From: hth@lanl.gov on behalf of Todd Haagenstad [hth@lanl.gov]
Sent: Wednesday, December 14, 2005 4:33 PM
To: Owens, Kirk W.; roles@saic.com
Cc: ewithers@doeal.gov; 'Ron Rager'; goldberg@lanl.gov; rhull@lata.com; isaacson@lanl.gov; sradz@lanl.gov
Subject: Other SWEIS Data Call Deliverables

Attachments: Generals Tanks Investigation activities.doc; The General's Tanks Characterization Activities Documented Safety Analysis.pdf

Kirk/Gary,

Ron Rager asked me to send along this more detailed description of investigation activities. Also included is the DSA for the General's Tanks Characterization.

Let me know if you have any questions.

Todd Haagenstad
Environmental Characterization and Remediation
Environmental Stewardship Division
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(505) 665-2936

Initial Entry and atmosphere stabilization, and sampling

Activity Scope

This task represents office, field and laboratory activities for the 2 Generals Tanks within PRS 21-014 MDA A at TA-21. The project is planned to be implemented as part of Surveillance and Maintenance of the MDA A Nuclear Environmental Site (NES) in compliance with 10 CFR 830, and is the provides the data needed for successful stabilization and long term disposal of the remaining tank contents.

This scope sequentially includes an initial criticality review of the passive characterization data collected in Phase 1, preparation of a USQ and modification of the DSA to accommodate Phase 2 field activities into the NES SER, fabrication and installation of AEA equipment, mixing of the tank contents and collection of samples from the mixed contents uses the AEA technology. Analysis of the post mixing samples at AEA identify modifications required to equipment in order to perform final mixing and stabilization and confirm the initial RCRA determination.

This scope includes:
- Fabrication of AEA equipment (Phase 2 activity)
- Preparation of a Documented Safety Analysis (DSA) for the task work (for Phase 2 activities),
- Modifying the Work Plan, if necessary (for Phases 2-3 activities),
- Modifying the Waste Characterization Plan, if necessary (WCP for Phases 2-3 activities),
- Coordinating the project execution planning/strategy (for Phase 2),
- Preparing a SSHASP, IWD, QAP, and training (for Phase 2 activities),
- Operational Readiness Reviews (Phase 2)
- Installation of AEA equipment (Phase 2 field activity)
- Mixing of the tank contents (Phase 2 activity)
- Mixed contents sampling and analysis (Phase 2 activity),
- Prepare final mix design (Phase 2 activity)

The USQ process is required by 10 CFR 830, and will address hazards associated with implementing the proposed Phase 2 field activities. If necessary, the Work Plan and Sampling plan prepared in Phase 1 will be modified. New SSHASP and IWD will be prepared to accommodate the new field activities. Work will be performed according to IMP 300-00-00.

The justification for this task is to fulfill the requirements of 10 CFR 830 the Nuclear Safety Management and to provide data for final stabilization of the tanks contents..

Specific Work Elements:

General's Tanks (GT) Work Plan: Preparation of the work plan for entry into the tanks, characterizing the tank contents, and stabilizing the contents by in-place mixing. The work plan, which includes the site-specific Health and Safety Plan (SSHASP), waste management plan (WMP), sampling analysis plan (SAP), quality assurance plan (QAP) and training of workers under these plans.

Documented Safety Analysis: This activity consists of revising a draft DSA and expanding to include tank entry, atmosphere stabilization, and passive sampling, to replace the DOE approved S&M DSA. This includes a zero scoping meeting with SBO, NWIS, and DOE, 30%, 70%, 90%, draft Final and Final DSR and TSD preparation and reviews, and Implementation Plan preparation, review and approval.

Operational Readiness Review (ORR for Phase 1 - Access stabilization and passive characterization): Requirements of the readiness review are outlined in the readiness review checklist found in QP 5.3, current revision, Readiness Review Procedure for the Environmental Restoration Project. Primarily an ER subcontractor performs these activities. This activity consists of all logistical, supply procurement, subcontracting, equipment and supply procurement, permit(s) acquisition, and document preparation for the readiness review. Some of these preparation activities include:

