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Section 1 of 3

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Flammable Gas Project Expert Elicitation Results for Hanford Site Double-Shell Tanks

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Abstract: This report documents the results of the second phase of parameter quantification by the flammable gas expert panel. This second phase is focused on the analysis of flammable gas accidents in the Hanford Site double-shell tanks. The first phase of parameter quantification, performed in 1997, was focused on the analysis of Hanford single-shell tanks.

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Flammable Gas Project Expert Elicitation Results for Hanford Site Double-Shell Tanks

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EXECUTIVE SUMMARY

This report documents the results of the second phase of parameter quantification by the flammable gas expert panel. This second phase is focused on the analysis of flammable gas accidents in the Hanford Site double-shell tanks. The first phase of parameter quantification, performed in 1997, was focused on the analysis of Hanford single-shell tanks.

Accidents caused by the ignition of flammable gases in the Hanford Site waste storage tanks are the subject of refined safety analysis. The refined safety analysis addresses the considerable technical uncertainty associated with these accidents and consists of best estimate analysis of accident frequencies and consequences with uncertainties quantified by use of "simulation" analysis techniques. The results of the refined safety analysis are accident risk estimates without controls and accident risk estimates under various control strategies. The analysis will form the basis for the Tank Waste Remediation System Authorization Basis ("Tank Waste Remediation System Basis for Interim Operation" [LMHC 1997a] and "Tank Waste Remediation System Technical Safety Requirements" [LMHC 1997b]) relative to flammable gas hazards. This refined safety analysis is needed because traditional deterministic analysis that bounds the technical uncertainty has not been adequate to support finalizing prudent waste management decisions for this hazard.

The analytical method used to perform the refined safety analysis is described in "Refined Safety Analysis Methodology for Flammable Gas Risk Assessment in Hanford Site Tanks, Part 1: Analysis Framework for Single-Shell Tanks, Part 2: Analysis Framework for Double-Shell Tanks" (DESH 1998a), hereafter referred to as the Analysis Framework. The Analysis Framework includes a number of analysis parameters that require input values. Many of these parameters are known from measurements, historical records, and other sources. However, other parameter values are less certain and, therefore, are quantified with uncertainty estimates provided by members of the flammable gas expert panel. This report summarizes the process for developing these parameter values and documents the aggregate uncertainty distributions developed from panel members' inputs provided during March 1998. Distributions in this report

are mostly for parameters required to evaluate the flammable gas risk and efficacy of controls in double-shell tanks. Aggregate uncertainty distributions for parameters used to analyze single-shell tanks were developed in 1997 and are reported in "Safety Controls Optimization by Performance Evaluation (SCOPE) Expert Elicitation Results for Hanford Site Single-Shell Tanks" (DESH 1997).

The process for obtaining uncertainty distributions from expert panel members was rigorous, formal, and well-documented. It included the selection of panelists, providing panelists with background information concerning the Flammable Gas Safety Issue, and holding a series of workshops where the Analysis Framework was discussed, revised, and finalized. In addition, key analysis parameters were reviewed, revised, and defined in these workshops including identification of those parameters requiring quantification through uncertainty distributions. The best available information relevant to flammable gas accident phenomena was presented to the experts by Hanford Site personnel and other technical specialists. Expert panel members then individually developed uncertainty distributions for the key parameters in the agreed upon final Analysis Framework (DESH 1998a).

The panelists were selected in a formal process that included nominations by 11 organizations with direct technical interest in the Flammable Gas Safety Issue in the Hanford Site tanks, followed by a review of nominees against selection criteria to ensure that the panelists, as a collective group, were knowledgeable in a wide range of phenomena involved with the Flammable Gas Safety Issue. Technical expertise was the foremost consideration in selecting experts. The experts were not required to have extensive direct experience with the Hanford Site tank issues, but they did need to have experience in a broad range of the applicable phenomenological areas. A total of 54 nominations were received. The Project Hanford Management Contract team finalized the list of 15 nominees, and the U.S. Department of Energy, Richland Operations Office provided final approval of the list in December 1997.

Workshops that focused on the analysis of single-shell tanks were held in 1997. Workshops that focused on the analysis of double-shell tanks were held early in 1998. The parameter

quantifications from the single-shell tank workshops (DESH 1997) and the proceeding of both sets of workshops (DESH 1998b, and DESH 1998c) support the parameter quantification described in this report.

Parameter quantification was performed in one-on-one interview sessions between the expert panelists and normative specialists. The expert panelists provided the normative specialists with a range of values for each parameter with associated levels of confidence for each value. The individual uncertainty distributions and rationale from each expert are reported in the appendices to this report. The aggregate uncertainty distribution for each parameter is included in the body of this report. It is these aggregate uncertainty distributions that are used in the safety analysis.

The parameters that were quantified by uncertainty distributions provided by panel members in March 1998 are listed in Table ES-1. Most parameters have several separate conditioning factors which multiply the actual number of uncertainty distributions. Conditioning factors are called such because the uncertainty distributions provided by the experts are conditional on the factors applying to a specific situation.

Table ES-1. Summary of Analysis Framework* Parameters and Conditioning Factors
Quantified by Uncertainty Distributions.

