ELECTRIC POWER RESEARCH INSTITUTE

Radioactive Wet Waste Reduction Opportunities for Waste Class B and Class C

LICENSED MATERIAL

Technical Report

Radioactive Wet Waste Reduction Opportunities for Waste Class B and Class C

1011727

Final Report, December 2005

EPRI Project Manager
P. Tran

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1395 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Suncoast Solutions, Inc.

ORDERING INFORMATION

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

CITATIONS

This report was prepared by

Suncoast Solutions, Inc.
1348 New Forest Lane
Osprey, FL 34229

Principal Investigator
P. Saunders

The following individuals provided technical support to this project

T. Carr	Callaway Station
R. Stigers	Susquehanna Station
T. Ball	Susquehanna Station
K. Johnson	Duke Energy
J. Bergeron	Callaway Station
R. Mitchell	Callaway Station
B. Kimray	Duke Energy
D. Vaught	Duke Energy
M. Rejcek	STP

This report describes research sponsored by the Electric Power Research Institute (EPRI).

The report is a corporate document that should be cited in the literature in the following manner:

Radioactive Wet Waste Reduction Opportunities for Waste Class B and Class C. EPRI, Palo Alto, CA: 2005. 1011727.

REPORT SUMMARY

10CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," Sub-Part 61.55, defines waste classifications for near-surface land disposal. Waste Class B/C wet waste, including filter and ion exchange media, is one of the most expensive radioactive wastes routinely generated by U.S. commercial reactors. Ninety percent of the U.S. industry is challenged with the loss of class B/C low-level waste (LLW) disposition access after 2008. This report is part of the EPRI initiative that is developing techniques and technologies to reduce the generation and accumulation of B/C wastes.

Background

Waste classifications for near-surface land disposal is defined in 10CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," Sub-Part 61.55. These classifications are determined by both long- and short-lived radionuclides. Waste classification for land disposal is defined as follows:

Class A waste is waste that is usually segregated from other waste classes at the disposal site. The physical form and characteristics of Class A waste must meet the minimum requirements set forth in § 61.56.

Class B waste is waste that must meet more rigorous requirements on waste form to ensure stability after disposal. The physical form and characteristics of Class B waste must meet both the minimum and stability requirements set forth in § 61.56.

Class C waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. The physical form and characteristics of Class C waste must meet both the minimum and stability requirements set forth in § 61.56.

Greater than Class C (GTCC) waste that is not generally acceptable for near-surface disposal is waste for which form and disposal methods must be different, and in general more stringent, than those specified for Class C waste. In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository.

Waste Class B/C wet waste, including filter and ion exchange media, is one of the most expensive radioactive wastes routinely generated by U.S. commercial reactors. At the present time, a few utilities no longer have access to offsite disposal facilities due to disposal site restrictions. As a result of current regulations related to disposal site access, this restriction will be imposed on the majority of U.S. nuclear plants by mid-2008.

Several proven and potential options exist for managing processing media that result, intentionally or otherwise, in reductions to the generated and disposed volume of B/C wastes. Several stations either use or are researching unique media selection, loading, and operating

strategies. The significance of current waste disposition cost and pending onsite waste storage warrants a detailed feasibility analysis of all options.

Objectives

To identify and evaluate proven and potential processing operation strategies that offer significant improvement in both generated Waste Class B/C wet waste volumes and overall economic performance.

Approach

Several options were selected from a broad list of potential candidates. The selection was based on applicability, viability, and potential impact on waste Class B/C generation. The four specific scenarios were

1. primary ion exchanger (CVCS) - online lithiation,
2. reactor water cleanup (RWCU) in-service run length,
3. fuel cleaning filter management, and
4. in-service media management - spent fuel pool.

Recent industry data were collected for each initiative and the volume and cost impact analyzed.

Results

Clearly, options exist for reducing the generated volume of Class B/C waste. Equally clear is that not all are cost-effective opportunities under all circumstances and that each option warrants a comprehensive, detailed, site-specific application analysis.

EPRI Perspective

Limited accessibility to Class B and Class C waste disposal facilities will be a chief concern facing the industry in the next couple of years. Opportunities exist for decreasing generation of this type of waste through innovative media, operational practices, and volume reduction methods. This report provides a review of various proven station initiatives for practical reductions of Class B/C wastes. Considerations for onsite storage were factored into some of the analyses and include cost factors related to onsite media movement, packaging, dewatering, volume reduction (if used), and final transfer to a storage facility. Individual stations are encouraged to use this report to develop their own Class B/C waste reduction initiative.

Keywords

Solid waste reduction
Class B/C waste
Volume reduction
Radwaste processing cost efficiency
Low-level waste storage
10CFR Part 61

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 PROJECT OVERVIEW

Background

Waste Class BC wet waste including filter and ion exchange media is one of the most expensive, radioactive wastes routinely generated by U.S. commercial reactors. At the present time a few utilities no longer have access to off site disposal facilities due to disposal site restrictions. As a result of current regulations related to disposal site access, this restriction will be imposed on the majority of U.S. nuclear plants by mid-2008.

Several proven and potential options exist for managing processing media that result intentionally, or otherwise, in reductions to the generated and disposed volume of BC wastes. Several stations either use or are researching unique media selection, loading, and operating strategies. The significance of the current waste disposition cost and pending on-site waste storage is such that all options warrant a detailed feasibility analysis.

Objectives

The primary objective of this project is to identify and evaluate proven and potential processing operation strategies that offer significant improvement in both generated Waste Class BC wet waste volumes and overall economic performance. Four specific scenarios have been defined:

1. Primary ion exchanger (CVCS) - on line lithiation
2. Reactor water cleanup (RWCU) in service run length
3. Fuel cleaning filter management
4. In service media management – Spent Fuel Pool

The research included the following secondary objectives:

1. Identify current and future potential performance and cost issues related to pending on-site storage.
2. Use of the EPRI Waste Logic™: Liquid Waste Manager (LWM) program to perform a cost analysis for each scenario.
3. Using the data from these three efforts, evaluate each option for viability and cost effectiveness.

Project Approach

Plant-specific performance and economic data was collected and analyzed for each of the four selected strategies. The data was specific to a process stream and included pre and post implementation data. As part of this data collection effort, on-site waste storage criteria and future transport and disposal options were reviewed to identify issues that may impact either the performance or cost effectiveness of future Class BC waste management options. Using that information and the LWM program, a detailed cost analysis was performed for each scenario. Those analyses included plant specific cost data as well as cost data that was based on historical or projected industry experience.

Data Collation and Analysis

Managing filter and ion exchange media significantly impacts a station in a variety of ways. The following queries were used to collate data for each operating strategy. Where applicable, the data represented both pre and post strategy implementation. Data sources included plant documents, telephone interviews, project questionnaire responses and historical EPRI data bases. The following list summarizes the general scope of the queries; details were modified to address specific options to ensure relevant data was captured or to fit the analysis requirements.

- General process and strategy descriptions
- Historical performance
- Process configuration
- Media type and specifications
- Change-out criteria
- Change-out criteria basis
- Historical, pre-improvement solid volume generated
- Alternate option solid volume generated - following improvement implementation
- Resource impact
- Waste packaging, volume reduction (VR) and disposal considerations
- Historical program costs
- Alternate option program costs
- Post 2008 program costs (where applicable)
- Summary of benefits and limitations

On-Site Storage

As a result of the pending 2008 disposal site access restriction, cost analyses to evaluate that impact were performed where applicable. However, the number and types of on site storage strategies being considered by US utilities is significant and widely variable. Many stations have not selected the option that is best suited for their application, and therefore cannot define the associated capital or O&M costs. Several of the strategies being employed or considered include:

- Stand alone buildings specifically designed for storage
- Modular bulk storage bunkers constructed partially below grade
- Modular bulk storage bunkers at grade
- Pre cast segregated modular shields [Secure Environmental Containers (SEC), On Site Storage Containers (OSSC)] at grade
- Storage in existing plant structures

Additionally, many stations are still evaluating volume reduction (VR) options. Off site processors would be required to process waste segregated by plant to preclude commingling solid waste for return to sites. At least one primary processor does not currently possess those capabilities. Similarly, most sites continue to evaluate final waste forms (VR, no VR) and their impact on meeting future disposal site acceptance criteria.

Finally, several stations are evaluating the correct disposal fee accrual strategy. It is assumed that at some point in the future, stored wastes will require disposition in a licensed repository. The cost associated with final repackaging, transport, and disposal fees would have to be estimated and accrued to support that effort.

As a result of this wide range of variables, <u>we chose in this project not to develop an industry standard for on site storage costs</u>. The storage data and results captured in this report **<u>do</u>** contain the cost factors related to on site media movement, packaging, dewatering, volume reduction (if employed) and final transfer to the storage facility. They **<u>do not</u>** include final storage facility/shield and off site VR options unless indicated otherwise, and therefore are not considered absolute. As a result, the storage option costs can be significantly higher and it is anticipated that this would impact the applicable cost benefit results.

Conclusions and Summary

This project targeted two primary goals, Class BC volume reduction and reductions to the O&M costs associated with Class BC processes. At many stations the volume of waste that falls into the Class BC category is a relatively minor fraction of the per-reactor total generated wet waste volume. However, the percentage of annual O&M costs associated with handling, packaging, volume reducing, and disposing or storing that waste can be disproportionately high relative to those, other waste streams.

The results of these analyses very clearly show that several very effective options exist for reducing the generated volume of Class BC waste and the associated program costs. It is equally clear that not all are cost effective opportunities under all circumstances and that each of the options warrant a comprehensive, detailed site specific application analysis.

Primary Ion Exchanger (CVCS) – On Line Lithiation

On line lithiation is a lithium management option that is typical of CE and B&W type PWRs and is used at only a few Westinghouse plants. Duke Energy operates the Catawba and McGuire units using this strategy **specifically targeting resin volume reduction.** This option is implemented by loading two mixed beds in parallel. One bed serves as a de-lithiator for a cycle. The other bed serves as the RCS clean up bed having been lithiated in the previous cycle. This option is limited to those stations that have the bed volume and piping configuration to support multiple bed media management. This option also requires a significant commitment from both the chemistry and operations organizations to ensure the beds are aligned in the proper sequence during the pertinent period of time. This analysis was performed using the plant specific per-cycle data provided by Duke for those stations.

The analysis results indicate that each unit could realize a cost reduction benefit of ~$91,662 each cycle. The life of plant savings would exceed $2,138,474. These savings are significant relative to fuel cycle O&M costs associated with this system. The life of plant savings illustrate the long term benefit that can be derived from this process. Additionally, and equally important is the fact that this improvement does not require hardware changes and can be implemented using programmatic revisions.

This option is very cost effective and reduces both generated and disposed volumes. In its current configuration it warrants evaluation by those stations that have adequate ion exchange vessel capacity.

Reactor Water Cleanup (RWCU) in Service Run Length

Susquehanna's chemistry organization was evaluating improvements to their RWCU program. As part of that process, the station conducted a poll of similar stations to identify opportunities for improvement. The chemistry staff was aware that their RWCU run lengths were shorter in duration than other stations and the survey confirmed this fact. As a result, the station evaluated extending the RWCU precoat run time based on a 60 day duration or effluent chemistry quality. The increased run length would result in an increase in the volume of Class BC waste generated impacting processing and disposition options. This scenario evaluated the inverse of that strategy, reducing run lengths from 60 days to 30 days to reduce the generated volume of Class BC waste. In addition, the impact of on site storage of Class BC waste in a post 2008 scenario was considered.

