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Deactivation of the P, C, and R Reactor Disassembly Basins at the SRS

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ABSTRACT

The Facilities Disposition Division (FDD) at the Savannah River Site is engaged in planning the deactivation/closure of three of the site's five reactor disassembly basins. Activities are currently underway at 105-R Disassembly Basin and will continue with the 105-P and 105-C disassembly basins. The basins still contain the cooling and shielding water that was present when operations ceased. Low concentrations of radionuclides are present, with tritium, Cs-137, and Sr-90 being the major contributors. Although there is no evidence that any of the basins have leaked, the 50-year-old facilities will eventually contaminate the surrounding groundwaters. The FDD is pursuing a pro-active solution to close the basins in-place and prevent a release to the groundwater. In-situ ion-exchange is currently underway at the R-Reactor Disassembly Basin to reduce the Cs and Sr concentrations to levels that would allow release of the treated water to previously used on-site cooling ponds. A NEPA Environmental Assessment (EA) is being prepared to select the preferred closure alternative for each of the three basins. The EA will be the primary mechanism to inform the public and gain stakeholder and regulatory approval.

INTRODUCTION

The 105-R Disassembly Basin is a reinforced concrete structure of blast-resistant design connected to the west side of the main reactor building. The R-Reactor Disassembly Basin is the largest of the production reactor basins, encompassing approximately 42,000 square feet and containing approximately 6.3 million gallons of water when full. The basin is unlined, with depths varying from 17 to 30 feet. The exterior walls range from 2 to 4 feet thick, while the foundation is 7.5 feet thick. The disassembly basin was primarily designed to cool irradiated assemblies and to provide a shielded environment for operators to prepare the materials for shipment to other processing areas. Operations were initiated in 1953 and the reactor and disassembly basin were retired from service in 1964.

The disassembly basin has been emptied of all fuel (fissile) and target materials. Although no basin management is currently being performed, a significant level of water remains in the basin, about 6 feet below normal full. The water is stagnated, as all deionizers, cooling systems, and filtration systems were phased out years ago. The basin has a 1/8 to ¼ inch layer of sludge (mainly aluminum and iron oxide) over much of the basin floor and there are pieces of scrap aluminum and universal sleeve housings on the floor. The basin water contains approximately 750 curies of radioactivity, primarily tritium. The potential for leakage of the basin water to the surrounding groundwater exists, which would result in immediate contamination, due to the high water table (5 to 8 feet below ground surface) in the R-Area vicinity.

The largest amount of radioactivity that remains in the 105-R Disassembly Basin are residues from an experimental calorimeter assembly. The assembly ruptured during a test in 1957, in the "Emergency Basin" (EB) section of the Disassembly Basin. The EB is a sub-portion of the overall Disassembly Basin, approximately 30 wide by 80 feet long, and ranged from 14 to 30 feet deep. The release of activity from the failed assembly caused contamination of the remainder of the Disassembly Basin water. Some of the basin water was transferred to a series of exterior Seepage Basins, and to the effluent ditch and to the intermediate cooling ponds leading to PAR pond. The failed assembly components in the Emergency Basin (EB) were removed during cleanup operations in 1964. The EB was dewatered using deionizers to remove most of the radioactivity. Some of the sludge at the bottom of the EB was transferred to the site waste storage tanks. The remaining radioactive sludge in the Emergency Basin was fixed in place by filling the EB with soil and then covering the tamped soil with 6 to 12 inches of concrete.

Both the 105-P and 105-C disassembly basins are similar to the 105-R basin in design, however both basins are smaller and have not been shut down for as long. The C, P, and R Disassembly Basin water capacities ranged from 3.6 million gallons for C-Reactor to 6.3 million gallons for R-Reactor. The water and sludge in both 105-P and 105-C contain considerably more radioactivity than 105-R. The long-range plan for these two basins is to start their closure process following the 105-R basin closure.

The FDD has completed an extensive chemical and radionuclide characterization of the R-Disassembly Basin water and sludge in 1998, and is preparing similar programs for C- and P-basins. The results of these characterizations will be used to prepare Alternative Assessments and Cost Studies for the various closure options. Potential options range from:

- doing nothing;
- treating the water at the SRS's Effluent Treatment Facility;
- treating the water in-situ and directly discharging the treated water to the cooling ponds;
- partially evaporating the water and grouting the remaining water in situ.

Preliminary cost studies point to millions of dollars in cost saving by removing the water and closing the basin "in-place".

FDD has begun the treatment of the basin water, using a highly selective nuclide removal system to reduce the concentration of the radionuclides Cs-137 and Sr-90 in the disassembly basin. This will preclude any environmental effects from these radionuclides should the basin develop a leak while the basin is in the surveillance and maintenance life cycle mode.

