Fill Materials for SRS Reactor Facility In-Situ Decommissioning

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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 Savannah River Site 105-P and 105-R Reactor Facility ISD requires about 250,000 cubic yards of grout to fill the below grade structure. The fills are designed to prevent subsidence, reduce water infiltration, and isolate contaminated materials. This work is being performed as a Comprehensive Environmental Response, Compensations and Liability Act (CERCLA) action and is part of the overall soil and groundwater completion projects for P- and R-Areas.

Cementitious materials were designed for the following applications:

- Below grade massive voids / rooms: Portland cement-based structural flowable fills for:
  - Bulk filling
  - Restricted placement and
  - Underwater placement.
- Special below grade applications for reduced load bearing capacity needs:
  - Cellular portland cement lightweight fill
- Reactor vessel fills that are compatible with reactive metal (aluminum metal) components in the reactor vessels
  - Calcium sulfoaluminate flowable fill
  - Magnesium potassium phosphate flowable fill.
- Caps to prevent water infiltration and intrusion of the areas with the highest levels of radionuclides
  - Portland cement based shrinkage compensating concrete

A system engineering approach was used to identify functions and requirements of the fill and capping materials. Laboratory testing was performed to identify candidate formulations and develop final design mixes. Scale up testing was performed to verify material production and placement as well as fresh and cured properties. The 105-P and 105-R ISD projects are currently in progress and are expected to be complete in 2012. Material property test results, placement strategies, full-scale production and delivery systems, and lessons learned in the SRS Reactor Facility ISD process will be described.

Reactor ISD Fill Material/Grout Requirements

Fill Material Function

- Fill massive void spaces below grade with physically stable cementitious material to:
  - Prevent Subsidence
  - Reduce water infiltration
  - Isolate contaminated materials from the environment
- Provide a radiological shielding layer over irradiated debris and sludge to encapsulate debris
- Provide a durable working surface for the superstructure demolition

General Material Characteristics

- Flowable
- Self-consolidating and leveling
- Minimal segregation / settling / phase separation
- > 0.34 MPa (50 psi) unconfined compressive strength (support 50 psi overburden)
- Low heat of hydration (mass placement)
- High volume placement rate

Types of Fill Materials

- Bulk Fill for below grade areas: Portland cement-based grouts
  - Dry areas
  - Underwater areas
- Special bulk fill for dry areas: Cellular Portland cement-based grout
- Reactor Vessel Low pH grout
  - Calcium sulfoaluminate cement-based grout
  - Magnesium potassium phosphate cement-based grout

Reactor ISD Fill Material/Grout Below Grade

Laboratory Tests
Fresh properties
Cured properties

Scale-up ⇒ R Reactor Disassembly Basin initial placement

Full Scale – Production 191,140 m³ total
R Reactor Disassembly Basin – 23,000 m³ (30,000 yds³)
P Reactor Bldg – 54,000 m³ (70,000 yds³)
R Reactor Bldg – 27,000 m³ (35,000 yds³)

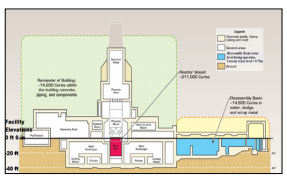
Fill material needed for low loading bearing application

SRS Reactor Facility Closures

Five Reactor Facilities -- P, R, C, K, & L

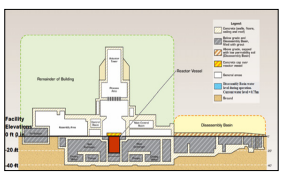
- P & R Reactor Facilities first two reactors to undergo the ISD process under the Comprehensive Environmental Response, Compensations and Liability Act (CERCLA)
- P & R-Reactors grout placement operations underway

Before ISD



- Reactor Facility extends 12 m (40 ft) below ground surface
- Existing concrete structure intact

After ISD



- Disassembly basin drained, grout filled, above structure removed & concrete cap installed
- Subsurface areas grout filled + Purification Area grout filled
- Reactor vessel grout filled & concrete cap installed
- Exhaust stack removed
- Existing reactor building structure remains intact

