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Key Words:
E-Area
Engineered Trench
B-25 Box

Retention:
Permanent

CORROSION AND POTENTIAL SUBSIDENCE SCENARIOS FOR BURIED B-25 WASTE CONTAINERS (U)

William E. Jones and Mark A. Phifer
Savannah River Technology Center

SEPTEMBER 2002

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under
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1.0 INTRODU CTION

This report describes various scenarios to be modeled for static loading of B-25 containers in Engineered Trench #1 (ET) at the Department of Energy's (DOE's) Savannah River Site in Aiken, South Carolina. Scenario information includes the static load to be used, estimated B-25 steel-volume loss with time due to corrosion, and waste characteristics.

The term "steel-volume loss" used herein refers to loss of original steel, not total volume-loss. Steel corrosion products may produce a net volume increase compared to the original steel volume, as Nozaki, et al. (2001) have pointed out. But corrosion products are assumed to contribute no structural strength. The values identified here for percent corrosion will be translated in structural finite element modeling to a remaining thickness of the B-25 wall, lid, or bottom (i.e., strength). Therefore, the term steel-volume loss is used.

The three steel-volume loss estimation methods are based on corrosion rates observed in an actual B-25 container buried near ET for eight years (Dunn, 2002), using best professional judgement. Projecting corrosion rates observed over a relatively short time forward over a much longer time into the future necessitates accepting some uncertainty. Kerry Dunn, who performed the B-25 corrosion study in 2001, has discussed the steel volume-loss-over-time issue with corrosion experts within SRTC and performed a literature search for relevant information. She has verified that the approaches taken here are reasonable, and the estimates derived by these approaches are within the boundaries indicated by her research.

"The literature on coupled chemical-mechanical processes in waste disposal systems is extremely sparse." (Nozaki et al., 2001). In fact, Nozaki, et al. (2001) is one of the few studies similar to this one. They evaluate glass and stainless steel corrosion in the arid environment of DOE's Hanford Site in Washington State. Their assumed stainless steel corrosion rates are on the order of 0.039 to 0.0039 mils per year (mpy). These arid, stainless steel corrosion rates seem to correspond reasonably with the more rapid, humid environment, low-carbon steel corrosion rates of 2.6 to 0.63 mpy observed in Dunn (2002).

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2.0 DISCUSSION

2.1 STATIC LOADING SCENARIOS

Two static loading scenarios will be modeled. The modeling objective is to identify subsidence resulting from static loads over the stacked B-25 boxes and the “thinning” (i.e., steel-volume/structural strength loss due to corrosion) of the B-25 lids, bottoms, and sides. Various B-25 steel thicknesses will be selected from the volume-loss vs. time curves derived from the Dunn (2002) corrosion study. The results will be used to estimate the amount of subsidence that might be expected at a given time following burial.

The first scenario involves placement of a 4 to 6-ft thick interim soil cover over the Engineered Trench for 25 years, followed by construction of the kaolin cap outlined in the closure plan (Cook, et al., 2000). Load values to be used for the interim soil cover and kaolin cap scenario are presented in Table 1.

The second scenario involves the following four stages:

1) Placement of a 4 to 6-foot thick interim soil cover over the Engineered Trench for 25 years.

2) Followed by construction of a temporary cap. The temporary cap will remain in place until a static surcharge on the trench (i.e. placement of a temporary, 25-feet-thick soil layer on the trench) can effectively produce consolidation of the B-25s and their contents.

3) When static surcharging can effectively produce consolidation, the temporary cap will be removed and the static surcharge will be placed on the trench for approximately 3 to 6 months.

4) After static surcharging is complete, the surcharge will be removed and the kaolin cap outlined in the closure plan will be constructed.

The objective of this scenario is to estimate the time (after burial) at which static surcharge might be expected to effectively consolidate the B-25 contents. Additionally, various surcharge thicknesses other than 25 feet can be evaluated to estimate the minimal necessary thickness. Load values to be used for the static surcharge scenario are presented in Table 2.

Table 1. Interim Cover and Kaolin Cap Soil Loading

Layer [1]	Average Thickness [1] (ft)	Dry Bulk Density, ρ_b (psf - g/cm^3)	Volumetric Moisture Content, θ [7] (V/V)	Gravimetric Moisture Content, ω [9] (M_w/M_s)	Wet Bulk Density [10] (psf)	Load [11] (psf)
Interim Soil Cover for 25 years						
Interim Soil Cover	6 [2]	90 – 1.44 [2]	0.2400 [8]	0.167	105.0	630
					Total	630
Total Load on B-25 Lid = 23.00 sq ft × 630 psf = 14,490 lbs.						
Kaolin Cap after 25 years						
Topsoil	0.5	90 – 1.44 [3]	0.2743	0.190	107.1	53.55
Backfill	2.5	104 – 1.664 [4]	0.2984	0.179	122.6	306.5
Geotextile Fabric	-	-	-	-	-	-
Gravel	1.0	105 – 1.68 [5]	0.2124	0.126	118.2	118.2
Clay	2.5	92.6 – 1.4816 [6]	0.5600	0.378	127.6	319.0
Backfill	3	104 – 1.664 [4]	0.2400	0.144	119.0	357
Interim Soil Cover	6 [2]	90 – 1.44 [2]	0.2400 [8]	0.167	105.0	630
					Total	1,784.25
Total Load on B-25 Lid = 23.00 sq ft × 1,784.25 psf = 41,038 lbs.						

Table 1. References:

[1] Cook et al. (2000) and McDowell-Boyer et al. (2000)
[2] Phifer and Wilhite (2001)
[3] The dry bulk density of the topsoil was taken as the same as that of the interim soil cover
[4] Johnson and Jensen (2001)
[5] Glover (2001)
[6] Phifer (1991)
[7] WSRC-TR-2002-00236, draft
[8] The volumetric moisture content of the interim soil cover has been taken as the same as that of the backfill immediately above it.
[9] ω (%) = $((\theta \times \rho_w) / \rho_b) \times 100$ where $\rho_w = 1$ g/cm^3 (the density of water)
[10] Wet bulk density = $(1 + \omega) \times \rho_b$
[11] Load = Wet Bulk Density × Average Thickness

Table 2. Interim Cover, Temporary Cap, Static Surcharge, and Kaolin Cap Soil Loading

Layer [1]	Average Thickness [1] (ft)	Dry Bulk Density, ρ_b (psf - g/cm^3)	Volumetric Moisture Content, θ [7] (V/V)	Gravimetric Moisture Content, ω [10] (M_w/M_s)	Wet Bulk Density [11] (psf)	Load [12] (psf)
Interim Soil Cover for 25 years						
Interim Soil Cover	6 [2]	90 – 1.44 [2]	0.2400 [8]	0.167	105.0	630
					Total	630
Total Load on B-25 Lid = 23.00 sq ft × 630 psf = 14,490 lbs.						
Temporary Cap after 25 years						
Topsoil	0.5	90 – 1.44 [3]	0.2743	0.190	107.1	53.55
Backfill	0.5	104 – 1.664 [4]	0.2984	0.179	122.6	61.3
Geosynthetic Clay Liner	NA	NA	NA	NA	NA	0.84 [13]
Backfill	1	104 – 1.664 [4]	0.2984	0.179	122.6	122.6
Interim Soil Cover	6 [2]	90 – 1.44 [2]	0.2400 [8]	0.167	105.0	630
					Total	868.29
Total Load on B-25 Lid = 23.00 sq ft × 868.29 psf = 19,971 lbs.						
Static Surcharge for 3 to 6 Months						
Static Surcharge	25	90 – 1.44 [3]	0.2743 [9]	0.190	107.1	2677.5
Interim Soil Cover	6 [2]	90 – 1.44 [2]	0.2400 [8]	0.167	105.0	630
					Total	3307.5
Total Load on B-25 Lid = 23.00 sq ft × 3307.5 psf = 76,072 lbs.						
Kaolin Cap after Static Surcharging						
Topsoil	0.5	90 – 1.44 [3]	0.2743	0.190	107.1	53.55
Backfill	2.5	104 – 1.664 [4]	0.2984	0.179	122.6	306.5
Geotextile Fabric	-	-	-	-	-	-
Gravel	1.0	105 – 1.68 [5]	0.2124	0.126	118.2	118.2
Clay	2.5	92.6 – 1.4816 [6]	0.5600	0.378	127.6	319.0
Backfill	3	104 – 1.664 [4]	0.2400	0.144	119.0	357
Interim Soil Cover	6 [2]	90 – 1.44 [2]	0.2400 [8]	0.167	105.0	630
					Total	1,784.25
Total Load on B-25 Lid = 23.00 sq ft × 1,784.25 psf = 41,038 lbs.						