INNOVATIVE ION EXCHANGE TECHNOLOGY

In FY99, the DOE Office of Science and Technology (OST) approved FDD's proposed Deployment Plan for the water cleanup at the 105-R Disassembly Basin. The OST (EM-50) allocated a total of $550,000 in FY's 1999, 2000, and 2001 for the deployment of a highly selective nuclide removal system provided by Graver Technologies, Newark, DE. Graver's system is based on the use of ion selective media provided by Selion OY (Fortrum), Finland. Total project costs are estimated to be $1.5M, with the difference funded by DOE-SR (EM-60).

In FY 2000, the Facilities Disposition Division partnered with another firm; 3M, St. Paul, MN to deploy a similar highly selective material at the R-Disassembly Basin. The funding for the construction of the 3M system was provided by the OST (EM-50) to 3M, while FDD is funding the operational costs.

Neither of these innovative ion-exchange technologies had been previously deployed at a Department of Energy site. The 3M Cs removal system had been tested at the R-Disassembly Basin in 1998, at 5 GPM, for a short period of time (2 weeks).

Both the 3M and Selion Cs-137 removal technologies are based on a cobaltihexacyannoferrate compound, which is extremely selective for Cs-137. The selectivity coefficients for various ion-exchange materials are compared below:

Table I CsTreat® Selectivity Coefficients for Cs vs. Na, for Various Media

Media	Na concentration, Moles/L	Selectivity Coefficient
Strong Acid Resin	NA	<10
Cs Selective (SRL R-F)	6.0	11,400
Zeolite	0.1	450
Crystalline Silicotitanate (CST)	5.7	18,000
CsTreat®	5.0	1,500,000

The high selectivity allows large volumes of wastewater to be treated, with very low secondary waste disposal volume. The Selion technology has been successfully used worldwide at various locations, including the Callaway nuclear plant in Fulton, MO; North Korea; Soviet Naval Bases in Estonia and Murmansk, Russia; and Japan.

Selion CsTreat®

The Selion CsTreat® removal technology is based on a packed bed of pure hexacyannoferrate, with a very high surface area. The bed is operated in a down–flow mode, with preferred flow rates in the range of 10 to 20 bed volumes per hour (BV/hr). At this flow rate, the CsTreat's anticipated removal efficiency is greater than 99.9% (DF >1,000). In the case of the SRS deployment, the system is being operated at 15 to 20 gallons/min. (GPM), or ~50 BV/hr, utilizing ~3 cubic feet of CsTreat® material. The basin water is being "recycled", by discharging the treated effluent back to the basin. This will probably require 2 to 3 "basin turnovers" to reach the treatment goals. Although a "recycle" technique is inefficient, it allowed SRS to begin treatment while the preparing the NEPA documentation for final closure is prepared and approved. At 20 GPM, the treatment will take approximately 6 to 8 months.

Treatment of the R-Basin water with the Selion CsTreat® system began 7/28/2000. As of 9/15/2000, over 500,000 gallons had been treated. The % removal is greater than 99% (DF 100).

3M Selective Separation Cartridge® (SSC)

The 3M system is based on an innovative membrane technology. The sorbent particles are loaded or enmeshed onto a web or membrane, which is then fabricated into a spiral-wound, cartridge-filter. The cartridge membrane is trademarked WWL® to distinguish it from 3M's Empore® membrane sampling technology. For the Cs removal system, 3M is also using cobalti-hexacyannoferrate as the selective material. The 3M system being used at SRS is comprised of 22 cylindrical cartridges, 2.5" in diameter by 21" in length. The 3M cartridge technology can provide higher flow rates than a standard packed bed system, and channeling is not a concern for the cartridge technology.

Treatment of the R-Basin water with the 3M WWL system began 6/16/2000. As of September 15, 2000, over 1.5 million gallons of water had been treated. The % removal of C-137 is >98.8% (~80,000 pCi/L to <1,000 pCi/L), or a Decontamination Factor (DF) of ~ 90-100.

Cs-137 Radiation Shielding

Although the total amount of Cs-137 in the R-basin water is not very great (~1.8 Curies), concentrating ½ of the Cs onto either the 3M cartridges or CsTreat® material would result in a significant radiation dose rate, ~3.5 R/hr at the surface of the containment tanks. Therefore, a one-inch thick lead shield was constructed and placed around the 3M Cs-137 removal tank. The Selion CsTreat® container tank is shielded in a similar technique, except that 2½ feet of water is being used, rather than lead.