a) Prepare and document the work performed through the Integrated Work Management (IWM) process, IMP 300-00-00.
b)Complete ESH-ID questionnaire for site activities at the General's Tanks within MDA A. All issues brought up by the ESH reviewers will be resolved prior to the readiness review.
c) Prepare and obtain approval of an IWD for the field activities. Requirements are found in the ER Project HASP, Revision 1, March 31, 1998, LPR 402-00-00.0 Worker Safety and Health, and others.
d) Prepare and obtain approval of a facility-tenant agreement with the Facility Management.
e) Obtain excavation permits and have utilities marked where appropriate. Requirements are found in LIR402-880-01, Excavation/Soil Disturbance Permit Process.
f) Obtain required permits, such as a Radiological Work Permit, Hot Burn Permit, and/or Special Work Permit. Other Special Work Permits can be found in other LIRs.
g) Coordinate and plan sampling activities with the Sample Management Organization (SMO).
h) Prepare and submit notifications to FSF, DOE, NMED, FMU, non-DOE property owners, Los Alamos County, etc, as appropriate.
i) Complete and verify training for all site workers, including LANL and other subcontractors.

Following preparation for the MSA and readiness review, a readiness review meeting will be held. All comments and issues arising from the readiness review meeting will be resolved prior to start of field work, and the readiness review checklist must be signed by the Project Leader, SMO representative, and Quality Program Project Leader. MSA documenting Memorandums of approval must be obtained from the RDL and RLM. A Laboratory readiness review will be prepared and conducted.

Field Implementation: A subcontractor will establish job-site controls including modification to the existing fence. Access will accommodate the Phase 2 and 3 operations. The tank access points will be designed by the subcontractor based on verified tank geometry and conditions, as well as the AEA equipment requirements. There will be three access locations in each tank. The design will establish adequate ventilation of the tanks to allow Phase 2 and 3 work to be accomplished without Level B PPE. The design will accommodate the AEA Fluidic System.

The subcontractor will fabricate and install the design modifications.

The subcontractor will fabricate a tube sampler capable of sampling the sludge at the six access locations. The subcontractor will sample the sludge and submit samples to the SMO for testing.

Data Summary Report: Following completion of analytical results, the data will be evaluated in order to confirm the RAD only assumption for the waste. The report will be shared with NMED in an effort to keep them informed of the contents of MDA A. It the sample results are shown to contain RCRA chemicals of concern, NMED would be notified, and an appropriate path forward negotiated.

Preliminary Engineering Design: The DOE Environmental Management (EM) program currently has a contract with a AEA Technologies for a proprietary system capable of providing tank heel sampling, mixing, removal or in-place grouting. A plant that can be modified to be capable of these operations is available at LANL. AEA will provide preliminary design and pilot testing of their modified equipment under the EM funded contract. The design takes into account the entry requirements into the tank, but is not inclusive of the actual excavation and general contracting requirements.

Estimating Assumptions and Exclusions for field construction activities:

1.Relied upon expertise from Joe Faldowski, AEA Technology
a.Design and engineering work to be accomplished with budget remaining on existing contract.
b.Experience gained at TA-50, following similar processes
c.Use of existing off-gasing skid will provide adequate service for both tanks; with following modifications (more economical than new equipment purchase):
i.New HEPA filters, plumbing, fittings, electrical supply, and possible instrumentation modifications
ii.Build platform to support equipment over tanks
iii.Remove, load onto truck, haul, unload and install on-site
iv.Six months of operating off-gasing skid (one-set of HEPA filters is adequate) will cover duration from initial access, testing, design, and actual treatment of the tanks.

d.Tanks are located 18 feet below grade. Assume need for some surface area removal, to lower the grade for equipment to operate closer to tank elevation and minimize pumping height.
e.Two additional 10-inch risers will be sufficient to access and treat the tanks (in addition to one current access point for each tank) for a total of three access points per tank. Survey team used to locate existing gas lines. Do not expect to have any interference from these lines, simply identify and mark for safety purposes.

Activity 2 Mixing and testing for cement design mix

Scope

This task represents office, field and laboratory activities for the 2 Generals Tanks within PRS 21-014 MDA A at TA-21. The project is planned to be implemented as part of Surveillance and Maintenance of the MDA A Nuclear Environmental Site (NES) in compliance with 10 CFR 830, and is the provides the data needed for successful stabilization and long term disposal of the remaining tank contents.

