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H-Area Tank Farm Grout and Concrete Degradation Modeling Information

The purpose of this memorandum is to document the cementitious material (i.e., grout and concrete) degradation assumptions that will be used in H-Area Tank Farm (HTF) Performance Assessment (PA) modeling. The degradation assumptions are based principally upon penetration depth modeling (thickness of affected material) from SRNL-STI-2010-00035.

Penetration Depth Modeling

According to SRNL-STI-2010-00035, the current Savannah River Site (SRS) HTF 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 on unsaturated concrete and grout. Carbonation was found to result in the greatest penetration as a function of time. For material with the porosity of the surrogate basemat concrete, 16.8 volume percent, the depth of penetration from carbonation was estimated to be 21 cm (8.27 inches) after 1,000 years. The estimated depth of penetration for the representative tank fill grout from carbonation reactions was 36 cm (14.17 inches) after 1,000 years. These values were applied to Type I, II, III, and IIIA tanks. For Type IV tanks, because they contain no cooling coils, the estimated depth of penetration for the representative fill grout was 8.2 cm (3.23 inches) after 1,000 years.

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 through the concrete. Based on calculated tank corrosion rates, a lag time is anticipated before carbonate actually contacts the grout and the carbonation front advances to the cooling coils.

For saturated concrete, acid leaching (i.e., decalcification) was the most aggressive degradation mechanism. The depth of severe decalcification at 1,000 years exposure was 6.5 cm (2.56 inches) for the surrogate vault concrete. Although several of the HTF tanks are located either within or below the water table, (Type I completely submerged, Type II with tank base below water table) the more conservative depth of penetration from carbonation, (21 cm [8.27 inches] after 1,000 years) was used.

Provided below is a summary of the degradation approach used for each tank type utilizing the concrete penetration depth information in SRNL-STI-2010-00035. The timing of the degradation of the tank cementitious materials is detailed in Table 1 for the various tank types. The table shows at what point in time the applicable cementitious material (grout or concrete) transitions from an initial state to a degrading period to a fully degraded state.

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

Cementious Material Stages	Type I	Type II	Type III	Type IIIA	Type IV
HTF Fill Grout (Initial Properties)	0 - 2,700	0 - 5,100	0 - 5,100	0 - 5,000	0 - 800
Degrading HTF Fill Grout	2,700 - 13,200	5,100 – 16,700	5,100 – 19,200	5,000 – 19,100	800 – 64,400
Fully Degraded HTF Fill Grout	13,200	16,700	19,200	19,100	64,400
HTF Concrete (Initial Properties)	0 – 1,350	0 – 2,550	2,550	0 – 2,500	0 - 400
Degrading HTF Aged Concrete	1,350 – 2,700	2,550 – 5,100	2,550 – 5,100	2,500 – 5,000	400 - 800
Fully Degraded HTF Aged Concrete	2,700	5,100	5,100	5,000	800

Tanks With Steel (Cooling Coils)

Type I, II, 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 (see Figure 1). A similar approach was applied to the Type II, III, and IIIA tanks (see Figures 2, 3, and 4 for concrete thickness). Also, it was assumed that degradation will start from the outside of the concrete, as compared to the inner liner protected side.

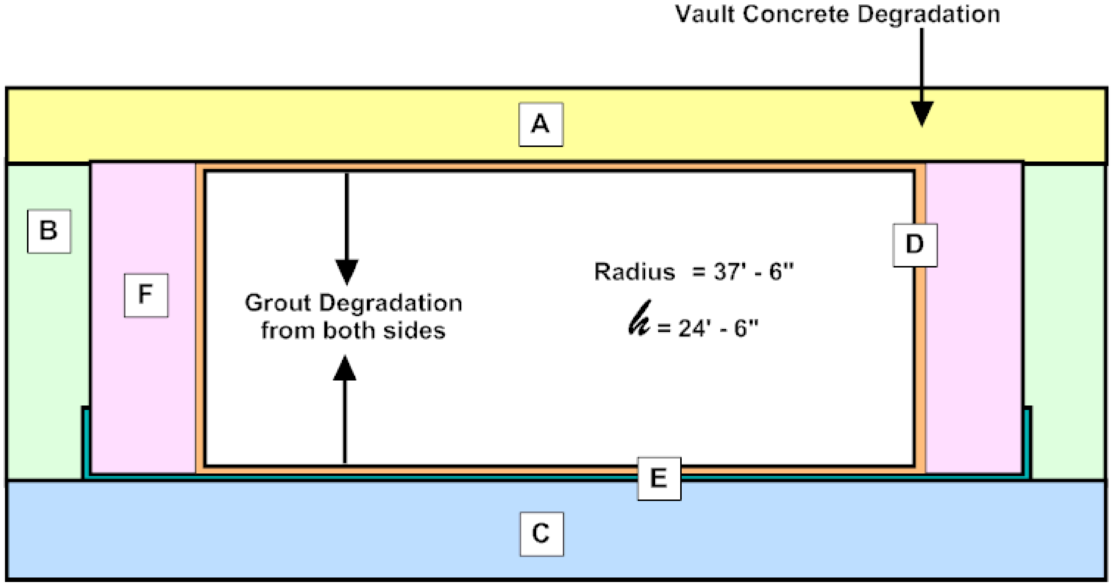
Tanks that contain cooling coils will experience carbonation after the tank has corroded or after fast flow pathways have developed. The rate of carbonation will be slightly faster than that estimated for the vault concrete because the porosity of the grout is slightly higher.