The analysis results project that as a result of the increased backwash frequency, the station would increase the volume of generated waste by 24 ft^3. However, the off site volume reduction options available for the alternate, Class A waste would reduce the disposed volume from approximately 32 ft^3 to 9.6 ft^3. Most significantly, the net annual cost savings are projected to be $176,937. This is primarily attributable to the lower (no milliCurie surcharge) disposal costs and reduced transportation cost associated with Class A wastes.

It was projected that on site storage of precoat media if maintained as Class BC would be less expensive than disposal if the media was backwashed more frequently as a Class A waste.

The analysis results clearly indicate that the run length reduction strategy was cost effective and reduced the final ***disposed*** or ***stored*** waste volume and warrants site specific evaluation by other sites.

Fuel Cleaning Filter Management

Ultrasonic fuel cleaning was originally developed for PWRs to enable them to operate with higher fuel duty and longer cycles. Under these conditions, sub-cooled nucleate boiling may occur in the upper fuel spans with resulting axially-asymmetric deposition of corrosion products. Boron can hide out in these deposits, causing a local flux depression called either axial offset anomaly (AOA), or more recently, crud induced power shift (CIPS). Ultrasonic fuel cleaning is an effective means for removing PWR fuel deposits, hence mitigating the CIPS problem. When ultrasonic fuel cleaning was applied at PWRs for the mitigation of CIPS, a reduction in ex-core dose rates, and consequently personnel exposure, was also observed. The removed activity is captured on cartridge filters where it is concentrated to levels that can rapidly create a Class BC filter waste. This analysis evaluated the Callaway station filter cleaning process and the implementation of a strategy that employs more frequent filter changeouts to maintain all filters as Class A waste.

As expected, the volume of waste generated using the alternate Class A waste strategy is significantly higher than the current, historical approach. The analysis projections indicate that this would increase the number of filters required to clean 96 assemblies from 3-4 to approximately 200 elements. The waste volume would increase from a current value of 1.8 ft^3 to in excess of 117 ft^3. Using current packaging and disposition options, this would result in approximately two additional waste shipments and impact the resources required to support those efforts.

The cost analysis projects a project cost increase of $319, 218. This is an 80% increase. The significant cost increase relative to historical/current data is primarily attributable to the sharp increase in the number of filters required at a cost of $1,125 each. Additional costs are incurred for waste packaging and shipping labor, and transportation costs.

The above data combined with limitations and challenges related to controlling the rate of filter activity accumulation during individual assembly cleaning cycles negates the cost efficiency of this alternate option. Individual site’s performance and costs, and/or revisions to VR and disposal options may improve the viability of this scenario. This option was specifically NOT recommended for Callaway, but may be viable for other stations under alternate circumstances.

In Service Media Management – Spent Fuel Pool

During the calendar years 2002 and 2003 STP undertook a significant and very successful improvement project targeting improved Class A resin and Class BC resin segregation. In 2005, it became apparent to the industry that the Class BC waste repository at Barnwell would be closed in 2008. With that in mind, once the site's actual Class BC constituents and generation rates were clear, STP began evaluating additional Class BC waste reduction opportunities. Similar to the majority of PWRs, the STP spent fuel pool (SFP) purification system was operated on a full time basis per the original design considerations. The station assessed that system's operation and media selection process and modified their historical strategy specifically targeting Class BC waste reduction.

That research resulted in the implementation of a stoichiometric mixed bed of IRN-170 resin in their SFP vessels. Additionally, it led to the conclusion that the ion exchangers could be placed in service only as needed for chemistry or activity control, versus the historical full time service runs. This strategy was specifically designed to extend the resin life and media throughput without compromising other program aspects including SFP water quality or general area dose rates. This scenario was evaluated as part of this Class BC waste reduction research.

The analysis concluded that the improved media selection and in service operating strategies provide several direct benefits to the station including:

- Reducing the annual program costs by ~$56,000
- Reducing the annual waste generation that currently requires disposal and that will require on site storage post 2008 by approximately 41.5 ft^3.
- Reducing the resource requirements to sluice, load and process spent media
- Improving the SFP water quality for an extended period of time

Currently, the station is evaluating additional opportunities for resin selection that should further enhance SFP purification media performance. The STP strategy is successful and warrants site specific evaluation by other operating stations.

Future

The proposed second phase of this project involves an evaluation of opportunities for implementing other processing or management options that will result in a tangible reduction to Waste Class BC wet waste volumes and program costs. Examples include source term reduction strategies that are not specifically intended to increase solid waste volumes such as Zinc (Zn) injection, Noble Metals Chemical Application (NMCA) and PWR primary system cleanup filtration options. As appropriate, other BC reduction opportunities may be included in the final analysis as they are identified. The evaluation process will assess the compatibility, efficiency and cost effectiveness for each option.

2 PRIMARY ION EXCHANGER—DUKE ON LINE LITHIATION

Process Overview

Generally, the majority of PWRs configure three to five ion exchange vessels to aid in controlling reactor coolant system (RCS) chemistry using their chemical and volume control system (CVCS). Specific functions include delithiating to control pH, boron removal (deborating) to control reactivity, and cleanup to remove system activity. Typically, each bed is removed from service dependent on its specific application and effluent chemistry requirements. In a few instances dose rates have been used to define removing vessels from service; this strategy is typically applicable only to shutdown cleanup mixed beds (MB). Many PWRs remove their cleanup mixed bed from service at the end of outage cleanup operations. If plant ion exchange vessel configurations allow, the media remains in the vessel for decay for the duration of the cycle. It is sluiced just prior to the next refueling outage and a new MB charge is loaded in preparation for that outage.

Configuration and Media

At Duke's Catawba and McGuire stations, and similar to many Westinghouse reactors, the CVCS letdown purification system employs two 30 ft^3 mixed bed ion exchangers followed by a 20 ft^3 cation bed. The system flow rates are as follows:

- Single vessel in service: 150 gpm
- Parallel vessel configuration: 180 gpm

The mixed beds are loaded with a 1:1 H:OH resin charge.

Alternate Option

On line lithiation is a lithium management option that is typical of CE and B&W type PWRs and is used at only a few Westinghouse plants. Duke Energy operates the Catawba and McGuire units using this strategy **specifically targeting Class BC waste volume reduction.** This option is implemented by loading two mixed beds in parallel. One bed serves as a de-lithiator for a cycle. The other bed serves as the RCS clean up bed having been lithiated in the previous cycle. In this configuration the cation component of the mixed beds can serve for two cycles performing a different function in each. This practice can reduce CVCS cation resin consumption and the associated lithium management costs. The plants operate on a 18 month fuel cycle.

Alternate Strategy Description

Note: In order to facilitate a clear depiction of the process, the mixed bed vessels are referred to as “A” and “B”.

The “A” MB is loaded with a fresh charge of H:OH resin near the end of a fuel cycle. It is first used intermittently towards the end of that cycle targeting the removal of the last 15 ppm of RCS boron. The “A” bed is then aligned in parallel with the “B” MB ion exchanger during shutdown. The station uses H2O2 to force a primary crudburst. The parallel configuration allows the station to employ the maximum shutdown crudburst cleanup flowrate (180 gpm), reducing the impact on the outage schedule. Following satisfactory completion of the cleanup effort, the “B” MB is isolated and the “A” MB is used as the single purification bed for the remainder of the outage.

After coming off residual heat removal at startup, the “A” bed is removed from service and the “B” bed is aligned for purification during the operating cycle. The RCS is lithiated and the “A” bed is placed in service as required (typically ~30 minutes per day) to remove the lithium that is produced from boron; Table 2-1 summarizes that reaction.

Table 2-1
Boron to Lithium Reaction

Nuclear Reaction	Target Isotopic Abundance (%)	Neutron Reaction	Cross-Section (barns)
$^{10}B\ (n,\alpha)\ ^{7}Li$	19.9	Thermal	3840 b

Approximately one half way through the operating cycle, sample analysis typically begins to show Li saturation of the “A” MB. A relatively small increase in RCS fluoride begins about two weeks prior to Li saturation. Flouride indicates the bed is almost lithiated as lithium borate lowers the fluoride capacity of the bed and pushes a wave of fluoride out; this is similar in concept to an eluent in Ion Chromatography.

Once the “A” MB is lithiated, then the station begins delithiation using the 20 ft^3 cation bed for the remainder of the cycle. Late in the cycle the “A” MB is placed in service as a purification bed and used as purification for the rest of the cycle; the “B” MB is isolated. That vessel is subsequently sluiced and reloaded with new H:OH resin.

Similar to the sequence initiation, the “B” MB is now used intermittently for boron removal for the last ~15 ppm boron and the “A” MB is used in parallel with “B” MB until shutdown crudburst cleanup is complete. The “A” MB is removed from service until the unit is off RHR during startup and then is used as the purification bed through most of cycle. It is reloaded near the end of the cycle.

The “B” MB goes through the same life cycle one fuel cycle off. This strategy has been employed for several cycles and continues to be an evolutionary process.

Solid Waste

The solid waste generation was analyzed using historical practices and the current on line Lithiation mode. The station operates on an 18 month fuel cycle. It is understood that there can be deviations from an absolute cyclic duration however, for the purposes of this analysis one cycle was equated to 18 months.

Historical Generated Volume per Cycle

Historically, McGuire and Catawba have experienced very significant shutdown crudbursts. Crud releases were controlled using a single, new bed. That bed was used through the outage and startup, then isolated for decay. The generated volumes are captured in Table 2-2.

Table 2-2
Historical Class BC Waste Generation per Cycle

Application	Class BC Volume (ft^3)
MB - shutdown crudburst cleanup and startup	30
MB - operating purification	30
Cation bed	20
Total Resin Consumption	80

Alternate Option Volume per Cycle

The on line lithiation strategy eliminates the need for one MB per cycle. The alternate option volumes of generated waste are summarized in Table 2-3.

Table 2-3
Alternate Option Class BC Waste Generation per Cycle

Application	Class BC Volume (ft^3)
MB - operating purification	30
Cation Bed	10
Total Resin Consumption	40

Packaging, VR, Disposal, and Storage

This operating strategy does not impact the historical packaging, VR, disposal, or storage options. The media is essentially the same material. Activity levels will fluctuate, but will remain within the historical activity band (Class BC waste) and VR and disposal facility acceptance criteria. The waste packages will be shipped in the same cask types and transportation charges will not be modified.

Alternate Option Resource Impact

On line lithation has a minimal impact on site staff resources. Additional chemistry scrutiny is required to monitor effluent activity, Li, ammonia and Na. Additionally, the level of effort to sluice, package and prepare the Class BC resin for shipment will be reduced scaled to one third of one liner of waste. That cost reduction is captured in the related cost analysis that follows.

Cost Analysis

The EPRI Waste Logic™: Liquid Waste Manager (LWM) cost analysis software program was used to analyze the historical and current costs. The program is capable of evaluating a comprehensive array of liquid and solid wet waste processing data. The program was used to model McGuire and Catawba plant process methodologies including their components, labor requirements, efficiencies, and disposition options; that data was analyzed to develop a detailed economic and performance summary. Program cost factors include:

- Capital improvements for liquid and solid waste processing.
- Labor for specific tasks.
- Media
- Process and packaging efficiency.
- Maintenance.
- Transportation.
- Storage.
- Disposal fees and surcharges.
- Equipment and processing changes.

Additionally, and most relevant to this project, the tool was used to analyze the costs and basic performance parameters associated with alternate process strategies and program enhancements that have the potential to impact processing program costs. Actual plant data was used for this analysis and was supported with data from accepted industry cost standards.

The costs in this analysis are very site specific and reflect current media, packaging and disposal site costs.

Note: As a result of its compact status, the analyzed site does not incur a milliCurie surcharge. This in turn reduces the overall cost benefit by reducing the impact of higher activity waste. The majority of stations in the US would realize a more significant benefit; that benefit is estimated based on industry cost standards and is included as appropriate in the following cost summaries.

