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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 in tact, structurally sound facilities that are no longer needed for their original purpose of, 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 24,424 cubic meters or 31,945 cubic yards. Portland cement-based structural fill materials were design and tested for the reactor ISD project and a placement strategy for stabilizing the basin was developed. Based on structural engineering analyses and work flow considerations, the recommended maximum lift height is 5 feet with 24 hours between lifts.

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 2,400 cubic yards (1,840 cubic meters) of structural concrete which will be placed over a twelve 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-Reactors 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.

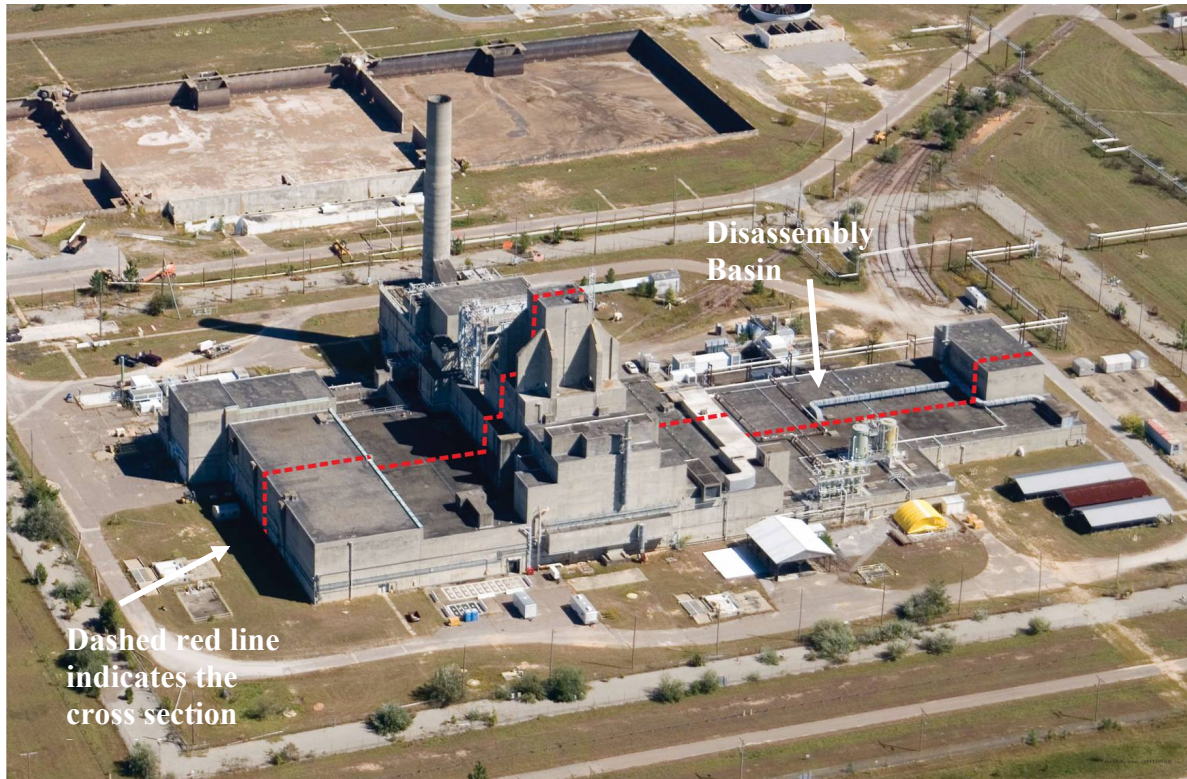


Figure 1. Photo of the 105-P reactor building (similar to the 105-R building).

