Bringing Best Industry Operating Practices to New Nuclear Plant Designs: An EPRI Radwaste Review

A philosophy of "maximum flexibility with a minimum of permanent equipment" guides the development of radwaste equipment designs for the next generation of nuclear power plants.

By Sean Bushart

There was a sense of excitement among the group gathered together immediately following the June 2002 Electric Power Research Institute (EPRI) International Low-Level Waste Conference. EPRI had just received the green light for a new project that was convening this team of utility professionals to review radwaste designs for the next generation of nuclear power plants. The project objective was to ensure that we would *incorporate the best industry operating practices into new plant designs.*

This group, consisting of radwaste engineers, site radwaste managers, and corporate radwaste managers, came from the leading U.S. nuclear utilities, including Exelon, Entergy, Pacific Gas and Electric (PG&E), Dominion, FirstEnergy Nuclear Operating Co. (FENOC), Tennessee Valley Authority (TVA), Texas Utilities (TXU), STP Nuclear Operating Co., Nuclear Management Co. (NMC), Southern Company, and Duke Energy. The group brought with them plenty of ideas about how to improve performance and reduce operating costs. Most significant, however, were strong opinions on what radwaste processing equipment was *not* needed in new plants. It seems that there was no shortage of experience with strategies for working around permanently installed equipment that had become obsolete after five to thirty years of operations. These experiences brought a philosophy of "maximum flexibility with a minimum of permanent equipment" that would be the driving force for the success that this group's efforts would have over the next few years.

Project Motivation: Initial URD Scoping Study

In 1989, the U.S. Nuclear Regulatory Commission established an alternative nuclear power plant licensing process (codified in the *Code of Federal Regulations,* Title 10, Part 52), offering greater predictability and stability, and thereby less financial uncertainty, than the existing licensing process. In response, the U.S. industry established the advanced light water reactor (ALWR) program, managed by EPRI. At a cost of one billion dollars, the program documented comprehensive owner/operator design requirements. The output of the program was the *Utility Design Requirements Document* (URD) for future plants. The URD, as the name implies, was written as a specification of the design features that the utility operators expected in the next generation of plants. New plant vendors, such as GE Energy and Westinghouse, are required to either incorporate these requirements into their designs or explain their absence.

Pervasive themes of these design requirements and of the conforming plant designs had been enhanced safety and improved reliability, compared with existing plants. In fact, during the 10-year duration of the EPRI ALWR program, the existing plants had extended their already excellent safety records and had achieved major improvements to reliability and plant capacity factors. This trend of exceptional performance improvement was also witnessed in LLW operations. For radwaste requirements, this caused a gap between the performance requirements from the time that the URD was written to the "industry best" effluent and waste volume reduction performance

