WASHINGTON SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

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Tank Farm Grout and Concrete Degradation

The purpose of this memorandum is to document the cementitious material (i.e., grout and concrete) degradation assumptions that will be used in F-Tank Farm (FTF) Performance Assessment (PA) modeling. The degradation assumptions are based principally upon penetration depth modeling (thickness of affected material) from WSRC-STI-2007-00607.

Penetration Depth Modeling Basis from WSRC-STI-2007-00607

According to WSRC-STI-2007-00607, the current Savannah River Site F-Tank Farm disposal environment is very benign with respect to chemical degradation of the reinforced concrete vaults and the tank fill grout material. Consequently, the degradation due to chemical processes will progress at a very slow rate. Simple empirical relationships or single phase diffusion equations were used to calculate distance of transport of the potentially corrosive species.

The penetration depth of the chemical species responsible for the degradation was assumed to be equivalent to the depth of degradation. The consequences of the degradation depended on the material porosity and whether or not the material contained steel reinforcing because steel rebar introduces an additional degradation process, i.e., concrete cracking due to formation of expansive metal corrosion products. The most extensive cementitious material attack was found to be from carbonation. Carbonation was found to result in the greatest penetration as a function of time. For material with the porosity of the surrogate base mat concrete, 16.8 volume percent, the depth of penetration from carbonation was estimated to be 21 cm (8.27 inches) after 1000 years. The estimated depth of penetration for the representative tank fill grout from carbonation reactions was 36 cm (14.17 inches) after 1000 years.

The impact of carbonation on the permeability of the cementitious barriers in the FTF closure concept depends on whether the barrier contains steel. Carbonation in itself may actually reduce permeability by plugging pores with calcium carbonate. However, it will affect the permeability of reinforced concrete because the concrete will crack due to formation of expansive iron hydroxide phases which form when steel corrodes. Steel passivation is lost when the pH of the pore solution is in equilibrium with calcium carbonate (pH~8.4) rather than calcium hydroxide (pH~12.5). Because the annulus fill grout and fill grout in the tanks without cooling coils (i.e., Type IV tanks) do not contain rebar or steel, the overall effect of carbonation should be minimal regardless of the depth of penetration. The permeability of these materials is not expected to change significantly due to carbonation. This is the case even though the rate of carbonate penetration is faster due to the higher porosity of the tank fill grout (26.6 volume percent).

Carbonation of the tank fill grout will not commence until the tank is breached due to corrosion or development of a fast pathway. Based on calculated tank corrosion rates a lengthy lag time is anticipated before carbonate actually contacts the grout and the carbonation front advances to the cooling coils. The corrosion rate is expected to be very slow in the absence of additional corrodents.

Cementitious Material Degradation Modeling

The grout and concrete penetration depth modeling in WSRC-STI-2007-00607 can be used to model the cementitious material degradation expected for the FTF tanks. With respect to concrete and grout degradation, the parameters of concern for FTF PA modeling are the cementitious materials hydraulic conductivity and effective diffusion coefficient. Unlike other material properties such as porosity, density, the hydraulic conductivities (WSRC-STI-2007-00369) and effective diffusion coefficients of the cementitious materials associated with FTF closure are expected to change over time. The concrete and grout hydraulic conductivities are assumed to increase by a factor of one-hundred due to degradation (WSRC-STI-2007-00607). The effective diffusion coefficient for grout and concrete is assumed to increase by a factor of seven, which is approximately the same ratio as the difference between un-degraded grout/concrete [diffusion coefficient of 8E-7 cm/s (SRNL-ESB-2007-00034)] and backfill (diffusion coefficient of 5.3E-6 cm^2/s). Degraded grout/concrete is modeled as taking on the physical properties of the surrounding backfill. The expected degradation timing for the tank cementitious materials can vary dependant on tank type. Provided below is a summary of the degradation approach used for each tank type utilizing the concrete penetration depth modeling in WSRC-STI-2007-00607. The timing of the degradation of the tank cementitious materials is detailed in Table 1 [Degradation Transition Times (Years) by Tank Type] for the various tank types. The table shows at what point in time the applicable cementitious material (grout or concrete) transitions from the initial state to a degrading state to a fully degraded state.

