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Savannah River Site R-Reactor Disassembly Basin In-Situ Decommissioning - 10499

Christine A. Langton¹, M. G. Serrato¹, J. K. Blankenship² and W. B. Griffin²

**¹Savannah River National Laboratory, Savannah River Nuclear Solutions
Savannah River Site, Aiken SC 29808**

**²Savannah River Nuclear Solutions
Savannah River Site, Aiken SC 29808**

ABSTRACT

The US DOE concept for facility in-situ decommissioning (ISD) is to physically stabilize and isolate intact, structurally sound facilities that are no longer needed for their original purpose, i.e., generating (reactor facilities), processing (isotope separation facilities) or storing radioactive materials. The 105-R Disassembly Basin is the first SRS reactor facility to undergo the in-situ decommissioning (ISD) process.

This ISD process complies with the 105-R Disassembly Basin project strategy as outlined in the Engineering Evaluation / Cost Analysis for the Grouting of the R-Reactor Disassembly Basin at the Savannah River Site and includes:

- Managing residual water by solidification in-place or evaporation at another facility,
- Filling the below grade portion of the basin with cementitious materials to physically stabilize the basin and prevent collapse of the final cap,
 - Sludge and debris in the bottom few feet of the basin will be encapsulated between the basin floor and overlying fill material to isolate it from the environment.
- Demolishing the above grade portion of the structure and relocating the resulting debris to another location or disposing of the debris in-place and
- Capping the basin area with a concrete slab which is part of an engineered cap to prevent inadvertent intrusion.

The estimated total grout volume to fill the 105-R Reactor Disassembly Basin is 24,384 cubic meters or 31,894 cubic yards. Portland cement-based structural fill materials were designed and tested for the reactor ISD project, and a placement strategy for stabilizing the basin was developed. Based on structural engineering analyses and material flow considerations, maximum lift heights and differential height requirements were determined.

Pertinent data and information related to the SRS 105-R Reactor Disassembly Basin in-situ decommissioning include: regulatory documentation, residual water management, area preparation activities, technology needs, fill material designs and testing, and fill placement strategy. This information is applicable to decommissioning both the 105-P and 105-R facilities. The ISD process for the entire 105-P and 105-R reactor facilities will require approximately 250,000 cubic yards (191,140 cubic meters) of grout and approximately 3,900 cubic yards (2,989 cubic meters) of structural concrete which will be placed over about an eighteen month period to meet the accelerated schedule ISD schedule. The status and lessons learned in the SRS Reactor Facility ISD process will be described.

INTRODUCTION

The 105-R Reactor Disassembly Basin will be the first Savannah River Site (SRS) reactor facility to undergo the In-Situ Decommissioning (ISD) process. The process consists of placing cementitious grout

materials below grade up to ground surface in the Disassembly Basin areas. The above grade structure over the Disassembly Basin areas will be demolished and removed. A concrete cap will cover the grouted area of the Disassembly Basin and this will be the final configuration.

This in-situ decommissioning process complies with the 105-R Reactor Disassembly Basin Project Strategy as outlined in the Engineering Evaluation/Cost Analysis for the Grouting of the R-Reactor Disassembly Basin [1] and the Removal Site Evaluation Report/Engineering Evaluation/Cost Analysis (RSER/EE/CA) for the 105-R Reactor Building Complex [2].

The SRS 105-P reactor facility is shown in Figure 1 and is very similar to 105-R building. The ISD concept for both 105-P and 105-R are illustrated in schematic cross sections in Figures 2 and 3. (The cross sections correspond to the red line on Figure 1.)

The 105 Reactor Disassembly Basin Grout Placement Strategy provides an initial data set for planning future in-situ reactor decommissioning projects and addresses the following topics:

1. 105-R Reactor Disassembly Basin Areas and Work Phases
2. Grout Mix Designs
3. Grout Placement Strategy and Delivery System Configurations
4. Grout Placement Construction Verification Scheme

Detailed information supporting the grout placement strategy is provided elsewhere [3].

Pertinent data and information related to grout formulations and concrete mix designs, placement strategy and concepts will also be applied to the decommissioning of the 105-P Reactor Disassembly Basin and to both the 105-P and 105-R Main Reactor Buildings.