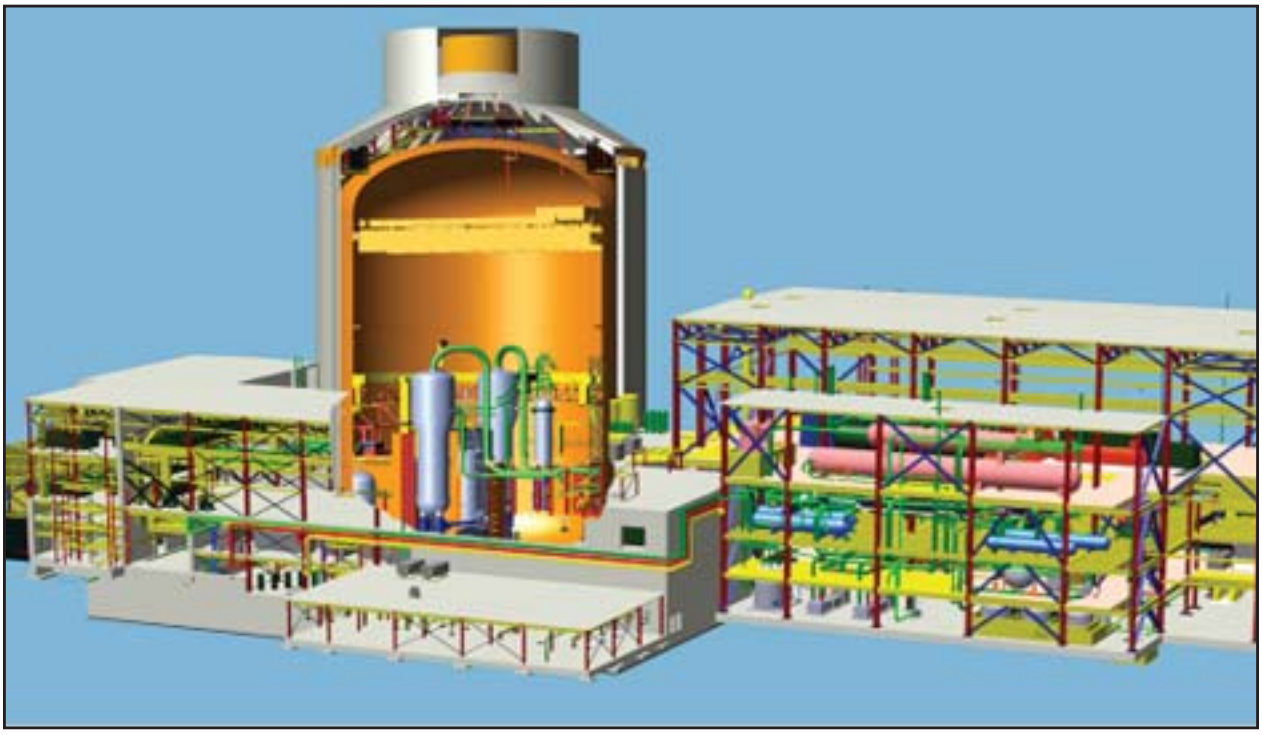

Fig. 1. Westinghouse AP1000 plant.

that had been achieved by today's operating plants.

For example, the URD specified an annual effluent release activity performance of 50 millicuries for new plants, while best operating plants were already performing at less than 10 mCi for pressurized water reactors (PWRs) and zero liquid discharge for boiling water reactors (BWRs). Likewise, for annual solid waste disposal volumes, the URD specified a 1750-cubic-foot performance for PWRs and a 3500-ft^3 performance for BWRs, while top performers were already at less than 150 ft^3 for PWRs and less than 1000 ft^3 for BWRs.

Several key advancements in radwaste processing technologies have made these improvements possible. The U.S. utilities benefit from a host of commercial options for the offsite processing of key wastes, such as resins, dry active wastes (DAW), and filters. Over the past decade, the industry has also undertaken a major modernization of its liquid processing systems through upgrades of plant installed equipment to new skid-mounted systems.

The group felt that today's radwaste designs should be *at least* as flexible and mobile as current top performers. To that end, the group set the following specific goals for new plant radwaste designs:

- *Economic Considerations:* Cost-competitive LLW processing strategies and technologies should be incorporated into the new plant designs, which would result in substantial operational and implementation cost savings.
- *Public Impact/Environmental Stewardship:* New plant designs need to take credit for the low liquid effluent activity and volume levels already achieved by the current industry.
- *Operational Independence from Disposal and Transportation Issues:* In a worst-case scenario, in which disposal or transportation options for LLW became unavailable, modern, advanced volume reduction and onsite waste storage options should be implemented that would sustain the operational viability of new plants throughout their lifetime.

Westinghouse AP1000 DCD Review

The next major task of the EPRI-Utility Review Team was to review the Westinghouse Design Control Document (DCD) sections related to radwaste. The AP1000 (see Fig. 1) DCD document contains the top-level, mostly safety-related, design components that are specified for NRC approval. Significant contributors to this part of the effort were Exelon, Entergy, FENOC, NMC, TXU, Southern California Edison, Wolf Creek, Florida Power and Light, Progress Energy, Arizona Public Service, PG&E, TVA, Constellation, Dominion, British Energy, and Duke. The group developed recommendations for increased volume reduction, effluent performance, and processing efficiencies. The group also suggested several AP1000 design modifications to increase performance.