This scope sequentially includes an initial criticality review of the passive characterization data collected in Phase 1, preparation of a USQ and modification of the DSA to accommodate Phase 2 field activities into the NES SER, fabrication and installation of AEA equipment, mixing of the tank contents and collection of samples from the mixed contents uses the AEA technology. Analysis of the post mixing samples at AEA identify modifications required to equipment in order to perform final mixing and stabilization and confirm the initial RCRA determination.

This scope includes:
- Fabrication of AEA equipment (Phase 2 activity)
- Preparation of a Documented Safety Analysis (DSA) for the task work (for Phase 2 activities),
- Modifying the Work Plan, if necessary (for Phases 2-3 activities),
- Modifying the Waste Characterization Plan, if necessary (WCP for Phases 2-3 activities),
- Coordinating the project execution planning/strategy (for Phase 2),
- Preparing a SSHASP, IWD, QAP, and training (for Phase 2 activities),
- Operational Readiness Reviews (Phase 2)
- Installation of AEA equipment (Phase 2 field activity)
- Mixing of the tank contents (Phase 2 activity)
- Mixed contents sampling and analysis (Phase 2 activity),
- Prepare final mix design (Phase 2 activity)

The USQ process is required by 10 CFR 830, and will address hazards associated with implementing the proposed Phase 2 field activities. If necessary, the Work Plan and Sampling plan prepared in Phase 1 will be modified. New SSHASP and IWD will be prepared to accommodate the new field activities. Work will be performed according to IMP 300-00-00.

The justification for this task is to fulfill the requirements of 10 CFR 830 the Nuclear Safety Management and to provide data for final stabilization of the tanks contents.

Specific Work Elements:

Support DOE in Contractor Procurement: This activity consists of preparing a Statement of Work (SOW) that describes the engineering design task, field mixing of the tanks contents, and laboratory analysis work to be performed by AEA, conducting reviews of the SOW, reviewing the proposal and performing technical evaluations. It is assumed that a hot-cell facility will be required.

Prepare a USQ/modify DSA/TSRs: This activity consists of revising a draft DSA and expanding to include AEA technology and sampling, mixing operations and final stabilization (Task 3), including DOE approval of a modification of the existing S&M DSA through the USQ process.

Prepare the Operational Readiness Review #2: Requirements of the readiness review are outlined in the readiness review checklist found in QP 5.3, current revision, Readiness Review Procedure for the Environmental Restoration Project. Primarily an ER subcontractor performs these activities. This activity consists of all logistical, supply procurement, subcontracting, equipment and supply procurement, permit(s) acquisition, and document preparation for the readiness review.   Some of these preparation activities include:

a) Prepare and document the work performed through the Integrated Work Management (IWM) process, IMP 300-00-00.
b)Complete ESH-ID questionnaire for site activities at the General's Tanks within MDA A. All issues brought up by the ESH reviewers will be resolved prior to the readiness review.
c) Prepare and obtain approval of an IWD for the field activities. Requirements are found in the ER Project HASP, Revision 1, March 31, 1998, LPR 402-00-00.0 Worker Safety and Health, and others.
d) Prepare and obtain approval of a facility-tenant agreement with the Facility Management.
e) Obtain excavation permits and have utilities marked where appropriate. Requirements are found in LIR402-880-01, Excavation/Soil Disturbance Permit Process.
f) Obtain required permits, such as a Radiological Work Permit, Hot Burn Permit, and/or Special Work Permit. Other Special Work Permits can be found in other LIRs.
g) Coordinate and plan sampling activities with the Sample Management Organization (SMO).
h) Prepare and submit notifications to FSF, DOE, NMED, FMU, non-DOE property owners, Los Alamos County, etc, as appropriate.

i) Complete and verify training for all site workers, including LANL and other subcontractors.

Following preparation for the readiness review, a readiness review meeting will be held. All comments and issues arising from the readiness review meeting will be resolved prior to start of field work, and the readiness review checklist must be signed by the Project Leader, SMO representative, and Quality Program Project Leader.

Fabrication of equipment: The AEA will modify existing equipment as needed to conform to the engineering design developed in work element F8. A subcontractor will be selected to install the AEA equipment.

Tank mixing and sampling: The tank contents will be mixed and samples will be obtained for analysis.

Analysis of Mixed Samples: The mixed samples will be tested to assure that mixing did not adversely impact anticipated performance of the grouted material. The results will be used to prepare the final grout mixing design and process.