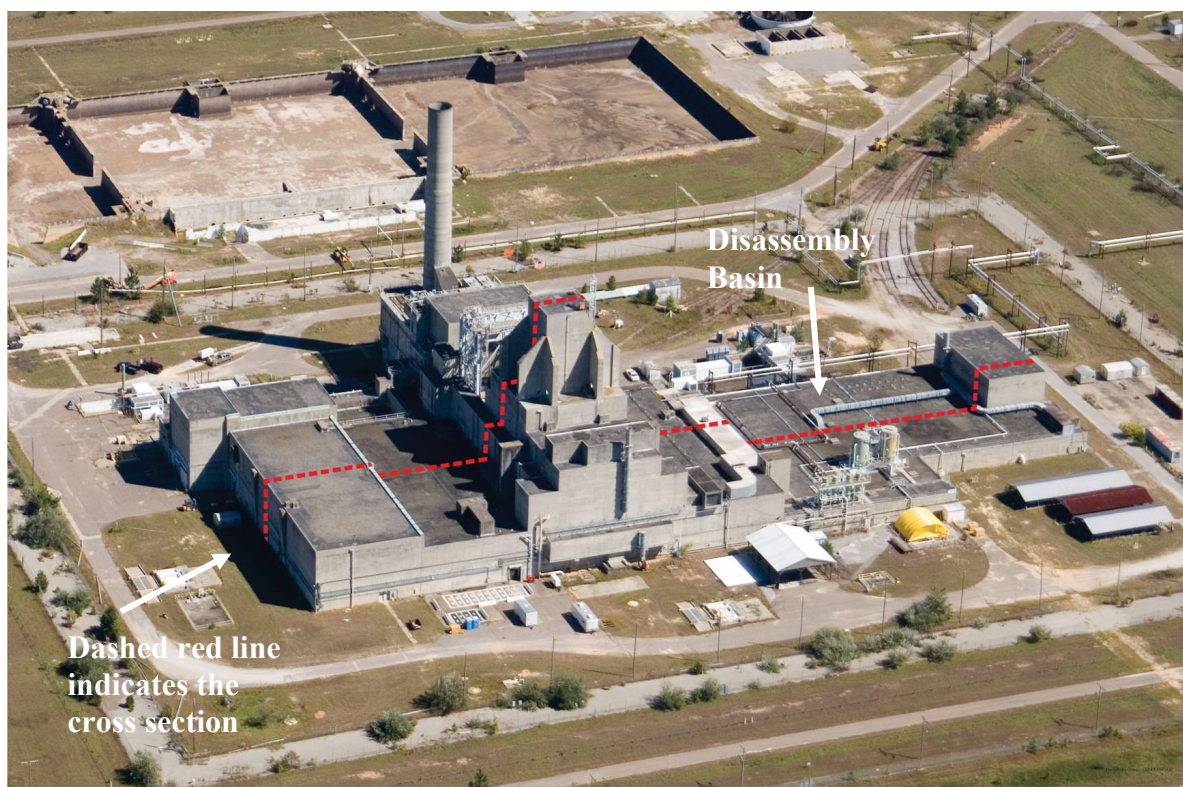


Figure 1. Photo of the 105-P reactor building (similar to the 105-R building).

Dashed red line indicates the cross sections in Figures 2 and 3.

