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Cementitious Grouts for High Level Waste Tank Closure

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DOE Tank Closure

April 2018

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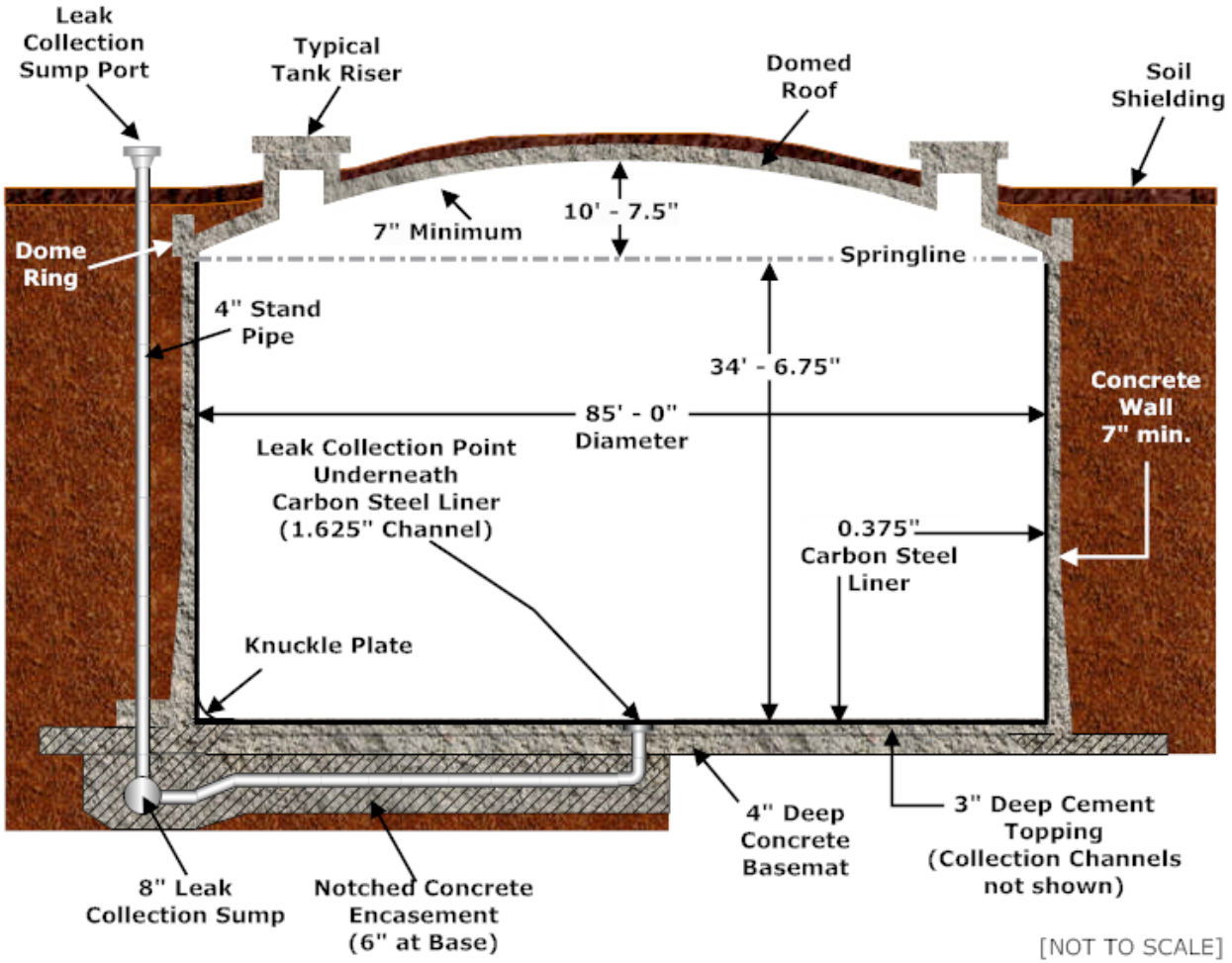
Outline

- SRS HLW Tank closure status
- SRNL grout design and testing
  - *Requirements*
  - *Mix designs and Properties*
  - *Scale-up Testing*
- Other Grout Applications
- Summary

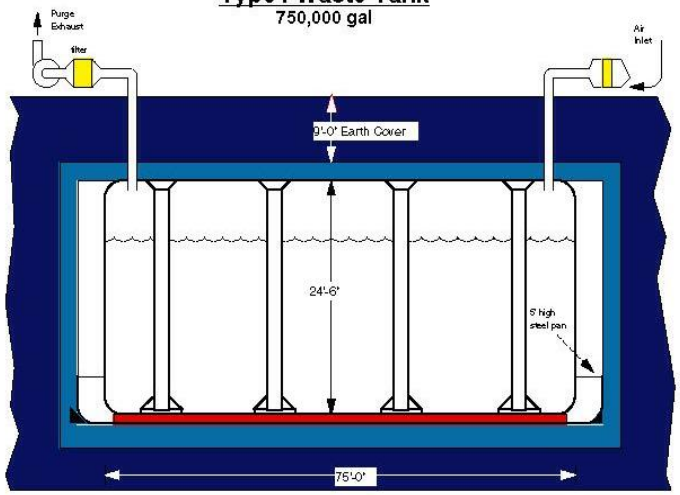


Opportunity to design materials with specific properties to achieve required performance

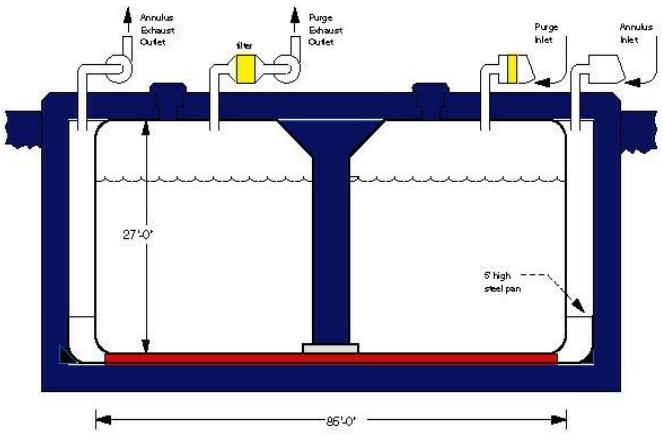
SRS High-Level Waste Tanks

•12 Tanks
•Built 1951 - 1953
•Only 5 foot Secondary
•Tanks 1-12
•Installed cooling coils
- Annulus ventilation is installed