Parameter Description	Conditioning Factors
Frequency of spontaneous GREs in tanks with a supernatant layer more than one meter deep but do not pass a criterion for buoyant displacement GRE behavior	Small versus medium versus large efficiency GREs
Probability of an ignition source being induced by a buoyant displacement GRE	Small versus medium versus large efficiency GREs
Total mass of transportable waste suspended (if no dome failure) or released (if dome failure) from a DST resulting from a headspace combustion event	Burn does not fail HEPA; burn fails HEPA but peak pressure <20 psig; burn >20 psig but no dome failure; dome failure from headspace deflagration; dome failure from headspace detonation
Total mass of respirable waste suspended (if no dome failure) or released (if dome failure) from a DST resulting from a headspace combustion event	Burn does not fail HEPA; burn fails HEPA but peak pressure <20 psig; burn >20 psig but no dome failure; dome failure from headspace deflagration; dome failure from headspace detonation
Duration of a buoyant displacement-type GRE	Small versus medium versus large efficiency GREs
Probability of an ignition source in a DST caused by an earthquake	100-year versus 1,000-year versus 10,000-year earthquake
Probability of a seismic-induced GRE in a tank with a supernatant layer more than one meter deep	100-year versus 1,000-year versus 10,000-year earthquake
Probability of a seismic-induced GRE in an SST	100-year versus 1,000-year versus 10,000-year earthquake; small versus medium versus large efficiency GRE; pumped versus unpumped; Facility Group 2 versus Facility Group 3

*DESH (1998a)

GRE = gas release event.

DST = double-shell tank.

SST = single-shell tank.

HEPA = high-efficiency particulate air (filter).

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LIST OF TERMS

AF	Analysis Framework (the risk evaluation methodology)
AT	Analysis Tool (the software implementation of the AF used to evaluate the impact of safety controls on risk)
DESH	DE&S Hanford, Inc.
DST	double-shell tank
GRE	gas release event
HEPA	high-efficiency particulate air (filter)
PHMC	Project Hanford Management Contract
RL	U. S. Department of Energy, Richland Operations Office
SNL	Sandia National Laboratories
SST	single-shell tank
TWRS	Tank Waste Remediation System

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1.0 INTRODUCTION

This report documents the results of the second phase of parameter quantification by the flammable gas expert panel. This second phase is focused on the analysis of flammable gas accidents in Hanford double-shell (DST) waste storage tanks. The first phase of parameter quantification, performed in 1997, was focused on the analysis of Hanford single-shell tanks (SSTs).

Parameter quantification was performed in one-on-one interview sessions between the expert panelists and normative specialists. The expert panelists provided the normative specialists with a range of values for each parameter with associated levels of confidence for each value. The individual uncertainty distributions and rationale from each expert are reported in the appendices to this report. The aggregate uncertainty distribution for each parameter is included in Section 4.0. It is these aggregate uncertainty distributions that are used in the safety analysis.

1.1 OVERVIEW OF THE REFINED SAFETY ANALYSIS PROCESS

Accidents caused by the ignition of flammable gases in Hanford Site waste storage tanks are the subject of refined safety analysis. Refined safety analysis addresses the considerable technical uncertainty associated with these accidents and consists of best estimate analysis of accident frequencies and consequences with uncertainties quantified by use of "simulation" analysis techniques. The results of the refined safety analysis are accident risk estimates without controls and accident risk estimates under various control strategies. The analysis will form the basis for the Tank Waste Remediation System (TWRS) Authorization Basis (*Tank Waste Remediation System Basis for Interim Operation* [LMHC 1997a] and *Tank Waste Remediation System Technical Safety Requirements* [LMHC 1997b]) relative to flammable gas hazards. This refined safety analysis is needed because traditional deterministic analysis that bounds the technical uncertainty has not been adequate to support finalizing prudent waste management decisions for this hazard.

The analytical method used to perform the refined safety analysis is described in *Refined Safety Analysis Methodology for Flammable Gas Risk Assessment in Hanford Site Tanks, Part 1: Analysis Framework for Single-Shell Tanks, Part 2: Analysis Framework for Double-Shell Tanks* (DESH 1998a), hereafter referred to as the Analysis Framework (AF). The AF includes a number of analysis parameters that require input values. Many of these parameters are known from measurements, historical records, and other sources. However, other parameter values are less certain and, therefore, are quantified with uncertainty estimates provided by members of the flammable gas expert panel. This report summarizes the process for developing these parameter values and documents the aggregate uncertainty distributions developed from panel members' inputs provided during March 1998. Distributions in this report are mostly for parameters required to evaluate the flammable gas risk and efficacy of controls in DSTs. Aggregate uncertainty distributions for parameters used to analyze SSTs were developed in 1997 and are

reported in *Safety Controls Optimization by Performance Evaluation (SCOPE) Expert Elicitation Results for Hanford Site Single-Shell Tanks* (DESH 1997).

The purpose of refining the safety analysis methodology for flammable gas risk assessment is to assess the impact of flammable gas controls (including past-practice controls) on safety. The results provide a technical basis for decisions on whether flammable gas risk is being maintained at an acceptably low level and what controls may be most effective at managing flammable gas risk. The primary metric for evaluating flammable gas controls is the total annual risk from flammable gas hazards associated with the waste in the underground high-level waste storage tanks. Controls that are computed to produce large reductions in total annual risk are more effective than those that cause little change in total annual risk.

The AF was developed to provide a consistent method for quantifying the risk impact of potential flammable gas controls in Hanford Site tanks. The AF provides a complete description of how flammable gas accident frequencies (or probabilities) and consequences are computed, how the impact of controls on flammable gas risk is evaluated, and how the uncertainty in key accident phenomenology impacts the computed risk. It is used to determine the baseline risk for combustion accidents and the change in risk that different flammable gas controls would cause for a single tank, a representative tank, or tanks with hypothetical future waste conditions.