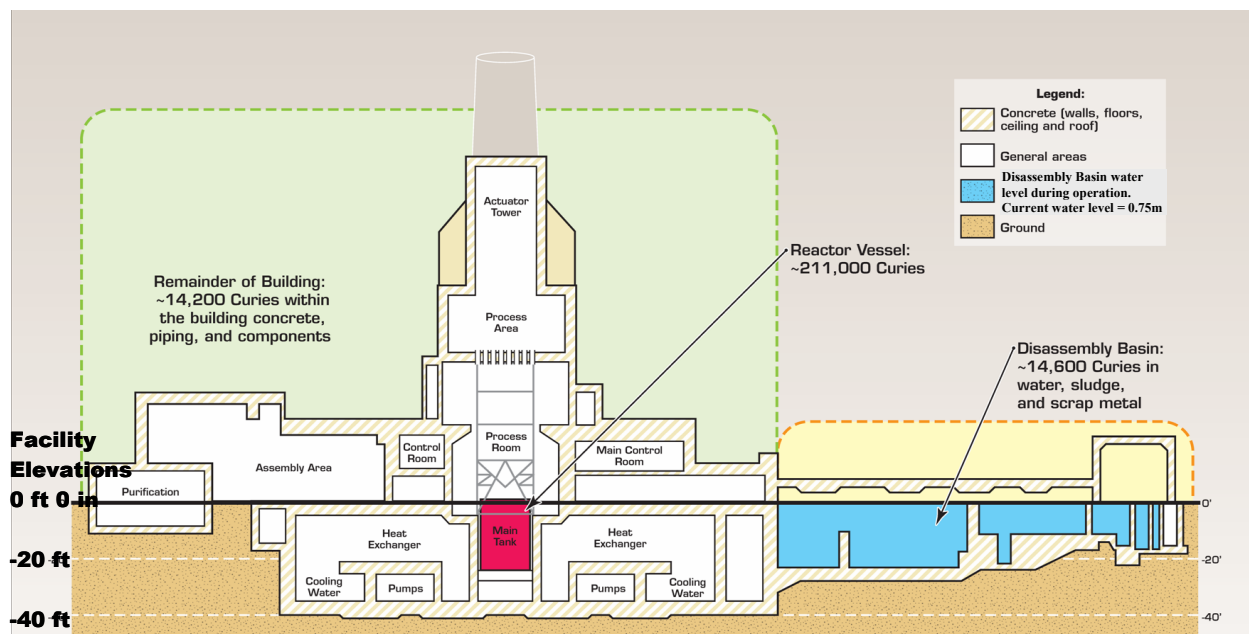


Figure 2. Cross-section through 105-P (105-R) reactor building before ISD.

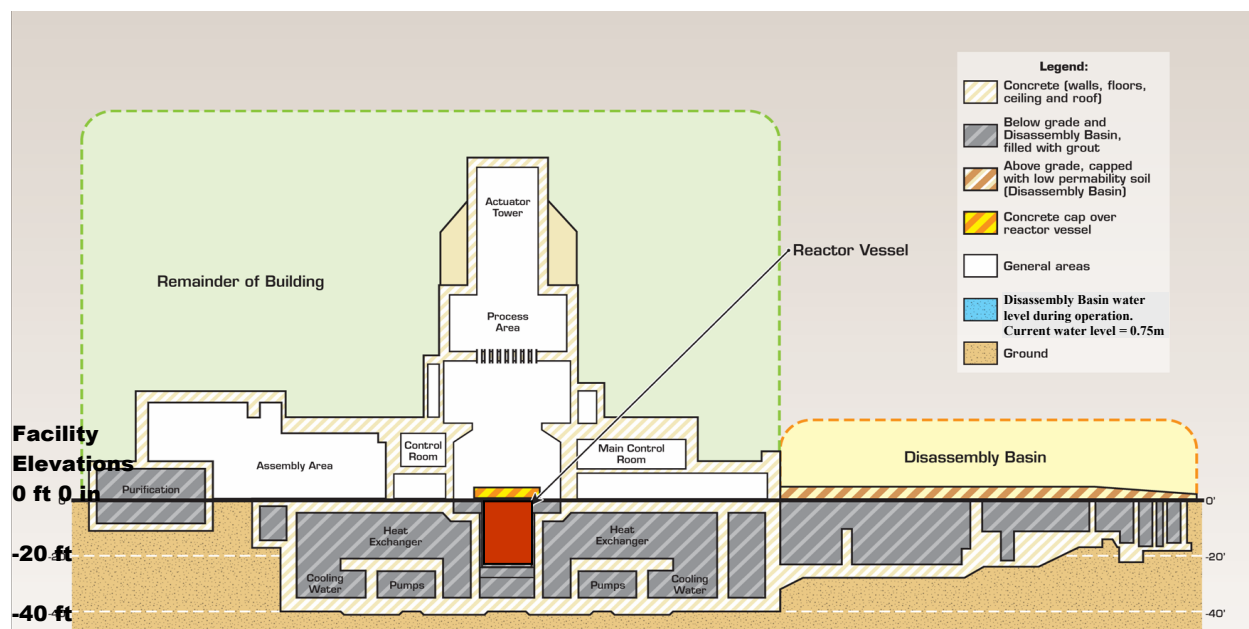


Figure 3. Cross-section through 105-P (105-R) reactor building after ISD.