Assumptions

The following assumptions were used to define the cost factors for the analyses:

- The cost analysis using historical generation rates and the current on line Lithiation rates.
- The station operates on an 18 month fuel cycle. It is understood that there will be deviations from an absolute cyclic period, however, for the purposes of this analysis, one cycle was equated to 18 full months.
- The media was direct disposed at the Barnwell disposal facility.
- On line lithiation is prepared for shipment and disposal using the same processes and packages.
- Segregated anion and cation strategy could utilize alternate waste packages for Class A anion media.
- On site storage assumes no volume reduction process is employed.
- On site storage facility/module costs will vary dramatically as discussed previously, therefore those costs are not included.

Historical Program Cost

This cost table represents the historical per-cycle performance at the station. It assumes that the cleanup mixed bed is replaced each outage.

Table 2-4
Historical Class BC Waste Generation and Program Costs

System	Generated Class BC Waste Volume	Disposed Class BC Waste Volume	No milliCurie Surcharge		With milliCurie Surcharge	
			Weighted Average Cost per Solid Volume Generated	Total Cost	Weighted Average Cost per Solid Volume Generated	Total Cost
	ft^3	ft^3	$/ ft^3	$	$/ ft^3	$
Historical RCS Purification Strategy	80	96.24	1,345	107,576	1,827	146,120

Alternate Option (On Line Lithiation) Program Cost

This scenario represents the per-cycle benefit derived through the implementation of on line lithiation.

Table 2-5
Alternate Option (On Line Lithiation) Class BC Waste Generation and Program Costs

System	Generated Class BC Waste Volume	Disposed Class BC Waste Volume	No milliCurie Surcharge		With milliCurie Surcharge	
			Weighted Average Cost per Solid Volume Generated	Total Cost	Weighted Average Cost per Solid Volume Generated	Total Cost
	ft^3	ft^3	$\$/ft^3$	$	$\$/ft^3$	$
Alternate RCS Purification Strategy	40	48.1	820	32,788	1,361	54,458

Post 2008 Storage Cost

Table 2-6 summarizes the analysis results for on site storage with on line lithiation.

The storage data and results captured in this analysis **do** contain the cost factors related to on site media movement, packaging, dewatering, volume reduction (is employed) and final transfer to the storage facility. They **do not** include final storage facility/shield and off site VR options unless indicated otherwise, and therefore are not considered absolute. As a result, the storage option costs can be significantly higher and it is anticipated that this would impact the applicable cost benefit results. Also, the disposed volume does not reflect potential off site volume reduction opportunities that may exist post 2008 for this waste stream.

Table 2-6
Alternate Option With On-Site Class BC Waste Storage Performance and Program Cost

System	Generated Class BC Waste Volume	Disposed Class BC Waste Volume	Weighted Average Cost per Solid Volume Generated	Total Cost
	ft^3	ft^3	$\$/ft^3$	$
Alternate RCS Purification Strategy - Storage	40	48.1	271	10,836

Segregated Cation and Anion Bed Example Cost Analysis

Taking "on-line" lithiation a step further could be accomplished by loading two cation beds in parallel followed by a borated anion bed. The lithiated cation bed would be placed in service with the down stream anion bed to provide reactor clean up. The other cation bed serves as a de-lithiating bed during its first cycle. On the next cycle it serves as the lithiated cation bed. This eliminates mixed beds and allows the segregated anion component whose capacity is used for RCS clean up to be disposed of as Class A waste at a significantly lower rate, versus as Class B/C waste at approximately two times the cost.

The following example is constructed using LWM n line Lithiation analysis data. The comparison is to historical performance.

The Catawba/McGuire average cost for Waste Class A resin processing disposition at the Envirocare facility (via Studsvik) is $\$711/ft^3$. There is no milliCurie surcharge related to this disposal option. The average historical cost for Waste Class BC resin disposition without a milliCurie surcharge is $\$1,345/ft^3$. That value increases to $\$1,827/ft^3$ with the milliCurie surcharge applied. Therefore it follows that the cost benefit associated with segregating Class A waste from BC waste equals $\$634/ft^3$ or $\$1,116/ft^3$ with the milliCurie surcharge applied.

If it is assumed that 20 ft^3 of resin would now be disposed as Class A versus the historically required Class BC, the station would realize a per-cycle savings of approximately $12,680 ($22,320 with milliCurie surcharge). The 35 year (23.3 fuel cycles) life of plant savings would exceed $295,444 ($520,056).

Summary of Benefits and Limitations

Benefits

There are non monetary benefits associated with these options. Several of those include:

- A 30 ft^3 per cycle reduction in solid waste volume that in turn reduces the impact related to on-site storage.
- A reduction in solid waste volume that in turn reduces the personnel exposure related to handling and packaging.
- On line lithiation by default results in reduced lithium additions ("free" Li)
- Employing a parallel MB configuration increases the shutdown crudburst cleanup rate, which in turn reduces the overall impact on the outage schedule.
  - 180 gpm in parallel
  - approximately 20% reduction in cleanup duration

Limitations

As with many processing options, there are several known limitations that impact the potential to use on line lithiation, or that impact the success of its implementation. Several considerations include the following:

- This option requires two demineralizers that can be aligned and designated to serve the same function.
  - At some stations, the RCS purification systems cannot be configured to run parallel operations, and/or may not have the number of vessels required to successfully implement this option.
- Dual unit stations may have dual demineralizers in each unit and share one or more common vessels. The shared use of the third vessel eliminates the option for controlling that vessel to support lithiation specific to either of the units.
- This process requires careful monitoring and trending for specific chemistry parameters including lithium, sodium, and ammonia.
- This process has the potential to result in additional carryover of contaminants from one cycle to the next due to long term media use and changing influent characteristics.
- Na is transferred from one cycle to the next
  - When reloading with Li form resin, the Li to Na ratio would be lower
  - As the bed is lithiating, it is also putting Na on that bed
  - This results in additional carryover of equilibrium levels
- A large ingress of contaminants would require a bed to be sluiced and reloaded.

   – This could result in ammonia loading on the bed. The ammonia level can be high dependent on the shutdown and startup operations.

- The exchange of ammonia and lithium may make the final lithiation somewhat indistinct. There is a different ammonia loading on the bed during shutdown followed by an exchange of Li for ammonia during de-lithiation and vice versa when the bed is placed in service for purification.
- Ammonia analysis is critical; the bed may appear to be removing lithium and sample analysis won't show lithium throw. It may in fact be throwing ammonia and the bed may be close to cation saturation. If this is the case, the bed should be placed in service and lithium additions used to complete the saturation process.

Conclusions

This option reduces the Class BC generation by 30ft^3 each fuel cycle. A cost summary for both options shown with and without a milliCurie surcharge is shown in Table 2-7.

Table 2-7
Cost Benefit Summary

Strategy	Millicurie Surcharge Applied	Per Cycle Cost Savings ($US)	35 Year (23.3 fuel cycles) Life of Plant Avoided Cost ($US)
On Line Lithiation	No	74,788	1,744,804
On Line Lithiation	Yes	91,662	2,138,474
Segregated Cation & Anion Vessels	No	12,680	295,444
Segregated Cation & Anion Vessels	Yes	22,320	520,056

The cost benefits for implementing either on line lithiation or cation and anion segregation are quite significant relative to the total wet waste cycle O&M costs and the implementation and support costs. The life of plant savings illustrate the long term benefit that can be derived from this process. Additionally, and equally important is the fact that this improvement did not require hardware changes and was implemented using programmatic revisions.

As stated previously, this option is limited to those stations that have the bed volume and piping configuration to support multi bed media management. This option also requires a significant commitment from both the chemistry and operations organizations to ensure the beds are aligned in the proper sequence during the pertinent period of time.

3
BWR REACTOR WATER CLEANUP IN SERVICE RUN LENGTH—SUSQUEHANNA

Process Overview

BWR Reactor water cleanup (RWCU) systems provide chemical and source term (activity removal) control functions for the reactor coolant system. The filter/demineralizers are required during operations to maintain reactor coolant chemistry and purity and during shutdown for crudburst cleanup and spent fuel pool clarity. A full dose precoat is typically utilized to maximize impurity cleanup and the use of minimum or non precoat septa (i.e., no-to-minimal ion exchange) is typically not practiced. The precoat is backwashed based on run length, effluent chemistry, or effluent activity levels. The solid waste generated by the system is the highest activity waste stream that a BWR site contends with on a routine basis. Maintaining the spent media activity at lower levels can reduce waste packaging, transport and disposal costs. However, when the media is backwashed based solely on run length or activity, the media frequently has remaining, and by default wasted, ion exchange capacity.

PPL LLC's Susquehanna Station operates two, General Electric, Type 4, Mark II BWRs that produce in excess of 1105 MWe each. The station has experienced minimal failed fuel excursions in the past decade and as a result, their RWCU influent activity concentrations (uCi/cc) are relatively low. However, the station's historical RWCU precoat waste activity levels result in a waste package that is close to the shipping cask external radiation level limits. The RWCU precoat waste is packaged and shipped in NUPAC EL-142 HICs that have an external volume of 132.4 ft^3 and an internal waste volume of 100 ft^3. The waste is shipped to Studsvik for pyrolysis and the residual is disposed at the Envirocare of Utah disposal site.

One of the primary reasons Susquehanna limited RWCU run lengths to 28 days, was to avoid generating a waste stream that exceeded those limits; by default, that would result in increased transportation charges and impact shipping schedules due to limited Type B cask availability.

Configuration and Media

The RWCU system is typically a dual train kidney loop that operates off the RCS system. The liquid is cooled and processed in the majority of stations at flow rates that vary from 1% to 2% of final feedwater flow. This typically equates to a process flow rate of approximately 200 – 500 gpm. Figure 3-1 illustrates a typical RWCU system configuration.

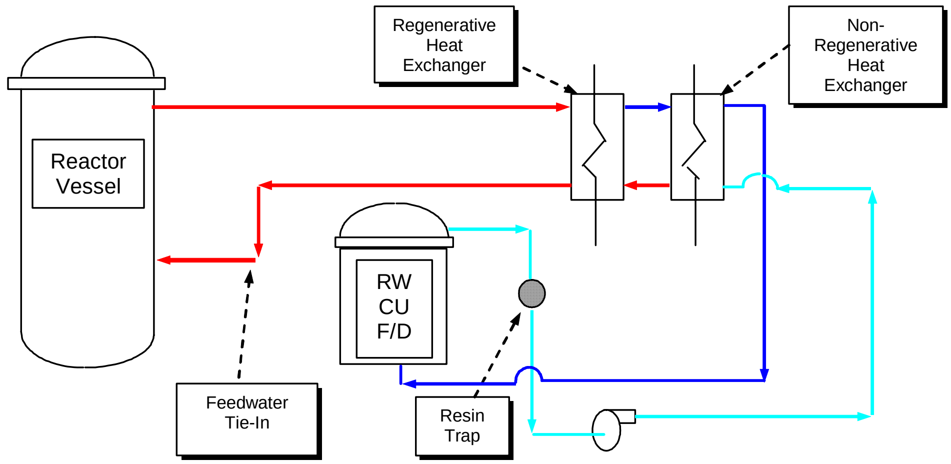


Figure 3-1
Typical RWCU Configuration

RWCU systems employ a precoat *volume* that varies by system flow and plant vessel/septa configuration. Many plants operate with a precoat volume range of 2-3 ft^3 per precoat. The media *type* is dictated by primary chemistry controls, flow rate, chemical and activity challenges, and in some instances, economics. Several commonly used commercial resins include Epicor Epifloc 21-H and 91H, and Graver P-202-H and 205H.