The risk reduction estimates, combined with separate estimates of the cost to install and operate each flammable gas control option on a tank, provide a technical basis for rating the cost/benefit performance of each control. The review and quantification of flammable gas accident phenomenology performed by the expert panel, and the subsequent analyses using this methodology, support the actions needed to manage or close many aspects of the Flammable Gas Safety Issue.

The AF uses conventional accident analysis techniques to calculate "best estimate with quantified uncertainty" values for radiological and toxicological dose consequences and accident frequencies. The uncertainty is quantified by using an expert judgment process to develop uncertainty distributions for the values of key parameters in the accident analysis calculations. A computer program, referred to as the Analysis Tool (AT), has been developed to perform the calculations described in the AF. The AT will be used to evaluate the impact of the uncertainty distributions shown in this report on flammable gas risk assessments. This report briefly summarizes the aggregate uncertainty distributions derived from the individual uncertainty distributions provided by the experts participating in the project. The distributions reported here, when combined with the previously reported distributions (DESH 1997) and the AF, are applicable to all SSTs and DSTs at the Hanford Site.

1.2 EXPERT PANEL QUANTIFICATION OF UNCERTAINTY

The process for obtaining uncertainty distributions from expert panel members was as follows.

1. An initial accident analysis model for extending the AF for SSTs to include behaviors and conditions unique to DSTs was developed by the flammable gas safety assessment project team.
2. The proposed AF additions and revisions were reviewed, discussed, and assessed by members of a flammable gas expert panel.
3. The best available information relevant to flammable gas issues was presented to the experts by Hanford Site personnel and other technical specialists.
4. As directed by the expert panel, the AF was revised to incorporate all the key phenomenology that the panel agreed was essential for the framework to properly estimate flammable gas risk.
5. Expert panel members individually developed uncertainty distributions for the key parameters in the agreed upon final AF.

Although the aggregate uncertainty distributions reported here are often regarded as the product of step 5, they are actually the result of this overall process. Additionally, the uncertainty distributions are only a secondary product of the flammable gas expert panel to support the panel's principal product, a complete and technically accurate AF.

A proposed extension of the AF to include DSTs was completed and sent to panel members on January 5, 1998. The experts completed steps 2, 3, and 4 in two intensive workshops in Richland, Washington, during the weeks of January 19 and February 9, 1998 (DESH 1998c). Agenda for the workshops are listed in Appendix D. At those workshops, numerous technical specialists presented information regarding flammable gas safety issues associated with the DSTs. Technical presentations and panel discussions with the project team were recorded for quality assurance purposes. The experts were provided a set of mandatory reading materials and had available a comprehensive technical library covering the many issues associated with the Hanford Site underground high-level waste storage tanks. The listing of documents in the technical library is included in *Flammable Gas Double-Shell Tank Expert Elicitation Presentations (Part A and Part B)* (DESH 1998c). Numerous caucus sessions were held for discussing, revising, and finalizing the AF. The uncertainty distributions were recorded on an individual basis during interviews between a normative specialist (an expert on decision analysis) and a flammable gas expert panel member during the week of March 9, 1998. Each panelist provided uncertainty distributions for a subset of a larger set of parameters (DESH 1998a). The interview sessions were taperecorded for quality assurance records. The normative specialist provided documentation of the uncertainty distributions recorded during the sessions with each panelist,

and the experts provided reports detailing their rationale for the uncertainty distributions they provided. These materials are all considered quality assurance materials and are included in appendices to this report.

The experts provided the normative specialists with a range of values for each parameter with associated levels of confidence for each value. The values were entered into a computer spreadsheet program, and the expert and the normative specialists interactively fitted a smooth distribution to the input values. The fitted curves could be a normal, lognormal, Weibull, Beta, uniform, or other distribution as selected by the expert. The interactive fitting of smooth curves to the experts' data ensured that the resulting uncertainty distributions correctly captured the physical trends expected by the expert without the need for the expert to develop extensive data sets to describe each uncertainty distribution.

2.0 QUALITY ASSURANCE

The quality of any expert judgment process is inherently tied to the quality of the experts who provide uncertainty distributions and the quality of information provided to those experts. Consequently, the processes for selecting experts to participate in the project and for conducting the workshops required strict quality assurance requirements. Those requirements are summarized below.

2.1 EXPERT PANEL NOMINEE SELECTION PROCEDURE

As technical lead for the project, Sandia National Laboratories (SNL) sent letters to 11 organizations with direct technical interest in the Flammable Gas Safety Issue in Hanford Site tanks. Those letters solicited nominations of experts who might be qualified to participate on the flammable gas expert panel. A form was sent to each nominating organization requesting specific information for each nominee. A total of 54 nominations were received. Letters were then sent to nominees soliciting their interest in participating on the expert panel. Interested nominees submitted résumés, lists of technical publications, and additional information regarding their areas of technical expertise.

The technical experts as a collective group were required to be knowledgeable about a wide range of phenomena involved with the Flammable Gas Safety Issue. Technical expertise was the foremost consideration in selecting experts. The experts were not required to have extensive direct experience with the Hanford Site tank issues, but they did need to have experience in a broad range of the applicable phenomenological areas. Potential panelists were evaluated using the two sets of criteria listed below.