LA-UR-03-6520
October 2003
ER2003-xxxx

THE GENERAL'S TANKS CHARACTERIZATION ACTIVITIES DOCUMENTED SAFETY ANALYSIS

Los Alamos
NATIONAL LABORATORY
Los Alamos NM 87545

D.1 INTRODUCTION

This Appendix describes the basis and methods to calculate inventories of transuranic radionuclides in the General's Tanks located at TA-21 MDA A. Calculated inventories may be compared to the category 2 nuclear facility thresholds described in DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* (DOE, 1992). Similarly, the inventory estimates may be used as the nuclear material at risk (MAR), subject to disturbance and dispersal associated with postulated accident scenarios. The General's Tanks were pumped and sampled several times in the 1970's and early 1980's, and analytical results are available for these events. Similarly, personal interviews have been collected with personnel performing the pumping and sampling in 1981 (Appendix C).

Calculations are performed using basic concepts and equations relating to radioactive decay and ingrowth from the time of the last sampling event, dimensional analysis based on available engineering drawings describing tank features, and reports regarding sludge levels at the last known sampling period. Key assumptions and conclusions related to the following analyses include:

- The use of sampling data associated with the most recent pumping event in 1981 provides the most conservative and current data set,
- No additional nuclear material has been added to the tanks for at least 30 years and all of this was prior to referenced pumping events,
- Analyses using 1970's memoranda describing Pu-239 inventory descriptions yield calculated nuclear material inventories far below that using tank dimensional analysis and sampling data,
- The Pu-241 to Pu-239 mass ratio is assumed to be 0.0025 (0.25%) – no Pu-241 data are available,
- Based on worker interviews and tank design, average depth of sludge/sediment in the tank is 0.458 ft, and
- Individually, neither tank exceeds the category 2 nuclear material threshold. Collectively, the nuclear material inventories exceed the category 2 threshold.

Supporting information regarding these assumptions and conclusions is provided in the following sections of this Appendix.

D.2 HISTORICAL SAMPLING DATA AND MEMORANDA

The liquids and solids in the General's Tanks were sampled on at least four occasions between 1973 and 1981. Summary data from the sampling events are provided in Table D-1. In some instances reporting units were not legible, thus are not entered in the table.

Table D-1. Analytical Data for the General's Tanks as Extracted from Original Sampling Reports.

Reference	Description of Episode	Am-241	Pu-238	Pu-239
(1)	West Tank Sediment	9.2E5 dpm/g	2.2E5 dpm/g	3.9E7 dpm/g
(1)	East Tank Sediment	2.4E5 dpm/g	6.5E4 dpm/g	1E7 dpm/g
(2)	Sluge (Sludge?) 75415	1.6E8 dpm/ml	1.71E8 dpm/ml	4.82E9 dpm/ml
(2)	75415 (#2)	<5,000 dpm/ml	1.62E+05	1.46E6 dpm/ml
(2)	75415 (#1 DPE Tank)	5,000 dpm/ml	1.80E+05	1.69E6 dpm/ml
(3)	75304	12,000 dpm/ml	1.62E+05	1.7E6 dpm/ml
(4)	Liquid 76253	6.9E3 dpm/ml	Not given	7.68E4 dpm/ml

(1) Bucholz; 1/27/1981; analysis # 81064

(2) Bucholz; 8/22/1975; analysis # 75415

(3) McGinnis; 6/23/1975; analysis #75304

(4) Valdez; 5/21/1976; analysis #76253

Of these information sources available, the most useful are believed to be the data from the January 1981 sampling episode by J. Bucholz. The Bucholz (1981) analytical results are assumed to be the most representative because they are the most recent, and they are coupled with interview results regarding the remaining sludge levels in 1981. It is also designated as "sediment", indicating that the majority of the liquid phase had been pumped from the tanks. The calculations provided herein use the analytical data from Bucholz (1981) and estimates of the average sludge thickness to obtain the total tank inventory estimates.

