C-2.

This is an important consideration, for the cost escalation factor must be offset by the future value of money when making long range cost estimates for plant construction, operation, and decommissioning. Table C-3 provides cumulative escalation factors over the same periods, and it assumes that, on average, the same amount of waste is generated each year (i.e., no unusual highs and lows).

The values in Table C-3 can be used for cost analyses which assume a continuous availability of disposal sites. This includes all analyses other than the life-of-plant storage contingency.

Table C-3
Straight-Line Escalation Factors for LLW Burial/Dispositioning

	Direct Disposal (Without Off Site VR)		Direct Disposal (With Off Site VR)	
Period (Years)	**PWR**	**BWR**	**PWR**	**BWR**
1	0.699	0.977	0.477	0.763
2	1.048	1.257	1.076	1.093
3	1.398	1.676	1.435	1.458
4	1.747	2.095	1.794	1.822
5	2.097	2.513	2.152	2.187
10	2.912	3.491	2.989	3.037
15	3.994	4.788	4.099	4.165
20	5.242	6.284	5.381	5.467
25	6.601	7.913	6.776	6.884
30	8.038	9.635	8.250	8.383
35	9.531	11.425	9.783	9.940
40	11.067	13.265	11.359	11.541
45	12.635	15.145	12.968	13.177
50	14.228	17.055	14.604	14.839
55	15.843	18.990	16.261	16.522
60	17.473	20.945	17.935	18.223

D
REFERENCE DOCUMENTS

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11. USNRC. REGULATORY GUIDE 1.110, *Cost Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors*; March 1976.

Program:

Nuclear Power

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