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

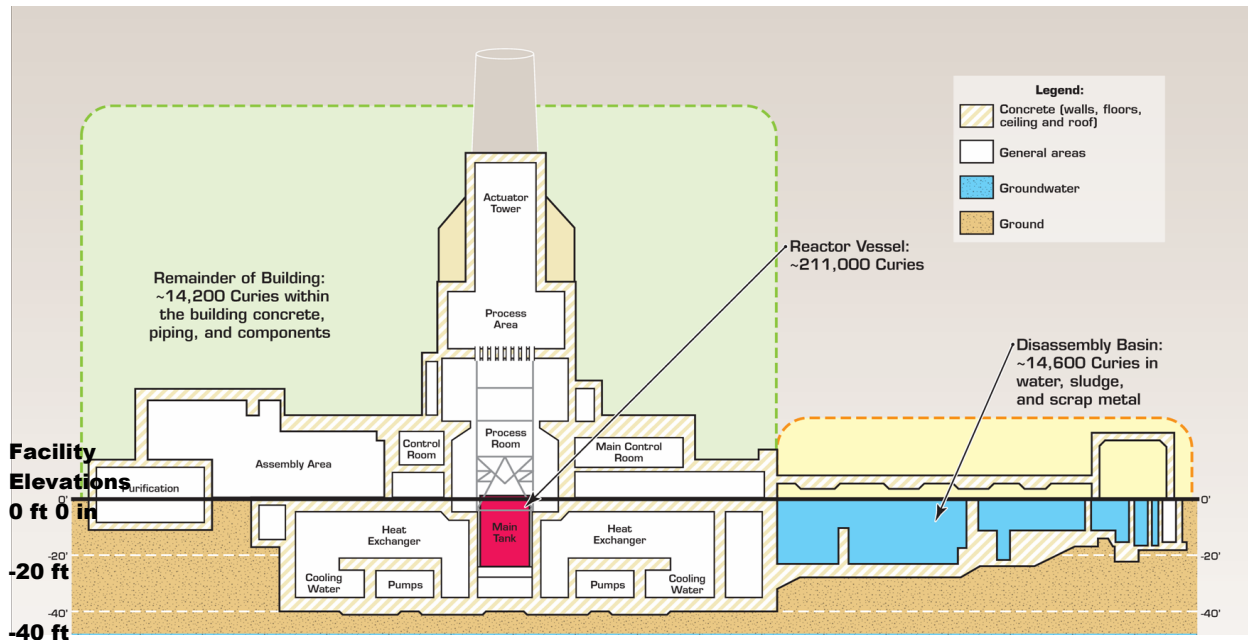


Figure 2. Cross-section through 105-P (105-R) reactor building before ISD.

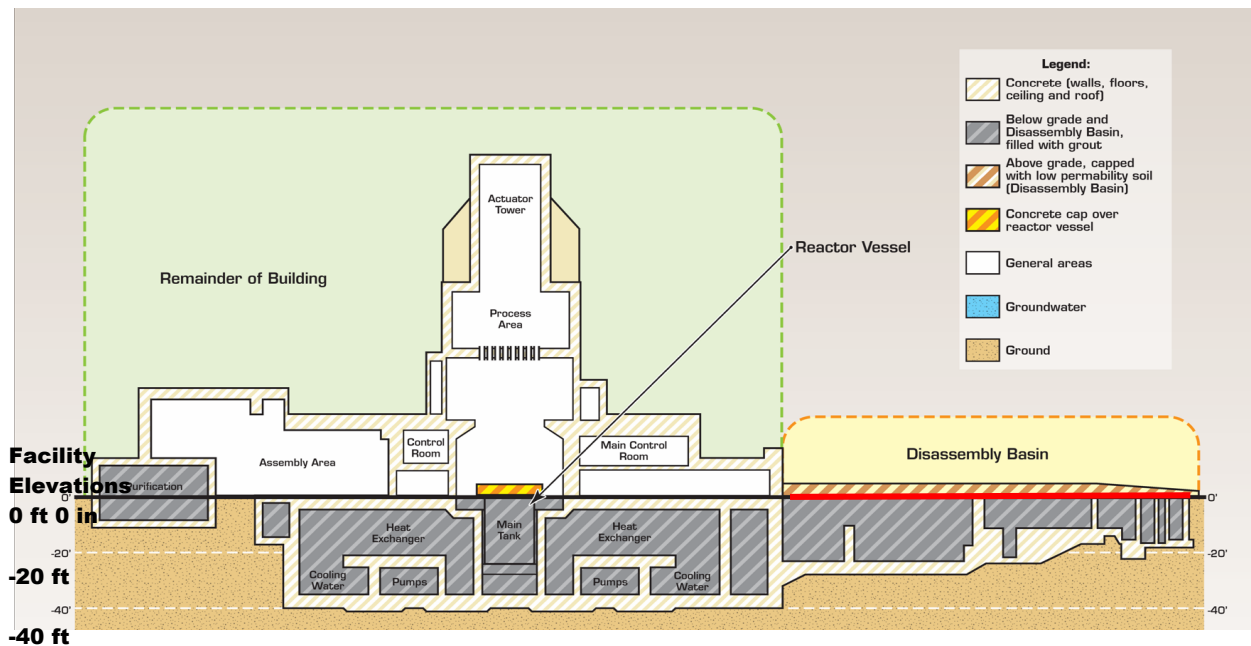


Figure 3. Cross-section through 105-P (105-R) reactor building after ISD.