For example, suggestions were made for improvements that would allow for reductions of filter waste. First, the group recommended methods for better segregation of Class A vs. Class B/C filters. Following segregation, specific volume reduction strategies such as filter shear or supercompaction can be employed. Similarly for resins, flexibility is needed to be able to segregate Class B/C resins from Class A resins. One improvement suggested to accomplish this was to add a bypass with a deionized water flush capability to allow spent ion exchange resin to bypass the spent resin tanks and go directly to a high-integrity container or liner. Enhanced B/C waste segregation strategies become highly important considering the likely event that the majority of the United States will lose its B/C disposal capabilities after 2008.

Table I summarizes the volume reduction and cost savings benefits of implementing these waste management strategies and recommendations. As summarized in Table I, the EPRI team's approach will result in an annual performance improvement (disposal volume reduction) of

approximately 2322 ft³ and an annual cost savings of $0.86 million.

The radwaste review team also undertook a critical review to determine the potential impacts of the loss of the Barnwell disposal option on AP1000 operations. Barnwell, the only disposal option for Class B/C LLW for the vast majority of U.S. states, is scheduled to close to all out-of-compact states in 2008. The review determined that it would be possible, through advanced segregation and volume reduction strategies, to reduce B/C LLW generation to 1000 ft³ for 60 years of AP1000 operation. This means that if it became necessary, operators could easily store B/C waste generated for the plant's lifetime, or until new options became available. Storage is not the most desirable or cost-effective strategy, but this result demonstrates that the loss of Barnwell will not have an impact on new plant viability.

Table I
Waste Volume and Cost Savings Improvements Recommended by EPRI Review Team for AP1000 LLW Operations

Waste Type	EPRI Review		Existing AP1000	
Primary Filters	Disposal Vol: Cost Savings:	9 ft³ $0.22 M	Disposal Vol:	250 ft³
Primary Resin	Disposal Vol: Cost Savings:	20 ft³ $0.33 M	Disposal Vol:	535 ft³
Compactable and noncompactable DAW	Disposal Vol: Cost Savings:	250 ft³ $0.23 M	Disposal Vol:	1010 ft³
Mixed Solid Waste	Disposal Vol: Cost Savings:	0.75 ft³ $0.07 M	Disposal Vol:	7.5 ft³
Mixed Liquid Waste	Disposal Vol: Cost Savings:	3 ft³ $0.01 M	Disposal Vol:	7 ft³
Total (Annual Savings)	Disposal Vol: Cost Savings:	283 ft³ $0.86 M	Disposal Vol:	2605 ft³

The group is still actively engaged in several specific design improvement discussions with Westinghouse. These and other design improvements that will benefit utility operations are important to resolve during the Combined Operating License (COL) phase, in which the balance of the AP1000 engineering design is finalized prior to construction. Specifically, the radwaste review team is engaged in discussions regarding demineralizer/filtration optimization of the chemical and volume control systems and mobile treatment system facility optimization. The latter item, the use of mobile treatment systems, is seen as a key factor in meeting the radwaste performance objectives of new plants.

Mobile Treatment Systems

What are mobile treatment systems? Mobile treatment systems in use today are typically skid-mounted systems or other flexible processing technologies that are usually not considered permanently installed plant equipment. The advantages of these mobile processing systems are flexibility, high performance, cost-effectiveness, and upgradeability

Figures 2 (filtration/demineralization) and 3 (reverse osmosis) show two examples of mobile treatment systems for liquid LLW processing. The industry has recently employed a host of such mobile processing technologies, also including ultrafiltration and polymer injection. In addition, it is expected that emergent technologies, such as electrodeionization and hollow fiber filtration, may become "proven technologies" in the United States by the time the first new plant is constructed. It is important that new plants allow for the implementation of both existing and emerging technologies throughout their operational history.

Fig. 2. Typical in-service filtration demineralizer system.

The current AP1000 design includes a mobile systems facility for treatment and volume reduction of all generated

wastes. A waste accumulation area is included as a central collection area for wastes and laundry generated throughout the plant. It also includes a storage area for packaged (processed and volume-reduced) wastes awaiting sample analysis, characterization, shipping casks, etc. The current AP1000 approach in general is to provide a waste processing building with bays and interfaces for mobile equipment connections, with the expectation that purchasers will implement and customize such features based upon their present circumstances (availability of shared waste processing facilities, current regulations and culture, and so forth).