Table 2. References:

[1] Layers and thicknesses for the interim soil cover and kaolin cap are from Cook, et al. (2000) and McDowell-Boyer, et al. (2000)

[2] Phifer and Wilhite (2001)

[3] The dry bulk density of the topsoil and static surcharge was taken as the same as that of the interim soil cover.

[4] Johnson and Jensen (2001)

[5] Glover (2001)

[6] Phifer (1991)

[7] WSRC-TR-2002-00236, draft

Table 2. References - continued

[8] The volumetric moisture content of the interim soil cover for all configurations has been taken from the kaolin cap configuration and it has been assigned the same moisture content as that of the backfill immediately above it.
[9] The volumetric moisture content of the static surcharge has been assigned the same moisture content as that of the top soil.
[10] $\omega = ((\theta \times \rho_w) / \rho_b)$ where $\rho_w = 1$ g/cm^3 (the density of water)
[11] Wet bulk density = $(1 + \omega) \times \rho_b$
[12] Load = Wet Bulk Density × Average Thickness
[13] GSE product data sheet for Bentofix® NSL at http://www.gseworld.com/global/United States/Products/Bentodix/Index.htm

2.2 CONCEPTU AL MODEL

The current modeling assumes that each B-25 lid in the uppermost layer of B-25s will be pushed down into its respective container by approximately 1.5 ft due to soil loading and heavy equipment activities prior to dynamic compaction or static surcharge. (See waste strength characteristics section.) The area above each pushed-down lid contains soil that has forced the lid into its respective B-25. It is assumed that B-25 lids will remain in place for the underlying three layers of B-25s, and will degrade in the same manner as that observed in the corrosion study.

The B-25s containers are known to have from 10 percent to 90 percent void space (Phifer and Wilhite, 2001). Modeling requires that a single void space percentage be selected, therefore, the mid-point of the 10 percent to 90 percent range (50 percent waste material/50 percent void space) will be used. A variety of materials are disposed in the B-25 containers (from cloth to steel), with a known average uncompacted density of 178.5 kg/m^3 (Phifer and Wilhite, 2001). Modeling requires specific material strength values, therefore the waste characteristics used by Gong (2001) will be used. Out of a total height of 17.3 ft., the subsidence potential of a stack of four uncompacted B-25s after interim soil placement is 13.6 ft (Phifer and Wilhite, 2001). This suggests a possible 79 percent long-term reduction in waste and container height, compared to the original waste and container height of 17.3 ft.

A B-25 stack degradation conceptual model is presented in Figure 1. The diagram shows the lid of the uppermost B-25 being pushed into the B-25 by the time the 4 to 6-ft interim soil cover and overlying kaolin closure cap are constructed. Subsequent to the pitting-breakthrough period for the fork-lift-abraded zones located between the risers on the B-25 bottoms, waste and accumulated water begin moving downward through these opened areas onto the underlying B-25. As corrosion progresses, the waste material and underlying B-25 lid begin moving down into the underlying B-25. Downward movement of the interim soil layer/kaolin closure cap material eventually results in irregular surface subsidence and eventually compromises the cap's surface water infiltration control.

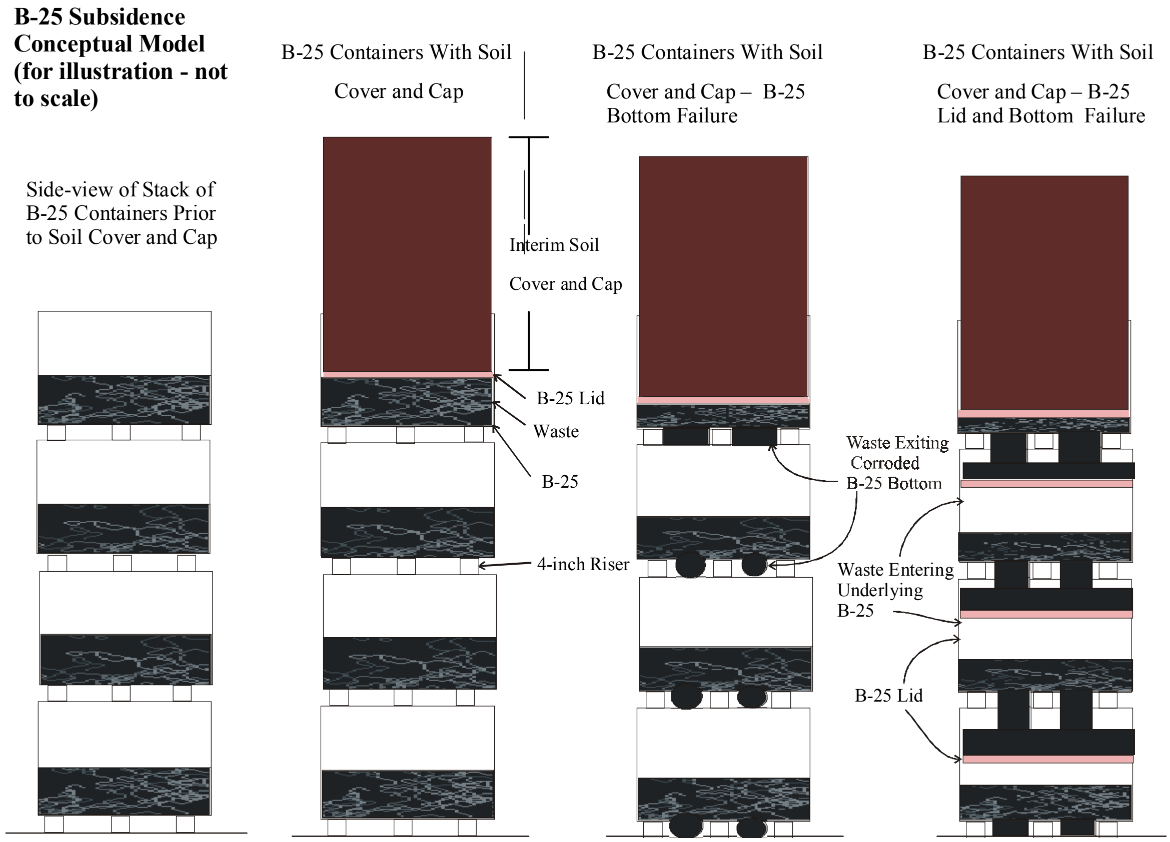

Figure 1. Subsidence Conceptual Model

2.3 CORROSION RATE MEASUREMENT

Dunn (2002) describes corrosion rates observed in a B-25 that had been buried for 8 years near the ET. The following is a summary of the B-25 lid, bottom, and sides corrosion observations and rates from Dunn (2002). Table 3 provides a summary of the Dunn (2002) corrosion rate data.