Gray hatched regions indicate areas to be filled with zero bleed flowable structural fills. The red in Figure 3 indicates a non corrosive neutral pH grout (probably a magnesium phosphate grout). Yellow and orange hatched areas indicate a 3000 psi shrinkage compensating capping concrete containing an integral waterproofing admixture.

BACKGROUND

The Savannah River Site was built in the early 1950's with the mission of producing special nuclear materials in a safe, efficient, and environmentally acceptable manner. The special nuclear materials were produced in five nuclear production reactors primarily for national defense. The production reactor of concern in the current analysis, designated R-Reactor was initially brought critical on December 28, 1953 and operated intermittently until it was shutdown on June 15, 1964 due to reduced requirements for defense-related products. Following shutdown, the R Reactor was de-fueled (all fissile materials were removed), and placed in cold shutdown with no capability of restart.

In 2006, SRS Site Deactivation & Decommissioning (SDD) removed 90% of the water in the R-Reactor Disassembly Basin. A small volume of water was left in the basin to provide shielding for irradiated scrap materials and sludge.

The R Reactor Complex was designated to be decommissioned as part of a CERCLA remedial action with an assumed end state of "in situ decommissioning" because the reactor facility is structurally robust and complete demolition is not necessary. The ISD objectives for the 105-R Reactor Disassembly Basin include [2]:

- Prevent industrial worker exposure to radioactive or hazardous contamination exceeding Principal Threat Source Material levels.
- Prevent industrial worker exposure to radioactive or hazardous contamination.
- Prevent to the extent practicable the migration of radioactive or hazardous contaminants from the closed facility to the groundwater so that concentrations in the ground water not exceed regulatory standards.
- Prevent animal intruder exposure to radioactive or hazardous contamination.

APPROACH

The approach for developing the grout placement strategy was to:

- Assemble a team of on-site personnel with the appropriate skill mix
- Develop a 3D-CAD model and rapid prototype model of the basin to facilitate visualization of the facility and proposed work activities
- Group areas within the Disassembly Basin according to relevant conditions and stabilization needs
- Identify stabilization material requirements for the various areas in the Disassembly Basin
- Design cementitious fill materials that meet both the ISD requirements and construction needs.
- Test the cementitious materials to confirm material requirements are met.
- Support procurement of fill materials for the R-reactor Disassembly Basin and for the R-Reactor ISD.

105-R REACTOR DISASSEMBLY BASIN DESCRIPTION

The 105-R Reactor Disassembly Basin consists of the thirteen distinct areas which are listed below:

1. Maintenance Bay Pit & Sump
2. Seismic Gap
3. D&E Utility Chase & Canal,
4. Isolation Tank
5. Deep Well (3) [submerged within Machine Basins]
6. Vertical Tube Storage (VTS)

7. Machine Basins (3)
8. Monitor Pin Basin
9. Dry Cave
10. Horizontal Tube Storage (HTS)
11. Transfer Pit
12. Maintenance Bay (remaining portion)
13. Emergency Basin (currently filled with soil and capped with concrete)

The 105-R Reactor Disassembly Basin is depicted in Figure 4 which provides the general locations for the designated areas. The areas within the Disassembly Basin range in depth from -51.25 to -5 feet¹ (Deep Wells and Maintenance Bay, respectively). As of November 2009, approximately 30 inches of water remain in the VTS, HTS, Isolation Tank, Machine Basins, and Transfer Canals and provide shielding for irradiated metal debris which will be left in the basin. Shielding water will be displaced during grouting activities and transferred to another facility for evaporation. The Emergency Basin Area, previously filled with clay and capped with concrete, is excluded from grouting activities.