Individual Criteria. The following criteria were used to evaluate each nominee's individual qualifications.

1. Potential panelists must have been nominated for panel membership by an organization with direct interest in the TWRS. Potential panelists, once nominated, must have expressed interest in panel membership by having responded to a solicitation of interest.
2. Potential panelists must have a technical degree(s), must have provided a current résumé, and must have a minimum of five years experience in one of the relevant technical areas listed below.

Chemistry	Radiolysis	Thermodynamics
Heat Transfer	Mass Transport	Chemical Analysis
Small-scale Testing	Accident/Risk Analysis	Waste Issues
Industrial Operation	Gas Release Events (GREs)	Ignition Sources
Combustion Behavior	Tank Farm Operations	Contaminant Resuspension
Statistics		

3. Panelists should have externally peer-reviewed publications in their field(s) of expertise. Credit was given to other publications in the relevant field(s). Potential panelists were requested to submit a list of publications.
4. Panelists should be currently or recently active in relevant technical work.
5. Consideration was given to prior participation in review committees and/or membership on expert panels.
6. Credit was given to potential panelists who exhibit familiarity with TWRS issues.
7. Panelists should have low actual and/or perceived conflict of interest with TWRS.
8. Panelists must be available to participate in the project.
9. Panelists must exhibit an ability and willingness to work in a team environment.

Collective Criteria. The following criteria were applied to assure that the panel as a whole had the necessary characteristics.

1. Strong coverage of all the key fields, with no key field covered by only one person.
2. Balance in diversity of technical views represented on key issues.
3. Balance in type of institution panelists are affiliated with (e.g., universities, national laboratories, Hanford Site, other U.S. Department of Energy sites, industry, and independent companies).
4. Individuals who would play substantial roles in other aspects of the project were not eligible for membership on the expert panel.

The expert panel selection team members were free to use scoring procedures to aid in the selection criteria (e.g., individuals may have been assigned to one of four ranks [outstanding, high, medium, low] with respect to each criterion as deemed useful). However, no rigid formula was defined and applied for the selection process. Flexibility was allowed to judge the criteria as they applied to each case.

The selection process consisted of the following:

1. Initial screening of potential panelists for eligibility, e.g., technical degree, experience, affiliation (Individual Criterion #1)
2. Scoring of remaining candidates based upon their expertise in relevant technical areas (Individual Criterion #2)

-
-
3. Matching individual candidates to each of the relevant technical areas listed in the Individual Criterion #2. (The collective panel of experts must have expertise in the majority of the most relevant technical areas.)
 4. Matching individual candidates to the remaining individual and collective criteria
 5. Iteration of steps 2 through 4 to select a final group of experts for the panel
 6. Submittal of tentative lists of panel members to U.S. Department of Energy, Richland Operations Office (RL).

A panelist selection team was assembled to review nominee responses and meetings were held to select panelists. A provisional list of panel members and alternates was submitted by SNL to the Project Hanford Management Contract (PHMC) team in December 1996. The PHMC team finalized the list of 15 nominees, and the RL provided final approval of the list in early January 1997 (Sohn 1997a).

The original strategy for the development of the enhanced GRE safety analysis (Funderburke 1996) set forth a plan to develop an AF applicable to SSTs before proceeding to the development of an AF for DSTs. One reason for the schedule was that the AF development process was new and different from past methods. The aim was to have the DST AF development benefit from lessons learned during the SST AF development. The project team intended to have the flammable gas expert panel participate in both parts of the project so the technical and project knowledge gained by the experts during the SST AF development would improve the process for the DST AF development. Eleven panel members participated in both AF development efforts, but for a variety of reasons, a few membership changes did occur. RL approved the membership changes in December 1997 (Sohn 1997b). Table 1 lists the members of the flammable gas expert panel, the portions of the AF they participated in developing, and the normative specialists.

The SNL and PHMC team staff identified documents required to provide experts with essential background information regarding the TWRS Flammable Gas Safety Issue. The set of documents assembled for the panel members for the DST AF development included the SST AF, the proposed DST AF, all of the documents assembled during the course of the SST AF development work, and a number of additional documents identified by the project team that are specific to DSTs. The complete set of documents was referred to as the project library. The project library was available to panel members at all times during the project workshops and personal copies were made for the experts when requested. The list of project library documents is available (DESH 1998c).

Table 1. Flammable Gas Expert Panel Members.

Stephen Agnew Los Alamos National Laboratory (SST & DST)	Nick Kirch Lockheed Martin Hanford Corp. (DST)
Edward Beahm Oak Ridge National Laboratory (SST & DST)	Glenn Paulson Paulson and Cooper, Inc. (SST & DST)
Paul d'Entremont Westinghouse Savannah River Co. (DST)	Arlin Postma G&P Consulting (SST & DST)
Clay Easterly Oak Ridge National Laboratory (SST & DST)	Dan Reynolds Lockheed Martin Hanford Corp. (SST)
Michael Epstein Fauske & Associates, Inc. (SST & DST)	Wallace Schulz W2S Co., Inc. (SST)
Phillip Gauglitz Pacific Northwest National Laboratory (SST & DST)	Charles Stewart Pacific Northwest National Laboratory (SST & DST)
Chet Grelecki Hazards Research Corporation (SST)	Kelly Thomas Westinghouse Safety Management Solutions (SST & DST)
Jerry Havens University of Arkansas (SST & DST)	Bob White Los Alamos National Laboratory (SST)
Mujid Kazimi Massachusetts Institute of Technology (SST & DST)	Michael Yost University of Washington (DST)
<u>Normative Specialists</u> Detlof von Winterfeldt, Thomas Eppel, Richard John Decision Insights, Inc.	