B-25 Lid

Two percent of the lid area was comprised of coalesced pitting with a corrosion rate of 2.4 mils per year (mpy). For a 14-gauge B-25 this would result in a reduction of 25 percent of the lid thickness in 8 years over this 2 percent of the lid area, and through-lid corrosion in 33 years. For a 12-gauge B-25, through-lid corrosion for this 2 percent of lid area will occur in about 46 years. The total lid area is 23.00 ft^2 (2.1 m^2). About 20 percent of the remaining lid area was comprised of scattered pitting, with a corrosion rate of 1.7 mpy, resulting in through-lid corrosion for a 14-gauge B-25 in about 46 years. Through-lid corrosion for this area for a 12-gauge B-25 will occur in about 64 years. 14 gauge steel is 0.075 inch thick, and 12 gauge is 0.1094 inch thick.

B-25 Bottom

The total bottom area is 23.00 ft^2 (2.1 m^2). Twenty-four percent of the bottom area (forklift abraded areas located between risers on the B-25 bottom) has a corrosion rate of 2.6 mpy (through-bottom in 30 years for 14 gauge and 42 years for 12 gauge). The remaining 76 percent of the bottom has a corrosion rate of 0.63 mpy, yielding a 6 percent reduction in wall thickness in 8 years, and through-bottom corrosion in 125 years for a 14-gauge B-25 (174 years for 12-gauge).

B-25 Sides

Scattered pitting of the B-25 sides was observed at a 1.3 mpy rate that cover about 20 percent of the surface area. This resulted in about a 13 percent reduction in thickness for a 14-gauge B-25 after 8 years burial, with through-wall penetration in about 61 years (84 years for 12 gauge). The total area for all four sides is 77.02 ft^2 (7.2 m^2).

Table 3. Summary Table (data from Dunn, 2002)

Part of B-25	Corrosion Type	Area of B-25 Part (sq ft)	12-gauge Thickness (ft)	Area of Corrosion (%)	Corrosion Rate (mils/yr)	Corrosion Rate (ft/yr)	Through Wall Corrosion (yr)
Sides	Scattered Pitting	77	0.0091	20	1.3	0.000108	84.2
Lid	Coalesced Pitting	23	0.0091	2	2.4	0.000200	45.6
	Scattered Pitting	23	0.0091	20	1.7	0.000142	64.4
Bottom	Forklift General	23	0.0091	24	2.6	0.000217	42.1
	Inside General	23	0.0091	76	0.63	0.000053	173.7

3.0 ESTIMATING STEEL-VOLUME LOSS OVER TIME

Corrosion rates can increase with time, remain constant over time (i.e., be linear), or decrease with time depending upon the specific conditions present. Since the data utilized to predict the future corrosion represents only one data point obtained at 8 years post-burial, it is not known whether the corrosion rate is increasing, constant, or decreasing over time. Therefore three methods have been used to estimate 12-gauge B-25 steel-volume loss over time for the lid, bottom, and sides in order to represent all possible corrosion rate scenarios. Each method is based on corrosion types and rates observed in one B-25 that was buried near the ET for eight years (Dunn, 2002). Because the best information available comprises a single study of a single B-25 for a system with numerous variables (different container and waste types, different initial states of corrosion, etc.) the corrosion rate estimates should be expected to provide very general predictions. The three methods used are thought to represent the range of possible corrosion scenarios, from the most aggressive (very conservative approach) to less aggressive (but reasonable, based on corrosion behavior principles).

3.1 CONSTANT VOLUME METHOD

The first method assumes that the corrosion rates observed by Dunn (2002) continue in a straight-line fashion until 100 percent of the steel is corroded. This method essentially represents the constant corrosion rate over time (i.e., linear). The B-25 lid, bottom, and sides are evaluated separately, due to the different corrosion types and rates. For each type of corrosion (coalesced pitting, general pitting, corrosion in the forklift tine abraded areas, and/or general corrosion) the area (sq.ft.) observed to be impacted in Dunn (2002) is converted to volume (cu.ft.) impacted by multiplying the area impacted by the B-25 thickness (ft.). The volume impacted is divided by the number of years for through-wall penetration. This yields a volume-loss rate (cu.ft/yr). At a given year since disposal, the volume loss for each type of corrosion can then be calculated and added together to yield total volume reduction (cu.ft.).

Lid Corrosion Rates

For the B-25 lid, corrosion begins with both coalesced pitting (through-wall penetration in 46 years) and scattered pitting (through-wall penetration in 64 years). This method assumes that the volume loss for the first 46 years is the volume-loss due to coalesced pitting plus volume-loss due to scattered pitting. After 46 years, when the area of coalesced pitting is completely corroded, coalesced pitting is no longer considered, and the rate of volume loss is assumed to be at the scattered pitting rate, continuing unchanged until 100 percent of the lid has corroded (314 years).

Bottom Corrosion Rates

It is assumed that all B-25 bottoms are affected by forklift abrasion and all degrade at the same rate as observed in the corrosion study. For the B-25 bottom, corrosion begins at a rapid rate (through-wall penetration in 42 years) occurring in the area between the risers that is abraded by forklift tines during B-25 handling, and with a much slower rate (through-wall penetration in 174 years) occurring over the remainder of the bottom. After 42 years, the corrosion in the abraded area is assumed to be complete. From this point, the rate of volume loss is assumed to be at the general corrosion rate and to occur uniformly across the entire remaining B-25 bottom, continuing unchanged until 100 percent of the bottom has corroded (174 years).

Side Corrosion Rates

For the B-25 sides, corrosion occurs by scattered pitting only. Through-wall penetration occurs in 84 years, continuing unchanged until 100 percent of the sides are corroded (420 years). All three of the volume-loss estimation methods described herein assume the corrosion rate of all B-25 sides is relatively uniform through time.

Volume-loss versus time estimates produced using the first method are provided in Figure 2. Table A-1 in Appendix A contains data and additional explanations for the volume-loss curves in Figure 2.

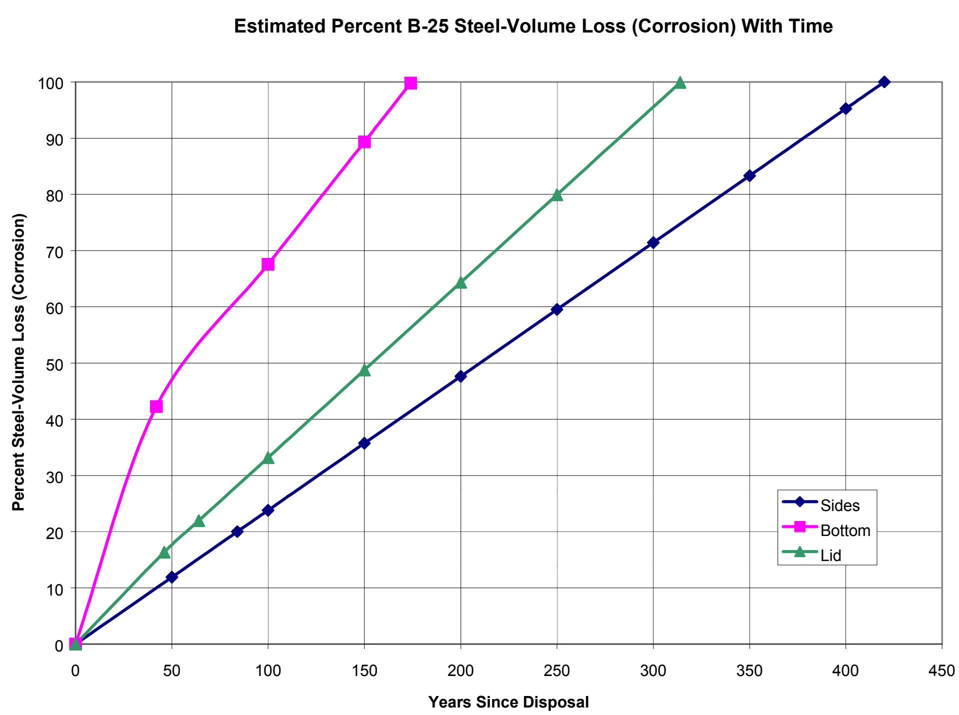

Figure 2. Estimated percent B-25 steel-volume loss with time (constant volume method)