Gray hatched areas are filled with zero bleed flowable fill (underwater fill in the VTS). Red area is filled with 3000 psi concrete. Yellow and orange hatched areas are special 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 the migration of radioactive or hazardous contaminants from the complex to the groundwater at concentrations that do not exceed regulatory standards to the extent practicable.
- 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 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.
- Identify construction verification activities to confirm that fill materials where needed.
- 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 twelve major, 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 disassembly basin range in depth from 51.25 to 5 ft. (Deep Wells and Maintenance Bay, respectively). 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.

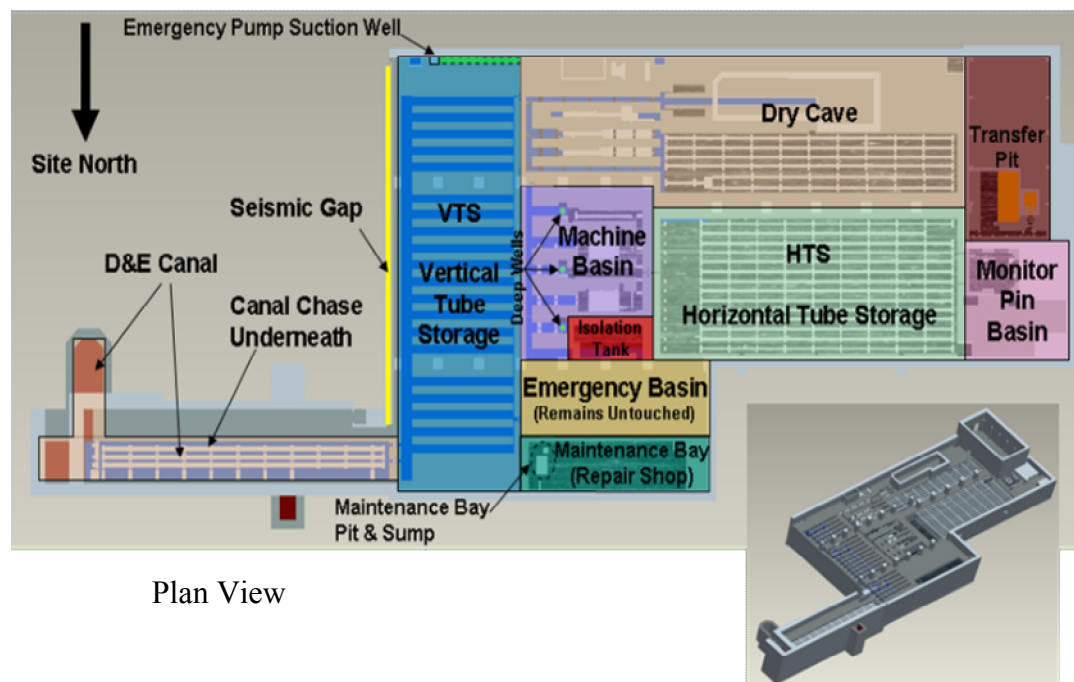


Figure 4. 105-R Reactor Disassembly Basin Areas.

A 3-D CAD model and rapid prototype model of the entire the 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-Reacto Disassembly Basin closure strategy are provided elsewhere [3]. This overview focuses on the first four physical stabilization stage (identified in sequential order) identified below.

Dry Area Physical Stabilization

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 22 cubic yards)
- Seismic Gap (-40 ft. to 0 ft. elevations)
- D&E Chase & Canal (-39 ft. to 0 ft. elevations)¹
- Emergency Pump Suction Well (connected to VTS, near SE corner; small volume)

Wet Area Stabilization and Scrap Encapsulation

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)¹
- 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 Treatment

The displaced water will be collected in the VTS area and transfer it 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 Stabilization

Flowable grout will be used to fill these areas listed below from the -17 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 Construction

The top 1.25 feet of the basin will be filled with a 3000 psi concrete 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.