The original inventory placed in the tanks may also be estimated from information contained in several other historical memoranda. These memoranda are described briefly below:

> (Gibson 1971). This is a memorandum from W.B.Gibson to W.J. Maraman dated December 6, 1971. It appears to indicate that the amount of alpha activity added to the tanks was equivalent to a mass of 340 g of Pu 239. This memo indicates that the gross alpha equivalent of 180 grams Pu-239 was present in the west tank and 160 grams was present in the east tank. These quantities are not used in subsequent calculations because they do not yield the highest possible inventory estimates.
>
> (McGinnis 1976). This is a memorandum from P.E.McGinnis to Margaret Anne Rogers dated March 12, 1976. It provides insight into the meaning of "total equivalent Pu-239 mass." In section II of the memo, it indicates that values reported as "total equivalent Pu-239 mass" includes the activity contributions from

other alpha emitters. Section IV of this memo indicates that the total equivalent Pu-239 mass was based on gross alpha activity.

Based on this information, it can be concluded that the initial mass of Pu-239 introduced to the tanks was ___ g. This amount of Pu-239 is substantially lower than that calculated using sample results and dimensional analysis as presented in this appendix. Reasons for this discrepancy might include incorrect initial assay as described in the historical memoranda, additional material added to the tank that was not accounted for, or a much lower sludge/sediment level exists in the tank than 1981 observations indicated. Nevertheless, this reference point provides valuable confirmation that the calculations performed in this document are likely quite conservative, and gives some qualitative benchmark for the uncertainty in the analysis. This relationship is described further in the conclusion to this appendix.

D.3 COMPUTATIONAL METHODS

Several calculation sequences were applied to develop and analyze the nuclear material inventory. In most instances, the Mathematica™ software was used to process equations after a set of input variables was described. Equations were obtained from a variety of reference sources and modified as necessary to support the calculation process.

D.3.1 Input Parameters

Table D-2 presents a listing and descriptions of each Mathematica term, its associated value and reference source. These terms are the building blocks of equations describing ingrowth and decay, and calculations using tank dimensions and sludge levels.

The mass ratio of Pu-241 to Pu-239, "MassRatioPu241toPu239" is estimated. Pu-241 is of interest because it is fissile and its decay results in ingrowth of Am-241 in the tank inventory. It is clear that the ratio must be very small since, as of 1981, only a small amount of Am-241 was present in the tank even though the available information suggests that no plutonium has been added to the tank in nearly 30 years. The assumed mass ratio value of 0.0025 should overestimate the inventory of both Am-241 and Pu-241 in the tanks.

Table D-2. Half-lives and Other Parameter Values

Term in Mathematica™ Equations	Meaning	Value	Source
HalfLifePu238	Half-life of Pu-238	87.75 years	Radiation Decay software package, version 3.5, distributed by Charles Hacker, October 25, 2000
HalfLifePu239	Half-life of Pu-239	24,131 years	
HalfLifePu241	Half-life of Pu-241	14.5 years	
HalfLifeAm241	Half-life of Am-241	87.75 years	
ActivityFactor	Activity conversion factor	Curie/2.22×10^{12} dpm	--
SpecificAcivityPu239	Specific Activity of Pu-239	0.0617557 Curie/gram	The Health Physics and Radiological Health Handbook, page 170 (Shleien 1984)[1]
MassRatioPu241toPu239	Assumed ratio of Pu-241 to Pu-239 during in 1981	0.0025	A high, but conservative estimate for 1940s vintage plutonium that has aged for more than 30 years. Professional judgment.
TankLength	Length of Tank	62 feet	Engineering drawings
Radius	Radius of Tank	6 feet	Engineering drawings
SludgeDensity	Density of Sludge	1 gram/cm^3	Engineering Estimate
SludgeThickness	Thickness of Sludge	0.455 feet	Interviews with sampling personnel

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[1] $$\text{SpecificAcivityPu239} = \frac{1.3 \times 10^8}{\text{HalfLifePu239} \times 365 \times 239}$$

It should be noted that the sludge thickness was developed based on the sampling personnel observations of 3-4 inches (0.33 ft), increased by 1.5 inches (0.125 ft) to account for the end to end slope of the tanks (3 inches total).