3.2 CONTINUOUS INCIPIENT AREA METHOD

The continuous incipient area method essentially represents increasing corrosion over time. The following assumptions are made for the continuous incipient area method:

- Corrosion is initiated on a fixed percentage of the area each year for each applicable type of corrosion.
- Once corrosion is initiated on an area, the initial type of corrosion continues until that area is completely corroded away.
- The corrosion rates remain constant over time, and are based upon rates determined by Dunn (2002).

Volume-loss versus time estimates by the continuous incipient area method are provided in Figure 3. Table A-2 in Appendix A contains the data and explanations for the volume-loss curves in Figure 3.

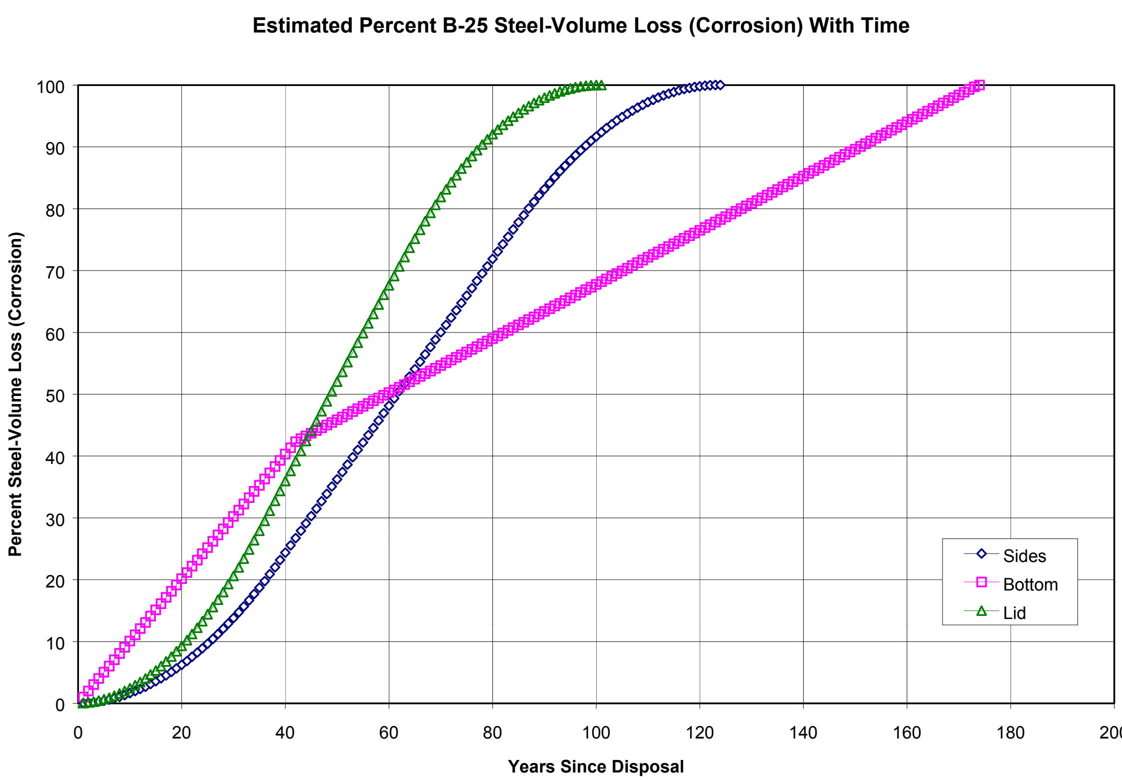

Figure 3. Estimated percent B-25 steel-volume loss with time (continuous incipient area method)

Lid Corrosion Rates
After eight years of burial, 2 percent of the B-25 box lid was determined to have been impacted by coalesced pitting with an estimated corrosion rate of 2.4 mpy, and 20 percent by general pitting with an estimated corrosion rate of 1.7 mpy (Dunn 2002). It is therefore assumed that coalesced pitting is initiated on 0.25 percent of the lid each year (i.e., 2 percent divided by 8 years) and corrodes at 2.4 mpy thereafter. It is further assumed that general pitting is initiated on 2.5 percent of the lid each year (i.e., 20 percent divided by 8 years) and corrodes at 1.7 mpy thereafter. Corrosion is assumed to initiate in this manner each year until 100 percent of the area is undergoing corrosion. In approximately 36 years, 100 percent is undergoing corrosion with approximately 9 percent of the area affected by coalesced pitting corrosion and 91 percent of the area affected by general pitting. With this method the lid is assumed to be 100 percent corroded in 101 years.

Bottom Corrosion Rates
After eight years of burial, 24 percent of the outside of the B-25 box bottom was subject to general corrosion induced by the use of forklifts with an estimated corrosion rate of 2.6 mpy; and 76 percent of the inside of the B-25 box bottom was subjected to general corrosion with an estimated corrosion rate of 0.63 mpy. For the bottom it is assumed that all corrosion is initiated in the first year (i.e., all 24 percent of the forklift corrosion and all 76 percent of the inside general corrosion begins the first year). With this method, the bottom is assumed to be 100 percent corroded in 174 years.

Side Corrosion Rates
After eight years of burial, 20 percent of the B-25 box sides were determined to have been impacted by general pitting, with an estimated corrosion rate of 1.3 mpy (Dunn, 2002). It is therefore assumed that coalesced pitting is initiated on 2.5 percent of the lid each year (i.e., 20 percent divided by 8 years) and corrodes at 1.3 mpy thereafter. Corrosion is assumed to initiate in this manner each year until 100 percent of the area is undergoing corrosion, which is assumed to occur in approximately 40 years. With this method, the bottom is assumed to be 100 percent corroded in 124 years.

3.3 SLOWING CORROSION METHOD

A third, volume-loss rate may be estimated by adjusting pit growth rate to slow (decrease) with time. According to Bradford (2001), maximum pit depth (p) varies with time (t) according to the equation:

$$p = kt^n$$

where k and n are constants.

If pitting does not slow, n equals 1. A higher value for n (approaching 0.8) applies to very poorly aerated soils. A higher n-value also applies to soils containing high concentrations of soluble salts, which may form soluble corrosion products rather than solid protective scale.

A lower *n*-value (around 0.1) applies to well-aerated soils, where the pitting rate readily slows (Bradford, 2001). For this study, a conservative *n*-value of 0.8, reflecting poorly aerated soils, has been selected based on the clayey, silty sands and apparent anaerobic conditions observed during the B-25 corrosion study (Dunn, 2001).

To employ this method, the same volume-loss rates (cu.ft./yr) developed using the constant volume method were used for each corrosion type. Total volume loss replaces "p" or maximum pit depth in the Bradford equation, the given year since disposal (t in the Bradford equation) is raised to the exponent of 0.8 and multiplied by the observed volume-loss rate (k in the Bradford equation).