Type I Waste Tank
750,000 gal



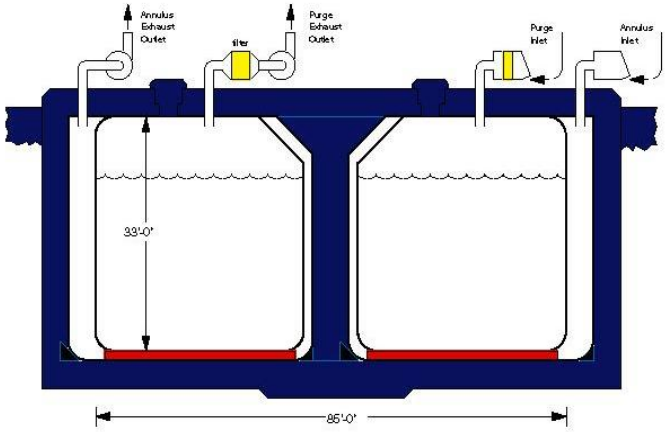
Type II Waste Tank
1,030,000 gal



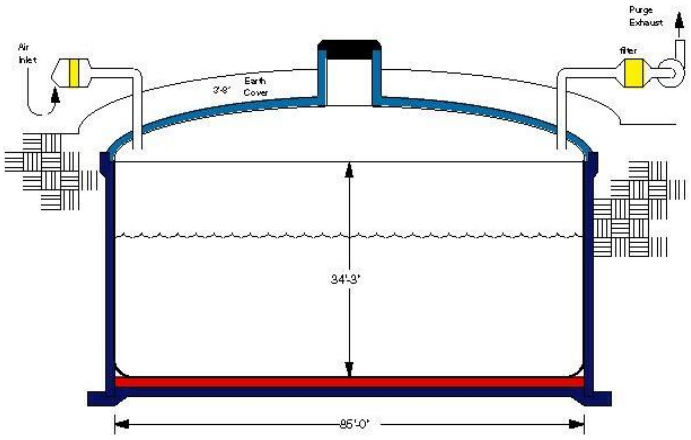
•4 Tanks
•Built 1955-1956
•Only 5 foot Secondary
•Tanks 13-16
•Installed cooling coils

•27 Tanks
•Built 1967-1981
•Full Secondary
•Tanks 25-51
•Installed cooling coils in all except Tanks 29-35 which have insertable (not necessarily removable) coils

Type III Waste Tank
1,300,000 gal



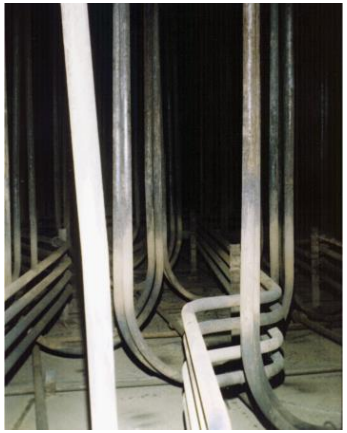
Type IV Waste Tank
1,300,000 gal



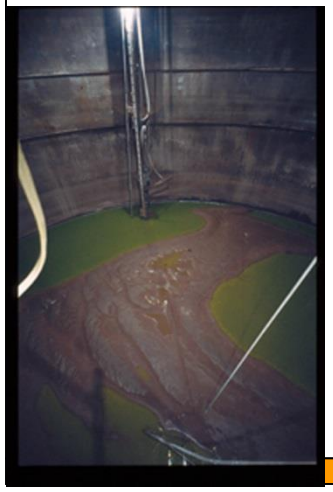
•8 Tanks
•Built 1958-1962
•No Secondary
•Tanks 17-24
•No cooling coils-handles low curie waste only

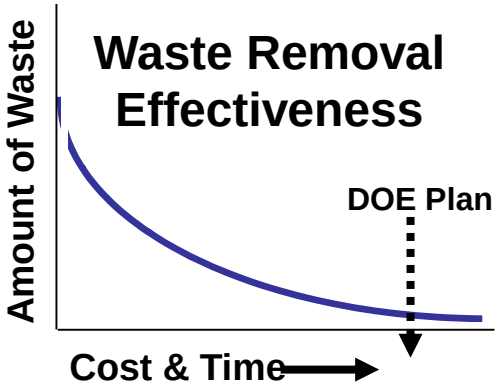
94X05168.03 AIL

SRS Tank Cleaning Tools and Results



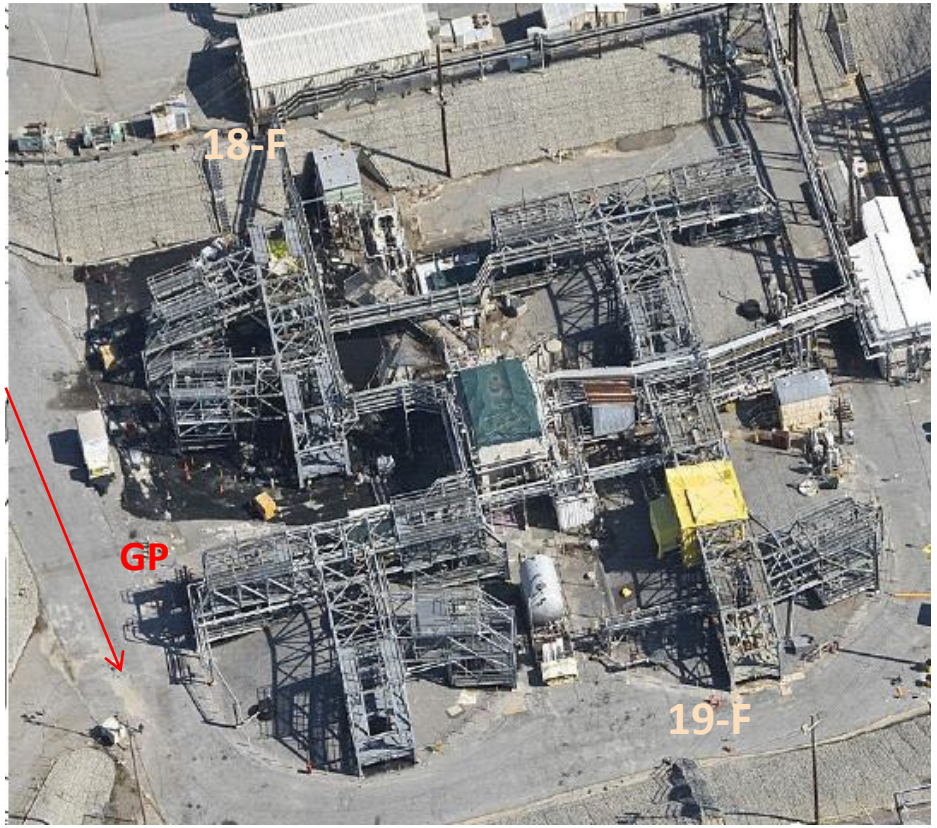
Chemical Cleaning





Background and SRS/SRNL Experience

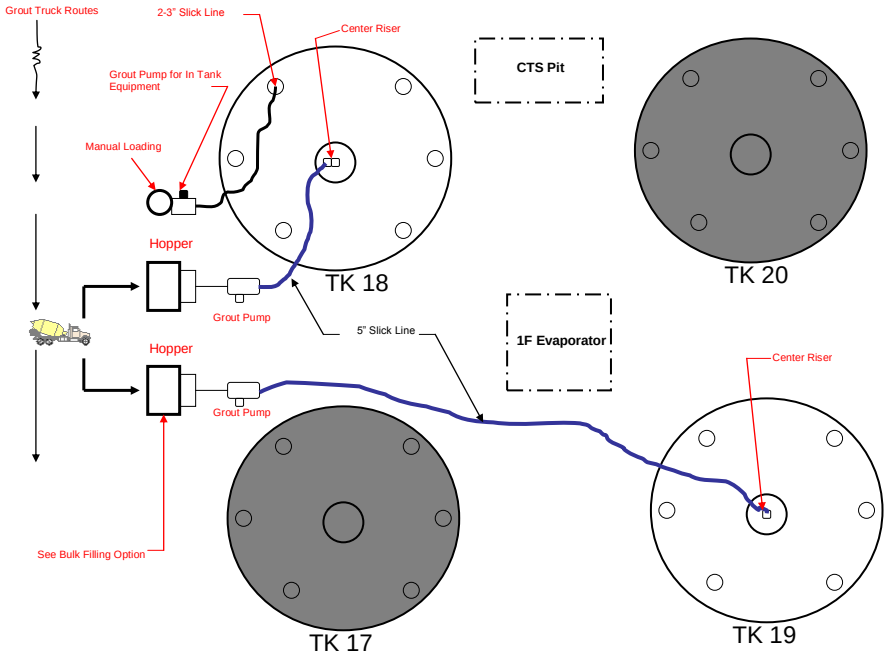
- **1997: Tanks 17-F & 20-F closed (1st in DOE complex)**
  - Three grouts (stabilization grout, bulk fill, capping grout)
  - Flowable, self leveling bulk fill
- **1998 & 2007: All-In-One grouts were designed and tested**
- **2011: Design Tank 18 and 19-F fill materials and process**
- **2012: Tanks 18-F & 19-F closed**
- **2013: Tanks 5-F & 6-F closed**
- **2015: Tank 16-H closed**
- **2016: Tank 12-H closed**
- **2009 /2010: P-and R-Reactor**
  - Designed and placed ~ 250,000 cubic yards of flowable fill and concrete