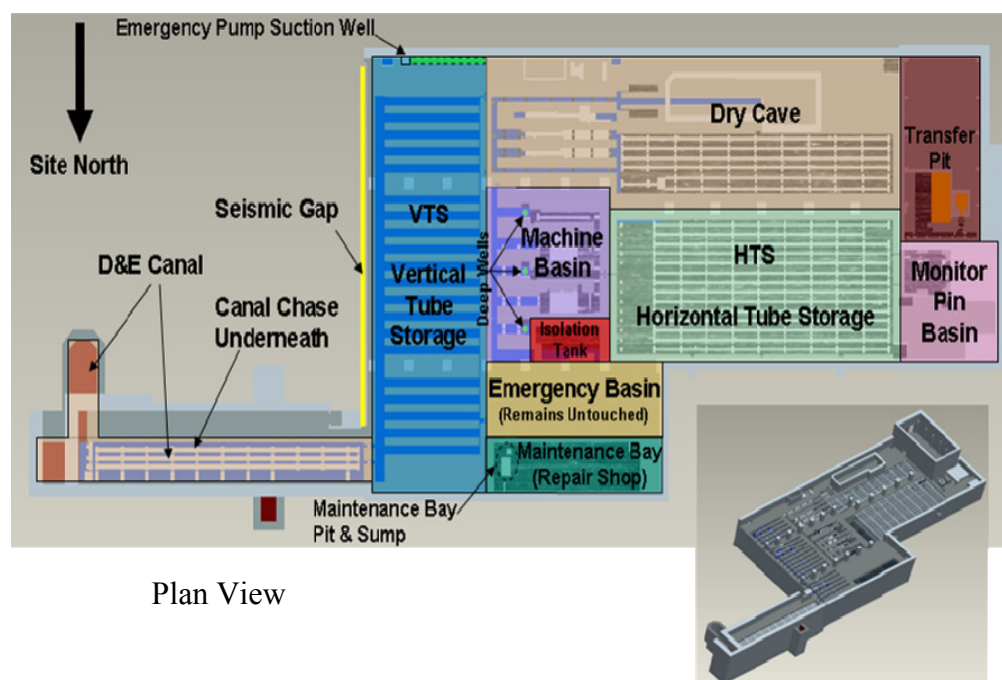


Figure 4. 105-R Reactor Disassembly Basin Areas.

A 3-D CAD model and rapid prototype model plastic of the entire 105-R Reactor Disassembly Basin were completed to facilitate the construction phase of this project [4]. These models were crucial in developing and visualizing the overall grout placement strategy and grout delivery system configuration.

105-R REACTOR DISASSEMBLY BASIN ISD IMPLEMENTATION PLAN

Implementation of the ISD for the reactor Disassembly Basin consists of several work stages. The numerous areas within the basin were grouped according to current conditions and fill material placement requirements. Details of the R-Reactor Disassembly Basin closure strategy are provided elsewhere [3].

¹ Elevations below grade are presented in *feet* because the original design and drawings are in English units. To convert *feet* to *meters*, multiply by 0.3048.

This overview focuses on the first four physical stabilization stages which are identified in sequential order below:

Dry Area Physical Stabilization¹

The first areas that will be stabilized are currently dry, free of obstructions, and relatively easily accessed even though they are in some of the deepest parts of the basin. Flowable grout will be used to fill these areas listed below:

- Maintenance Bay Pit Sump (small volume about 16.8 cubic meters or 22 cubic yards)
- Seismic Gap (-40 ft. to 0 ft. elevations)
- D&E Chase & Canal (-42 ft. to 0 ft. elevations)²
- Emergency Pump Suction Well (connected to VTS, near SE corner; small volume)

Wet Area Stabilization and Scrap Encapsulation¹

Currently about 30 inches of water provide shielding of contaminated scrap in certain areas of the basin. This water will be displaced by an underwater grout. Approximately 5 ft. of flowable grout suitable for underwater placement (referred to as the Shielding Grout layer) will be used to fill the basin from the -30 ft. to -25 ft. elevations.