So, the Bradford equation is rewritten as:

$$V_l = kt^{0.8}$$

where, V_l is the total volume lost (cu.ft.), k is the volume-loss rate (cu.ft./yr), and t is the time since disposal (year).

Total volume loss is the combination of the volumes of each type of ongoing corrosion. When one type of corrosion has consumed its designated volume, the remaining corrosion type continues at its given rate until the lid, bottom, or sides mass is 100 percent corroded.

Volume-loss versus time estimates by the third method are included in Figure 4. Tables A7 through A9 in Appendix A contain data and additional explanations for the volume-loss curves in Figure 4.

Lid

Lid corrosion begins with coalesced and scattered pitting processes. The coalesced pitting is completed after 237 years. Scattered pitting alone continues until 100 percent of the lid is corroded at 1,299 years.

Bottom

Bottom corrosion begins with rapid corrosion in the area between the risers that is abraded by the forklift tines and general corrosion occurring over the remainder of the bottom. The abraded area is 100 percent corroded after 209 years. General corrosion alone continues until the entire bottom is corroded after 462 years.

Sides

Only scattered pitting corrosion occurs on the sides. This type corrosion continues until the entire sides' volume is impacted after 1,901 years.

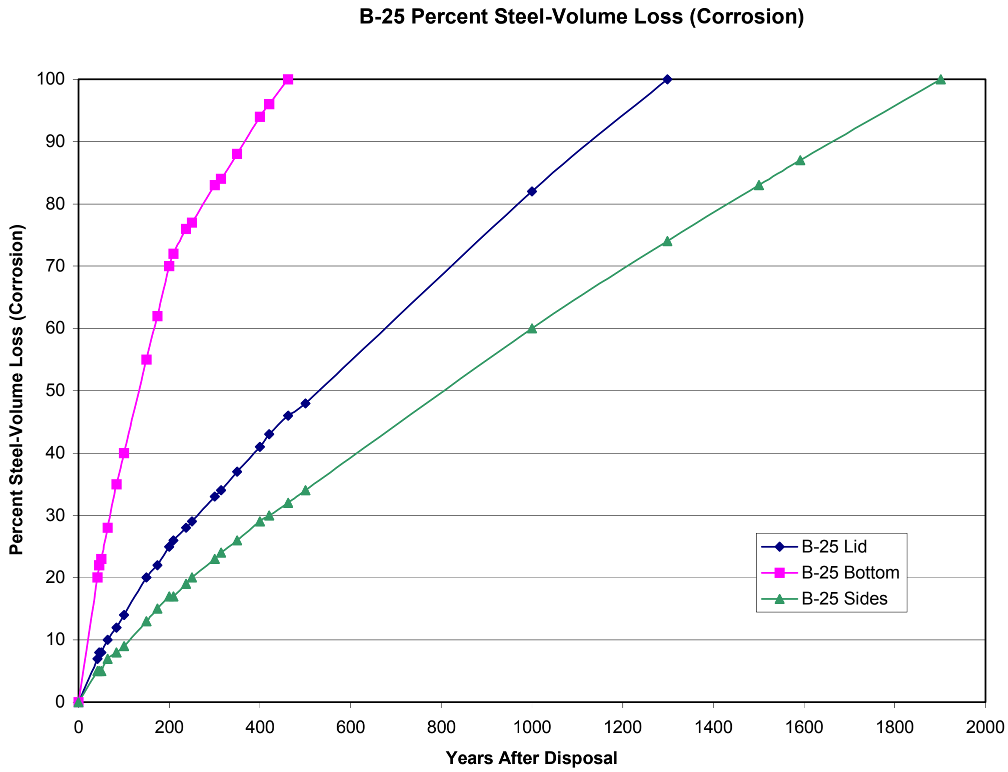

Figure 4. Estimated percent B-25 steel-volume loss with time (slowing corrosion method)

4.0 WASTE CHARACTERISTICS

Gong (2001) assumes two waste types for the initial finite element modeling. The modeling parameters for the two waste types are based on Celotex™ (a man-made packaging material manufactured from sugarcane fibers) properties. The average waste density of 0.1785 g/cm^3 (178.5 kg/m^3) documented in Phifer and Wilhite (2001) for uncompacted waste is used here because SRS Solid Waste Division plans on placing compacted waste in the E-Area Vaults and uncompacted waste in trenches (SWD-SWO-2001-00039, 2001). Although the ET will contain some compacted waste, the density for uncompacted waste is more representative of the waste density for materials going into trenches in the future, and is also a more conservative (i.e., will yield greater subsidence) value than a denser value.

The 178.5 kg/m^3 density falls below the Gong (2001) density values of 200.308 kg/m^3 and 240.308 kg/m^3. It is closest to Gong (2001)'s Waste Type 1 value, therefore the parameters for Waste Type 1 will be used. Those values are:

Parameter	**Waste Type 1**
Density (kg/m3)	200.308
Modulus of Elasticity (Pa)	2.54765E+08
Poisson's Ratio	0.0
Initial Yield Surface Position	1.15
Strength in Hydrostatic Tension (Pa)	2.02327E+04
Initial Yield Stress in Uniaxial Compression (Pa)	5.10040E+05

Waste Container Variability

Containers placed in the ET Phase 1 are primarily B-25 containers of the type described in Jones and Li (2001). A smaller number of other containers have also been placed. These containers include 55-gal. drums, B-12 containers (similar in construction to, and about half the size of B-25 containers), and blue B-25-size containers. Because the B-25 containers modeled by Gong (2001) are by far the most common type in the ET, these containers alone will continue to be modeled as most representative of ET container behavior.

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5.0 STATIC MODELING INPUT

Static structural finite element modeling reflects consolidation behavior resulting from static loading rather than dynamic compaction. The static modeling objective is to evaluate the behavior of B-25s, soil, and waste under certain static soil loads in regard to different B-25 steel thickness. As corrosion progresses, the steel in the B-25 lid, bottom, and sides is assumed to structurally behave as "thinner" steel. At some point, the load of the soil column overlaying a B-25 stack will overcome the weakening B-25 lids and bottoms and begin to move downward through the B-25 interiors. The steel-volume loss calculations presented in Figure 2, Figure 3, and Figure 4 have been used to identify several sets of lid, bottom, and sides' thickness that may be used in the static modeling. The B-25 thicknesses are summarized in Table 4 through Table 6.

Table 4. B-25 Thickness for Static Modeling (from Constant Volume Method)

Years Since Disposal	Lid Percent Loss	Lid Thickness (in.)	Bottom Percent Loss	Bottom Thickness (in.)	Sides Percent Loss	Sides Thickness (in.)
42	15	0.0930	42	0.0635	10	0.0985
64	22	0.0853	52	0.0525	15	0.0930
100	33	0.0733	68	0.0350	24	0.0831
150	49	0.0558	89	0.0120	36	0.0700
174	56	0.0481	100	0.0000	41	0.0645
237	76	0.0263	100	0.0000	56	0.0481

Table 5. B-25 Thickness for Static Modeling (from Continuous Incipient Area Method)

Years Since Disposal	Lid Percent Loss	Lid Thickness (in.)	Bottom Percent Loss	Bottom Thickness (in.)	Sides Percent Loss	Sides Thickness (in.)
42	39.2	0.0665	42.3	0.0631	26.7	0.0802
50	52	0.0525	45.9	0.0592	36.2	0.0698
68	79.3	0.0226	53.8	0.0505	57.6	0.0464
124	100	0.0000	78.3	0.0237	100	0.0000

Table 6. B-25 Thickness for Static Modeling (from Slowing Corrosion Method)

Years Since Disposal	Lid Percent Loss	Lid Thickness (in.)	Bottom Percent Loss	Bottom Thickness (in.)	Sides Percent Loss	Sides Thickness (in.)
64	10	0.0985	28	0.0788	7	0.1017
150	20	0.0875	55	0.0492	13	0.0952
250	29	0.0777	77	0.0252	20	0.0875
462	46	0.0591	100	0.0000	32	0.0744
1000	82	0.0197	100	0.0000	60	0.0438

6.0 SUMMARY

Three methods have been used to project the corrosion of ET B-25 containers through time. All three methods are based upon corrosion types and rates observed for a B-25 exhumed in May 2001 (Dunn, 2002).