Table 1 – Degradation Transition Times (Years) by Tank Type

Cementitious Material Lifetimes	Type I Tank	Type III Tank	Type IIIA Tank	Type IV Tank
FTF Spec Fill Grout Lifetime (Initial Properties)	0 - 2,600	0 - 5,000	0 - 4,800	0 - 800
Degrading FTF Spec Fill Grout Lifetime	2,600 - 13,000	5,000 - 18,900	4,800 - 18,700	800 - 63,800
Fully Degraded FTF Spec Fill Grout Lifetime	13,000	18,900	18,700	63,800
FTF Aged Concrete Lifetime (Initial Properties)	0 - 1,300	0 - 2,500	0 - 2,400	0 - 400
Degrading FTF Aged Concrete Lifetime	1,300 - 2,600	2,500 - 5,000	2,400 - 4,800	400 - 800
Fully Degraded FTF Aged Concrete Lifetime	2,600	5,000	4,800	800

Tanks with Steel (Cooling Coils)

Type I, III & IIIA tanks contain cooling coils, hence carbonation was identified as the most aggressive chemical degradation mechanism. Due to the carbonation effect, the permeability of the concrete will increase and the concrete will lose its strength. Concrete degradation was assumed to start once the carbonation effect reaches the one-half span of the actual concrete thickness. For Type I tanks the thickness of the thinnest side was 22 inches, so it was assumed that degradation will begin once the thickness is reduced to 11 inches. A similar approach was applied to the Type III and IIIA tanks (see

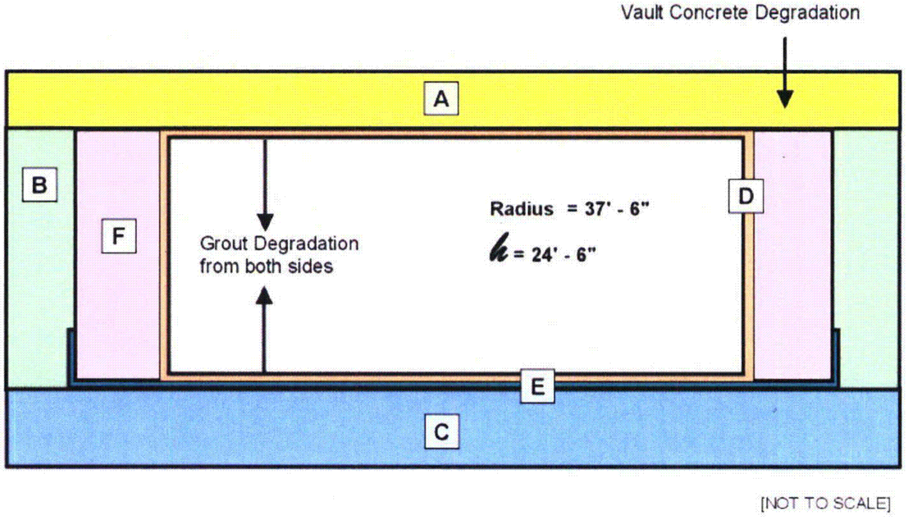
Figure 2 and 3 for concrete thickness). Also, it was assumed that degradation will start from the exposed side of the concrete, as compared to the liner protected side.

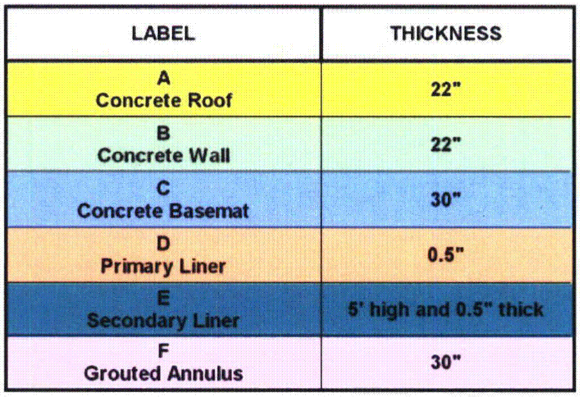
Tanks that contain cooling coils will experience carbonation after the tank has corroded or after fast flow pathways have developed. The rate of carbonation will be slightly faster than that estimated for the vault concrete because the porosity of the grout is slightly higher. It was assumed that the grout will start degrading once the carbonation effect has traversed the vault concrete and reached the grout. The degradation effect for grout will start from all sides, vertically and horizontally. It is expected that degradation for the grout will start simultaneously from all directions. However vertical degradation as shown in Figures 1, 2 and 3 was considered for this analysis because it was the critical driver for the grout degradation process based on the closed tanks dimensions. Additional details relating to Type I, III and IIIA tank specifics are provided below:

Type I Tanks

The tank annulus, primary liner and secondary liner were assumed to have a negligible impact on concrete/grout degradation (i.e., no credit was taken for the liners). The vault concrete degradation was calculated using the thinnest side (the concrete roof which is 22 inches). Grout degradation was assumed to have a similar effect (i.e., time to achieve degradation) from both sides and the grout was assumed to fully degrade in the middle of the actual grouted height, which is approximately 147 inches.

Figure 1 – Type I Tank Concrete Grout Degradation



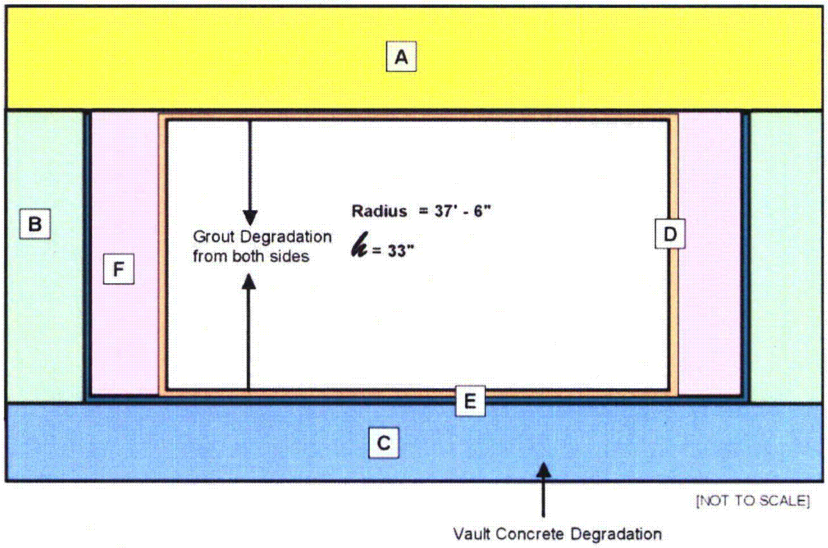


LABEL	THICKNESS
A Concrete Roof	22"
B Concrete Wall	22"
C Concrete Basemat	30"
D Primary Liner	0.5"
E Secondary Liner	5' high and 0.5" thick
F Grouted Annulus	30"

Type III/IIIA Tanks

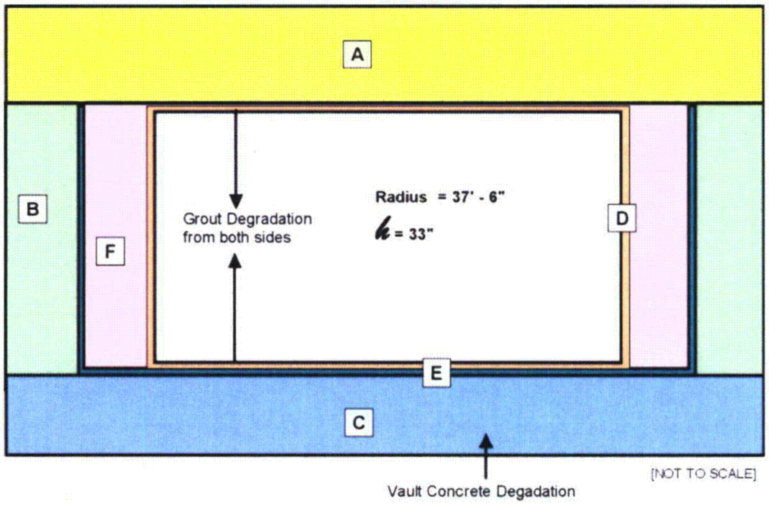
The tank annulus, primary and secondary liners were assumed to have a negligible impact on concrete/grout degradation (i.e., no credit was taken for the liners). The vault concrete degradation was calculated using the thinnest side (the concrete basemat, which is 42 inches for Type III and 41 inches for Type IIIA). Grout degradation was assumed to have a similar effect (i.e., time to achieve degradation) from both sides and the grout was assumed to fully degrade in the middle of the actual grouted height, which is approximately 198 inches.