D.3.2 Solution of Ingrowth and Decay Equations for Target Radionuclides

The following equations relate the decay of Pu-241 and the ingrowth of Am-241 so that the activity can be corrected from 1981 to 2003. Pu-241 has the following decay scheme:

$$Pu241 \rightarrow Am241 \rightarrow \text{long-lived } Np\text{-}237$$

The Pu-241 and Am-241 equations have the following basis:

Let "pu(t)" and "am(t)" be the number of atoms of Pu-241 and Am-241as a function of time. Then pu'(t) and am'(t) represent the rate of change in the number of atoms present as a function of time. Then, Equations (D-1) and (D-2) provide the numbers of atoms present as a function of time:

Equation (D-1):

$$pu'(t) = -\,(0.693/HalfLifePu241) * pu(t),$$

Equation (D-2):

$$am'(t) = (0.693/HalfLifePu241) * pu(t) - ((0.693/HalfLifeAm241) * am(t))$$

Multiply both sides of equation D-1 by "0.693/HalfLifePu241" to obtain it in terms of activity, yielding equation (D-3).

Equation (D-3):

$$Pu241activity\,'(t) = -\,(0.693/HalfLifePu241) * Pu241activity(t)$$

In equation (D-2), replace "(0.693/HalfLifePu241) * pu(t)" with "Pu241activity(t)" and replace "(0.693/HalfLifeAm241) * am(t))" with "Am241activity(t)", then multiply both sides of equation (D-2) by "(0.693/HalfLifeAm241)" to obtain equation (D-4):

Equation (D-4):

$$Am241activity\,'(t) = (0.693/HalfLifeAm241) *(Pu241activity(t) - Am241activity(t))$$

Equations (D-3) and (D-4) are solved using Mathematica 5.0 (Wolfram, 2003) for generalized boundary conditions that correspond to the 1981 inventory estimates. The equations that describe the amounts of Pu-238, Pu-239, Pu-241 and Am-241 activity as functions of the 1981 inventory and time are given by equations (D-5) through (D-8):

Equation (D-5):

$$Pu238activityTime[Pu238Act,\ t] = Pu238Act \times e^{\frac{-t \times 0.693}{HalfLifePu238}}$$

Equation (D-6):

$$Pu239activityTime[Pu239Act,\ t] = Pu239Act \times e^{\frac{-t \times 0.693}{HalfLifePu239}}$$

Equation (D-7):

$$Pu241activityTime[Pu241Act,\ t] = Pu241Act \times e^{-0.0477931 \times t}$$

Equation (D-8):

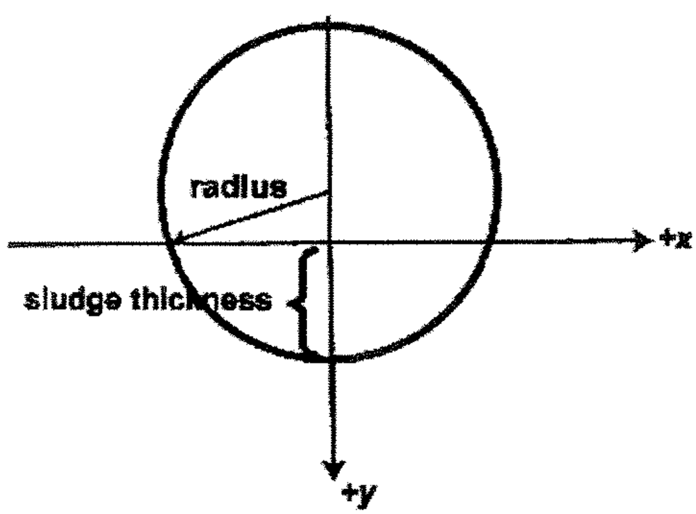
$$Am241activityTime[Am241Act,\ Pu241Act,\ t] = Am241Act \times e^{-0.001604166 \times t} + 0.0347305 \times Pu241Act \times \left(e^{-0.00160416 \times t} - e^{-0.04779310 \times t}\right)$$

In Equations D-5 through D-8, "t" represents the time in years with the convention that 1981 is year 0. Pu238Act, Pu239Act, Pu241Act and Am241Act are the 1981 inventories.

D.3.3 Sludge Volume and Mass

The following calculations derive the cross sectional area of the sludge and the sludge volume as Length x Cross Sectional Area. Parameter inputs have been identified in Table D-2. Figure D-1 is a cross sectional view of one of the General's Tanks.

Figure D-1. Cross sectional view of one of the General's Tanks



Equation (D-9) is used to calculate the total tank volume of 1.98559 x10^8 cm3.