Alternate Option

Alternate Strategy Description

Susquehanna's chemistry organization was evaluating improvements to their RWCU program. As part of that process, the station conducted a poll of similar stations to identify opportunities for improvement. The chemistry staff was aware that their RWCU run lengths were shorter in duration than other stations and the survey confirmed this fact. As a result, the station evaluated extending the RWCU precoat run time based on a 60 day duration or effluent chemistry quality. Based on system chemistry and related projections, the increase would not adversely impact reactor chemistry, but would significantly increase the waste precoat activity level. At first glance, this option appeared to offer several attractive benefits including reductions in:

- Program cost
- Generated waste media
- Number of waste shipments
- shipment liability
- On site vendor processing costs
- Off site vendor processing costs

NOTE: When reviewing this section of the report, it is important to recognize that the inverse of this strategy was used for this project, defining the impact of reducing reactor water cleanup run length to produce a Class A waste stream that remains acceptable for off site volume reduction and/or disposal.

Solid Waste - Packaging, VR, Disposal, and Storage

Option 1 - 60 Day Run Annual Volume Generation

Using the 30 day run data as a foundation and industry experience related to activity, volume and shipping scaling, a 60 day run length scenario was constructed using the EPRI LWM program. The results of that analysis are shown in Table 3-1. In this scenario, the waste activity levels exceed the waste receipt criteria activity limits established by Studsvik. As a result, the waste is not volume reduced and is direct disposed at the Barnwell, SC site, the only licensed Class BC waste facility available to Susquehanna. The increase in volume (generation versus disposed) is attributable to the HIC packaging efficiency.

This scenario represents this project's less desirable, Class BC waste management option.

Table 3-1
Option 1 - 60 Day Run, Annual Waste Class BC Volume

Waste Class and Disposition Option	Liquid Volume Processed	Generated Solid Waste Volume	Disposed Solid Waste Volume
	gal	ft^3	ft^3
BC - Barnwell	84,096,000	24	31.78

Option 1- 30 Day Run Annual Volume Generation

The Susquehanna plant precoat experience was used to develop the solid waste generation volume for their historical 30 day runs. As stated previously, backwash and precoat cycles were based on historical practices to limit the activity. Table 3-2 summarizes the EPRI LWM results based on their 2003 data. The Studsvik pyrolysis process results in an average 5:1 volume reduction that is reflected in the "Disposed Solid Waste Volume" column.

This scenario represents this project's more desirable, Class A waste management option. This option allows the waste to be disposed following the pending Barnwell Class BC waste disposal site closure.

Table 3-2
30 Day Run, Annual Waste Class A Volume

Waste Class and Disposition Option	Liquid Volume Processed	Generated Solid Waste Volume	Disposed Solid Waste Volume
	gal	ft^3	ft^3
A – Envirocare via Studsvik	84,096,000	48	9.6

Alternate Option Resource Impact

Reducing the run length for the RWCU system from 60 days to 30 days would increase the associated labor requirements by 50%. Similar to most BWR stations, Susquehanna uses station operators for backwash and precoat evolutions. However the level of effort required is relatively insignificant relative to balance of plant operator responsibilities. An increase in the staff resource requirements would be realized ranging from the warehouse (new media receipt/delivery) to security (cask protected area access inspection and escort). The volume of waste requiring packaging would be increased by 50%, producing a similar resource allocation effect for the contracted packaged waste technician. It is likely that chemistry oversight could be reduced as the shorter run lengths are less likely to adversely impact reactor water quality. Additional backwash/precoat and waste packaging/shipping evolutions would also require additional planning and scheduling resources.

The personnel exposure impact could not be accurately projected. More frequent waste shipments may result in an increase in site personnel exposure, however, the per package activity/dose rate would be lower for Class A packages than for Class BC packages.

The costs associated with the resource requirements are captured in the following section.

Cost Analysis

The EPRI LWM program was used to define and evaluate the cost impact associated with reducing run lengths. Historical site cost and performance information was input to the program to create a baseline 30 day run database. That data was extrapolated and volume reduction and disposal options modified to reflect the projected higher activity waste and a 60 day run cost analysis was performed.

Assumptions

The following assumptions were used to define the cost factors for the analyses:

- The station used their Radman™ waste classification and shipping software to define the breakpoint from Class BC to Class A waste. Alternatively, programs such as MegaShield™ could be used to define the dose to curie scaling factor. MegaShield provides for multiple source sizes, materials, shield regions and materials in most geometric configurations and is used to perform calculations that convert package dose rates to curie. Radman and MegaShield constitute two of several waste classification programs available to the industry. Both the Radman and MegaShield programs (or similar) are routinely used by the industry to evaluate current performance and to project alternate options using site specific nuclide distributions associated with specific waste streams.

- It was projected that transitioning from a 60 day run to a 30 day run length would reduce the per package activity by approximately 43%.
- On site storage would result in decay that would ultimately reduce the disposed mCi fee if and when Class BC waste disposal options became available and if that option included an activity surcharge.
- Studsvik will be used for volume reduction of the Class A waste stream prior to disposal at the Envirocare of Utah facility.
- The Barnwell facility imposed an activity surcharge.
- The Studsvik to Envirocare option did not include an activity surcharge.
- The station has opted for container refurbishment for Class A waste containers; a fee applies to that option and is included in the cost analysis.
- Vendor dewatering services were used for all liners regardless of waste classification.
- On site storage costs were specifically excluded. As discussed previously, for all scenarios, there are costs associated with initial design, engineering, procurement and construction. Those capital costs are followed by O&M costs related to routine and corrective facility maintenance, operation, and radiological surveys, etc. The level of effort will vary dramatically by site based on storage strategy (e.g. structural facility vs. temporary shields). Inclusion of those values would skew the analysis results as they might apply to other stations.

60 Day Run Program Cost

Table 3-3 summarizes the costs associated with a 60 day run length. The analysis assumed that all precoat media would be a higher activity BC waste requiring direct disposition at the Barnwell facility.

Table 3-3
60 Day Run, Annual Waste Class B Program Cost

Waste Class and Disposition Option	Weighted Average Cost per Solid Volume Generated	Total Cost
	$/ ft^3	$
BC - Barnwell	11,250	269,990

30 Day Run Program Cost

Table 3-4 represents the costs associated with a lower activity, Class A waste stream. This waste is volume reduced off site and disposed at the Envirocare facility.

Table 3-4
30 Day Run, Annual Waste Class A Program Cost

Waste Class and Disposition Option	Weighted Average Cost per Solid Volume Generated	Total Cost
	$\$/ft^3$	$
A – Envirocare via Studsvik	1,939	93,052

Post 2008 Storage Cost

Table 3-5 illustrates the impact of on site storage. It is assumed that Class BC waste would be stored on site and that if the station was able to produce only Class A waste, it would continue to be disposed of at the Envirocare site. The notable difference between this scenario's BC waste and the previous Barnwell disposal strategy is the absence of the activity surcharge.

The storage data and results captured in this report **do** contain the cost factors related to on site media movement, packaging, dewatering, volume reduction (is employed) and final transfer to the storage facility. They **do not** include final storage facility/shield and off site VR options unless indicated otherwise, and therefore are not considered absolute. As a result, the storage option costs can be significantly higher and it is anticipated that this would impact the applicable cost benefit results.

Table 3-5
Class BC Post 2008 On-Site Storage

Waste Class and Disposition Option	Weighted Average Cost per Solid Volume Generated	Total Cost
	$\$/ft^3$	$
BC -Site Storage	1,525	36,610

Summary of Benefits and Limitations

Benefits

Reducing the run length from 60 days to 30 days may provide additional benefits to the station.

- Backwashing more frequently may promote a longer septa life. Additionally, the media's primary function is used to control reactor water chemistry and activity. Operation with new media on a more frequent basis may improve the media removal efficiency for soluble and insoluble species.

- Reducing the run length, and activity and dose rate will allow shipment in larger liners. The use of the larger liners will result in a reduced number of shipments and the associated cost, exposure, and liability.
- The reduced number of shipments will reduce program cost and the associated exposure and liability risks inherent to packaging and shipping waste.
- Reducing the activity concentration reduces the risk of generating waste that is >Class C that may require extended, or indefinite, on site temporary storage for decay to an acceptable Class C waste level.
- Transportation security regulations have already impacted high activity (>200 Ci Cobalt) shipments during elevated national security threat periods. Reducing the package activity mitigates the potential for this shipping constraint.

Limitations

Several key factors require careful consideration:

- 30 day runs result in waste activity levels that approach the shipping limits for Type A shipments. Additional activity may result in dose rates that restrict the plant's ability to transport in the media.
- This change in strategy would require a detailed evaluation of the shipping cask(s) Certificate of Compliance (C of C), the station Process Control Program (PCP), and procedures.
- The increased liner volume could result in the same number of shipments in spite of the increase in generated volume, however, Type B shipping cask availability is already at a premium and that cask availability may be a limiting factor for managing this waste stream.

In 2008 the only available disposal site for high activity wastes, Barnwell, will no longer accept out of compact (e.g., Susquehanna's) waste. As this date draws closer, the availability of high activity casks will be at a premium due to utilities aggressive efforts to reduce the on site inventory of high activity waste streams prior to disposal site closure.

Conclusions

Table 3-6 summarizes the costs associated with the current Barnwell Class BC and Envirocare Class A options.

Table 3-6
Susquehanna Annual Cost Benefit Summary – Disposal

Waste Class and Disposition Option	RWCU Media Service Run Length	Weighted Average Cost per Solid Volume Generated	Total Cost
	days	$/ ft^3	$
BC - Barnwell	60	11,250	269,989
A – Envirocare via Studsvik	30	1,939	93,052

Reducing the run length to maintain a Class A waste product can result in an annual cost savings in excess of $176,900. This is a very significant cost benefit to the station; additional benefits may be derived from the improved performance that is often associated with more frequent septa backwash and new media precoats.

The costs associated with on site storage of BC waste and disposal of Class A waste at Envirocare are summarized in Table 3-7. This table indicates that both annual and per cubic foot of waste generated costs for site storage would be less cost effective than disposal at Envirocare. The Class A disposal cost would be approximately $56,440 higher than site storage. However, as discussed previously in this section, that cost will be impacted by site specific storage cost factors. The total cost for storage can be significantly higher impacting the as shown analysis results.

Table 3-7
Susquehanna Annual Cost Benefit Summary – Storage and Disposal

Waste Class and Disposition Option	RWCU Media Service Run Length	Weighted Average Cost per Solid Volume Generated	Total Cost
	days	$/ ft^3	$
BC – Site Storage	60	1,525	36,610
A – Envirocare via Studsvik	30	1,939	93,052

4
FUEL CLEANING FILTER MANAGEMENT

Process Overview

Ultrasonic fuel cleaning was originally developed for PWRs to enable them to operate with higher fuel duty and longer cycles. Under these conditions, sub-cooled nucleate boiling may occur in the upper fuel spans with resulting axially-asymmetric deposition of corrosion products. Boron can hide out in these deposits, causing a local flux depression called either axial offset anomaly (AOA), or more recently, crud induced power shift (CIPS). Ultrasonic fuel cleaning is an effective means for removing PWR fuel deposits, hence mitigating the CIPS problem. When ultrasonic fuel cleaning was applied at PWRs for the mitigation of CIPS, a reduction in ex-core dose rates, and consequently personnel exposure, was also observed.

The EPRI fuel cleaning system consists of one or multiple cleaning chamber(s), provision for pumping fuel-pool water through the cleaner, and a waste-collection module. The cleaner and waste collection modules are interconnected with flexible hose, so the installation can be adapted to the space available at the plant. The cleaning chamber consists of a rectangular channel that contains the fuel assembly to be cleaned, surrounded by the matrix of ultrasonic transducers, and an external reflector-channel to reflect and focus the ultrasonic energy into the fuel assembly. Pool water is drawn into the open top of the cleaning chamber, carrying away the dislodged corrosion products to the bottom, through the flexible hose, into the waste collection module, and back to the pool. Typically, waste collection has been through a bank of disposable cartridge filters, although alternate collection options have been explored as well.