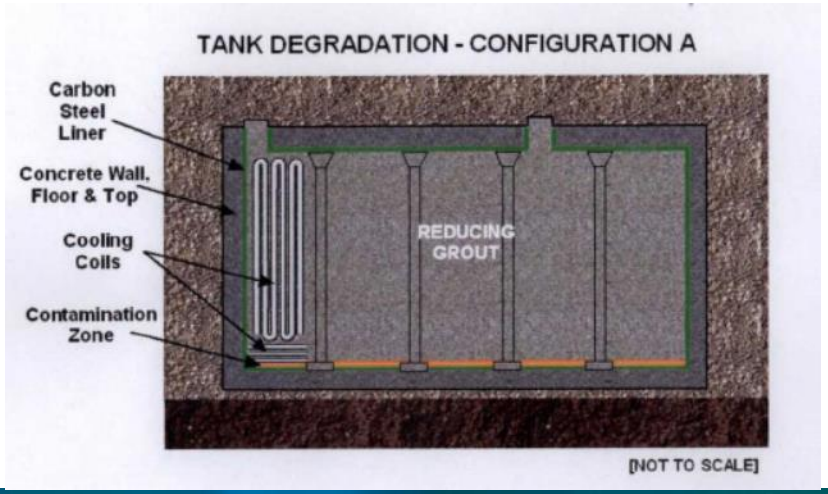


Tanks 17, 18, 19, and 20-F

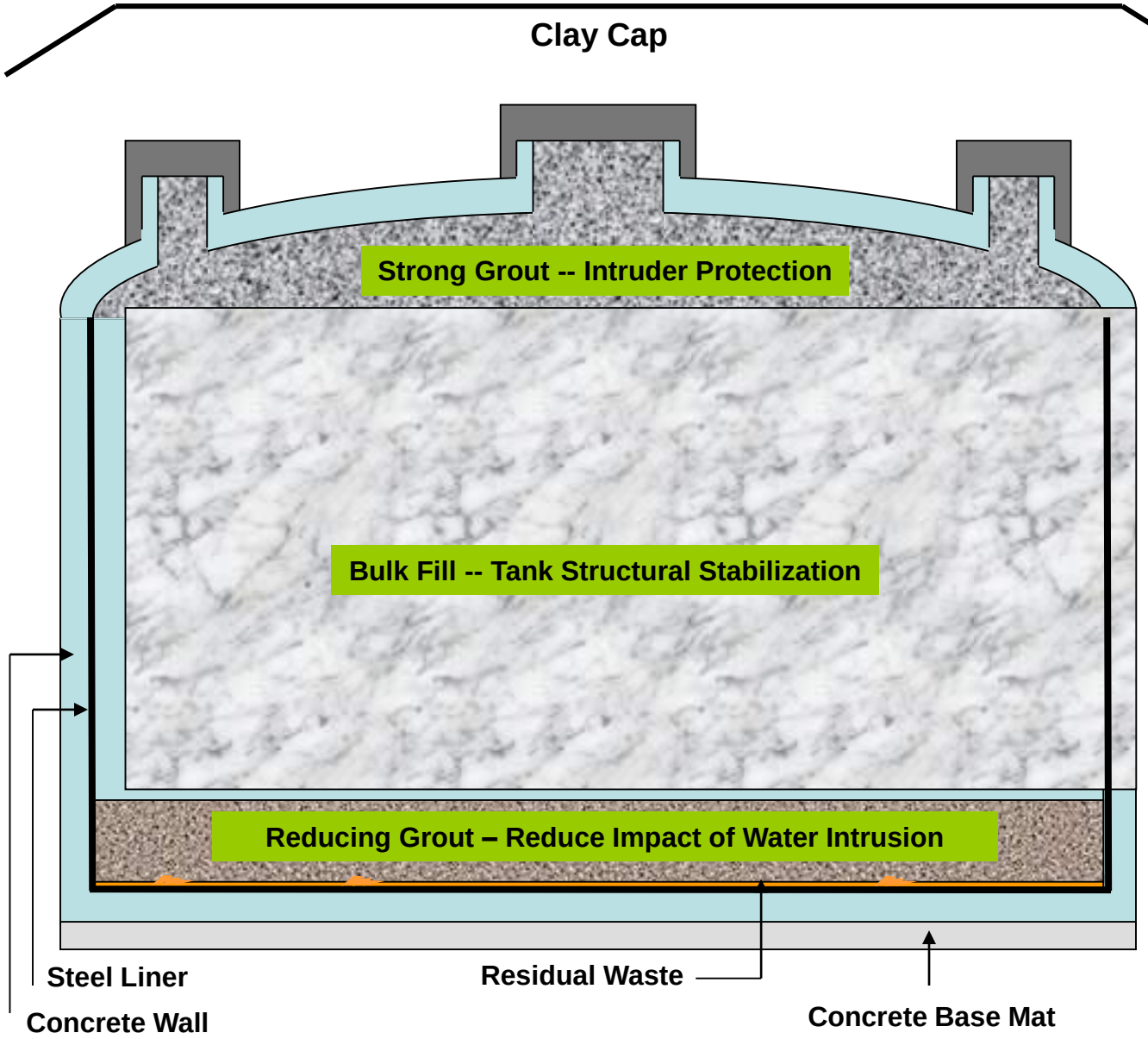
Grouting Process and Closed Tank Concept

- **Place approximately 5,000 m^3 (~6,500 cyd) of flowable, self-compacting, zero-bleed structural fill (grout) in each empty HLW tank**
- **Fill ancillary equipment and cooling coils to extent practical**