In both of these systems, neither of the final resin materials will be regenerated. The hexacyannoferrate forms a chemically stable precipitate with the Cs-137, and regeneration is not feasible. Therefore, the final exchange materials will be disposed "as is", by removing the lead or water shielding, transferring the containment tanks to B-25 containers, and disposing at the site Low Level Waste (LLW) vaults.

Selion SrTreat®

The Selion ion-exchange system for Sr-90 is based on a sodium titanium oxide, again with a very small particle size and high surface. However, the SrTreat® is not as selective for Sr-90 as the CsTreat® is for Cs-137. In fact, two of the major cations present in the basin water, Ca (at 13 ppm), and Mg (at 0.5 ppm) interfere strongly with strontium-90 removal. Therefore, the basin water will be "pretreated" with a conventional water softening resin, "GRAVEX® GX –080". This resin is a sulfonated styrene and divinylbenzene strong acid exchange resin, produced by Graver Technologies, DE. Graver Technologies has licensed the Selion OY ion exchange media for United States deployments. The Gravex® water softening resin will be used to remove the majority of the Ca and Mg ions, prior to a final treatment with the SrTreat®. The tanks containing the water softening resin will not be regenerated; they will be disposed as LLW.

3M Strontium Removal (WWL®) Cartridge System

The 3M strontium selective removal system is based on a sulfonated divinylbenzene compound, similar to Graver's water softening resin. Calcium and magnesium also interfere strongly with Sr-90 removal for the 3M material. Two sets of the 3M Sr-90 removal cartridges were tested in the R-Basin in June 2000, at 20 gallons per minute. Initial Sr-90 removal during the first 5,000 gallons treated was greater than 99% (DF >100). After this point, Ca and Mg started to saturate the available exchange sites, and 50% breakthrough for Sr-90 occurred at ~12,000 gallons.

Operating Conditions

Both systems are operated around the clock and over weekends, with very limited operator coverage. Currently, the systems are checked on Monday morning and Thursday afternoon. Samples are collected periodically, and the prefilters are changed as necessary. The pressure drop across the twenty-two 3M Cs WWL® filters is about 2-3 psi, at 15-17 gallons/min. The pressure drop across the Selion CsTreat material is ~30-psi, at 17 gpm.

The 3M system employs 2 and 0.2 micron prefilters, which require changing at approximately 400,000 and 1.2 million gallons, respectively. The Selion/Graver system uses 5 and 1-micron prefilters, with the 1-micron filter needing to be changed at about 500,000 gallons. It is believed that calcium carbonate is the material blinding the prefilters, as it is saturated in the basin water. As the water continues to be treated, it is expected that the prefilter blinding rate will decrease, as the calcium carbonate is removed. The Selion/Graver water softening resin should also reduce the blinding rate in the pre-filters. The cost effectiveness of both the Selion and 3M technologies will be compared on a head-to-head basis, with both systems treating millions of gallons of water.

TREATMENT GOALS

The objectives of the in-situ treatment is to remove the majority of the Cs-137 and Sr-90, and demonstrate that the systems can be operated with little to no operational oversight. The treatment goals are summarized below.

Table II Treatment Goals for the In-Situ R-Basin Deployments

Radionuclide	Initial Concentration pCi/L	Deployment Goal (During Recycle) pCi/L	DOE Release Guide (DOE 5400.5) pCi/L
Cs-137	92,800	25,000 (73%)	3,000
Sr-90	23,500	10,000 (67%)	1,000

The % removal goal for the Sr-90 is not as aggressive as the Cs-137, due to the interference of Ca and Mg, and due to the possibility that some additional Ca or Mg could leach from the concrete walls of the basin. It is expected that a high Decontamination Factor (DF) and a high reliability for each system will be demonstrated during the recycle operational period. At that time, assuming approval of the Environmental Assessment, the water could be treated one final time, and discharged to the drainage canal. DF's of only 8 for Cs and 10 for Sr would be needed at that time to ensure that the treated water would be less than the DOE Derived Concentration Guides for release to a surface drinking water supply. As discussed previously, both the Selion and 3M Cs-137 systems have each demonstrated a DF of ~100.

Even though it is planned to meet these release goals, if the treated water were discharged from the R-Reactor Disassembly Basin, it would not reach a surface drinking water supply directly. The Disassembly Basin previously used a system of canals and small holding ponds to discharge and cool the reactor water before reaching the main lake (PAR Pond). The cooling ponds are currently well below overflow levels, with 20 to 50 times the available volume of the R-Basin contents. With the majority of the Cs and Sr removed by the ion-exchange treatments, the only remaining radionuclide above the DOE release guides is tritium. The tritium concentration in the R-Basin water is ~38xE3 pCi/ml, while the DOE release guide is 2xE3 pCi/ml. It is expected that most, if not all, of the tritiated water would evaporate. This is due to the fact that the transfer canals are deeply incised (cut) into the water table, and represent a point of discharge of the groundwater. Therefore, the discharged water from the Disassembly Basin would be in a "gaining" surface water body, and could not discharge into the groundwater.