The spent cartridge filters are designed to capture the removed corrosion products and processed as radioactive waste.

Historical Industry Experience

Several stations have successfully completed one or more fuel cleaning campaigns. PWR experience is the most abundant, however a recent pilot and scaled up fuel cleaning at a BWR (Quad Cities) resulted in the removal of a significant amount of crud and the associated activity. For all fuel cleaning campaigns to date, the dose rate limit was reached well before the pressure drop (ΔP) limit mandated by the manufacturers of the filter cartridges. The composition of the ultrasonically dislodged crud can be determined by side-stream sampling of the suspension in the line transferring crud from the cleaning module to the filter bank.

The first three plants discussed here are included as summary information only. The Callaway experience will be used for the cost benefit analysis.

Quad Cities

Exelon's Quad Cities dual units are 912 MWe GE Type 3, Mark I boiling water reactors. The station was the first US BWR to perform ultrasonic fuel cleaning. As part of that pilot program, four thrice-burned (discharge) fuel bundles were selected and cleaned. The bundles were selected based on power history and presence in core during critical plant chemistry parameter changes. That effort resulted in generation of four (4) 0.45 micron filters to capture the removed crud. The filter activity was calculated to be a total of 661 curies of which Co-60 contributed 210 curies. The final dose rates on the 4 filter cartridges were 450 to 600 Rem/hr (4.5 to 6.0 Sv/hr). Figure 4-1 illustrates the filter's dose rate buildup rate during the cleaning process.

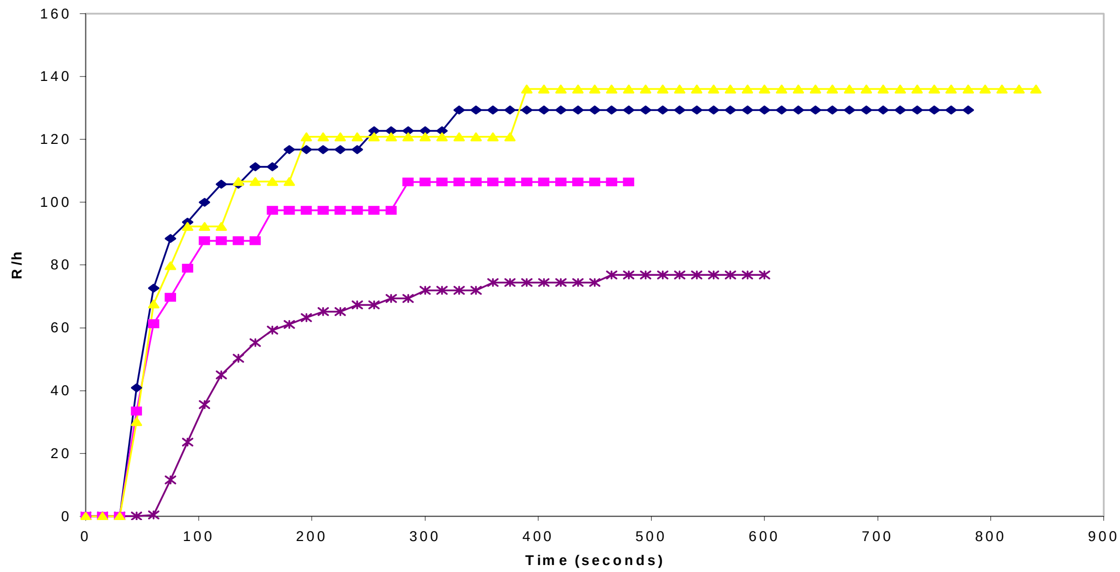


Figure 4-1
Quad Cities Fuel Cleaning Filter Dose Rate Buildup Rate

It can be seen that the activity buildup occurs very rapidly, challenging the plant's ability to reduce the per filter activity and subsequently its waste class.

During the subsequent campaign, 16 once burned fuel assemblies were cleaned during Q2R17. Four filters were used to collect crud resulting in contact dose rates of 436 to 837 Rem/hr (4.4-8.4 Sv/hr). The station estimated that 300 Curies of activity (~100 Curies Co-60) were removed as a result of that cleaning. All four filters were classified as Class C waste.

An alternative crud collection method was proposed for the fuel cleaning. Metal-media filter cartridges were used, but they were manifolded into a high integrity container (HIC) so that the crud from an entire fuel cleaning campaign could be shipped off-site without handling the individual spent filter cartridges.

STP

STP operates two 1275 MWe, 4 loop PWRs that began operation in 1988/1989. The station cleaned 128 assemblies and generated eight (8) organic membrane filter cartridges. The utility established a filter dose rate limit based on analysis of the radioisotopes and transportation and disposal criteria. Although no quantitative assessment was made of the crud collected from a given assembly, the filter dose rates were monitored. The dose from the four parallel filter cartridges increased on the order of 5-8 R/hr for each assembly that was cleaned until they reached the 150 R per filter limit. The cartridges were stored in the spent fuel pool for radioisotope decay until the next refueling outage approximately18 months later. The filters will be shipped as Class B waste.

Vogtle

Southern Nuclear Operating Company's Vogtle Station operates twin 1152 MWe Westinghouse PWRs. In 2002, fuel assemblies from both units were cleaned. The filters were replaced at 40 R/hr. The cleaning and filter generation data are summarized in Table 4-1.

Table 4-1
Vogtle Fuel Cleaning Summary

	Unit 1	**Unit 2**
Assemblies Cleaned	117	113
Filters Used	16	12
Assemblies/Filter	7	9

Alternate Option

Organic media tend to have a relatively brief useful life in the high radiation field of the crud captured on the filters and/or the radiation fields present if stored in the spent fuel pool for extended periods. More recent filter designs have used sintered-metal media to provide more flexibility as to the length of time the spent cartridges could be stored in the fuel pool before disposal. Maximizing the activity captured on a single filter cartridge may not be the most optimal strategy. The recent advances in filter construction materials and alternative solid waste volume reduction technologies including pyrolysis, may make more frequent, lower dose rate filter changeouts a more cost-effective and exposure-effective approach to managing this waste stream. This section explores the cost impact of that option as well as the associated considerations.

Callaway Case Study

Callaway is a 1125 MWe 4 loop Westinghouse PWR operated by the Union Electric Company. As a result of their high duty core and CIPS, the station has cleaned fuel assemblies each refuel outage for three cycles, therefore this plant's data is considered the optimum candidate for a Class BC waste reduction analysis. Table 4-2 summarizes the Callaway fuel cleaning history. The cleaning operation required 2 fuel handlers on the bridge crane, 1 licensed Senior Reactor Operator (SRO) and a Radiation Protection Technician on an as needed basis. Equipment setup required approximately 24 hours and the subsequent cleaning rate was approximately 2-3 assemblies per hour (~48 hours for cleaning).

Table 4-2
Callaway Fuel Cleaning History per Fuel Cycle

Refueling Outage	Number of Assemblies Cleaned
R13	96
R12	96
R11	96
Totals	**288**

System Configuration

Following a testing campaign, Callaway opted for using a dual train filter system with four elements per train operated in parallel. Each filter housing was constructed of stainless steel mesh and the housings and elements were designed for inside-to-out flow. This facilitated direct discharge of filter effluent through the mesh directly to the spent fuel pool (SFP) liquid volume. The system was operated with one train in service and one train in standby with fresh elements.

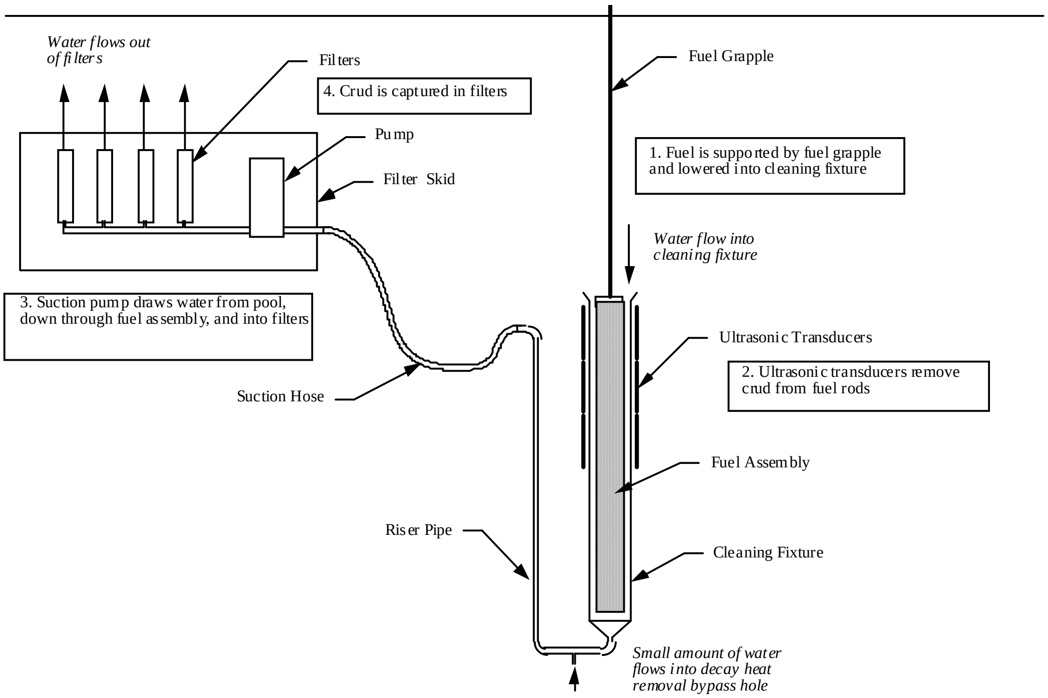


Figure 4-2 Schematic Diagram of Ultrasonic Fuel Cleaning System

Filter Specifications

The cartridges for the Callaway employed organic membrane media. The intent was to dispose of the spent filters relatively soon after the cleaning campaign was completed, therefore radiolytic or other decomposition mechanisms associated with extended storage were not considered to be relevant. The filter specifications are shown in Table 4-3.

Table 4-3
Callaway Filter Specifications

Parameter	Description
Size	6.375"D X 32"L
Volume	0.587 ft^3
Weight	12 lbs
Media	0.5 micron
Construction	SS core, outer expansion support, end caps, handle and inlet check valve. Polypropylene drainage and support layer

Historical Filter Management

Changeout Criteria

Callaway used the Radman™ program and an analysis performed by the fuel cleaning vendor support team to define their Greater Than Class C (GTCC) dose rate termination value of 133 R/hr (submerged underwater). This value includes a margin for error of approximately 20% to ensure the GTCC limit (Class N) is not exceeded. The primary nuclides of concern were transuranics and ^{63}Ni. Table 4-4 summarizes the Radman waste classification output.

Table 4-4
Waste Class BC Radman Results

Source: Sample	**Dose/Curie Factor:** 0.101	**Distance Reading:** 1 inch (2.54 cm)
Waste Class	**Lower Threshold Dose Rate Reading (mRem/hr)**	**10CFR61 Table Driving Waste Classification**
C	2,285	1

Generated Volume – Class BC Waste

The number of filters used per cleaning is relatively insignificant and generates a relatively small volume of waste.