Fig. 3. Typical power plant reverse-osmosis mobile processing unit.

The EPRI new plant radwaste review team was pleased with the general approach of the currently outlined AP1000 mobile systems facility. The group, however, has taken the concept further to suggest an expansion of the current facility plans to include more capacity for critical LLW management tasks, with the intent to further remove the capital costs of unwanted "installed" equipment and to allow for best available performance during operations.

Figure 4 shows a possible configuration for an optimized AP1000 mobile treatment facility. The idea would be to have a large enough facility to accommodate indi-

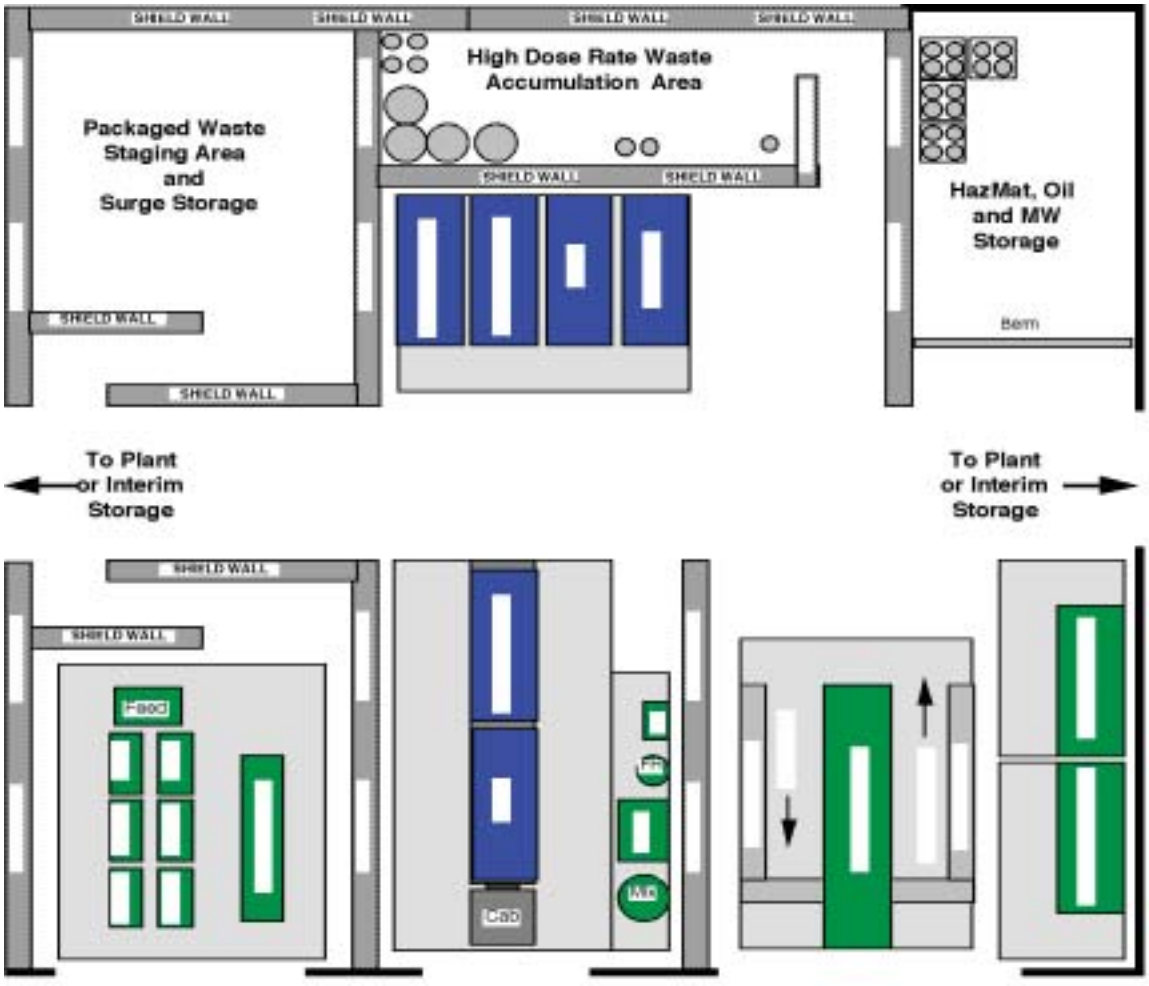

Fig. 4. Potential configuration for an idealized mobile treatment system facility for new plants.