Tank Closure Concept for Tanks 17-F and 20-F

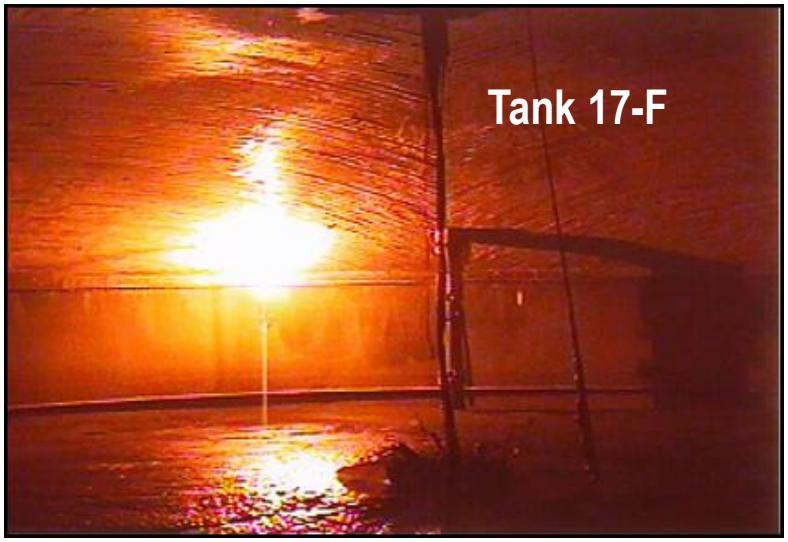


- Risk-based approach
  - Protect public
  - Protect workforce
- Applying best available technology for cleaning and closure
- Obtaining EPA and State agreement with closure plans

Applications: HLW Tank Closure Grout

- **HLW Tank Closures: SRS and Idaho**
  - Flowable Grouts and Concretes
    - 4000 m^3 flowable grout placed in each of 8 SRS HLW Tank
    - Cooling coils (5 cm pipes)
    - Ancillary equipment
    - Annulus space
    - Risers and Transfer lines

SRS F-Tank Farm



Application: HLW Tank Closure Grout

Empty SRS HLW Tank w/ cooling coils

Grout level during filling tank with cooling coils

Annulus Filling

SRS Tank Closure Grout History

		Tanks 17-F and 20-F 1997			1998 All-In-One (mod. of 1997 flowable fill)	2007 Alternative All-In-One Study	2011 Structural Fill Grout
Ingredients		SRS Reducing Grout	SRS Zero-Bleed Flowable Fill	SRS Zero-Bleed 2000 psi Grout	SRS All-In One Zero Bleed Reducing Fill/Grout# OPCEXE-X-P-0-BS	All-In-One Mix 070070	LPS#8-16
Portland Cement Type I/II	lbs/cyd kg/m^3	1353 803	150 89	550 326	75 44	185 110	125 74
Slag Grade 100 (lbs / cu yd)	lbs/cyd kg/m^3	209 124	---	---	210 125	260 154	210
Fly Ash, Class F (lbs / cu yd)	lbs/cyd kg/m^3	---	500 297	---	375 222	850 504	119 215
Silica Fume (lbs / cu yd)	lbs/cyd kg/m^3	90 53	---	---	---	---	--
Quartz Sand ASTM C-33	lbs/cyd kg/m^3	1625 964	2300 1365	2285 1356	2300 1365	942 559	1790 1062
ASTM C-33 No. 8 Stone Granite	lbs/cyd kg/m^3	---	---	---	---	946 561	800 1062
Water	gal/cyd (kg/m^3)	86.4 (428)	63 (312)	65 (322)	60 (297)	61 (300)	48.5 (239.4)
HRWR	(fl oz/cyd)	250	90* Adva Flow	140 Adva Flow	90* Adva Flow	54 Adva Flex	41 Sika 2100
Viscosifier Kelco-crete®	g/cu yd	---	275	275	275	216	200 Diutan Gum
Set Retarder Hydration Stabilizer	fl oz / cyd	150	---	---	---	Up to 4 Recover as required	As required
Sodium Thiosulfate	lbs /cyd	2.1	---	---	2.1 (optional)	2.1 (optional)	--

Tank Closure Grout Fresh Property Requirements

Fresh Slurry Properties	Requirement	Test	Basis
Slump-Flow, Laboratory (in) *(cm)*	24 to 28 *61-71*	ASTM C1611	SRNL / SRNS Reactor Facility Closure Experience
Initial Flow (in) *(cm)*	≥ 10.5 ≥ *26.7*	ASTM D6103	SRNL / SRS Tank 17-F and 20-F Closure Experience
Static Flow performed after 30 min. static conditions (in) *(cm)*	≥ 8 *20.3*	SRNL Modified ASTM D6103	SRNL / SRNS Reactor Facility Closure Experience
Air Content (vol. %)	≤ 8	ASTM C231	SRNL / SRNS Reactor Facility Closure
Set Time (hr.)	< 24	Modified ASTM C403 or Ultrasonic Pulse Velocity method	SRNL / SRNS Reactor Facility Closure Experience
Bleed water after 24 hr (Vol.%)	0	ASTM C232	SRNL / SRNS Reactor Facility
Wet Unit Weight (lbs/cu ft)	No requirement	ASTM C138	Value required for QC
Maximum temperature during curing (°C)	65	Calculated from adiabatic calorimeter data, specific heat and thermal conductivity	SRR Operations input in order to manage moisture evaporation during filling and temperature transients during curing
Specific Heat	No requirement	SRNL Method	Values used in temperature rise calculation and thermal transient modeling
Thermal Conductivity			
Slurry pH	≥12.4	> 75 lbs Portland cement/cyd *> 44 kgs Portland cement/m^3*	2007 FTF PA* High alkalinity is consistent with the waste tank operating conditions and does not require further analysis for tank corrosion and residual solubility

Tank Closure Grout (Structural Fill) Requirements

Property	Requirement	Test	Basis
Cured Properties			
Compressive Strength (psi)	≥ 2000 at 28 days (≥ 13.8 MPa)	ASTM C39	2007 FTF PA*
	≥ 2000 at 90 days (≥ 13.8 MPa)	ASTM C39	Engineering Design and QC Criteria
Effective Porosity (vol. %)	Measure for input to closure PA	Modified ASTM C642	2007 FTF PA
Dry Bulk Density (g/cm^3)	Measure for input to closure PA	Modified ASTM C642	2007 FTF PA
Particle Density (g/cm^3) (Averaged particle density)	Calculate for input to closure PA (bulk density and porosity) $\rho_p = \rho_b / (1 - (\eta / 100))$	Calculated from porosity and dry bulk density[1]	2007 FTF PA
Dimensional Stability (Shrinkage)	TBD	TBD	Relevant to PA
Cracks	TBD	TBD	Relevant to PA
Alkalinity of water in contact with sample cured for 90 days	pH ≥ 12.4 ≥ 75 lbs/cyd ≥ 44 kg/m^3 Portland cement	QC ≥ 75 lbs/cyd ≥ 44 kg/m^3 Portland cement	2007 FTF PA*
Reducing Capacity	Eh ~ -200 to - 400 mV Slag ≥ 210 lbs/cyd ≥ 125 kg/m^3	Quality Control Slag ≥ 210 lbs/cyd ≥ 125 kg/m^3	2007 FTF PA*
Durability	Minimize potential for chemical degradation	Degradation rate analysis	2007 FTF PA*

Tank Closure PA has been subsequently updated.