The total volume of water in PAR is >1000 times the total water volume in the R-Basin. Even if ALL of the basin water reached PAR Pond immediately via the cooling canal and holding ponds – which is impossible - the tritium concentration in PAR Pond would be 38 pCi/ml, which is ~50 times less than the DOE Release guide. Due to "turnover" of the water in PAR pond, the PAR pond discharge would have a tritium concentration of ~4 pCi/ml, which is less than the EPA drinking guide (20 pCi/ml) - before the PAR Pond water discharged to the Savannah River.

In-situ treatment of the basin water should reduce the Cs-137 and Sr-90 to less than the DOE release guides, and as discussed above, tritium would not reach the Savannah River or the groundwater due to the local hydrology. However, release of the treated basin water would impact the cooling canals and ponds, which are currently classed as "Operable CERCLA" units. These units are included in the site's Federal Facilities Agreement, as low priority units to be addressed in the future. The treated water would contain low levels of many radionuclides, and would slightly increase the radionuclide concentrations in the soils of the canal and cooling ponds. This potential impact to the environment led WSRC to the selection of evaporation of a significant fraction of the Disassembly Basin water, followed by in-situ grouting of the remainder. This option eliminates any release to the surface soils, with only tritiated water being released to the atmosphere.

BASELINE TECHNOLOGY

In order to determine the potential cost savings of the in-situ ion-exchange deployments, FDD estimated the cost of on-site treatment at the site's centralized wastewater treatment facility, the F & H Effluent Treatment Facility (F/H ETF). The F/H ETF is primarily designed to accept effluents from the F and H separation "canyons". It is designed for ~18,000,000 gals./yr., and uses crossflow ceramic filters, activated carbon, and reverse osmosis as the primary treatment systems. It utilizes a Mitsubishi HPK-25 resin to remove Cs-137. The operating cost is ~$0.70/gallon (direct costs), or ~$0.96/Gal. (with fully loaded site overheads). The F/H ETF has a truck unloading station, which is limited to 2-3 shipments per week (5,000 gallon tank car). At this rate, it would take to 6 to 8 years to transfer the 5,000,000 gallons (1,000 tank trips), based on past experience of shipping radioactive waters to the ETF. The baseline cost to ship and treat 5,000,000 gallons of R-Basin water at the F/H ETF was ~$5.5 million. The in-situ ion-exchange deployment is estimated to cost ~$0.85 million over 2 years. The R-Basin estimated saving for in-situ ion-exchange is greater than $4.6 million, as neither the cost for a loading station at R-Basin nor the operational costs to pump the water into the tank trucks were included in the baseline estimate.

CLOSURE OPTIONS

An Alternative Closure Analysis has been prepared for the potential alternative options for the closure of the R-Disassembly Basin. The Alternatives Analysis will serve as the primary reference for a NEPA Environmental Assessment (EA), which will be prepared for regulatory and public comment/input. The Alternatives Analysis considered a number of water treatment and closure option combinations, which are summarized below.

Assumption: Emergency Basin Disposition

As described previously, the Emergency Basin (EB) was backfilled with soil, and a six-inch to one-foot concrete cover was installed. The EB contains the majority of the radionuclide inventory in the entire Disassembly Basin, with approximately 100 Curies (Ci) of Cs-137 and Sr-90. The water and sludge in the remainder of the Disassembly Basin contains less than 2 Ci of Cs and Sr. A groundwater impact assessment has been conducted that indicates that if the Disassembly Basin is dewatered, then none of the radionuclides in the Emergency Basin would impact the surrounding groundwater (above EPA drinking water standards). Therefore, all of the various closure options have as a base case assumption that the EB would NOT be excavated and disposed to the SRS Low Level Waste trenches or vaults. The cost of excavating the soil from the EB is estimated to be greater than $20,000,000, and the risk of worker exposure to radioactive exposure or contamination is significant. In addition, the inventory of I-129 in the EB exceeds the current waste acceptance criteria for the SRS LLW vault. I.e.; if the EB were excavated, the contents would have to be transported to an off-site disposal facility. Even though the Disassembly Basin (and the EB portion) extend below the water table, the 4-foot thick outer walls and the 7-foot thick base provide more resistance to radionuclide transport and groundwater contamination than the on-site vaults (thinner walls/foundation). Therefore, all of the closure alternatives assume that Emergency Basin would remain in place, along with all of the underground structural walls and support columns. The basin would then be backfilled and closed in place.