vidual plant needs for liquid processing, waste staging, waste segregation, media change-outs, and packaging without being prescriptive. Flexible designs and moveable shield walls would allow individual utilities to tailor the facility to their own current and future needs.

The EPRI team defined performance parameters, such as waste generation and effluent products (water quality, packaged waste, etc.), for the technologies that would be utilized in the mobile treatment facilities. The team also made some recommendations for best available technologies to use in these facilities based upon today's power plant experiences. However, because it may be three to five years or more before these facilities are constructed, the team worked toward designing facility options that would be able to take advantage of any new technology that might come along. To accomplish this, an extensive survey was sent out to all of the current major vendors of mobile processing equipment in use today to identify as broad a range of equipment needs as possible, such as services, footprints, and plant interfaces.

These key parameters are being shared with new plant vendors for incorporation into the plant construction design phase. These mobile facility concepts have universal applicability to all new plant designs. In particular, these mobile processing concepts were also utilized by GE for the economic simplified boiling water reactor (ESBWR).

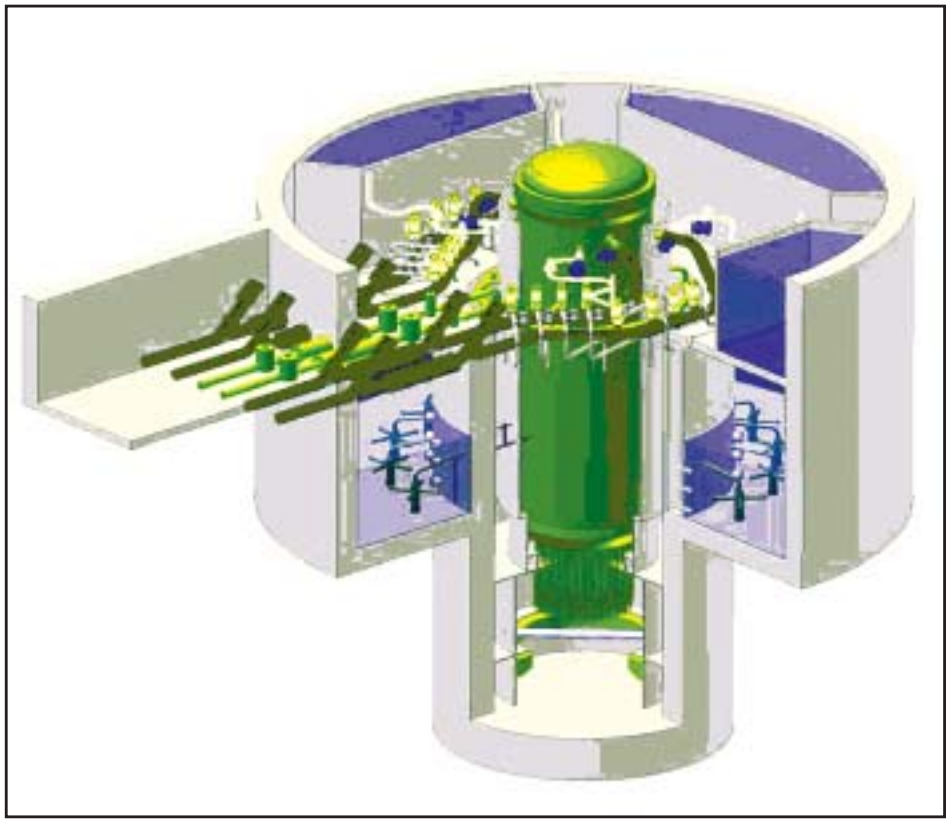

Fig. 5. GE ESBWR view (from DCD Submittal Document).