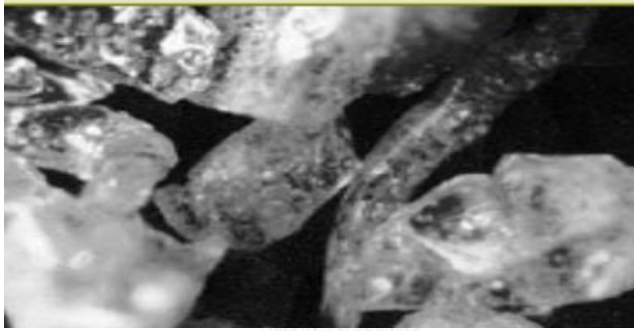
Tank Closure Grout Hydraulic Performance

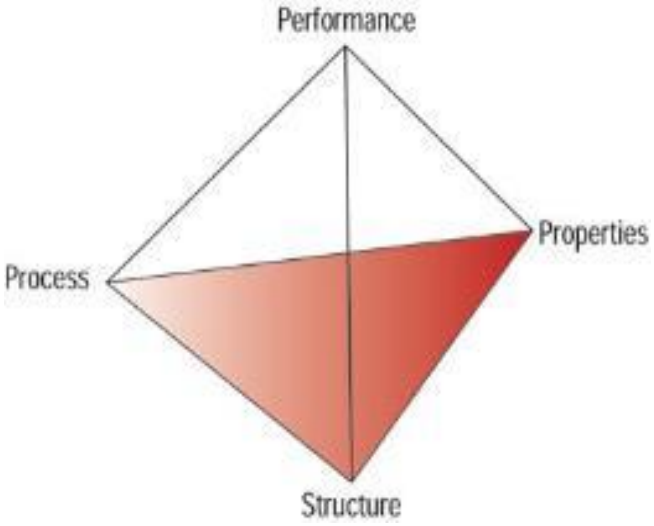
Property	Requirement	Test	Basis
Transport Properties			
Effective Diffusion Coefficient (D_e) (cm^2/s)	≤ 8.00E-07	D_e is a representative literature value applied to all soluble ions	2007 FTF PA*
		SIMCO Migration Test to determine tortuosity used to calculate D_e	Option to 2007 FTF PA* Material specific data
Tortuosity (τ) (-)	≤ 20	Tortuosity is calculated from a representative molecular diffusion coefficient (D_m)	2007 FTF PA*
		SIMCO Migration Test for determining material specific tortuosity which is used to calculate D_e.	Option to 2007 FTF PA* Material specific data
Saturated Hydraulic Conductivity at 20°C, average ($K_{hsat@\ 20°C}$) (cm/s)	≤ 3.6E-08	ASTM D 5084 Method F	2007 FTF PA*
		ASTM D 5084 Method C	
		SIMCO Drying Test for intrinsic permeability used to calculate saturated hydraulic conductivity	The SIMCO Drying Test has a lower detection limit than the ASTM D5084 method
K_{ds} and for selected contaminants	2007 FTF PA	Determined for select species	2007 FTF PA

Tank Closure PA has been subsequently updated.

Tank Closure Grout Starting Materials

- Locally available ASTM concrete sand and No. 8 coarse aggregate have particle size distributions which are less than ideal for flowable grouts
- Blending several size fractions adds cost and complexity to production
- Optimum Proportioning for local No. 8 crushed granite stone ~ 475kg/m^3 (800 lbs/cyd)
- HRWR used to achieve flowable grouts
- Diutan gum (VMA) was used to compensate for coarse aggregate and sand grading deficiencies and eliminate segregation of fluid grouts





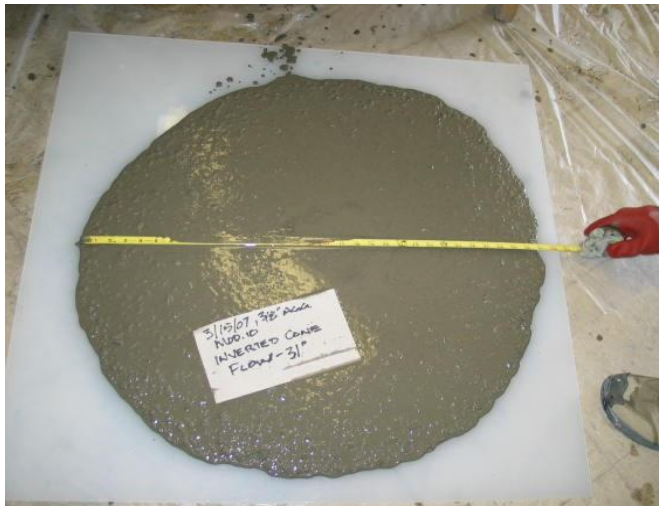
SRS Tank Closure Grout Ingredients

Material	Specification	Supplier / Address
Portland cement Type I/II	ASTM C150	LaFarge, Cement, Harleyville, SC obtained from Lafarge Ready Mix Augusta, GA
Slag cement (Grade 100)	ASTM C987	Holcim, Inc., 3235 Satellite Blvd., Duluth, GA 30096
Fly ash (Class F)	ASTM C618	Wateree Power Plant,* SC, SEFA, Inc.
Concrete sand	ASTM C33	SCMI, Clearwater, SC
No. 8 stone (0.98 cm) 3/8 inch gravel (granite)	ASTM C33	Martin Marietta Quarry Augusta, GA obtained from Lafarge Ready Mix, Jackson, SC
HRWR		
Sika ViscoCrete 2100	ASTM C494 Type F	Sika Corporation
Hydration Stabilizer**		
Recover	ASTM C494 Type B	W.R. Grace & Co., 62 Whittemore Ave. Cambridge, MA 02140
Viscosifier		
Kelco-Crete D® (Diutan Gum)		CP Kelco, Inc., 8355 Aero Dr. San Diego, CA 92123
SRS domestic water		SRS

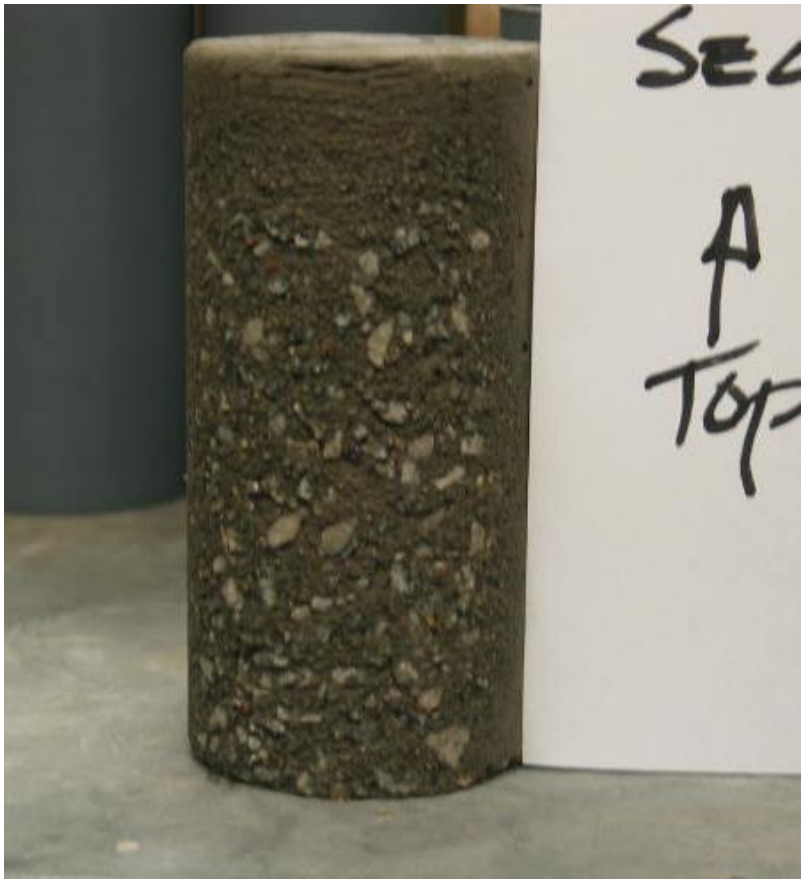
SRNL Trial Mix Design and Testing

LP#8 Grout series

- **Combined tank fill grout chemistry (slag) and Reactor fill grout flow properties (No. 8 stone, i.e., 3/8 inch gravel)**
- **Screened 16 trial mixes**
  - Water : cementitious material (0.500 to 0.641)
  - Total cement (100 to 185 lbs/cyd) (60-110 kg/m3)
  - Total slag (210 to 260 lbs/cyd) (125 to 155 kg/m3)