Figure 2 – Type III Tank Concrete Grout Degradation



LABEL	THICKNESS
A Concrete Roof	48"
B Concrete Wall	30"
C Concrete Basemat	42"
D Primary Liner	0.5"
E Secondary Liner	3/8"
F Grouted Annulus	30"

Figure 3 – Type IIIA Tank Concrete Grout Degradation



LABEL	THICKNESS
A Concrete Roof	48"
B Concrete Wall	30"
C Concrete Basemat	41"
D Primary Liner	0.5"
E Secondary Liner	3/8"
F Grouted Annulus	30"

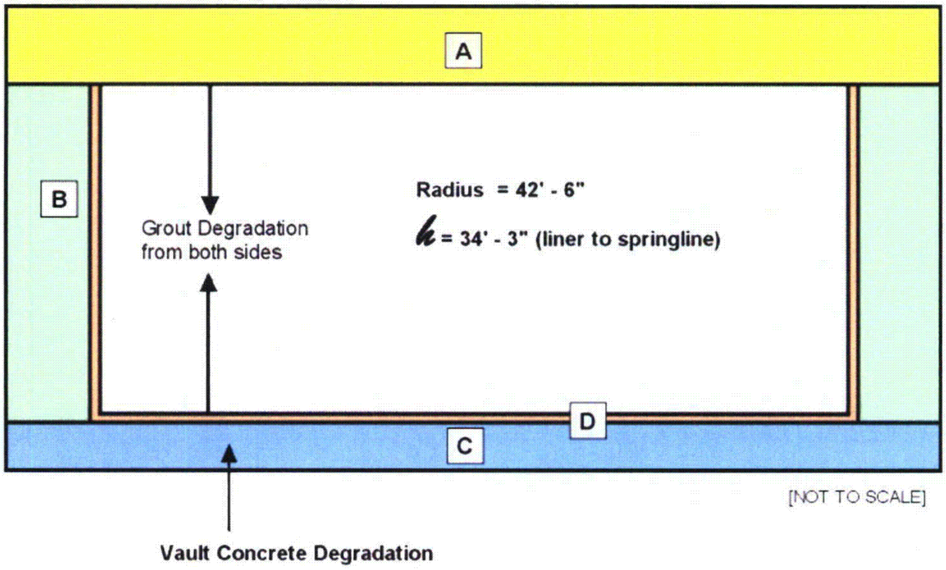
Tanks without Cooling Coils

Type IV tanks contain no cooling coils, hence calcium leaching / acid attack was considered as the major source of degradation. The estimated depth of penetration for the representative fill grout from calcium leaching / acid attack was 8.2cm (3.23 inches) after 1000 years. The rate of attack depends on the flow rate and chemistry of the water contacting the grout, temperature and whether the water flows through or over the material. The rate of attack also depends on the availability of calcium hydroxide in the grout. Carbonation will play a major role in vault concrete degradation.

Type IV Tanks

The tank grouted height was measured from the tank bottom to the spring line and the tank dome height was not taken in consideration while calculating degradation. The vault concrete degradation was calculated using the effective thickness (the concrete basemat which is approximately 6.9 inches). No credit was taken for the liner, which was assumed to have a negligible impact while calculating concrete/grout degradation. Grout degradation was assumed to have a similar effect (i.e., time to achieve degradation) from all sides and the grout was assumed to fully degrade in the middle of the actual grouted height, which is approximately 206 inches.

Figure 4 – Type IV Tank Concrete Grout Degradation



LABEL	THICKNESS
A Concrete Roof	7"
B Concrete Wall	7"
C Concrete Basemat	6.9025"
D Primary Liner	0.375"

References:

1) WSRC-STI-2007-00607, Langton, C, Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project, Revision 0, September 2007
2) WSRC-STI-2007-00369, Dixon, K / Phifer, M, Hydraulic and Physical Properties of Tank Grouts for FTF Closure, Revision 0, October 2007
3) SRNL-ESB-2007-00034, Dixon, K / Phifer. M. Recommended Effective Diffusion Coefficient for FTF Base Mat Surrogate and Tank Grouts, October 2007

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