The U.S. utilities benefit from a host of commercial options for the offsite processing of key wastes, such as resins, DAW, and filters. Over the past decade, the industry has also undertaken a major modernization of its liquid processing systems through upgrades of plant installed equipment to new "skid-mounted" systems.

ESBWR Review

Early in 2005, GE approached the EPRI team for technical assistance in the development of radwaste system design criteria for the ESBWR (see Fig. 5). Their goal was to ensure that their radwaste design reflected top-tier performance and practices incorporating new technology, flexibility, performance, and cost-effective operation. The primary means to accomplish these goals were to incorporate the mobile systems concepts developed by the EPRI team into ESBWR designs.

The EPRI team provided input to the Hitachi engineers (who developed the actual designs for the ESBWR DCD) on the industry requirements for mobile processing previously described. For example, the team gave input on the plant tanks, pumps, piping, and services needed to support primary mobile (skid-mounted) liquid radwaste processing systems. Maximum emphasis was placed on waste reduction and specifically on the minimization of B/C wastes.

In support of the development of the ESBWR radwaste designs, the EPRI team was tasked with developing liquid radwaste (LRW) system design criteria that reflect the current domestic BWR operating practices and preferences and lessons learned. Because the ESBWR is a relatively new plant design with no U.S. operating experience, it was reasonable to establish goals for top decile performance relative to the existing domestic fleet.

Industry data, including liquid and resultant wet solid waste volumes, media performance, and the impact of balance of plant processes from several sources, were analyzed to identify the best performers, industry averages, and maximum surge volume. The industry data evaluation clearly demonstrated that incorporating a very high level of process flexibility is a critical success factor. Plant

operators must have the flexibility to alter process configurations (liquids and solids) in response to rapidly evolving or unanticipated events that impact LRW processes. Influent liquid characteristics, plant mode changes, and even disposal site access can all impact LRW processing strategies. Those factors can necessitate alterations to tank, ion exchanger, and storage tank configurations to ensure that waste streams are properly segregated to optimize media and process success. In support of the flexibility concept, the team recommended *significant increases to collection, surge, and sample tank capacities.*

As a result, Hitachi defined many of the key radwaste design concepts for the ESBWR based on the EPRI team's requirements and assumptions. For example, the ESBWR was designed to have the option of 100 percent recycle, zero release for its liquid waste goals. (The decision to use this zero-release option would be up to the station owner, based upon individual site environmental impact goals.) The team also defined minimized solid waste disposal volumes and optimizations of operation staff and time. For standard operation and mode changes, the system was designed so that the radwaste staff could process on a 40 hour per week, 8 hour per day, Monday through Friday schedule through the optimization of liquid waste equipment and systems. Figure 6 shows a schematic diagram of the ESBWR high-conductivity waste (HCW) treatment system developed by Hitachi for the DCD, which incorporates the use of flexible mobile processing equipment as defined by the EPRI team.

Next Steps

The EPRI radwaste review team is ensuring that significant operational benefits are achieved in the next generation of nuclear power plants. To solidify their recommendations and efforts, several final steps must occur before new plant construction.

First, the team will update the URD Chapter 12 for radioactive waste processing. This will document and add formality to the recommendations made. The group will define and approve URD radwaste