No Action Alternative

The initial option considered was "No Action". In this case, the basin would remain as is, with Surveillance and Maintenance (S & M) for at least 100 years (assumed period of institutional control). New roofing would be required every 15 years. It is assumed that some leakage of the basin water would occur in the 100-year period, and that the groundwater immediately adjacent to the basin would be impacted above drinking water standards. This "release to the environment" would trigger CERCLA regulatory oversight, and groundwater remediation might be required. All of the other options were compared to the "No Action" option as a reference case.

Closure Alternatives - Water Treatment

In order to close the basin, it must be "dewatered" first. The treatment options considered were:

- Transport the water to the on-site centralized wastewater treatment facility,
- Treat the water in-situ to meet the DOE limits for Cs and Sr release, and discharge the water to the previously used cooling canal and ponds, or
- Evaporate the water and use a low expansion grout formulation to stabilize remaining water.

Closure Alternatives - Building and Equipment Disposition

After the majority of the water is removed, the following closure options were considered:

- Remove, dry, and size reduce all of the treatment equipment (saws, shears, transfer buckets, duct work, conduits, etc.), place in B-25s (or other containers), and dispose as LLW. Stabilize the remaining water (and the sludge and the bottom of the basin) with grout, remove, and dispose as LLW. Demolish the above grade ceiling and walls and dispose as rubble, or if radioactively contaminated, as LLW. Backfill the empty basin with clay, and install a low permeability cap.
- Leave all equipment in the empty basin. Stabilize the remaining water (and the sludge and the bottom of the basin) with grout, and leave in place. Demolish the ceiling and walls and emplace the building debris into the basin. Backfill any remaining space with clay, and install a low permeability cap.
- Leave all equipment in the empty basin. Stabilize the remaining water (and the sludge and the bottom of the basin) with grout, and leave in place. Leave the ceiling and walls intact, and backfill the basin with clay. No cap would be installed. This option has the lowest estimated short-term closure cost, due to not demolishing the building, and not disposing of the building debris. However, the long term cost is higher than the other options, since surveillance and maintenance (replace the roofing periodically) would be required.

A detailed study has been conducted to determine the "preferred" closure option. The following impacts were considered:

- short term cost (6 to 8 years),
- long term cost (up to 100 years),
- public risk (exposure to radioactive releases),
- risk to on-site workers (operating, construction, and radioactive dose),
- the effect of the various options on the environment vs. regulatory guidelines (flora/ fauna),
- public perception of the various options,
- the time to remove the risk of water leaking from the basin (and contaminating the groundwater), and
- whether or not the closure option would cause the closure process to be regulated under CERCLA (vs. NEPA).

Based on this study, the preferred option is to evaporate ~50% of the basin water, grout the remaining water with a low expansion grout, demolish the above grade building, and leave all the debris in the remainder of the basin. A low permeability cap would be placed over the Disassembly basin, and the closed facility would be monitored through the period of institutional control.

SUMMARY

The Facilities Disposition Division (FDD) at the Savannah River Site has started the planning process for closure of three of the sites Reactor Disassembly Basins. Deployment of innovative highly selective ion-exchange materials has been initiated at the R-Reactor Disassembly basin. The objective of the ion-exchange program is to reduce the Cs-137 and Sr-90 concentrations to levels that would minimize the effect on the surrounding groundwater, if the basin water leaked during the Surveillance and Maintenance period. Reduction of the Cs-137 and Sr-90 concentrations in the basin water (to DOE release guides) would also allow direct release to on-site cooling ponds if this alternative were selected as a result of the final Environmental Assessment approval.

The ion-exchange systems were supplied by the 3M Company, St. Paul, MN, and by Selion, OY, Finland. Both of the systems utilize cobaltihexacyannoferrate to selectively remove Cs-137, and both systems have demonstrated Decontamination Factors (DFs) greater than 100. Both systems are operating around the clock, at 15-20 gallons/minute, with twice weekly inspections. Treatment of the basin water, using a recycle mode, is expected to take 6 to 8 months.

The FDD is also preparing a National Environmental Protection Act (NEPA) Environmental Assessment (EA), which will evaluate closure alternatives and propose as the preferred alternative that ½ of the basin water be evaporated and the remainder grouted in-place. Similar closure alternatives (evaporation and grouting) for two other Disassembly basins (P & C) will also be evaluated in the EA.