The **Constant Volume Method** assumes that the observed annual volume of steel corroded continues into the future without change until the entire B-25 volume is corroded. This is considered to reflect a linear corrosion rate.

The **Continuous Incipient Area Method** converts the percent area observed impacted to an annual percent area that newly begins to corrode at the observed rates. This method essentially represents increasing corrosion over time.

The **Slowing Corrosion Method** follows the Constant Volume Method approach and raises the time since disposal (years) to an exponent of 0.8 to slow the corrosion rate with time. This method is based on a method presented in Bradford (2001), where maximum pit depth (p) varies with time (t) according to the equation:

$$p = kt^n$$

where k and n are constants.

For this study, p is replaced with total volume loss (V_l) in cu. ft., k is the observed rate of volume-loss in cu.ft./yr, and n is 0.8. This method is an effort to incorporate the potential for corrosion to slow with time, and presents less aggressive corrosion rates. Predictions using the three methods described herein are based on essentially one data point, the single exhumed B-25 described in Dunn (2002). Additional data points (i.e., exhuming and studying remaining buried B-25s in the future) would provide additional data points to indicate which of these three methods offers the best predictive tool.

Recommendations for quasi-static modeling of B-25 subsidence waste characteristics and steel thickness are included. Although the ET will have containers other than B-25s, only B-25s will be modeled since they are the most common container.

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APPENDIX A

STEEL-VOLUME LOSS ESTIMATES

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Table A1. Constant Volume Method – Lid Percent Volume Loss Over Time

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[2]	Thru-Wall Penetration (years)[1]	Steel-Volume Reduction Rate (vol. impacted/thru-wall yrs.)[3]	Year (since disposal)	Volume Reduction (cu. ft.)[4]	Volume Reduction (percent)[5]
Lid							0	0	0
							42	0.0313	15
(area = 23.00 sq. ft.)	Coalesced Pitting	2	0.46	0.0042	46	0.0000913 cu ft/yr	**46**	0.0343	**16**
(volume = 0.21 cu. ft.)	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	50	0.0369	18
(thickness = 0.009116 ft.)	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	**64**	0.0461	**22**
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	84	0.0592	28
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	100	0.0697	33
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	150	0.1024	49
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	174	0.1181	56
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	200	0.1351	64
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	209	0.1410	67
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	237	0.1594	76
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	250	0.1679	80
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	300	0.2006	96
	Scattered Pitting	20	4.6	0.0419	64	0.0006547 cu ft/yr	**314**	**0.2098**	**100**

Comments:

B-25 inside dimensions 3 ft 10 in. width x 6 ft. length x 3 ft 10 in. height.

B-25 lid, bottom, and side-wall thickness is 0.009116 ft.

2 percent lid area coalesced pitting (corrosion rate 2.4 mils/yr).

20 percent lid area comprised of scattered pits (corrosion rate 1.7 mils/yr).

Assume steel volume reduction rate is volume impacted/thru-wall penetration years.

Assume volume reduction is original volume minus volume reduction rate(s) x number of years since disposal.

Assume volume reduction at 64 yrs. is sum of coalesced pitting rate and scattered pitting rates volume losses.

Assume volume reduction rate after 64 years is at rate for scattered pitting only.

[1]From Dunn (2002)

[2]Area Impacted (sq. ft.) = Area Impacted (percent) x Area of lid, bottom or sides. Volume Impacted (cu. ft.) = Area Impacted (cu.ft.) x thickness (ft.).

[3]Steel-volume reduction rate = Volume Impacted (cu.ft.)/Thru-wall Penetration (years).

[4]Volume Reduction (cu. ft.) = Steel-Volume Reduction Rate(s) x Years Since Disposal (summed where more than one type corrosion occurring).

[5]Volume Reduction (percent) = (Volume Reduction (cu. ft.) / Total Volume of lid, bottom or sides) x 100.

Table A2. Constant Volume Method – Bottom Percent Volume Loss Over Time

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[2]	Thru-Wall Penetration (years)[1]	Steel-Volume Reduction Rate (vol. impacted/thru-wall yrs.)[3]	Year (since disposal)	Volume Reduction (cu. ft.)[4]	Volume Reduction (percent)[5]
Bottom	Abraided Area	24	5.52	0.0503	42	0.0011976 cu ft/yr	**42**	0.0888	**42**
(area = 23.00 sq. ft.)	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	46	0.0924	44
(volume = 0.21 cu.ft.)	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	50	0.0961	46
(thickness = 0.009116 ft.)	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	64	0.1089	52
	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	84	0.1272	61
	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	100	0.1419	68
	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	150	0.1876	89
	General Corrosion	76	17.48	0.1593	174	0.0009155 cu ft/yr	**174**	**0.2096**	**100**

Comments:

Abraded area corrosion rate 2.6 mils/yr. General corrosion rate 0.63 mils/yr.
Assume volume reduction at 42 years is total volume from forklift-abraded area rate plus volume prorated volume from general-corrosion area rate.
Assume volume reduction rate after 42 years is at rate for general corrosion.

[1]From Dunn (2002)

[2]Area Impacted (sq. ft.) = Area Impacted (percent) x Area of lid, bottom or sides. Volume Impacted (cu. ft.) = Area Impacted (cu.ft.) x thickness (ft.).

[3]Steel-volume reduction rate = Volume Impacted (cu.ft.)/Thru-wall Penetration (years).

[4]Volume Reduction (cu. ft.) = Steel-Volume Reduction Rate(s) x Years Since Disposal (summed where more than one type corrosion occurring).

[5]Volume Reduction (percent) = (Volume Reduction (cu. ft.) / Total Volume of lid, bottom or sides) x 100.

Table A3. Constant Volume Method – Sides Percent Volume Loss Over Time

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[2]	Thru-Wall Penetration (years)[1]	Steel-Volume Reduction Rate (vol. impacted/thru-wall yrs.)[3]	Year (since disposal)	Volume Reduction (cu. ft.)[4]	Volume Reduction (percent)[5]
Sides	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	42	0.0702	10
(area = 77.02)	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	46	0.0769	11
(volume = 0.702 cu.ft.)	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	50	0.0836	12
(thickness = 0.009116 ft.)	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	64	0.1070	15
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	**84**	0.1404	**20**
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	100	0.1671	24
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	150	0.2507	36
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	174	0.2908	41
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	200	0.3343	48
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	209	0.3493	50
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	237	0.3961	56
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	250	0.4179	60
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	300	0.5014	71
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	314	0.5248	75
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	350	0.5850	83
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	400	0.6686	95
	Scattered Pitting	20	15.404	0.1404	84	0.0016714 cu ft/yr	**420**	**0.7020**	**100**

Comments:

Scattered pitting corrosion rate 1.3 mils/yr.

Assume single, constant volume reduction rate.

[1]From Dunn (2002)

[2]Area Impacted (sq. ft.) = Area Impacted (percent) x Area of lid, bottom or sides. Volume Impacted (cu. ft.) = Area Impacted (cu.ft.) x thickness (ft.).

[3]Steel-volume reduction rate = Volume Impacted (cu.ft.)/Thru-wall Penetration (years).