DST = double-shell tank.

SST = single-shell tank.

2.2 EXPERT PANEL WORKSHOPS

The expert panel workshops consisted of presentations and discussions involving subject matter experts, the project team and its subcontractors, and the flammable gas expert panel. The purpose of the workshops was to: (1) provide the expert panel members with the best available information relevant to their task, (2) provide a forum in which the experts could improve the AF accident analysis model, and (3) formulate their uncertainty distributions by interacting with each other and with the subject matter experts. Finalization of the AF and the list of parameters that

would be quantified by uncertainty distributions was considered a quality level 2 process according to *Safety Controls Optimization by Performance Evaluation (SCOPE) Project - Project Quality Assurance Plan* (SNL 1996).

Quality procedures were written for the conduct of the workshops. The procedures addressed the general conduct of the meetings, preparation and recording of agendas, maintenance of attendance sheets, quorum requirements, audio recording requirements, identification of technical presenters, retention of presentation materials for quality records, recording of action items, assembly and maintenance of a document reference library for the members, and other quality assurance requirements.

Panel workshops were under the direction of a panel moderator. The panel moderator defined rules for discussions, presentations, and interactions between the experts and observers and maintained order during the workshop sessions. Several organizations were invited to send observers to monitor the meetings. To maximize the time available for the panel members to discuss issues with technical specialists, participation in the workshop discussions by observers was limited. However, discussions between panel members and observers outside of the formal sessions were encouraged.

Sound recordings of all workshop proceedings were made for quality assurance records. This was particularly important for documenting issues and technical points made during the course of the discussions. Because the panel was able to modify the workshop agenda to make the most efficient use of its time, the recordings were needed to capture agenda changes made during the sessions. A two-thirds quorum was required to conduct workshop sessions so the members could benefit from technical discussions among the diverse group of experts. Complete copies of materials were sent to the few experts who were unable to attend for one day of a workshop. Although the panel was large and all of the members had other commitments competing for their time, their personal interest in and support for the project was so high that maintaining a quorum was never an issue; a quorum was present for all workshop meetings. The proceedings of the workshops were also recorded and published (DESH 1998c).

During the first workshop for the SST AF development, normative specialists conducted a decision analysis training session with the panel members. The materials used for the training are included in DESH (1998b). At the end of the second workshop, the normative specialists reviewed the decision analysis training and discussed at length the details of the process by which they would interview the panel members and record the uncertainty distributions from each expert. SNL separately developed quality assurance procedures for the aggregation of the uncertainty distributions recorded by the normative specialists in *SCOPE-AT Version 1.0: Procedure for Aggregation of Expert Opinion Data* (SNL 1997) and software requirements specifications for the incorporation of the aggregate uncertainty distributions into the AT in *Safety Controls Optimization Performance Evaluation (SCOPE) Analysis Tool—Software Requirements Specification (SRS)* (SNL 1998).

Three panel members participated only in the DST AF development efforts (D'Entremont, Kirch, and Yost) and were not present at the SST AF workshops when the normative specialists

conducted the decision analysis training sessions. Therefore, these panel members attended a special two-day "mini-workshop" held on December 8 and 9, 1997, at SNL. The normative specialists conducted decision analysis training sessions with the new panel members at that workshop. Additionally, the project team reviewed the proceedings of the SST AF workshops (DESH 1998b), the technical discussions of the expert panel, and the decisions reached by the panel during the first set of workshops.

3.0 EXPERT PANEL UNCERTAINTY DISTRIBUTIONS

The aggregate uncertainty distributions shown in Section 4.0 are the core of the quantitative results from the expert panel. This section provides discussion on how to interpret those figures.

3.1 CUMULATIVE PROBABILITY DISTRIBUTIONS

All of the uncertainty distributions provided by the flammable gas expert panel members are in the form of cumulative probability distributions. The x-axis is the range of possible values for a given parameter, and the y values assigned at each x value are the cumulative probability for the value of x. Because the probability by definition must be between 0 and 1, the y-axis always has a dimensionless scale from 0 to 1. The notation $P(<x)$ is assigned to the y-axis, which is read as the probability that the true value of the x-axis parameter is less than the corresponding value on the x-axis. For an individual expert's curve, the x-axis value where $P(<x) = 0.5$ is the median value where the expert determines that the true value of the parameter is equally likely to be greater than or less than the x-axis value. Similarly, the expert concludes there is only a 10% chance that the true value is larger than the x-axis value where $P(<x) = 0.9$, or a 10% chance that the true value is smaller than the x-axis value where $P(<x) = 0.1$.

Using the aggregate curve in Figure 1 and Table 2 to illustrate, the aggregated probability distribution estimate is 0.2282, or about a 23% chance, that the retained gas void fraction in waste in an unpumped Facility Group 2 tank is less than 5%. The estimated probability is about 43% that it is less than 10%, about 62% that it is less than 15%, etc. There is a 100% chance that the void fraction is less than 100%. By definition, if the void fraction is 100%, there is no waste. Consequently, the curves all have an asymptotic value of 1 at $P(<100\%)$. (The full range of x-axis values are not shown in Figure 1.) Similarly, there is 0% chance that the void fraction is less than 0%, so the curves all start at $P(<0\%) = 0$. Uncertainty distributions presented as cumulative probability distributions will, by definition, increase monotonically from left to right. Consequently, individual uncertainty distributions are typically S-shaped in cumulative probability figures. As discussed in Section 3.3, however, aggregate uncertainty distributions are not necessarily S-shaped in these figures.