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, 3, and 4 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, II, 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



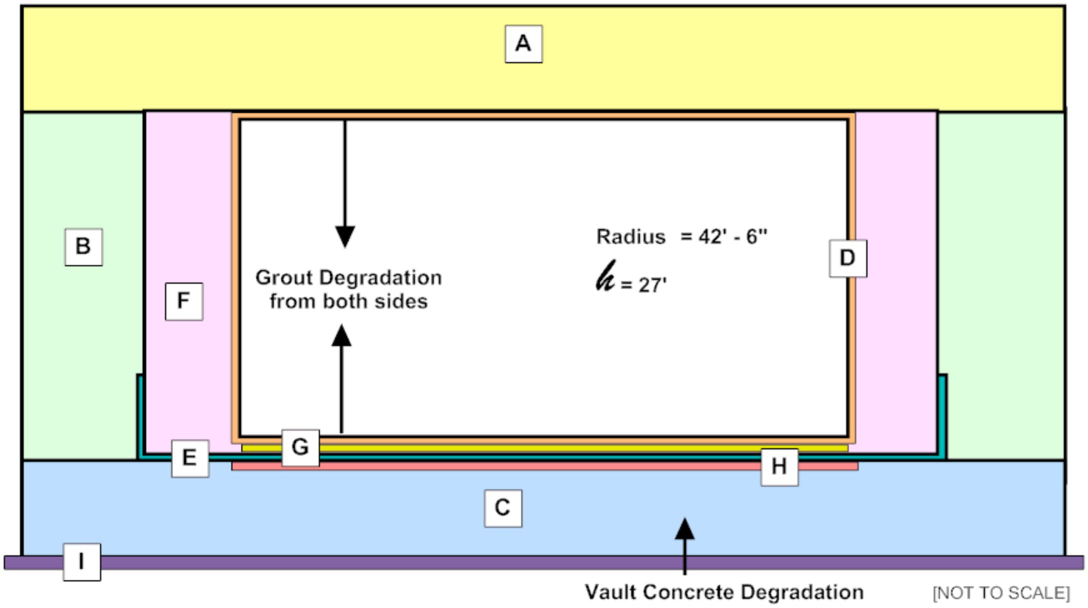
[NOT TO SCALE]

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 II 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 primary and secondary sand liner beds were also not included in this assessment as they are not affected by carbonation. In addition, for conservatism, the 6 inch thick working slab below the basemat was not included in this assessment. The vault concrete degradation was calculated using the thinnest side (the concrete basemat which is 42 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 162 inches.