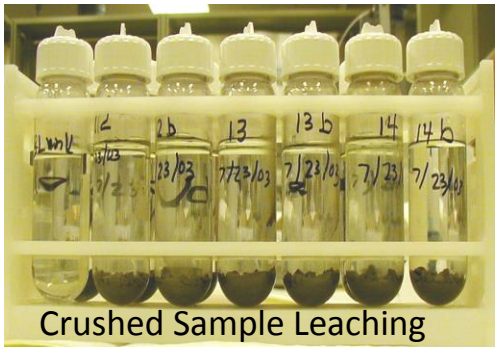


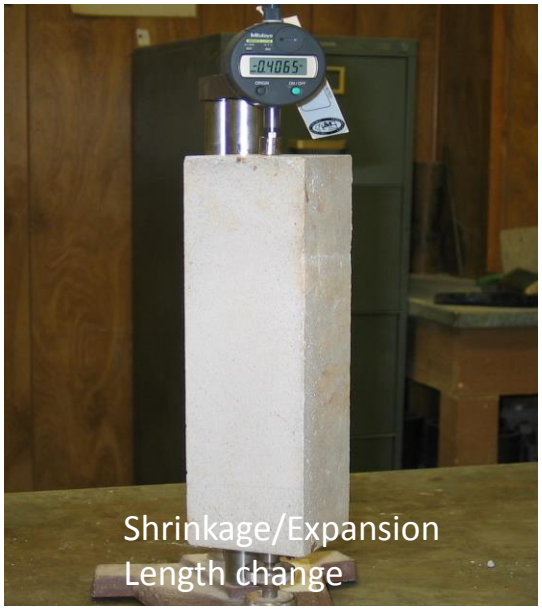
Effect of Segregation



Grout with (left) and without (right) diutan gum viscosity modifier

SRNL Laboratory Testing


Crushed Sample Leaching

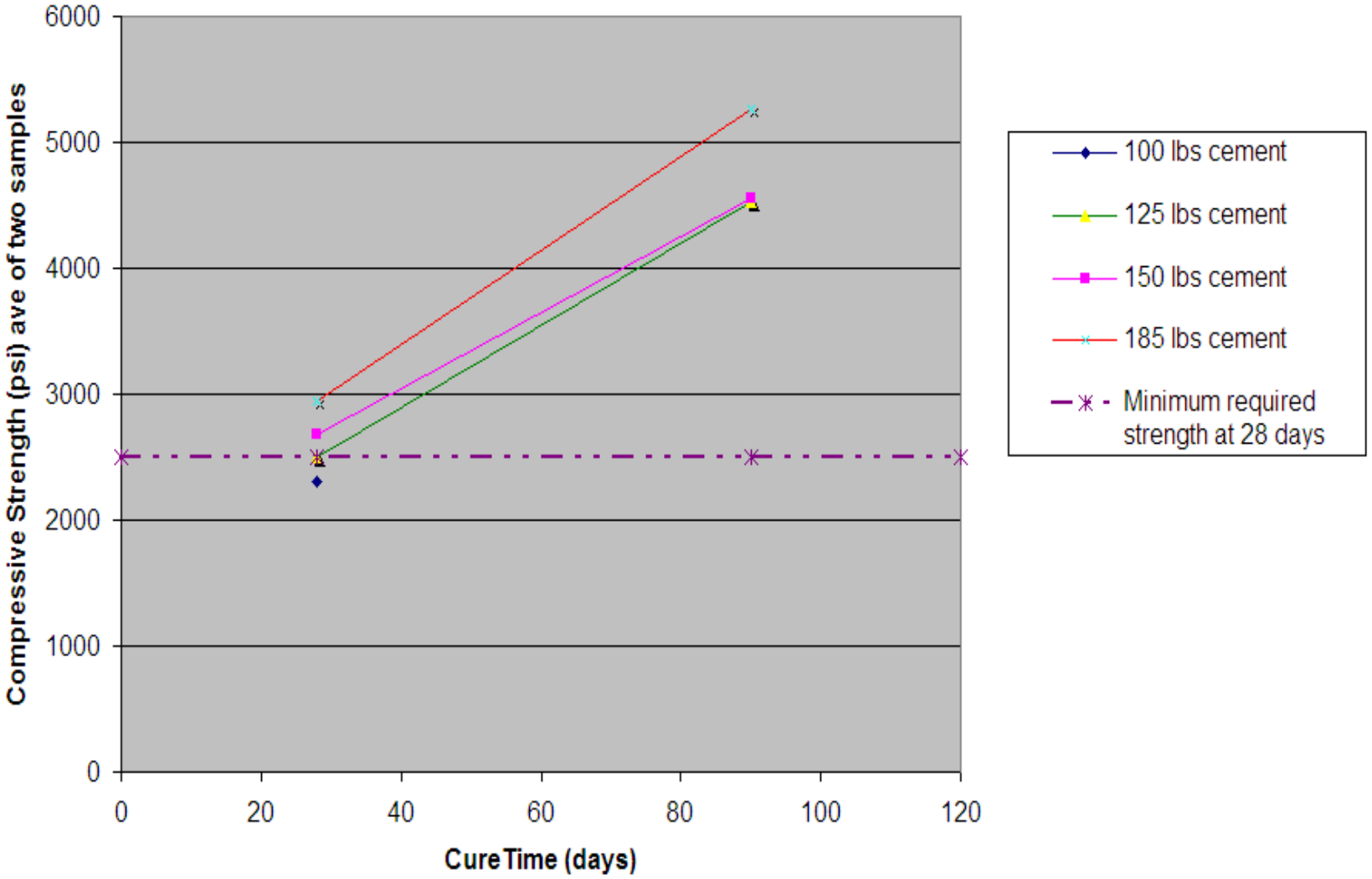

Shrinkage/Expansion
Length change


Hydraulic conductivity

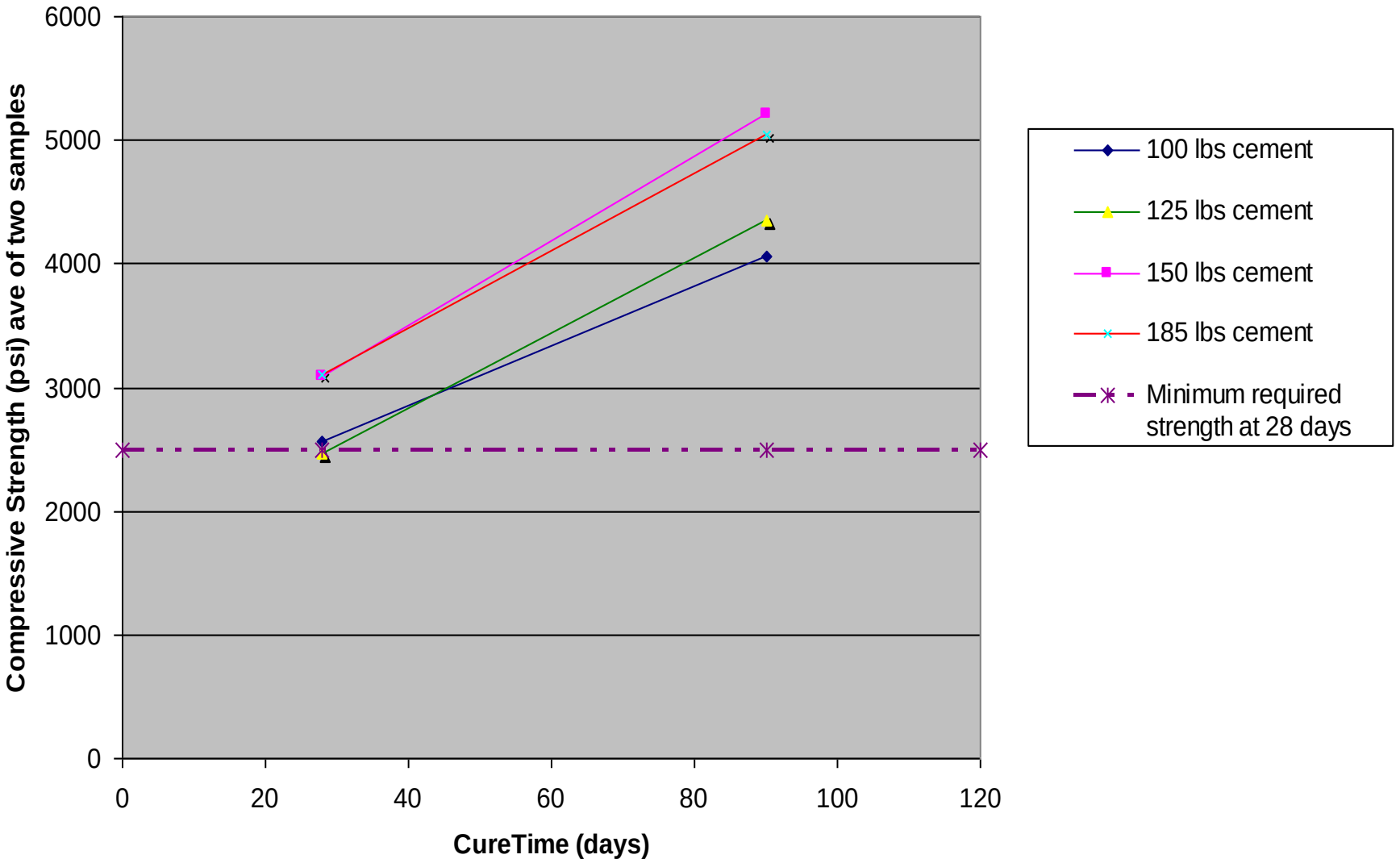

Monolith Leaching for D_{eff}


Compressive Strength

Strength as a function of Cement Content (w/cm 0.580)