[4]Volume Reduction (cu. ft.) = Steel-Volume Reduction Rate(s) x Years Since Disposal (summed where more than one type corrosion occurring).

[5]Volume Reduction (percent) = (Volume Reduction (cu. ft.) / Total Volume of lid, bottom or sides) x 100.

Table A4. Continuous Incipient Area Method - Lid Percent Volume Loss Over Time

Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Percent	0.04	0.13	0.27	0.44	0.66	0.93	1.24	1.60	1.99	2.44	2.93	3.46	4.03	4.65	5.32
Years	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Percent	6.03	6.78	7.58	8.42	9.31	10.24	11.22	12.24	13.30	14.41	15.56	16.76	18.00	19.28	20.61
Years	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Percent	21.99	23.41	24.87	26.38	27.93	29.53	31.14	32.75	34.36	35.97	37.59	39.20	40.81	42.42	44.03
Years	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Percent	45.64	47.25	48.85	50.44	52.03	53.61	55.19	56.76	58.33	59.89	61.44	62.99	64.53	66.07	67.61
Years	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Percent	69.13	70.66	72.17	73.68	75.16	76.60	77.99	79.34	80.64	81.90	83.12	84.29	85.41	86.49	87.53
Years	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
Percent	88.52	89.47	90.38	91.24	92.05	92.82	93.55	94.24	94.89	95.50	96.07	96.60	97.10	97.55	97.97
Years	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	**101**				
Percent	98.35	98.68	98.98	99.25	99.47	99.65	99.80	99.90	99.97	100.00	100.00				

Table A5. Continuous Incipient Area Method – Bottom Percent Volume Loss Over Time

Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Percent	1.01	2.02	3.02	4.03	5.04	6.05	7.06	8.06	9.07	10.08	11.09	12.10	13.10	14.11	15.12
Years	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Percent	16.13	17.14	18.14	19.15	20.16	21.17	22.18	23.19	24.19	25.20	26.21	27.22	28.23	29.23	30.24
Years	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Percent	31.25	32.26	33.27	34.27	35.28	36.29	37.30	38.31	39.31	40.32	41.33	42.34	42.82	43.26	43.69
Years	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Percent	44.13	44.57	45.01	45.45	45.88	46.32	46.76	47.20	47.63	48.07	48.51	48.95	49.38	49.82	50.26
Years	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Percent	50.70	51.13	51.57	52.01	52.45	52.89	53.32	53.76	54.20	54.64	55.07	55.51	55.95	56.39	56.82
Years	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
Percent	57.26	57.70	58.14	58.58	59.01	59.45	59.89	60.33	60.76	61.20	61.64	62.08	62.51	62.95	63.39
Years	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**	**103**	**104**	**105**
Percent	63.83	64.26	64.70	65.14	65.58	66.02	66.45	66.89	67.33	67.77	68.20	68.64	69.08	69.52	69.95
Years	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**
Percent	70.39	70.83	71.27	71.70	72.14	72.58	73.02	73.46	73.89	74.33	74.77	75.21	75.64	76.08	76.52
Years	**121**	**122**	**123**	**124**	**125**	**126**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**
Percent	76.96	77.39	77.83	78.27	78.71	79.15	79.58	80.02	80.46	80.90	81.33	81.77	82.21	82.65	83.08

Table A5. Continuous Incipient Area Method - Bottom Percent Volume Loss Over Time - continued

Years	**136**	**137**	**138**	**139**	**140**	**141**	**142**	**143**	**144**	**145**	**146**	**147**	**148**	**149**	**150**
Percent	83.52	83.96	84.40	84.83	85.27	85.71	86.15	86.59	87.02	87.46	87.90	88.34	88.77	89.21	89.65
Years	**151**	**152**	**153**	**154**	**155**	**156**	**157**	**158**	**159**	**160**	**161**	**162**	**163**	**164**	**165**
Percent	90.09	90.52	90.96	91.40	91.84	92.27	92.71	93.15	93.59	94.03	94.46	94.90	95.34	95.78	96.21
Years	**166**	**167**	**168**	**169**	**170**	**171**	**172**	**173**	**174**						
Percent	96.65	97.09	97.53	97.96	98.40	98.84	99.28	99.72	100.00						

Table A6. Continuous Incipient Area Method - Sides Percent Volume Loss Over Time

Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Percent	0.03	0.09	0.18	0.30	0.45	0.62	0.83	1.07	1.34	1.63	1.96	2.32	2.70	3.12	3.56
Years	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Percent	4.04	4.55	5.08	5.64	6.24	6.86	7.52	8.20	8.91	9.65	10.43	11.23	12.06	12.92	13.81
Years	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Percent	14.73	15.69	16.67	17.68	18.72	19.79	20.88	22.01	23.17	24.36	25.55	26.74	27.93	29.11	30.30
Years	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Percent	31.49	32.68	33.87	35.05	36.24	37.43	38.62	39.81	41.00	42.18	43.37	44.56	45.75	46.94	48.13
Years	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Percent	49.31	50.50	51.69	52.88	54.07	55.26	56.44	57.63	58.82	60.01	61.20	62.39	63.57	64.76	65.95
Years	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
Percent	67.14	68.33	69.52	70.70	71.89	73.08	74.27	75.46	76.65	77.81	78.94	80.05	81.12	82.16	83.18
Years	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**	**103**	**104**	**105**
Percent	84.16	85.12	86.04	86.94	87.81	88.64	89.45	90.23	90.97	91.69	92.38	93.04	93.67	94.26	94.83
Years	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**
Percent	95.37	95.88	96.36	96.81	97.23	97.62	97.98	98.32	98.62	98.89	99.13	99.34	99.53	99.68	99.80
Years	**121**	**122**	**123**	**124**											
Percent	99.90	99.96	100.00	100.00											

Table A7. Slowing Corrosion Method – Lid Percent Volume Loss Over Time

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[3]	Corrosion Rate (mils/yr)[1]	Corrosion Rate (cu.ft/yr)[4]	Year (since disposal)	Volume Corroded (cu. ft.)[5]	Volume Corroded (percent lid/bottom/ or sides)[6]	Total Volume Reduction (cu. ft)[7]	Total Volume Reduction (percent lid/ bottom/or sides)[8]
Lid							0				0
(area = 23.00 sq. ft.)	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	42	0.00182	0.86		
(volume = 0.21 cu. ft.)	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	42	0.01302	6.20	0.01484	7
(thickness = 0.009116 ft.)	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	46	0.00195	0.93		
(thickness = 109.4 mils)	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	46	0.01400	6.67	0.01596	8
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	50	0.00209	0.99		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	50	0.01497	7.13	0.01706	8
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	64	0.00254	1.21		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	64	0.01824	8.68	0.02078	10
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	84	0.00316	1.51		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	84	0.02267	10.80	0.02583	12
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	100	0.00363	1.73		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	100	0.02606	12.41	0.02970	14
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	150	0.00503	2.39		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	150	0.03605	17.17	0.04108	20
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	174	0.00566	2.70		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	174	0.04060	19.33	0.04626	22
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	200	0.00633	3.01		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	200	0.04538	21.61	0.05171	25
	Coalesced Pitting	2	0.46	0.0042	2.4	0.0000913	209	0.00656	3.12		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	209	0.04701	22.38	0.05356	26
	Coalesced Pitting	2	Coalesced Pitting Area 100% Corroded				237	0.00726	3.46		
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	237	0.05205	24.79	0.05931	28

Table A7. Slowing Corrosion Method - Lid Percent Volume Loss Over Time - continued