Equation (D-9):

$$\text{TotalTankVolume} = \text{radius}^2 \times \text{TankLength} \times \text{Pi} \times \left(\frac{2.54\ \text{cm} \times 12\ \text{inch}}{\text{inch}}\right)^3$$

Equation (D-10) is the equation for a circle of radius "radius" centered at x,y coordinates (0, sludge thickness - radius), which has been solved for Y.

Equation (D-10):

$$Y = \sqrt{\text{radius}^2 - x^2} - a,$$

where "a" equals "radius - SudgeThickness". Equation (D-10) yields the limits of integration that are subsequently used in Equation (D-11). To obtain them, Y is set to zero and Equation (D-10) is solved for x.

Mathematica 5.0 is used to solve Equation (D-11) to obtain the cross sectional area of the sludge, 1.40134 ft^2. [2]

Equation (D-11):

$$\text{SludgeCrossSectionalArea} = \int_{-(\text{radius}^\wedge 2 - a^\wedge 2)^\wedge 0.5}^{+(\text{radius}^\wedge 2 - a^\wedge 2)^\wedge 0.5} Y\, dx$$

Equation (D-12) is used to calculate the sludge volume as 2.46026×10^6 cm^3. At a density of 1, the estimated sludge mass in a tank is 2.46026×10^6 cm^3:

Equation (D-12):

$$\text{SludgeVolume} = \text{TankLength} \times \text{SludgeCrossSectionalArea} \times (2.54 \times 12)^3$$

D.3.4 Hazard Category Determination

Of particular interest is whether the tanks are likely to contain more than the category 2 nuclear facility threshold of Pu and Am. The category 2 threshold is exceeded if the following condition is met:

Equation (D-13)

$$\frac{Pu238}{62\,Ci} + \frac{Pu239}{56\,Ci} + \frac{Pu240}{55\,Ci} + \frac{Pu241}{2900\,Ci} + \frac{Am241}{55\,Ci} > 1$$

Sections D.3.5 and D.3.6 present methods to determine the total quantity of these radionuclides in the East and West Tanks. Equation (D-13) is then applied to these quantities to determine each tanks fraction of the category 2 threshold.

D.3.5 Inventory Estimates for East Tank

Base parameters for Mathematica calculations have been presented in Table D-2. Several Mathematica radionuclide ratio parameters specific to the inventory of the East Tank are developed, including:

Pu238toPu239ActivityRatio - Ratio of Pu-238 to Pu239 on an activity basis = 0.0065

AmToPu239activityRatio - Ratio of Am-241 to Pu-239 on an activity basis = 0.024

Both of these ratios are derived from sample results (#81064) presented in Bucholz (1981).

Equation (D-14) provides the Pu-239 concentration, in activity units, 4.5045×10^{-6} Curie/gram for reference year 1981:

Equation (D-14):

$$\mathbf{Pu239conc} = 1.0 \times 10^{7} \, \frac{\mathbf{dpm}}{\mathbf{gram}} \times \mathbf{ActivityFactor}$$

Equation (D-15) is used to calculate the Pu-239 inventory for reference year 1981, 11.0822 Curie.

Equation (D-15):

$$\text{Pu239Act} = \text{Pu239conc} \times \text{SludgeMass}$$

Equation (D-16) is used to calculate the Am-241 inventory for reference year 1981, 0.265974 Curie.

Equation (D-16):

$$\text{Am241Act} = \text{AmToPu239activityRatio} \times \text{Pu239Act}$$

Equation (D-17) is used to calculate the Pu-241 inventory for reference year 1981, 46.1078 Curie.

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[2] This same result can obtained as the difference in the areas of a "pie slice " and the isosceles triangle that results from replacing the arc with a line segment.

Equation (D-17):

$$Pu241Act = \frac{MassRatioPu241toPu239 \times HalfLifePu239 \times Pu239Act}{HalfLifePu241}$$

Equation (D-18) is used to calculate the Pu-238 inventory for reference year 1981, 0.0720345 Curie.

Equation (D-18):

$$Pu238Act = Pu238toPu239ActivityRatio \times Pu239Act$$

The 1981 inventory values for the East Tank are corrected for ingrowth using Equations (D-5) through (D-8) and presented in Table D-3 below. Calculations are performed for theoretical radionuclide inventory in the years 1992, 2003 and 2014. Individual radionuclide inventories are then analyzed with Equation (D-13) to determine the category 2 fraction.