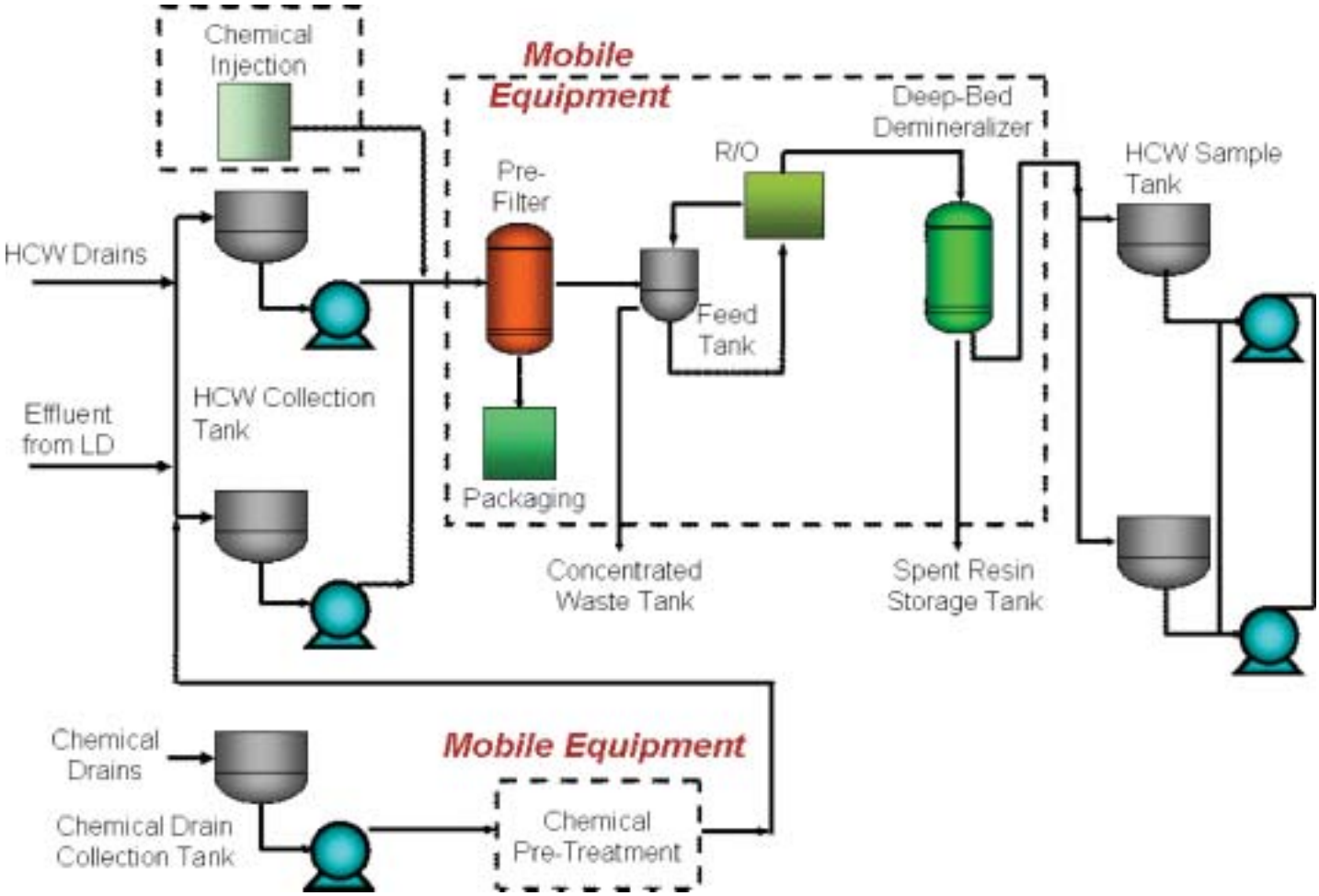

Fig. 6. Schematic diagram of ESBWR HCW treatment system showing the use of utility-determined mobile equipment.

elements such as current best industry performance and strategies, currently available technologies, mobile process options and opportunities, and effluent release or recycle options. However, the new URD Chapter 12 will be published in a new format that will be flexible, nonprescriptive, and performance based, thus, it is hoped, eliminating the nature of such a document to become gradually outdated.

In addition, the team will be engaged in several outstanding issues in the near term. Further vendor interactions will be needed in the COL phase, as this is the time when much of the hard design of the radwaste systems will be determined. Activities will be coordinated with other industry groups (e.g., NUSTART) that are actively engaged in the Part 52 licensing process. The group also has a role in working with vendors of new plants to ensure that lessons learned from the current set of decommissioned plants related to waste minimization and contamination control are incorporated into new plant designs. Finally, discussions have begun internationally regarding how to utilize the EPRI team's expertise for other plant designs, such as the advanced boiling water reactor and the European pressurized water reactor.

By following this team's recommendations through to construction, we will be able to advertise the new nuclear plant fleet's top performance in waste minimization and effluent quality.

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