Table 4-5
Historical Callaway Class BC Filter Generation per Fuel Cycle

Refueling Outage	Number of Assemblies Cleaned	Number of Class BC Filters Generated	Class BC Waste Generation (ft^3)
R13	96	3	1.8
R12	96	2	1.2
R11	96	4	2.3
Totals	**288**	**9**	**5.3**

(Source: Callaway Radman Database 2005)

Changeout Evolution

Dose rates were taken on the filter closest to the crud transport/flushing pump. The changeout of the fuel cleaning filters is performed by a single technician supported by a single Radiation Protection technician. A long handled tool (hook) was used to remove the filters from the submerged housings and transfer them underwater to a submerged storage rack or basket suspended near the filter housings on the side of the spent fuel pool. The rack was capable of accommodating four (4) spent elements, however it was generally used for staging new filter cartridges. Underwater baskets staged on the SFP floor could hold eight (8) filter elements and the station had approximately 6 baskets available for use. The baskets were sized for 55 gallon drums.

Solid Waste Packaging

A typical packaging sequence follows:

1. Filters dose rated underwater in the SFP.
2. The filter basked is transferred into a 55 gallon/7.5 ft^3 drum in a shielded drum host on the SFP operating deck.
3. A lid is placed on the drum and the lid on the shielded drum host.
4. A gross survey is performed on the drum shield.
5. The shield is lowered to a forklift in the SFP building truck bay.
6. The shielded host is transferred to the RW processing building truck bay.
7. The drum host lid is removed.
8. The crane is used to remove the drum from the host.
9. Electronic dosimeters (ED) are used to obtain 12" dose rates for shipping requirements.
10. The drum is moved to high level waste storage/staging.

Solid Waste VR, Disposal, and Storage

The historical generation rates indicate that all filters generated from cleaning 96 assemblies could be packaged in a single drum. When a sufficient quantity of other waste is accumulated (14 drums), the drum is shipped for volume reduction processing and disposal in a 14-195 cask. The specific type of processing performed is dependent on the drum dose rates and activity. Current options employed by the site include supercompaction or overpack and direct dispose.

As a result of the dose rate associated with this waste stream, the filters were direct disposed.

Alternative Filter Management

Changeout Criteria

Callaway used the Radman™ program to define a dose rate termination value that would be used for maintaining the filters as waste Class A. It is critical to note that as a result of the nuclide mix, there is a very low dose rate threshold to shift from Class A waste to Class B waste. That value is 2,284 mR/hr (submerged underwater). The primary nuclides of concern were transuranics and ^{63}Ni.

Table 4-6 summarizes data from the Radman program illustrating the contact (1", 2.54 cm) dose rate values and their associated waste classification.

Table 4-6
Waste Class A Radman Results

Source: Sample	**Dose/Curie Factor:** 0.101	**Distance Reading:** 1 inch
Waste Class	**Dose Rate Reading (mRem/hr**	**10CFR61 Table Driving Waste Classification**
A	< 2,284	1

(Source: Callaway Radman Database 2005)

Generated Volume - Class A Waste

Using the alternative waste classification dose rate values and historical filter generation data, the quantity of Class A filters that would be generated was projected. That value is an estimate and it is recognized that a linear extrapolation is not representative of actual generation rates. Numerous factors such as filter media performance, nuclide distribution, and media loading rates can impact the number of filters generated. Table 4-7 captures the estimated number of filters and their associated solid waste volume. The number of filters generated is scaled from the actual plant data for those cleaning evolutions. The waste volume is based on the number of filters and the per filter volume of 0.587 ft^3.

Table 4-7
Alternative Callaway Class A Filter Generation per Fuel Cycle

Refueling Outage	**Number of Assemblies Cleaned**	**Number of Projected Class A Filters**	**Projected Class A Waste Generation (ft^3)**
R13	96	200	117.4
R12	96	133	78.1
R11	96	266	156.1
Totals	**288**	599	351.6

Change-out Evolution

The change-out evolution could be completed using historical methods. Lower dose rate filters may make it more effective to move individual filters directly to a drum stored in a shielded drum host. This would eliminate one filter change-out handling step related to filter placement in the basket or rack on the SFP floor. This also minimizes the volume of interference material in the SFP.

Solid Waste Packaging

An alternative packaging sequence could be used. The revised process may be similar to the following:

1. A lid is placed on the drum and the lid on the shielded drum host.
2. A gross survey is performed on the drum shield.
3. The shield is lowered to a forklift in the SFP building truck bay.
4. The shielded host is transferred to the RW processing building truck bay.
5. The drum host lid is removed.
6. The crane is used to remove the drum from the host.
7. Electronic dosimeters (ED) are used to obtain 12” dose rates for shipping requirements.
8. The drum is moved to high level waste storage/staging.

Due to the significant increase in the number of waste filters, this option would increase the number of waste packages required. Based on the quantity projections in Table 4-7 and a drum capacity of 8 elements per drum, this option would require 25 waste containers.

Solid Waste VR, Disposal, and Storage

Lower activity, Class A filters would support volume reduction and alternate disposal options. In this scenario, it is assumed that the filters would be super compacted and/or direct disposed at the Envirocare of Utah facility. The super compaction option assumes that this process would not result in creation of a greater than Class A final waste.

At least one other option exists; package and overfill with reforming residue (RR) at the Studsvik facility followed by final disposal at the Envirocare site. This is most likely the best overall option for this alternate, Class A waste stream.

Resource Impact

The alternate filter management option would increase the level of effort required for filter procurement, staging, change-out, packaging, shipment and on site storage. However, as a result of the similarities in the operation, packaging, and shipping strategies, there are no other projected resource impacts.

Cost

This cost analysis was performed using the EPRI Waste Logic™ Solid Waste Manager and Liquid Waste Manager programs.

Assumptions

All assumptions are based on actual site data and projections.

All costs are normalized for cleaning 96 assemblies.

System operators and change-out crew members have collateral duties during fuel cleaning evolutions; their level of effort would not change during the cleaning process.

Filter waste transport and disposal costs are:

- Class A filters: 292.63 per ft^3
  - Super compaction and disposed at Envirocare
- Class BC filters: $1,032.54 per ft^3
  - Packaged for direct disposal at Barnwell

The fuel cleaning equipment cost of $537,500 is amortized over 10 cleaning evolutions.

Setup and Operation Labor is as summarized in Table 4-8.

The total activity removed is the same for both options; therefore the surcharge remains the same.

Table 4-8
System Setup and Operation Labor

Labor Category	Hours per 96 Assemblies	
	System Operation (hours)	Mobilization and Demobilization (hours)
Contracted Refueling Technician	96	24
Licensed Operator	48	0
Radiation Protection Technician	32	12
Radwaste Technician	0	12
Reactor Engineer	48	24

Results

The following results were generated by the Waste Logic™ software suite.

Current Fuel Cleaning Filtration Cost

The costs associated with the most recent fuel cleaning (96 assemblies) waste are shown in Table 4-9. The results reflect fees associated with amortized fuel cleaning filter systems, new filter media, labor, waste packaging, transport, and disposal.

Table 4-9
Historical Fuel Cleaning Filtration Cost

System	Class BC Waste Generation	Weighted Average Cost per Volume Generated	Total Cost
	ft^3	$/ ft^3	$
Historical Fuel Cleaning Filter System	1.77	46,446.68	82,363.24

Alternative Filter Management Cost (2006 – 2008 and Post 2008)

The results in Table 4-10 represent the costs associated with maintaining all filters as Class A waste. Similar to Table 4-9, the results reflect fees associated with amortized fuel cleaning filter systems, new filter media, labor, waste packaging, transport, and disposal. In this scenario, all waste will be disposed at the Envirocare of Utah disposal site and will not impact on site storage post-2008.

Table 4-10
Alternative Fuel Cleaning Filtration Cost

System	Class A Waste Generation	Weighted Average Cost per Volume Generated	Total Cost
	ft^3	$/ ft^3	$
Alternative Fuel Cleaning Filter System	118.22	3,396.92	401,580.90

Summary of Benefits and Limitations

Benefits

Reducing the per-filter activity increases the options that are available for volume reduction and disposal. All filter waste can be super compacted and disposed at the Envirocare of Utah site; no on site storage would be required following the Class BC waste disposal site (Barnwell) closure in 2008.

Class C fuel cleaning filters are segregated from other high activity filter waste. Therefore 3-4 filter elements would occupy a full 7.5 ft^3 waste drum during on site storage. In the alternate scenario, all waste would be disposed, therefore the station would realize an on site storage volume reduction of ~7.5 ft^3 per cleaning evolution. This is a negligible, but tangible benefit.

Class BC filters are stored on site for an extended period of time for decay of short lived isotopes. This strategy would no longer be required for Class A filters.

Repeating fuel cleanings each outage will result in a reduced source term and will reduce the number of filter elements required for subsequent fuel cleaning evolutions.

Additional, Non Waste Benefit: Dose rate reductions on the order of 50% were observed for an outage following operation with cleaned reload fuel. This has had a significant positive impact on cumulative radiation exposure.

Limitations

There are several factors that have a significant impact on changing filters at lower activity levels. Those factors include, but are not limited to the following:

- The rate of activity increase on filters is significant. The most recent R13 cycle cleaning data indicates that the filter dose rate increased ~2-4 R/hr per cleaned assembly.
- The number of filter changes required is significant for the fuel cleaning scheduled time (approximately 48 hours).

Additional considerations include:

- Determining the correct waste stream characteristics for waste classification PRIOR to the first assembly is challenging. A slip stream can be provided to capture and analyze crud once cleaning has commenced. Activity to dose rate analysis should be confirmed at that time to ensure subsequent filters are properly characterized.
  - Transuranics and other key isotopes should be carefully evaluated for their impact on waste classification.
- Crud capture media (filters) should be selected based on planned disposition of that waste stream.
  - Organic based membranes can be used if "immediate" VR or disposition is the planned approach.
  - Long term storage of that media in a high radiation field may result in premature structural breakdown in the fuel pool.
  - The use of scintered-metal media provides storage duration flexibility prior to final packaging and disposal.
- Waste classification, transport, and disposal criteria must be incorporated into fuel cleaning plans.
- Industry experience clearly indicates that BWR fuel cleanings produce significantly higher levels of crud and activity compared to PWR evolutions.
  - In addition, the activity from BWRs is predominantly long-lived 60Co, rather than the 58Co predominating in PWR crud.

Conclusions

The volume of waste generated using the alternate, Class A waste strategy is significantly higher than the current, historical approach. This would result in approximately two additional waste shipments and impact the resources required to support those efforts. Table 4-11 summarizes that increase for each of the historical fuel cleanings.

Table 4-11
Fuel Cleaning Waste Generation

Refueling Outage	Number of Assemblies Cleaned	Historical Class BC Volume Generation (ft^3)	Alternative Class A Volume Generation (ft^3)	Volume Differential (ft^3)
R13	96	1.8	117.4	115.6
R12	96	1.2	78.1	76.9
R11	96	2.3	156.1	153.8
Totals	**288**	**5.3**	**351.6**	**346.3**

Table 4-12 summarizes the historical and alternative fuel cleaning filter management program costs.

Table 4-12
Comparison Callaway Filter Generation per Fuel Cycle

System	Generated Solid Waste Volume	Weighted Average Cost per Solid Volume Generated	Total Cost
	ft^3	$/ ft^3	$
Historical Fuel Cleaning Filter System – Class BC Waste	1.77	46,446.68	82,363.24
Alternative Fuel Cleaning Filter System – Class A Waste	118.22	3,396.92	401,580.90

As expected, the analysis projected a very significant increase in both cost and volume for each cleaning cycle (96 assemblies). The cost increased by 82% ($319,218) and the generated waste volume increased by 116.5 ft^3. The cost increase relative to historical/current data is primarily attributable to the sharp increase in the number of filters required at a cost of $1,125 each. Additional costs are incurred for waste packaging and shipping labor, and transportation costs.