Table D-3. Inventory estimates for the East Tank

Year	Pu-241 (Ci)	Am-241 (Ci)	Pu-238 (Ci)	Pu-239 (Ci)	Category 2 Fraction
1981	46.1	0.266	0.0720	11.0822	0.220
1992	27.3	0.888	0.0660	11.0787	0.224
2003	16.1	1.24	0.0605	11.0752	0.227
2014	9.5	1.44	0.0555	11.0717	0.228

D.3.6 Inventory Estimates for West Tank

Base parameters for Mathematica calculations have been presented in Table D-2. Several Mathematica radionuclide ratio parameters specific to the inventory of the East Tank are developed, including:

Pu238toPu239ActivityRatio = Ratio of Pu-238 to Pu239 on an activity basis = 0.00564

AmToPu239activityRatio = Ratio of Am-241 to Pu-239 on an activity basis = 0.024

Both of these ratios are derived from sample results (#81064) presented in Bucholz (1981).

Equation (D-19) calculates the Pu-239 concentration, in activity units, 1.75676×10^{-5} Curie/gram for reference year 1981:

Equation (D-19):

$$Pu239conc = 3.9 \times 10^{7} \times ActivityFactor$$

Equation (D-20) calculates the Pu-239 inventory for reference year 1981 as 43.2207 Ci.

Equation (D-20):

$$\mathbf{Pu239Act = Pu239conc \times SludgeMass}$$

Equation (D-21) calculates the Am-241 inventory for reference year 1981, 1.01957 Ci.

Equation (D-21):

$$\mathbf{Am241Act = AmToPu239activityRatio \times Pu239Act}$$

Equation (D-22) calculates the Pu-241 inventory for reference year 1981, 179.821 Ci.

Equation (D-22):

$$\mathbf{Pu241Act = \frac{MassRatioPu241toPu239 \times HalfLifePu239 \times Pu239Act}{HalfLifePu241}}$$

Equation (D-23) provides an estimate of the Pu-238 inventory for reference year 1981, 0.243809 Ci.

Equation (D-23):

$$\mathbf{Pu238Act = Pu238toPu239ActivityRatio \times Pu239Act}$$

The 1981 inventory values for the West Tank are corrected for ingrowth using Equations (D-5) through (D-8) and presented in Table D-4. Individual radionuclide inventories are then analyzed with Equation (D-13) to determine the category 2 fraction.

Table D-4. Inventory Estimates for the West Tank.

Year	Pu-241 (Ci)	Am-241 (Ci)	Pu-238 (Ci)	Pu-239 (Ci)	Category 2 Fraction
1981	179.8	1.02	0.243	43.22	0.856
1992	106.3	3.45	0.224	43.21	0.874
2003	62.8	4.83	0.205	43.19	0.884
2014	37.1	5.60	0.188	43.18	0.889

D.3.6 Fissile Material Estimates for the East and West Tanks

Fissile material inventory (I) in grams is determined through the following relationship:

Equation (D-24):

I (g) = Activity of fissile radionuclide (Ci) / specific activity of radionuclide (Ci/g)

Table D-5 presents the fissile material mass for the East and West Tanks as calculated for the year 2003. The radionuclides Pu-239 and U-235 are included. It should be noted that isotopic uranium results are unavailable in Bucholz (1981), and it is assumed that U-235 is present at 5% enrichment. Details regarding the calculation of U-235 activities are presented in Appendix E.

Table D-5. Fissile Nuclear Material Mass Estimates (2003).

East Tank				West Tank			
Isotope	Activity (Ci)	Specific Activity (Ci/g)	Mass (g)	Isotope	Activity (Ci)	Specific Activity (Ci/g)	Mass (g)
Pu-239	11.07	0.0618	179	Pu-239	43.19	0.0618	699
U-235	0.0003	2.17E-6	139	U-235	0.0011	2.17E-6	511

D.4 SUMMARY OF RESULTS

Based on the results of this evaluation, the Category 2 threshold may be exceeded when the tank inventories are combined. Subsequently, the tanks as a combined unit are a category 2 nuclear facility using DOE-STD-1027-92 "Hazard Categorization and Accident Analysis Techniques for compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports." The west tank has a higher inventory than the east tank. Bounding accident analyses should be based on the west tank's inventory for initiating events other than deflagration, which will conservatively combine the contents of both tanks for accident scenario analyses.

D.5 REFERENCES

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