¹ 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].

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. In addition to fill grouts, a 3000 psi concrete for the -1.25 to 0 ft. elevation working surface and a concrete for the basin cap are also required. The 3000 psi concrete in the current SRS specification will be used in the top 15 inches of the basin. 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	>10 inches	Placement*
Slump-Flow	ASTM C 1611	24 ± 4 inches	Placement*
Underwater Slump-Flow	ASTM C 1611	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	>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	> 80 lbs / cu ft.	> water
Yield	ASTM C 138	1 ± 0.1	Balanced mix

* Minimize labor involved with placement.

** Semi adiabatic

The potential for hydrogen generation during placement was evaluated.² The focus was on the rate at which aluminum alloys react in the with corrosive high pH portland cement based grout (pH >13) to produce hydrogen gas, thereby creating a potential hazardous deflagration/explosion condition in the 105-R Reactor Disassembly Basin.³ The evaluation results are:

“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. Conservative calculations estimate that there is insufficient aluminum present in the basin VTS area to result in significant hydrogen evolution.”

² A similar evaluation of the 105-P Reactor Disassembly Basin was completed resulting in the same

³ Aluminum scrap metal debris will be left in the Vertical Tube Storage section of the disassembly basin as part of the reactor ISD.

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 suit 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 filled the “bulk fill” mixes, PF-ZB-FF-8 and / 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 a remote site for evaporation.

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

Material (lbs / cu yd)	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	150	150	150	150
Fly Ash Type F	500	500	500	500
Sand (quartz) C-33	2318	1700	1850	1832
Gravel (granite) No. 8	0	800	800	800
Water (lbs / cu yd) (gal / cu yd)	525 (63)	441 (53)	416 (50)	344 (41.5)
HRWR maximum (fl. oz / cu yd)				
Polycarboxylate polymer	120*	79*	79*	68**
VMA (g / cu yd)				
Welan Gum	275	275	0	0
Duitan Gum	0	0	200	0
Set Accelerator maximum (gal / cu yd)				
Calcium nitrate based [#]	10	10	10	10
Properties				
Flow D-6103 (inches)	11.5	11.5	13	9.5
Flow C 1611 (inches)	Not measured	25	26	19
Set Time ^{##} (hr)	< 24	< 24	< 24	<10
Bleed Water 24 hr.	0	0	0	0
Unit Weight (lb/cuft)	127.5	134.5	137.5	135.8
Compressive Strength (ave. of 2)				
7 days (psi)	160	200	Not measured	380 @ 14d
28 days (psi)	390	540	390 @ 14d	820
Temperature Rise (calculated semi adiabatic)	<25°	<25°	<25°	<25°

* 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.

The potential for hydrogen generation during grout operations was evaluated to address safety concerns related to interactions of residual metal scrap debris in the VTS in direct with contact with portland cement based fill material which has a pH of about 12.4 which is highly corrosive to aluminum metal and alloys [5]. This evaluation focused on the reactive metals – aluminum alloys reacting with corrosive high pH grout (grout-CLSM pH >13) resulting in hydrogen gas generation and creating a potential deflagration/explosion hazardous condition in the 105-R Reactor Disassembly Basin. The evaluation results can be summarized as follows:

“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. Conservative calculations estimate that there is insufficient aluminum to present in the basin VTS area to result in significant hydrogen evolution.”

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) is will be procured through the existing SRS Site Concrete contract. LaFarge, Inc., the supplier, will batch the fill materials at the 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 pump the grout into the basin. A delivery system consisting of several trunk lines, four-inch slick lines, configured 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 area.

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 height is 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 ft 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 underlying 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 not deterioration of the gates, a maximum differential of 2 ft 6 should be maintained between lifts if the canal gates remains closed.

The grout filled disassembly basin will provide the heavy equipment working platform to initiate demolish 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 and this 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 24,424 cubic meters or 31,945 cubic yards of 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, the recommended maximum lift height is 5 feet with 24 hours between lifts.

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. Quality Control will be provided by USR Washington Group.

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 2,400 cubic yards (1,840 cubic meters) of structural concrete which are expected to be placed on an accelerated schedule.

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