Figure 2 – Type II Tank Concrete Grout Degradation

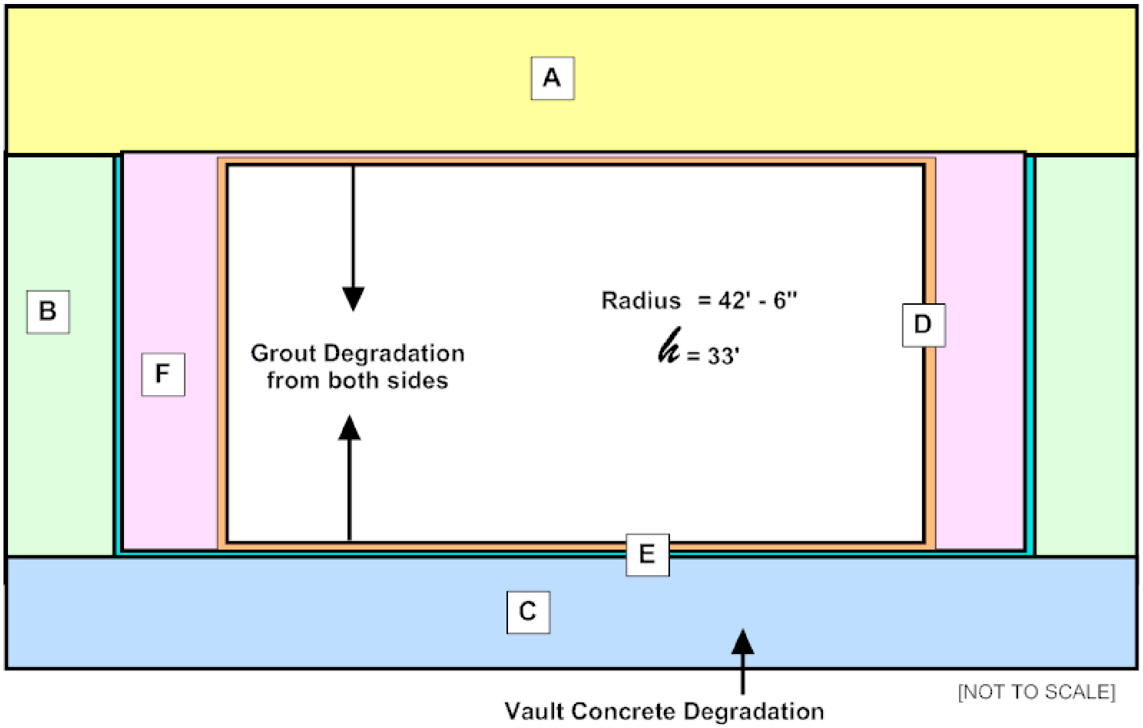


LABEL	THICKNESS
A Concrete Roof	45"
B Concrete Wall	33"
C Concrete Basemat	42"
D Primary Liner	0.5"
E Secondary Liner	5' high and 0.5" thick
F Grouted Annulus	30.625"
G Primary Liner Sand Bed	1"
H Secondary Liner Sand Bed	1"
I Concrete Working Slab	6"

Type III/IIIA Tanks

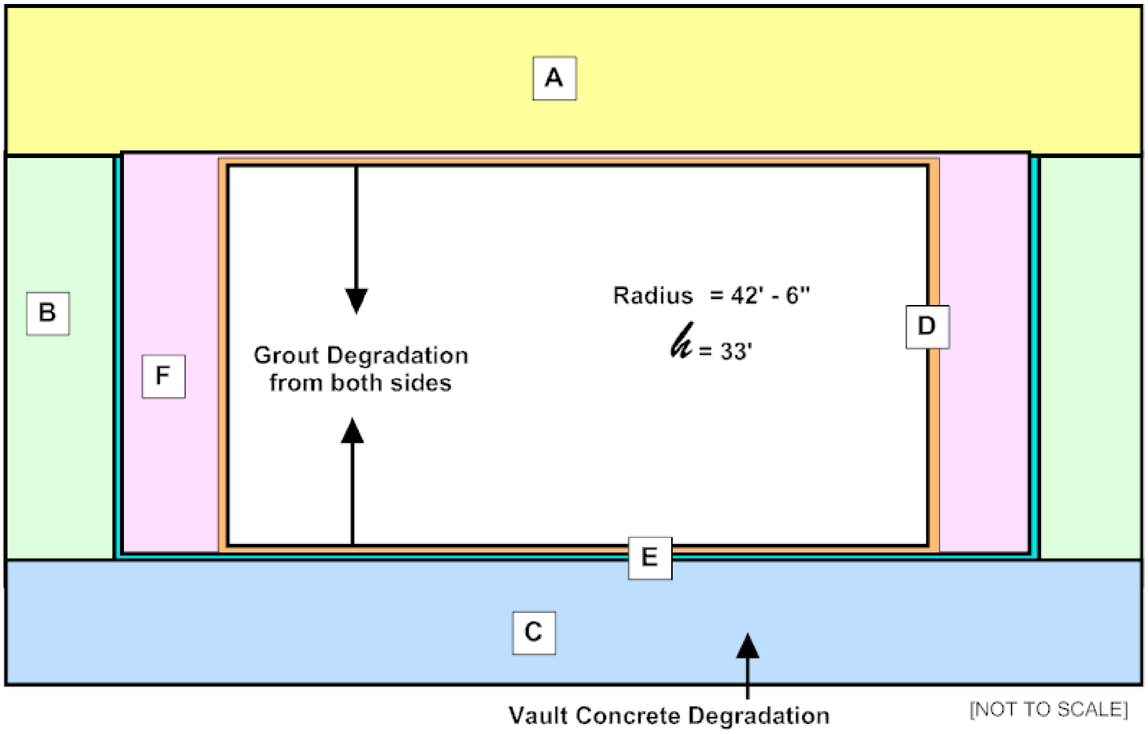
The tank annulus, primary and secondary liners were assumed to have a negligible impact on concrete/grout degradation (i.e., no credit was taken for the liners). The vault concrete degradation was calculated using the thinnest side (the concrete basemat, which is 42 inches for Type III and 41 inches 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 3 – 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	0.375"
F Grouted Annulus	30"