The above data combined with the limitations and challenges related to controlling the filter activity during individual assembly cleaning cycles negates the cost efficiency of this alternate option. Individual site's performance and costs, and/or revisions to VR and disposal options may improve the viability of this scenario. This option is specifically NOT recommended for Callaway, but may be viable, and at a minimum should be evaluated for future application at other reactors.

5
IN SERVICE MEDIA MANAGEMENT - STP SPENT FUEL POOL

Process Overview

STP Nuclear Operating Co. operates twin 1275 MWe, 4 loop PWRs that began operation in 1988 and 1989. In 2000 STPNOC undertook an effort to increase the throughput of the Spent Fuel Pool demineralizers. Similar to the majority of PWRs, the STP spent fuel pool (SFP) purification system was operated on a full time basis per the original design considerations. During the calendar years 2002 and 2003 STP undertook a significant project to empty their resin storage tanks as part of an improvement plan for Class A resin and Class BC resin segregation. In 2002, STP generated 1,192 ft^3 of co-mingled resin that collectively was waste Class BC. Following this cleanout campaign, segregated packaging began in 2003 and Class BC resin generation was reduced by 43%. In 2004, STP generated 505 ft^3 of Class BC resin and 150 ft^3 of Class A resin. The STP percentage of resin that is Class A has increased from 0% in 2002 to 20% in 2003 and 23% in 2004.

In 2005, it became apparent to the industry that the Class BC waste repository at Barnwell would be closed in 2008. With that in mind, once the site's actual Class BC constituents and generation rates were clear, STP began evaluating additional Class BC waste reduction opportunities. The station assessed that operation and modified their historical strategy specifically targeting Class BC waste reduction.

Configuration and Media

STP operates dual SFP demineralizers for each unit (1A, 1B; 2A, 2B) with a post filter for each demineralizer. The beds can be aligned in a single vessel configuration or in parallel, but not in series. The SFP demineralizers are also used to purify the refueling water storage tank (RWST), therefore the station typically has the A vessel aligned with the RWST and the B vessel aligned for SFP purification. The demineralizers were historically charged with a 75 ft^3 mixed bed and just prior to their most recent strategy change, a 77 ft^3 charge a high capacity mixed bed resin (IRN-170).

Historical Media Management

Change-out Criteria

STP has a very successful chemistry and source term control program. Additionally, as discussed in the previous section of this document, the station has implemented a fuel cleaning campaign. That effort has resulted in further reductions in the challenge to primary system and SFP processing media. The SFP ion exchanger change-out decision process was always driven by demineralizer effluent sulfates concentration. Sulfate and TOC behavior at the SFP demineralizer inlet and effluent are indicative of cation resin degradation. Similar to other stations, STP has validated the fact that radiolytic decomposition of the SFP water generates peroxide. The peroxide oxidizes the cation component of the mixed bed and releases polystyrene sulfonate (PSS). Equation 1 illustrates the applicable reaction.

Equation 1: $H_2O \rightarrow e^-_{aq}, OH, H, H_2O_2, H_2, H^+ \longrightarrow$ Cation resin $\longrightarrow SO_4^{2-}$, PSS

The PSS results in an increase in sulfate levels in the SFP; sulfates are both a SFP and reactor coolant system chemistry concern. Similar to both PWR and BWR reactors, this body of cooling water is cross connected to the reactor coolant system during refueling evolutions. As a result of the waste reduction efforts and the peroxide induced resin failure, the station began to explore alternative bed management options.

Alternate Option

Alternate Strategy Description

The results of the previously discussed research led to the implementation of a stoichiometric mixed bed of IRN-170 resin in their SFP vessels. Additionally, that research led to the conclusion that the ion exchangers could be placed in service only as needed for chemistry or activity control, versus the historical full time service runs. This strategy is specifically designed to extend the resin life and media throughput without compromising other program aspects including SFP water quality or general area dose rates.

Media Specifications and Change-out Criteria

IRN-170 is a mixed H-OH bed resin that contains a higher capacity 16% cross linked IRN-99 cation resin that is more resistant, but still susceptible to peroxide degradation. Although the IRN-170 media is more impervious to peroxide attack, the peroxide-cation reaction's generation of sulfates is still limiting the life of the SFP media.

Solid Waste

Historical Generation

Similar to any ion exchanger's performance, the STP SFP demineralizers' media life is impacted by plant operations, influent water quality and media type and volume. Historically, each of the SFP 75 ft^3 charges would require change-out on 12-16 month interval. The annual generation and disposal performance is captured in Table 5-1.

Table 5-1
STP Historical Class BC Waste Data

System	Class BC Waste Generation	Disposed Class BC Waste Volume
	ft^3	ft^3
Historical SFP Processing	112.5	13.7

Alternate Generation

Modifying the resin type to the higher cross linked resin extended the media life to approximately 18 months. However, in their continuing effort to improve, the station recently achieved a two (2) year bed life, primarily by not operating the bed on a 24/7 basis thus setting a new standard for this process. This results in an annual generation volume of 77 ft^3. That value is currently used in the station's long range resin management database. That data and post 2008 analysis results are shown in Table 5-2.

Table 5-2
STP Alternate and Post 2008 Waste Data

System	Class BC Waste Generation	Disposed Solid Waste Volume
	ft^3	ft^3
Alternate SFP Option - Disposal	77.0	9.4
Alternate SFP Option - Storage	77.0	98.9

Packaging, VR, Disposal, and Storage

Historical and Alternate

STP packages 90 (usable) ft^3 of Class BC resin in an 8-120 HIC. The media is volume reduced by a factor of 10:1 at the Studsvik reforming facility and the residue from that process is disposed at the Barnwell BC waste repository. This process will continue until the site is restricted from Barnwell in 2008.

The station's piping configuration routes the SFP demineralizer to a low activity spent resin tank. Historically, this resulted in commingling the Class BC SFP resin with lower activity resin in the tank, creating by default a larger volume of Class BC waste. The station has modified SFP sluice procedures and now requires the LASRST to be empty, then the SFP is sluiced directly to the tank and the tank directly to a liner (fundamentally, a wide spot in the pipe). This results in generating liners that have ~77 ft^3 of resin versus the liner's 90 ft^3 capacity; this leaves a void space of 15%. Because the liner is shipped to Studsvik this is not a regulatory, disposal site, or on site storage issue. This will present a challenge post 2008 when the void space in liners would create an unnecessary financial and volume burden.

Post 2008

Currently, the site has the option of using off site volume reduction options for Class BC waste. However, for on site storage scenarios, that option would require that the waste be segregated while at the Studsvik facility and that only STP Reforming Residue (RR) is returned to the site. The most significant issue related to this is compliance with the STP site radioactive materials license requirements that restrict the plant from receiving radioactive waste generated by other reactors. Additionally, and equally obvious is that the VR benefit would be negatively impacted by overfilling with other site's waste and is therefore impractical.

The state of Texas is in a unique position in that it is aggressively pursuing a state repository that is expected to be licensed for Class BC wastes. STP will store their BC waste on site in above ground storage shields in a controlled, outside area until that site opens; that date is projected to be 2009. The alternate SFP media strategy results in an approximate waste reduction of 37% to 50%. This is significant in that it will reduce the number of storage shields required for post 2008 operation.

Resource Impact

The change in strategy does not have any appreciable non-cost impact on the station's resources. A level of effort was, and continues to be required to evaluate alternate resins and the associated chemistry and activity results.

Cost

Assumptions

All pre 2008 resin is volume reduced off site and direct disposed at the Barnwell facility.

77 ft^3 of waste is packaged per liner.

Post 2008 waste volume per liner will be improved to a minimum of 90 ft^3.

On site storage will be required post 2008.

The station will store waste in concrete shields that are manufactured locally using a modified Comanche Peak design. The per-shield cost for design, engineering, fabrication, transport, and placement is $25,000.

Historical Program Cost

The STP historical cost data was input to the EPRI LWM program. That analysis includes all aspects of the program including labor, materials, operation, and waste packaging, transport, volume reduction and disposal. The cost summary data is shown in Table 5-3.

Table 5-3
Historical Class BC SFP Waste - Annual Cost

System	Class BC Waste Weighted Average Cost per Solid Volume Generated	Total Cost
	$/ft³	$
Historical SFP Processing	1,770	199,104

Alternate and Post 2008 Program Cost

Using plant data and industry experience, two alternative cost analyses were performed. The first is representative of the station's current SFP management program costs. The second analysis addresses on site storage of waste following the 2008 Barnwell site closure.

The storage data and results captured in this section **do** contain the cost factors related to on site media movement, packaging, dewatering, volume reduction (is employed) and final transfer to the storage facility. They **do not** include the minimal O&M costs associated with outside, vaulted storage and does not include disposal fee accrual costs. Those values have not been defined by the station to date. The disposal accrual fee could significantly impact the storage option results. Table 5-4 summarizes the results of the two analyses.

Table 5-4
Alternate and Post 2008 Class BC SFP Waste - Annual Cost

System	Class BC Waste Weighted Average Cost per Solid Volume Generated	Total Cost
	$/ft^3$	$
Alternate SFP Option – Disposal	1,972	151,810
Alternate SFP Option –Storage	1,405	103,954

Summary of Benefits and Limitations

Benefits

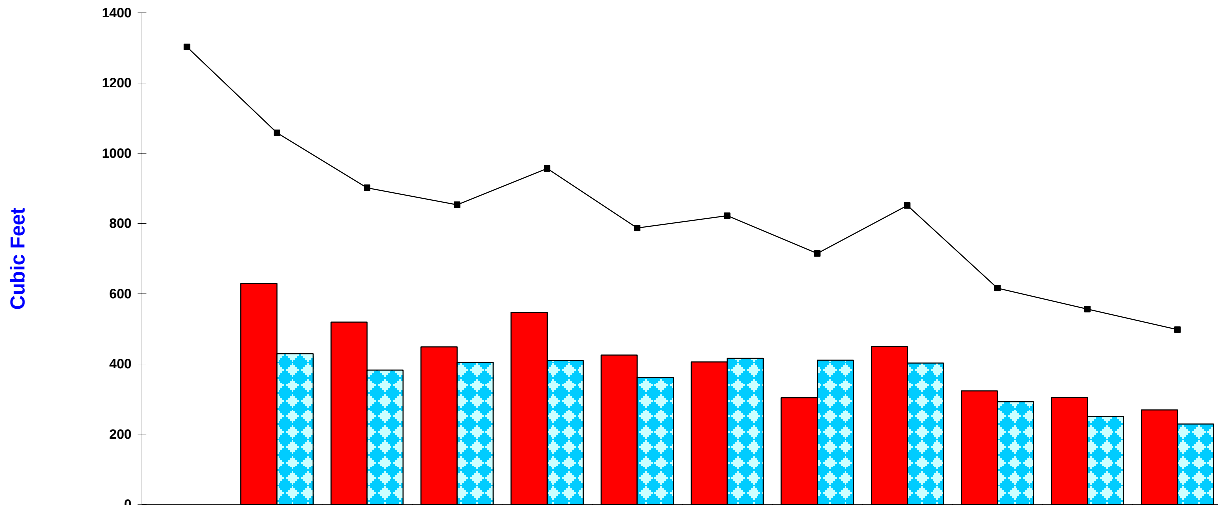
Improved resin (IRN-170) and reductions in in-service durations has resulted in a recent 24 month run length for their SFP demineralizer. That performance has contributed to an annual reduction in Class BC waste generation of approximately 35.5 ft^3. The annual cost benefit associated with that improved performance is $53,986. The analysis on site storage results are accurate based on available data. However, as stated previously, that cost efficiency will be impacted by the site O&M costs and disposal fee accruals. Equally important is the increase in solid waste volume requiring storage. As discussed previously the currently available VR options do not support segregation and return to site for this waste stream; the as packaged volume will require storage.