Portland Cement Based ISD Bulk Fills

Portland Cement, Fly Ash (Class F), Sand, Gravel, Water, Admixtures -- HRWR + VMA

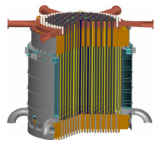
Material Property	Screening Criteria	Dry Area Fill	Underwater Fill
Unit Wt ASTM C 138, kg/m^3	> 1281	2202	2175
Hydraulic Conductivity ASTM 5084, cm/sec	N/a	4.65 X 10^{-7}	N/a
Slump - Flow ASTM C 1610, cm	61 ± 10 Dry Areas 46 ± 10 Underwater	61	46
Bleed Water after 24 hours	0	0	0
Set Time ASTM C 403, hours	< 24 Dry Areas < 15 Underwater	18	12
Compressive Strength @ 7 days ASTM C 39, MPa	> 0.35	1.83	3.45

Reactor Vessel Fill Material Requirements

- **Flowability**
- **Self-consolidating & leveling**
- **Zero Bleed**
- **Compatible with internal aluminum components**

Portland cement based fills are incompatible with internal aluminum components
Potential for hydrogen generation > 60 % LFL,

- **Pumpability**
- **Radiation effects**

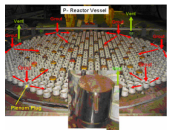


Reactor Vessel Fill Material Requirements

- Specialty fill material is required for material compatibility
  - Magnesium potassium phosphate cement-based grout
  - Calcium sulfoaluminate cement based grout

Laboratory & Scale-up Testing

- Scale-Up Testing
- Batching Process
- Pumping-Delivery System
- Mock-up Vessel Flow Test



Reactor Vessel Fill Materials – Laboratory Testing

Material Property	Screening Criteria	Calcium Sulfoaluminate	Magnesium potassium phosphate
Slurry Properties (Fresh Properties)			
pH	≤ 10.5	9	8
Flow Cone ASTM C 939, seconds	< 100	22 – 34	30 – 50
Static Working Time Modified ASTM D 6103, minutes	> 30	45 +	15 (minimal energy input re-liquefies this material)
Dynamic Working Time Modified ASTM D 6103, minutes	> 60	60 +	60
Set Time ASTM C 403, hours	2 to 24	~ 5	~ 12
Density – wet unit weight ASTM C 138, kg/m^3	< 2242	1954	2114
Cured Properties			
Compressive Strength @ 7 days ASTM C 109, MPa	1.38	4.83	5.62
Adiabatic Temperature Rise	< 60^{0}C	~ 30^{0}C	~ 40^{0}C

Reactor Vessel Fill – Scale-up Testing

Verifying production boundary conditions

- **Batch Testing**
  - Materials blending sequence
  - Mixing time
- **Pumping-Delivery System**
  - Paddle mixer
  - Positive displacement pump + recirculation loop
- **Mock-up Vessel Flowability Test**
  - Drop height – 4.8 m
  - Flow around congested mock-up tube array

CONCLUSIONS

- Functions and technical requirements for flowable fills were developed by SRNL to support SRS reactor facility in-situ D&D
- Laboratory testing and scale up testing were performed to support mix designs for:
  - Dry Areas (bulk fill)
  - Underwater placement
  - Low density application
  - Reactor Vessel containing a large amount of reactive metal (aluminum components)
  - Reactor Vessel with little reactive metal components
- Portland cement-based grouts were used for all fill materials except for the reactor vessel containing reactive metal.
- Low pH, non portland cement flowable fills were developed
  - Calcium sulfoaluminate
  - Magnesium potassium phosphate (in conjunction with D. Singh, ANL)
- Calcium sulfoaluminate cement based grout was selected for filling P-Reactor vessel based on fresh properties, material availability and cost
- Placement sequencing and strategies were developed and provided for full-scale implementation
- Implementation to date is meeting the technical and productions requirements and an accelerated schedule

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