- 3-Deep Wells submerged within Machine Basins (-51.25 ft. to -30 ft. elevations)²
- VTS (sludge & debris layers)
- Isolation Tank (-30 ft. to -1.25 ft. elevations, residual water will be pumped to the VTS for subsequent treatment).
- Transfer Canal in the Dry Cave (-30 ft. to -25 ft. elevations)
- 3-Machine Basins (-30 ft. to -25 ft. elevations)
- Miscellaneous Transfer Canal Segments in the HTS (-30 ft. to -25 ft.) and East and West Pits in the Transfer Pit (-30 ft. to -25 ft. and -21 ft. to -17 ft. elevations, respectively).

Displaced Shielding Water Removal and Treatment¹

The displaced water will be collected in the VTS area and transferred to the P Reactor Disassembly Basin for evaporation. Selection of the treatment option was based on a decision by the SRS Area Completion Projects (ACP)/SDD after regulatory approval.

Remaining Dry Area Physical Stabilization¹

Flowable grout will be used to fill these areas listed below from the -25 ft. to -1.25 ft. elevation:

- VTS
- HTS
- Dry Cave
- Transfer Pit
- Monitor Pin Basin
- Maintenance Bay (remaining portion at -5 ft. to -1.25 ft. elevations).

Working Surface Construction¹

After removing floor boards, hand rails, etc, the top 1.25 feet of the basin will also be filled with the same structural flowable fill materials which will serve as a working surface for the subsequent demolition.

Superstructure Demolition

The above-grade disassembly basin structure, primarily walls and roof over the basin, will be demolished and disposed in a separate location for facility construction debris.

Engineered Cap Construction

An engineered cap will be installed over the reactor disassembly basin. The cap will consist of a concrete slab. The cap concrete is a shrinkage compensating formulation that contains an integral water proofing admixture to address potential cracks.

² A camera survey in the Deep Wells and in the D&E Canal and Chase will be conducted during grouting.

R-REACTOR DISASSEMBLY BASIN STRUCTURAL FILL MATERIALS

Cementitious fill (grout) will be used to stabilize the Disassembly Basin. The fill material requirements for the 105-R Reactor Disassembly Basin decommissioning activities include: 1) providing a radiological shielding layer over irradiated debris and sludge; 2) filling void volume to provide physical stabilization of the below-grade space for the ISD, and 3) providing a durable non radioactive surface for the superstructure demolition [2]. General characteristics of the grout fill materials include:

- Flowable
- Self-consolidating and leveling
- Minimal segregation / settling / phase separation
- > 50 psi unconfined compressive strength (support 50 psi overburden) [3].

Satisfying these characteristics necessitated a hybrid approach for designing and testing candidate materials. A combination of flowable fill, structural grout, and self-consolidating concrete concepts and test methods were enlisted. A series of tests were identified to measure properties related to the desired characteristics of the R-Reactor grouts. The test methods and screening test criteria are listed in Table 1. A shrinkage compensating 3000 psi concrete containing an integral water proofing admixture has been specified for the cap.

Table 1. Test Methods and Screening Criteria for R-Reactor Structural Fill Materials.

Property	Test Methods	Screening Criteria	Basis
Flow	ASTM D 6103	>25.4 cm (10 inches)	Placement*
Slump-Flow	ASTM C 1611	61 ± 10cm (24 ± 4 inches)	Placement*
Underwater Slump-Flow	ASTM C 1611	45.7 cm (18 ± 4 inches)	Placement*
Bleed Water (segregation)	ASTM C 232	0 after 24 hr.	Placement,* Uniform Material
Set Time	ASTM C 403	<24 hr.	
Compressive Strength 7 days	ASTM D 4832	>0.35 MPa (50 psi)	Self supporting
Saturated Hydraulic Conductivity	ASTM D 5084	< 1E-06 cm/s	Less than clay
Temperature Rise	SRS Adiabatic calculations	<35°C**	Suitable for Mass Placement
Air Content	ASTM C 231	<8 volume %	Quality control
Unit Weight	ASTM C 138	> 1.28 g/cc (80 lbs / cu feet)	> water
Yield	ASTM C 138	1 ± 0.1	Balanced mix

* Minimize labor involved with placement.