Within the Monte Carlo-type runs to evaluate risk using the AF methodology, values for parameters quantified by uncertainty distributions are determined as follows. A random number generator computes a number between 0 and 1 before each run. The x-axis parameter value, at which the aggregate uncertainty distribution equals this random number, is then selected for that run. In Figure 1, a horizontal line is drawn at the y-value corresponding to the random number and at the x-value where that line crosses the aggregate uncertainty distribution used for that run.

Figure 1. Illustration of How Uncertainty Distributions from the Flammable Gas Expert Panel Members are Aggregated. Example for the Retained Gas Void Fraction in Unpumped Facility Group 2 Tanks.

Table 2. Example Calculation of the Aggregate Uncertainty Distribution in Figure 1.

Expert/Void Fraction	5%	10%	15%	20%	25%	30%	35%	40%
Expert 1	0.4099	0.7467	0.8822	0.9402	0.9674	0.9812	0.9886	0.9928
Expert 2	0.1900	0.4921	0.7385	0.8868	0.9581	0.9866	0.9963	0.9991
Expert 3	0.2500	0.5000	0.7500	1.0000	1.0000	1.0000	1.0000	1.0000
Expert 4	0.2030	0.4609	0.6704	0.8140	0.9019	0.9513	0.9771	0.9897
Expert 5	0.0375	0.2346	0.4580	0.6305	0.7497	0.8293	0.8823	0.9178
Expert 6	0.0103	0.1236	0.5000	0.8764	0.9897	0.9997	1.0000	1.0000
Expert 7	0.1323	0.3216	0.5029	0.6539	0.7693	0.8520	0.9084	0.9450
Expert 8	0.2352	0.5073	0.7131	0.8455	0.9221	0.9629	0.9832	0.9928
Expert 9	0.0201	0.0620	0.1525	0.3040	0.5000	0.6960	0.8475	0.9380
Expert 10	0.1451	0.3581	0.5571	0.7146	0.8266	0.9001	0.9451	0.9712
Expert 11	0.8774	0.9130	0.9298	0.9402	0.9474	0.9527	0.9569	0.9602
Aggregate	0.2282	0.4291	0.6231	0.7824	0.8666	0.9193	0.9532	0.9733

3.2 HOW UNCERTAINTY DISTRIBUTIONS FROM EXPERT PANEL MEMBERS ARE AGGREGATED

A detailed explanation of how uncertainty distributions are aggregated and the rationale for the methodology can be found in *Eliciting Probabilities from Experts in Complex Technical Problems* (Keeney and von Winterfeldt 1991). The method is illustrated here with actual uncertainty distributions provided by expert panel members for SSTs. Complete details for all of the aggregate curves shown in Section 4.0 are included in the appendices, and details for all uncertainty distributions provided by the panel in May 1997 are included in DESH (1997).

Figure 1 shows the uncertainty distributions developed by 11 experts for the retained gas void fraction in Facility Group 2 tanks that have not been salt well pumped. The numerical values for each curve where they cross the vertical grid lines are shown in Table 2. At each point on the x-axis, the aggregate curve is simply the average of the individual cumulative probability distributions at that point. This is often graphically described as averaging on the vertical lines. Averaging on horizontal lines is not done for reasons detailed in Keeney and von Winterfeldt (1991). In Figure 1, most of the uncertainty distributions are grouped within a band, showing general consensus of opinion about the potential range of values for the void fraction. Expert 11 may be termed comparatively optimistic that there is little retained gas because his curve indicates that he expects nearly 88% of tanks of this type to have retained gas void fractions less than 5%. In contrast, Expert 9 may be termed comparatively pessimistic since his curve indicates that he expects the average retained gas void fraction value (corresponding to 0.5 on the y-axis) to be about 25%.

3.3 NOTES ON INTERPRETING THE AGGREGATE UNCERTAINTY DISTRIBUTIONS

It is apparent when results are displayed graphically that an individual expert's uncertainty distribution can have a numerical impact on the tails of the aggregate uncertainty distribution. However, the graphical effect of a single expert is limited to only one tail per curve, and the numerical magnitude of the effect is never greater than one divided by the total number of experts providing distributions. Of course, the impact of an individual expert to potentially persuade other panel members to their particular technical position, and thus influence the distributions provided by other experts, cannot be quantified. One reason for having a large number of independently selected panel members, such as the flammable gas expert panel, is that one expert will not be able to sway a large number of other panel members unless the others determine there are strong technical merits to the line of reason. The panel members serve as peer reviewers of each other's technical analyses. If the panel largely agrees with the one expert's analysis of a parameter, then the influence of the one expert is to reduce the range of uncertainty quantified by the panel because the expert's analysis stands up to peer review.