Figure 4 – Type IIIA Tank Concrete Grout Degradation



LABEL	THICKNESS
A Concrete Roof	48"
B Concrete Wall	30"
C Concrete Basemat	41" (Typical) (43" - Tanks 35 - 37)
D Primary Liner	0.5"
E Secondary Liner	0.375"
F Grouted Annulus	30"

Tanks Without Cooling Coils

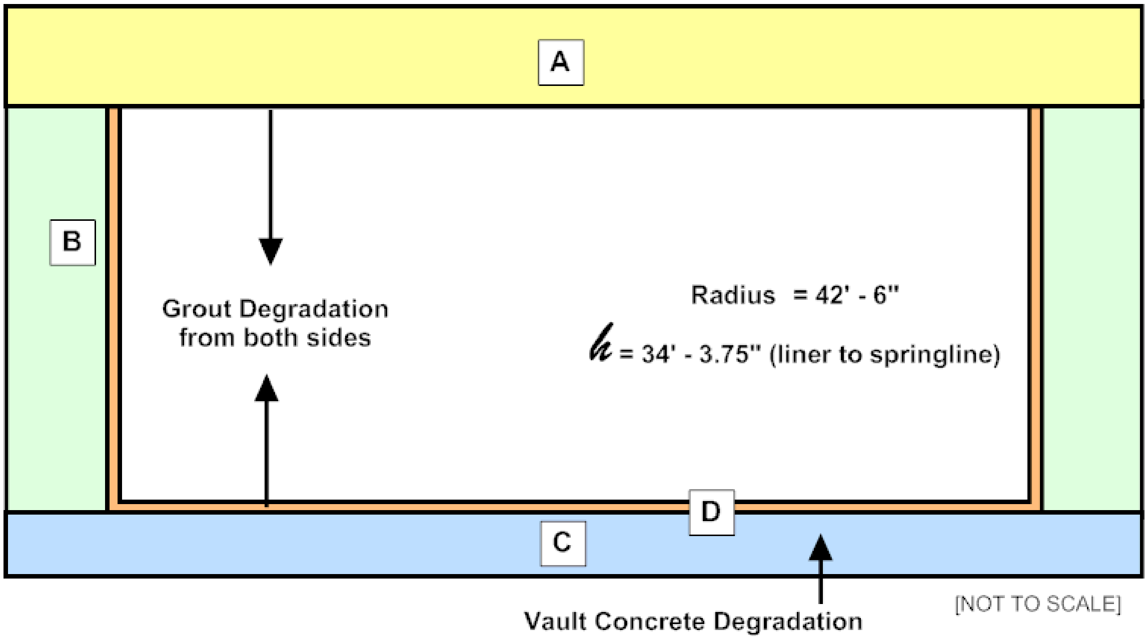
Type IV tanks contain no cooling coils, hence calcium leaching/acid attack was considered as the major source of degradation. The estimated depth of penetration for the representative fill grout from calcium leaching/acid attack was 8.2 cm (3.23 inches) after 1,000 years. The rate of attack depends on 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.

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 Figure 5 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 IV tank specifics are provided below:

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 5 – Type IV Tank Concrete Grout Degradation



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

References:

SRNL-STI-2010-00035, Langton, C. A., *Chemical Degradation Assessment for the H-Area Tank Farm Concrete Tanks and Fill Grouts*, Savannah River Site, Aiken, SC, Rev. 0, March 2010.