** Semi adiabatic

Laboratory testing was conducted to formulate grout mixes that are flowable, pumpable, self-leveling, and have low heat of hydration characteristics to support mass grout placement. The current group of structural fills identified for the R-reactor Disassembly Basin ISD are provided in Table 2. Relevant property data are also provided. Over 95 volume percent of the basin will be decommissioned using the “bulk fill” mixes, PF-ZB-FF-8 and / or PF-ZB-FF-8-D. The underwater mix, PR-UZB-FF-8 will be used to cover irradiated scrap metal that will be left in certain areas of the basin. This structural fill will provide shielding while the 30 inches of water

currently covering the scrap are displaced upward and then pumped out of the basin for transfer to another SRS facility for evaporation.

Table 2. R-Reactor ISD Structural Fill Mix Designs and Properties.

Material (kg / m³) (lbs / yd ³)	Conjested Dry Area Placements	Unconjested Dry Area Placements		Underwater Placements
	PF-ZB-FF	PF-ZB-FF-8	PF-ZB-FF-8-D	PR-UZB-FF-8
Portland Cement Type I/II	89 (150)	89 (150)	89 (150)	89 (150)
Fly Ash Type F	297 (500)	297 (500)	297 (500)	297 (500)
Sand (quartz) C-33	1375 (2318)	1008 (1700)	1850 (1097)	1086 (1832)
Gravel (granite) No. 8	0	475 (800)	475 (800)	475 (800)
Water (kg / m ³) (lb / cu yd) (gal / cu yd)	525 (311) (63)	441 (262) (53)	416 (247) (50)	344 (41.5)
HRWR maximum (L / m ³) (fl. oz / cu yd)				
Polycarboxylate polymer	0.46* (120)*	0.30* (79)*	0.30* (79)*	0.26** (68)**
VMA (g / m ³) (g / cu yd)				
Welan Gum	360 (275)	360 (275)	0	0
Duitan Gum	0	0	262 (200)	0
Set Accelerator maximum (L / m ³) (gal / cu yd)				
Calcium nitrate based [#]	49.5 (10)	49.5 (10)	49.5 (10)	49.5 (10)
Properties				
Flow D-6103 (cm) (inches)	29 (11.5)	29 (11.5)	33 (13)	24 (9.5)
Flow C 1611 (cm) (inches)	Not measured	63 (25)	66 (26)	48 (19)
Set Time ^{##} (hr)	< 24	< 24	< 24	<10
Bleed Water 24 hr.	0	0	0	0
Unit Weight (g/cc) (lb/cu ft)	2.0 (127.5)	2.15 (134.5)	2.20 (137.5)	2.18 (135.8)
Compressive Strength (ave. of 2)				
7 days (MPa) (psi)	1.1 (160)	1.4 (200)	Not measured	2.6 (380 @ 14d)
28 days (psi)	2.7 (390)	3.7 (540)	5.4 (780)	5.6 (820)
Temperature Rise (calculated semi-adiabatic)	<25°C	<25°C	<25°C	<25°C

* SIKA Inc. Viscocrete 2100 and 6100 and W. R. Grace Inc. Advacast 575 were tested and found to be compatible with the gum VMA. Compatibility was defined as being capable of forming a fluid slurry when premixed with the gum VMAs.

* * W.R. Grace Adva 405 was tested.

[#] As required to meet production needs. W. R. Grace Inc. DCI and SIKA Inc. SIKASET NC were tested.

^{##} Values for mixes without set accelerator.

Aluminum scrap metal and alloys currently in the Vertical Tube Storage section of the R-Reactor Disassembly Basin will not be removed prior to the ISD. However, these metals and alloys corrode when exposed to high pH (e.g. fresh portland cement grout (pH = 12+)) to produce hydrogen gas and thereby a potential hazardous deflagration/explosion condition. Consequently the potential for hydrogen generation

during the ISD grouting operations was evaluated to address safety concerns related to corrosion reactions of the scrap metal [5].³ The evaluation indicated the risk of accumulation of a flammable mixture of hydrogen above the surface of the water during placement of grout-CLSM into the R-Basin VTS disassembly area is very low because the amount of reactive debris is low.⁴ Recommendations were provided to further minimize the potential for hydrogen evolution and are listed below:

1. Minimize the initial temperature of the water and grout-CLSM as much as practical. Lower temperatures will mean lower hydrogen generation rates.
2. Ventilate the building above the basin rim as much as practical (e.g., leave doors open) to further disperse hydrogen.
3. As much as possible, minimize interruptions to the grout-CLSM placement process. Interruptions will result in higher water temperatures and hence higher hydrogen evolution rates.