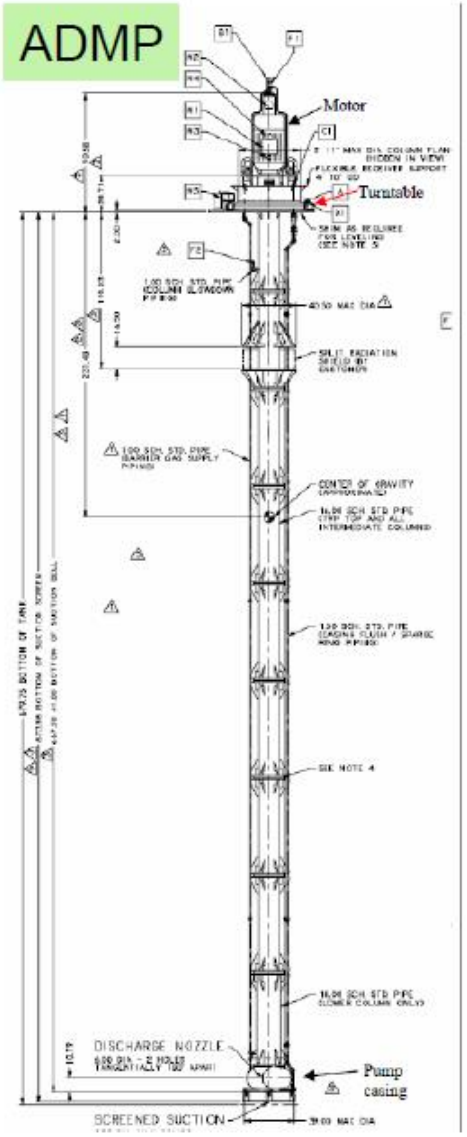
Strength as a function of Cement Content (w/cm 0.550)

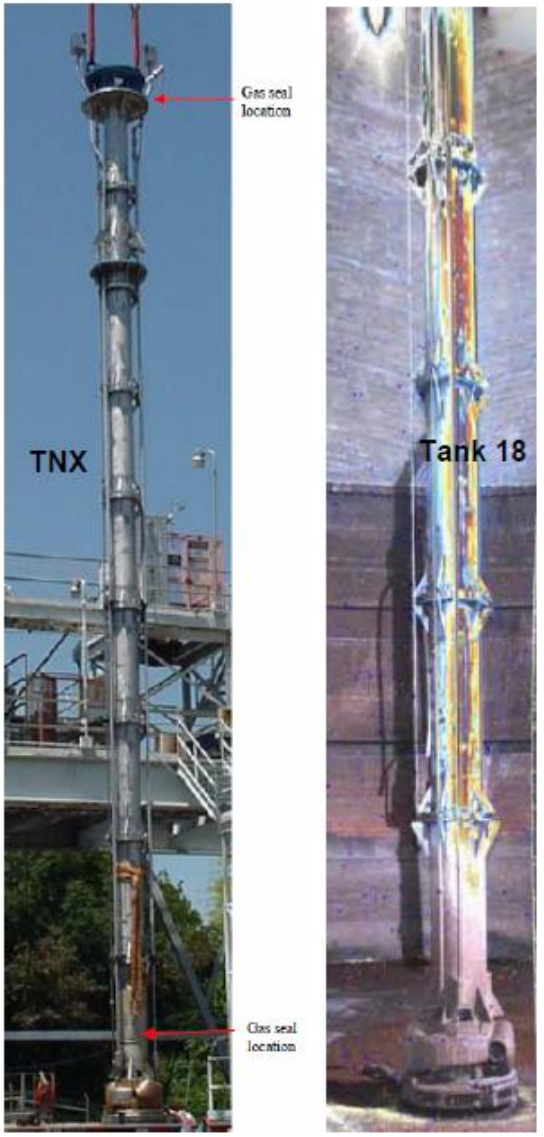


Scale up: Grout Production, Delivery, and Properties

- Batch 4 cyd of Mix 16 at a local ready mix plant and deliver to F-Tank Farm
- Fill 1 cyd insulated form and monitor temperature over 4 weeks
- Evaluate fresh properties
- Cast samples for cured properties
- Measure cured properties