Table 5-5 summarizes the plant volume and cost data.

Table 5-5
STP SFP Media Management Cost and Performance Summary

System	Generated Solid Waste Volume	Disposed Solid Waste Volume	Weighted Average Cost per Solid Volume Generated	Total Cost
	ft^3	ft^3	$/ft^3$	$
Historical SFP Processing – Class BC	112.5	13.7	1,782	205,796
Alternate SFP Option – Class BC Disposal	77.0	9.4	1,972	151,810
Alternate SFP Option – Class BC Storage	74.0	98.9	1,405	103,954

Additionally, the station's aggressive media minimization efforts have resulted in very clear cost, volume and resource requirement reductions. Figure 5-1 clearly illustrates the success of those efforts by showing their improvement trend for **Class A and BC waste streams**.



	1991-93	1992-94	1993-95	1994-96	1995-97	1996-98	1997-99	1998-00	1999-01	2000-02	2001-03	2002-04
U1 3-Year		629	519	449	547	425	406	304	449	323	305	269
U2 3-Year		429	382	405	410	362	416	411	403	293	251	229
Site 3-Year	1303	1058	902	853	957	787	822	714	852	616	556	498

Figure 5-1
STP Media Generation History – 3 Year Rolling Average – All Media Class

Limitations

The IRN-170 media is an improvement when compared to historical media types, however it is susceptible to peroxide attack and the beds continue to be removed from service based on effluent sulfate.

The station's waste segregation program has reduced the quantity of Class BC resin each year since its inception, however it has forced STP to use smaller waste containers (8-120 HICs). As a result of the station's resin packaging station structural limitations, this places an additional burden on the scheduling and resin transfer staff.

Conclusions

This option provides several direct benefits to the station including:

- Reducing the annual program costs by ~$54,000
- Reducing the annual waste generation that currently requires disposal and that will require on site storage post 2008 by approximately 35.5 ft^3.
- Reducing the resource requirements to sluice, load and process spent media
- Improving the SFP water quality for an extended period of time

Figure 5-2 and Figure 5-3 illustrate the SFP water quality history. Note that the reductions to media volume and ion exchanger in service periods have not adversely impacted effluent water quality.

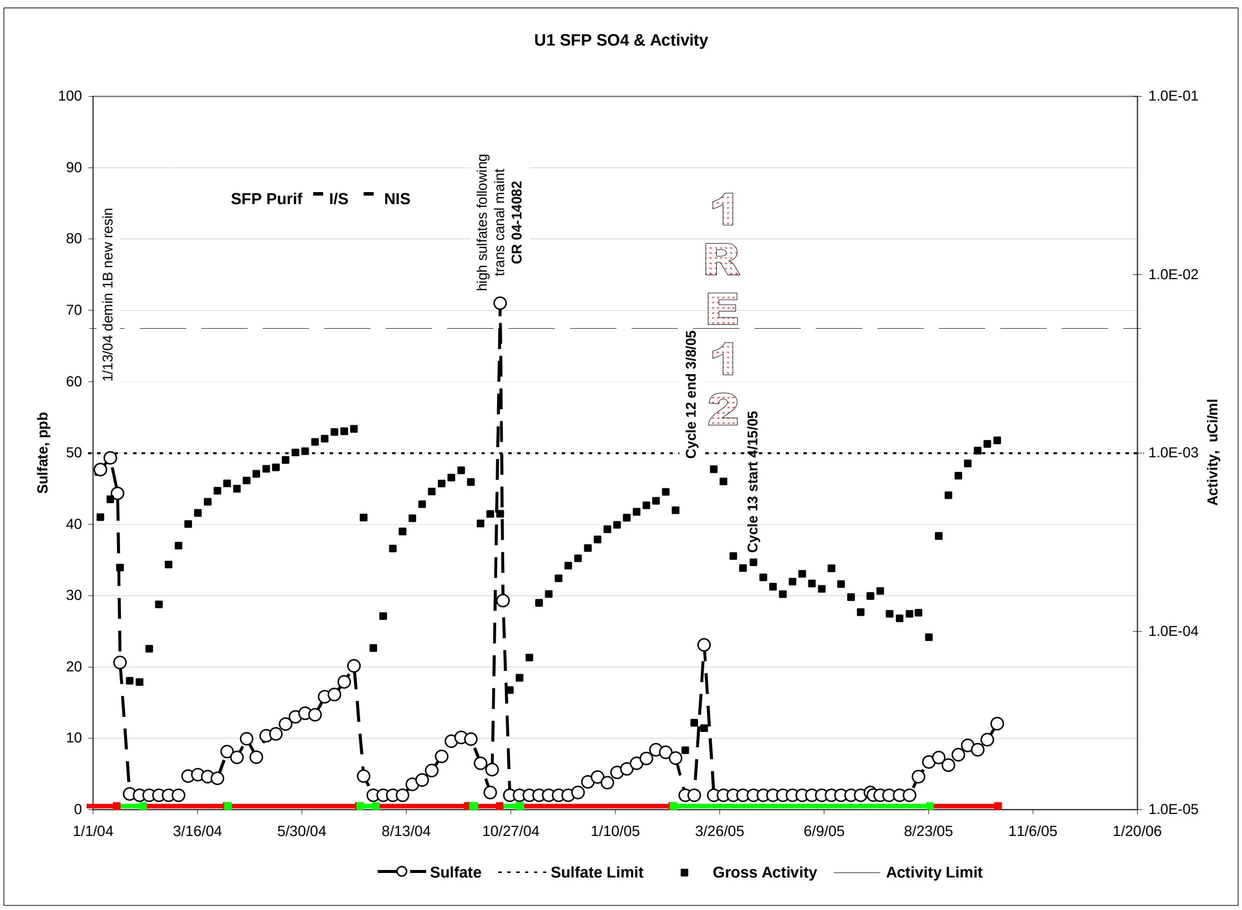


Figure 5-2
Unit 1 SFP Water Quality History

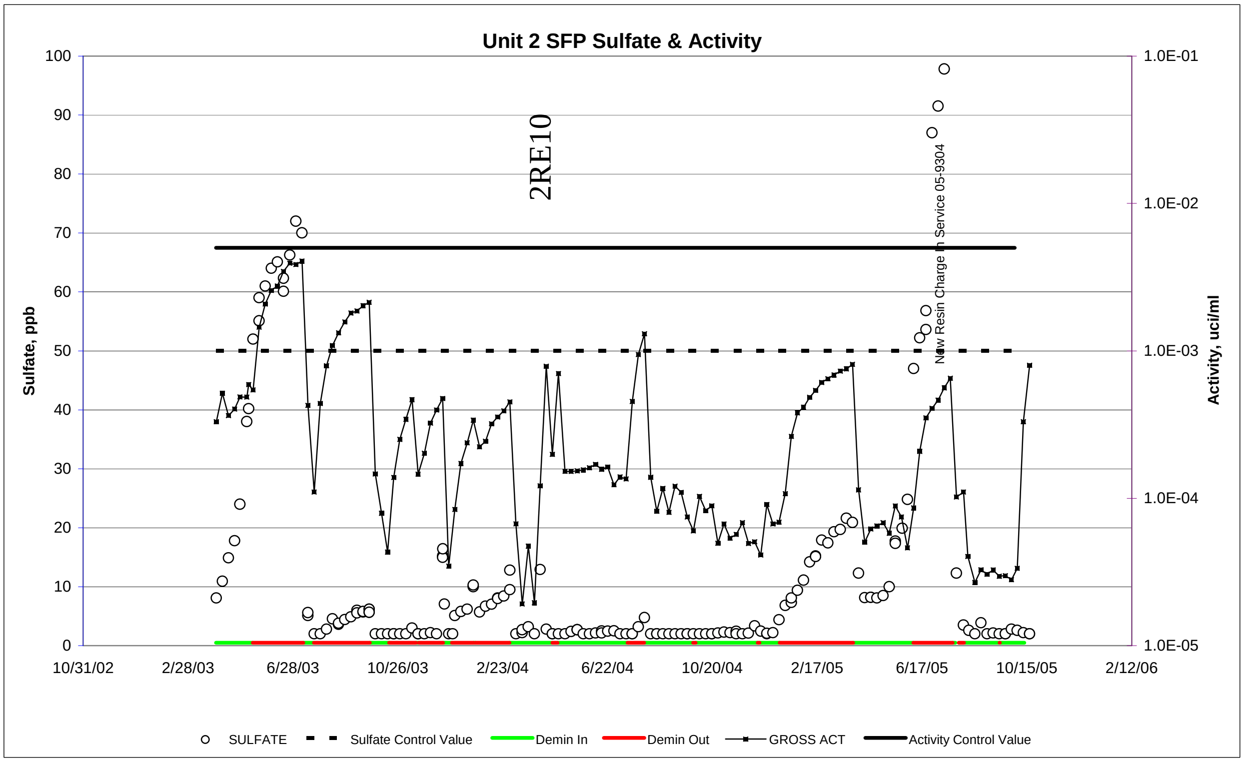


Figure 5-3
Unit 2 SFP Water Quality History

Currently, the station is evaluating macroporous anion resin options for top loading as a sacrificial media targeting sulfonate removal to protect the balance of the bed's media. Shikoku Electric Power Company operates three PWRs in Japan and has proven that in a 16% cross-linkage cation resin can result in a 30% reduction in resin consumption in this application. This may be an option that further enhances the SFP purification system performance.

A
PLANT QUERIES

The following queries were used to develop the foundation for the plant specific analysis. As with any evaluation, once the data was initially analyzed, additional information was requested. That information was incorporated directly into individual sections of this report and into the plant specific cost analyses.

	Pre Implementation	Post Implementation
General process and strategy descriptions		
Process goals (effluent quality, activity limit, etc.)		
Alternatives evaluated		n/a
Media		
Type		
Specifications		
Configuration - where is it in system, loading, etc.		
Changeout criteria		
Changeout frequency		
Changeout criteria basis		
Solid Waste Volume		
Historical, pre-improvement ANNUAL solid volume generated		n/a
Current ANNUAL solid volume generated (following improvement implementation)	n/a	

	Pre Implementation	Post Implementation
Waste Handling and Packaging		
Changeout - sluice, transfer shield, on site VR		
Waste packaging considerations		
Process change impact on options for on and off site VR		
Process change impact on disposal		
Resources		
Process impact on labor and other support (non cost)		
Cost		
This will be calculated using the EPRI LWM format		
Current disposal cost		
Post 2008 storage cost		
ALARA program impact		
Summary of benefits and limitations		

B
REFERENCES

1. EPRI. TR 1002889, *Condensate Polishing Guidelines for Pressurized Water Reactor and Boiling Water Reactor Plants – 2004 Revision*; March 2004.
2. EPRI. NP-7386-V3P2, *Radwaste Desk Reference: Volume 3, Parts 1 and 2*; May 1994.
3. EPRI. TR-103326, *Sourcebook on Ion Exchange for Liquid Radwaste Treatment: Materials, Systems, and Operations*; November 1993.
4. Plant specific data.

Export Control Restrictions

The Electric Power Research Institute (EPRI)

The Electric Power Research Institute (EPRI), with major locations in Palo Alto, California, and Charlotte, North Carolina, was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together members, participants, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of electricity generation, delivery, and use, including health, safety, and environment. EPRI's members represent over 90% of the electricity generated in the United States. International participation represents nearly 15% of EPRI's total research, development, and demonstration program.

Together...Shaping the Future of Electricity

Program:
Nuclear Power

Printed on recycled paper in the United States of America

1011727

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1395 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com