FILL PLACEMENT STRATEGY AND DELIVERY SYSTEM CONFIGURATION

The structural fill (grout) will be provided via an SRNS subcontract with an off site supplier. LaFarge, Inc., the supplier, will batch the fill materials at their Jackson Ready Mix Plant, which is about 40 minutes from R-Area. The SRS site D&D work force will receive the materials in R-Area and pump the grout into the basin. A delivery system consisting of several trunk lines (i.e., four-inch slick lines) configured with a series of valves and branch lines will be used for the bulk of the placements. Two-inch lines will be used to fill a few of the small areas.

The strategy is to install trunk lines required for initial dry area placements and begin filling these areas while the remaining trunk lines and branches are installed in the remainder of the basin. Only the grout trunk-slick lines for the areas being filled will be charged with grout at any one time. The remaining lines will be isolated and capped until needed. The lift heights in some cases are limited to 5 feet in order to not overload walls and stop logs. The set time of the fill material will be adjusted to meet the work schedule which in some cases may require daily 5 foot lifts in certain parts of the basin. A set accelerator is required because the high range water reducers used in the quantity necessary to produce a flowable, zero bleed mix also result in delayed set times.

Structural engineering analyses for several key areas were performed for the R-Disassembly Basin ISD and are summarized below:

- The concrete slab adjacent to the western side of the Dry Cave shows signs of deterioration and structural engineering analysis recommends restricting floor live loads to less than 40 psf [6].
- To alleviate a structural shear capacity issue for the D&E canal floor in an unsupported configuration, the Chase underlying the D&E Canal should be filled prior to filling the D&E Canal [7]
- The canal gates are not qualified for a 5-ft grout lift. Consequently the gates should be opened before grouting. Alternatively, assuming no deterioration of the gates and the gates remain closed, a maximum differential between pour height elevations of 2 ft 6 in should be maintained on opposite sides of the gates [8].

³ A similar evaluation of the 105-P Reactor Disassembly Basin was completed resulting in the same

⁴ Based on the low level of contamination of the metal scrap, the ISD performance evaluation, ALARA, and the above analysis, the scrap metal will be decommissioned in place rather than removed and disposed in the SRS low-level waste disposal facility.

The grout-filled Disassembly Basin will provide the heavy equipment a working platform to initiate demolition activities of the above ground structure over the Disassembly Basin. At the conclusion of the above ground structure demolition, a concrete cap will be installed over the grout-filled Disassembly Basin. This will serve as the final in-situ decommissioning project configuration for the 105-R Reactor Disassembly Basin.

CONCLUSIONS

The 105-R Disassembly Basin is the first SRS reactor facility to undergo the in-situ decommissioning (ISD) process. Approximately 24,384 cubic meters or 31,894 cubic yards of flowable structural fill will be used to physically fill the 105-R Reactor Disassembly Basin. Portland cement-based fill materials were developed and tested for this project. The materials are structural fills which are flowable, zero-bleed grouts that contain cement, Class F fly ash, sand, and 3/8 inch granite gravel (No. 8 stone). Results of a structural engineering study of the existing basin and test results for the selected materials were incorporated into the placement strategy, which also addressed the desire for rapid completion. Based on structural engineering analyses and work flow considerations, maximum lift heights and differential lift heights were determined.

The materials will be produced by an off-site concrete ready mix plant and trucked to R-Area at SRS, where they will be received by site D&D and pumped into the basin. Point-of-delivery testing will be provided by an on-site testing laboratory, operated under a SRNS subcontract.

The structural fills and placement strategy developed for the SRS R-Reactor Disassembly Basin are also applicable to decommissioning the P-Reactor Disassembly Basin and the below grade portions of both the 105-P and 105-R facilities. The ISD process for the entire 105-P and 105-R reactor facilities will require approximately 250,000 cubic yards (191,140 cubic meters) of grout and 3,900 cubic yards (2,989 cubic meters) of structural concrete, which are expected to be placed on an accelerated schedule.

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