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[3]	Corrosion Rate (mils/yr)[1]	Corrosion Rate (cu.ft/yr)[4]	Year (since disposal)	Volume Corroded (cu. ft.)[5]	Volume Corroded (percent lid/bottom/ or sides)[6]	Total Volume Reduction (cu. ft)[7]	Total Volume Reduction (percent lid/ bottom/or sides)[8]
Lid							0				0
	Scattered Pitting	20	Scattered Pitting corrosion rate alone continues				250	0.05425	25.83	0.06151	29
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	300	0.06277	29.89	0.07003	33
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	314	0.06510	31.00	0.07236	34
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	350	0.07101	33.81	0.07826	37
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	400	0.07901	37.62	0.08627	41
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	420	0.08216	39.12	0.08942	43
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	462	0.08867	42.22	0.09592	46
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	500	0.09445	44.98	0.10171	48
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	1000	0.16445	78.31	0.17171	82
	Scattered Pitting	20	4.6	0.0419	1.7	0.0006547	**1299**	**0.20275**	**96.55**	**0.21001**	**100**

Comments:
[1]From Dunn (2002).
[2]Area impacted percent x total sq. ft. area of total lid, bottom, or 4-sides.
[3]Area impacted (sq. ft.) x thickness (0.009116 ft.).
[4]Volume impacted /number of years for through-wall penetration.
[5]Modified Bradford equation (vol corroded cu. ft = (years since disposal$^{0.7}$) x corrosion rate cu. ft/yr).
[6](Volume corroded for given corrosion type/total volume) x 100.
[7]Sum of the volumes of the various corrosion types.
[8]Total volume reduction (volume corroded)/ total lid, bottom, or 4-sides' volume.

Table A8. Slowing Corrosion Method – Bottom Percent Volume Loss Over Time

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[3]	Corrosion Rate (mils/yr)[1]	Corrosion Rate (cu.ft/yr)[4]	Year (since disposal)	Volume Corroded (cu. ft.)[5]	Volume Corroded (percent lid/bottom/ or sides)[6]	Total Volume Reduction (cu. ft)[7]	Total Volume Reduction (percent lid/ bottom/or sides)[8]
							0				0
Bottom	Abraided Area	24	5.52	0.0503	2.6	0.0011976	42	0.02382	11.34		
(area = 23.00 sq. ft.)	General Corrosion	76	17.48	0.1593	0.63	0.0009155	42	0.01821	8.67	0.04203	20
(volume = 0.21 cu.ft.)	Abraided Area	24	5.52	0.0503	2.6	0.0011976	46	0.02562	12.20		
(thickness = 0.009116 ft.)	General Corrosion	76	17.48	0.1593	0.63	0.0009155	46	0.01958	9.32	0.04520	22
(thickness = 109.4 mils)	Abraided Area	24	5.52	0.0503	2.6	0.0011976	50	0.02738	13.04		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	50	0.02093	9.97	0.04832	23
	Abraided Area	24	5.52	0.0503	2.6	0.0011976	64	0.03336	15.89		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	64	0.02550	12.14	0.05887	28
	Abraided Area	24	5.52	0.0503	2.6	0.0011976	84	0.04147	19.75		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	84	0.03170	15.10	0.07317	35
	Abraided Area	24	5.52	0.0503	2.6	0.0011976	100	0.04768	22.70		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	100	0.03645	17.36	0.08412	40
	Abraided Area	24	5.52	0.0503	2.6	0.0011976	150	0.06595	31.40		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	150	0.05041	24.01	0.11636	55
	Abraided Area	24	5.52	0.0503	2.6	0.0011976	174	0.07426	35.36		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	174	0.05677	27.03	0.13103	62
	Abraided Area	24	5.52	0.0503	2.6	0.0011976	200	0.08301	39.53		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	200	0.06346	30.22	0.14647	70
	Abraided Area	24	Abraded Area 100% corroded			0.0011976	209	0.08599	40.95		
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	209	0.06573	31.30	0.15172	72
	General Corrosion	76	General Corrosion alone continues			0.0009155	237	0.07269	34.61	0.15867	76
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	250	0.07586	36.12	0.16185	77

Table A8. Slowing Corrosion Method - Bottom Percent Volume Loss Over Time - continued

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[3]	Corrosion Rate (mils/yr)[1]	Corrosion Rate (cu.ft/yr)[4]	Year (since disposal)	Volume Corroded (cu. ft.)[5]	Volume Corroded (percent lid/bottom/ or sides)[6]	Total Volume Reduction (cu. ft)[7]	Total Volume Reduction (percent lid/ bottom/or sides)[8]
Bottom							0				0
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	300	0.08777	41.80	0.17376	83
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	314	0.09103	43.35	0.17702	84
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	350	0.09929	47.28	0.18528	88
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	400	0.11049	52.61	0.19647	94
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	420	0.11488	54.71	0.20087	96
	General Corrosion	76	17.48	0.1593	0.63	0.0009155	**462**	**0.12403**	**59.06**	**0.21001**	**100**

Comments:
[1]From Dunn (2002).
[2]Area impacted percent x total sq. ft. area of total lid, bottom, or 4-sides.
[3]Area impacted (sq. ft.) x thickness (0.009116 ft.).
[4]Volume impacted /number of years for through-wall penetration.
[5]Modified Bradford equation (vol corroded cu. ft = (years since disposal$^{0.7}$) x corrosion rate cu. ft/yr).
[6](Volume corroded for given corrosion type/total volume) x 100.
[7]Sum of the volumes of the various corrosion types.
[8]Total volume reduction (volume corroded)/ total lid, bottom, or 4-sides' volume.

Table A9. Slowing Corrosion Method – Sides Percent Volume Loss Over Time

B-25 Inside Area/Volume (sq. ft./cu. ft.)	Type Corrosion	Area Impacted (percent)[1]	Area Impacted (sq. ft.)[2]	Volume Impacted (cu. ft.)[3]	Corrosion Rate (mils/yr)[1]	Corrosion Rate (cu. ft/yr)[4]	Years (since disposal)	Volume Corroded (cu. ft.)[5]	Volume Corroded (percent lid/bottom/ or sides)[6]	Total Volume Reduction (cu. ft)[7]	Total Volume Reduction (percent lid/ bottom/or sides)[8]
							0				0
Sides	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	42	0.03324	4.74	0.03324	5
(area = 77.02)	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	46	0.03575	5.09	0.03575	5
(volume = 0.702 cu.ft.)	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	50	0.03822	5.44	0.03822	5
(thickness = 0.009116 ft.)	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	64	0.04656	6.63	0.04656	7
(thickness = 109.4 mils)	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	84	0.05788	8.24	0.05788	8
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	100	0.06654	9.48	0.06654	9
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	150	0.09204	13.11	0.09204	13
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	174	0.10364	14.76	0.10364	15
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	200	0.11585	16.50	0.11585	17
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	209	0.12000	17.09	0.12000	17
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	237	0.13270	18.90	0.13270	19
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	250	0.13849	19.73	0.13849	20
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	300	0.16024	22.83	0.16024	23
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	314	0.16620	23.67	0.16620	24
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	350	0.18127	25.82	0.18127	26
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	400	0.20171	28.73	0.20171	29
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	420	0.20974	29.88	0.20974	30
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	462	0.22636	32.24	0.22636	32
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	500	0.24113	34.35	0.24113	34
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	1000	0.41984	59.81	0.41984	60
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	1299	0.51757	73.73	0.51757	74
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	1500	0.58070	82.72	0.58070	83
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	1592	0.60902	86.76	0.60902	87
	Scattered Pitting	20	15.404	0.1404	1.3	0.0016714	**1901**	**0.70200**	**100.00**	**0.70200**	**100**