ADMP Mock up for Grout Filling

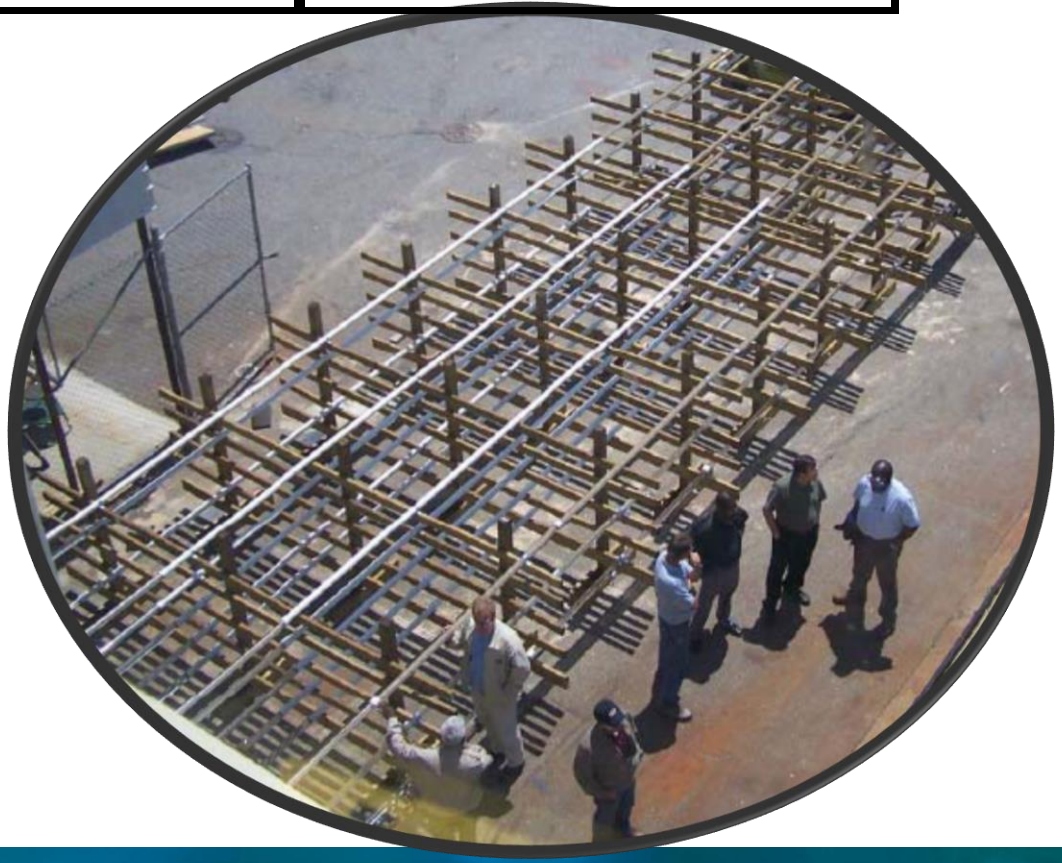




SRNL-STI-2011-00564, D.B. Stefanko and C.A. Langton, Tank 18 and 19-F Tier1A Equipment Fill Mock up Test Summary

SRS Tank Cooling Coil Design and Testing

Identifier	Expansion at 100 % RH % after 28 days	Contraction at ambient RH % after 14 days
MF 816 + Slag	0.035	0.066
MF 1341 + Slag	0.047	0.056
OPC + Slag	Not measured	Not measured



INTEC Tank Closure Grouts

Table 2-3. Composition of the two grouts identified for closing waste tanks at the Idaho Nuclear Technology and Engineering Center (INTEC).

Component	Pipe Grout	Tank Grout
Portland Cement, Type I/ II (lbs/cyd)	680	320
Fly Ash, Class F (lbs/cyd)	1,600	640
Sand (lbs/cyd)	N/A	2,200
Water (gallons/cyd) *(lbs/cyd)*	96 max *(800 max)*	52 max *(433 max)*

WSRC-TR-2001-00359 Rev. 0, C.A. Langton Roger D. Spence and John Barton, "State of the Art Report on High-Level Waste Tank Closure"

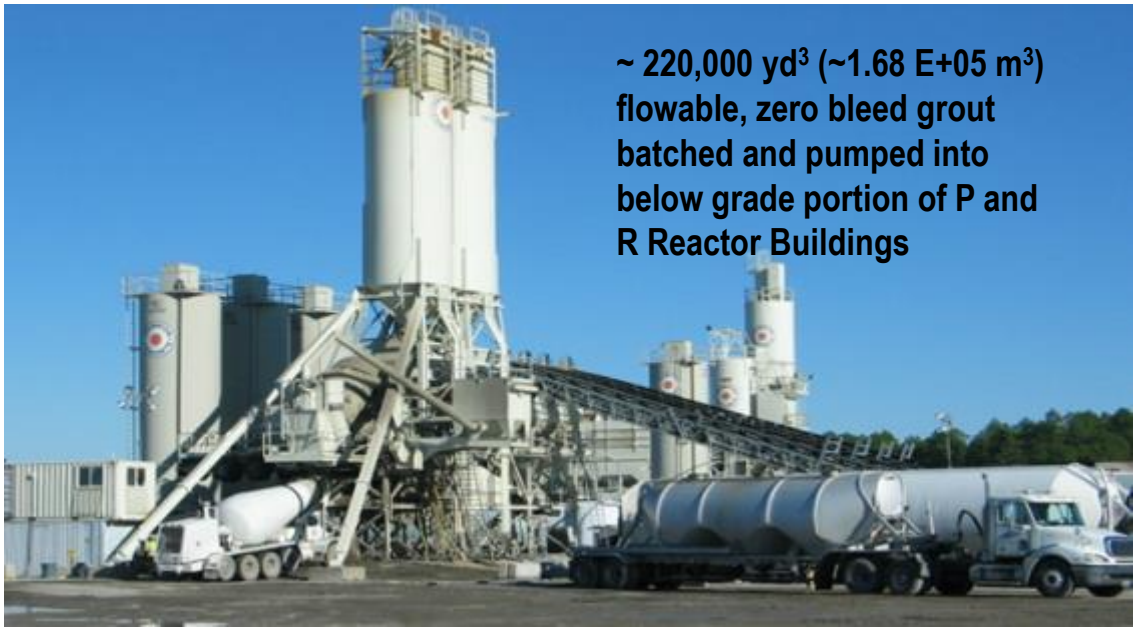
SRNL Scale-up Test for Hanford Tank Closure Grout

WSRC-TR-2003-0056 Rev. 0, C.A. Langton et al. "Grout Placement and Property Evaluation for Closing Hanford HLW Tanks – Scale-up Testing"

Application: SRS Reactor Facility In-situ Decommissioning

Decommissioning P and R Reactors

- Specialty grout: calcium sulfo-aluminate developed for reactor vessel fill material to address material compatibility issues
- Flowable, self-consolidations, and self-leveling grout



~ 220,000 yd^3 (~1.68 E+05 m^3) flowable, zero bleed grout batched and pumped into below grade portion of P and R Reactor Buildings

Summary – Tank Closure Grout Design and Deployment

- Structural flowable grout / concrete **"SELF-LEVELING"**
  - Low Portland cement (125 lbs portland cement and byproduct cementitious materials (fly ash and slag)

    "GREEN DESIGN"
  - 2000 psi at 28 days, > 4000 psi at 90 days
  - Low heat

    "MASS POUR"
  - Low permeability

    "DURABLE"
  - Zero bleed

    (non segregating)

    "HOMOGENEOUS"

Acknowledgements

Thank You

Questions?

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