Of the 67 different aggregate distributions reported here, 6 are derived from 12 experts' inputs, 12 are derived from 10 experts' inputs, 13 are derived from 9 experts' inputs, and 36 are the aggregate of 6 experts' inputs. These last distributions are for the probability of a seismic-induced

GRE in an SST. Salt well pumping has been proposed as a practical control for reducing the flammable gas risk associated with seismic-induced GREs. For the May 1997 results (DESH 1997), the panel was not asked to condition their uncertainty distributions for the probability of a seismic-induced GRE in an SST on whether a tank had been salt well pumped. Therefore, during the second set of workshops, the experts who had provided uncertainty distributions for this parameter were asked to review their previous analyses and quantify how knowledge of a tank's pump status would affect their uncertainty distributions, if at all. The number of experts providing input to this parameter is smaller than for the other parameters. The panel and the project team agreed that input should be limited to only those who had previously developed uncertainty distributions for this parameter.

The numerical impact of an individual expert's uncertainty distributions on the overall computed risk is far less than the impact on an individual aggregate uncertainty distribution. No expert provided distributions for all parameters, so no individual influenced all the aggregate distributions. Additionally, the experts provided uncertainty distributions for specific parameters that affect risk but not for the aggregate risk which is calculated by the AF model.

Some aggregate distributions have a staircase-like appearance. This behavior is typically the result of two or more disparate groups of technical opinions, with different groups of experts estimating a parameter value in widely different ranges from each other. The result is a bimodal or multimodal distribution with parameter values selected in Monte Carlo-type runs tending to divide among the different groups. When it cannot be determined which group is most correct in their analyses, the methodology for selecting values inherently gives statistical weighting to values representative of the different groups and de-emphasizes values that are not representative of any group.

There are two special degenerate uncertainty distributions provided by flammable gas expert panel members that visually affect the aggregate uncertainty distributions for the probability of events. The two cases are the distributions for when an expert is truly certain that (1) an event is sure to happen, or (2) an event absolutely cannot happen.

When an expert is certain that an event will happen, their estimate for the event probability is zero for all event probabilities less than unity. Symbolically, $P(<\text{any event probability less than unity}) = 0$. This is a curve that lies on the x-axis and has a non-zero y value only at $x = 1$. In figures of the cumulative probability distributions for the probability of an event, this appears as a line along the x-axis and up the right side of the figure at $x = 1$. The aggregate distributions will approach a value less than 1 at the right side of the figure. For example, if there are 10 experts and one is certain that an event is sure to happen, the aggregate curve will approach $P(<x) = 0.9$ as $x \rightarrow 1$. This is interpreted as a 10% probability that $x = 1$.

When an expert is certain that an event will not happen, their estimate for the cumulative probability of the event is unity for all event probabilities greater than zero or for all parameter values larger than a given x-value. Symbolically, $P(<\text{any finite value}) = 1$ if the x-axis parameter is a probability, or $P(<x) = 1$ for all x values above a given limit. If the x-axis parameter is a probability, this degenerate case is a curve that immediately rises up on the y-axis to a value of

$P(<x) = 1$ and appears as a line across the top of the figure. The aggregate distributions appear to approach a value greater than zero at the left side of the figure. For example, if there are eight experts and one is certain that an event cannot possibly happen, the aggregate curve will approach $P(<x) = 0.125$ as $x \rightarrow 0$. This is visually most apparent on plots with a logarithmic scale on the x-axis, which is the case for the figures in Section 4.0. For this example, the result is interpreted as a 12.5% probability that $x = 0$. Figure 1 illustrates the case where an expert is certain that a parameter cannot be larger than a given value. In Figure 1, Expert 3 is certain that the retained gas void fraction in unpumped Facility Group 2 tanks could never exceed 20%, so his distribution is flat across the very top of the figure for all values larger than 20%.

3.4 SUMMARY OF UNCERTAINTY DISTRIBUTIONS PROVIDED BY THE PANEL MEMBERS

Table 3 summarizes the parameters that were quantified by uncertainty distributions provided by panel members in March 1998. Most parameters have several separate conditioning factors which multiply the actual number of uncertainty distributions. Conditioning factors are called such because the uncertainty distributions provided by the experts are conditional on the factors applying to a specific situation.

Section 4.0 presents approximately one figure per AF parameter shown in Table 3. To facilitate cross-comparisons of results for different conditioning cases, a few additional figures are provided for the results pertaining to the probability of a seismic-induced GRE in an SST. Appendix C shows the individual uncertainty distributions provided by flammable gas expert panel members that were aggregated together to form the distributions shown in Section 4.0. For clarification, the AF defines a small efficiency GRE as one that releases less than 5% of the total amount of retained gas, a medium efficiency GRE as one that releases between 5% and 25% of the retained gas, and a large efficiency GRE as one that releases more than 25% of the total retained gas. An unpumped SST is defined as one that contains saturated solids, while a pumped tank has had the drainable liquid removed. Partially drained tanks are analyzed as unpumped tanks because the risk calculations for unpumped tanks have been determined to bound results for pumped tanks when all other conditions are the same.

Table 3. Summary of Analysis Framework* Parameters and Conditioning Factors Quantified by Uncertainty Distributions.

Parameter Description	Conditioning Factors
Frequency of spontaneous GREs in tanks with a supernatant layer more than one meter deep but do not pass a criterion for buoyant displacement GRE behavior	Small versus medium versus large efficiency GREs.
Probability of an ignition source being induced by a buoyant displacement GRE	Small versus medium versus large efficiency GREs
Total mass of transportable waste suspended (if no dome failure) or released (if dome failure) from a DST resulting from a headspace combustion event.	Burn does not fail HEPA; burn fails HEPA but peak pressure <20 psig; burn >20 psig but no dome failure; dome failure from headspace deflagration; dome failure from headspace detonation.
Total mass of respirable waste suspended (if no dome failure) or released (if dome failure) from a DST resulting from a headspace combustion event.	Burn does not fail HEPA; burn fails HEPA but peak pressure <20 psig; burn >20 psig but no dome failure; dome failure from headspace deflagration; dome failure from headspace detonation.
Duration of a buoyant displacement-type GRE	Small versus medium versus large efficiency GREs
Probability of an ignition source in a DST caused by an earthquake.	100-year versus 1,000-year versus 10,000-year earthquake
Probability of a seismic-induced GRE in a tank with a supernatant layer more than one meter deep.	100-year versus 1,000-year versus 10,000-year earthquake
Probability of a seismic-induced GRE in an SST	100-year versus 1,000-year versus 10,000-year earthquake; small versus medium versus large efficiency GRE; pumped versus unpumped; Facility Group 2 versus Facility Group 3.

*DESH (1998a)

GRE = gas release event.

DST = double-shell tank.

SST = single-shell tank.

HEPA = high-efficiency particulate air (filter).

4.0 UNCERTAINTY DISTRIBUTIONS AND OBSERVATIONS

The numerical impact of the uncertainty distributions on risk estimates shown in this section can only be evaluated with the AT. Nevertheless, there are some observations and conclusions that may be drawn from the uncertainty distributions even without numerical assessments by the AT. This section briefly summarizes a number of observations that are expected to have significant impact on risk considerations.

Frequency of spontaneous GREs in tanks with a deep supernatant layer but no buoyant displacement GRE behavior. The flammable gas expert panel concluded that the depth of a supernatant layer could potentially affect the frequency of gas releases that occur by mechanisms other than buoyant displacement. The uncertainty distributions for spontaneous GREs in SSTs that the panel quantified in May 1997 (DESH 1997) were determined not to be applicable to DSTs if the supernatant layer in a DST is deeper than about one meter. The May 1997 results were conditioned on a tank being an SST, and there are no SSTs that currently have a supernatant layer more than about one meter deep that overlies a deep layer of potentially gas-retaining settled solids. The panel concluded that separate uncertainty distributions were required for the case where a deep supernatant layer is present over settled solids. The panel also concluded that when a deep layer of supernate is not present in DSTs, the uncertainty distributions for unpumped Facility Group 2 SSTs are applicable.

The "working definition" of a deep supernatant layer used by the panel was a layer more than one meter in depth. In the AF, the criterion for when a deep supernatant layer is present is when the tank conditions result in at least one of two release energy ratio criteria being met. The criteria are dependent on the bulk density and shear strength of the settled solids layer and the density of the supernate. Consequently, the exact depth of supernate required to constitute a deep layer is tank-specific. When applied to current DST conditions, the supernatant depth values computed by the criteria range from about 0.75 to 1.25 meters.

The panel developed six criteria for when the AF evaluates a tank which exhibits buoyant displacement GREs. If one or more of the criteria are met when a deep supernatant layer is present, the AF uses the buoyant displacement model (DESH 1998a) to compute GRE amounts and frequencies. When a deep supernatant layer is present but no criterion for buoyant displacement behavior is met, the AF uses the same computational methodology as for evaluating SSTs and the uncertainty distributions for frequency of spontaneous GREs shown in Figure 2. The roughly parallel spacing of the three different curves, with a separation distance of about one decade on a horizontal line through the mid-range of y-values, indicates the frequency of small efficiency GREs generally will be computed to be about an order of magnitude more frequent than medium efficiency GREs. This, in turn, will generally be computed to be about an order of magnitude more frequent than large efficiency GREs.

Figure 2. Frequency of Spontaneous Gas Release Events in Tanks That Have a Deep Layer of Supernatant But Do Not Meet the Criteria for Buoyant Displacement-Type Gas Release Event Behavior.

Probability of an ignition source being induced by a buoyant displacement GRE. The panel concluded that the large waste motions that occur during buoyant displacement GREs are capable of moving waste-intrusive equipment. The equipment motion may cause electrical or mechanical sparks. Therefore, the panel members developed uncertainty distributions for the probability of a small, medium, or large efficiency GRE inducing an ignition source conditioned on the knowledge that the GRE is a buoyant displacement-type release. Even though large buoyant displacement GREs like those observed in DSTs have not been observed in SSTs, SSTs have experienced large waste motions associated with post-pumping subsidence events. During the development of the AF for SSTs, the panel members considered the potential for subsidence events when evaluating uncertainty distributions for this parameter. That may be why the uncertainty distributions reported in Figure 3 are very close to reported results (DESH 1997) for GRE-induced ignition source probabilities. It appears that GRE-induced ignition source contributions to the risk calculations evaluated with the AT will be little affected by whether a release is a buoyant displacement-type GRE.

Figure 3. Probability of a Buoyant Displacement-Type Gas Release Event Inducing an Ignition Source.

Mass of waste suspended (if there is no dome failure) or released (if there is dome failure) resulting from a headspace combustion event in a DST. The expert panel determined that the structural differences between SSTs and DSTs, such as the number and size of risers and the presence of a steel dome liner in DSTs, could affect how much waste may be released from a tank as the result of a headspace combustion event. The panel endorsed the methodology developed for computing the quantity of material released when there was no gross structural failure of the dome. For these cases, the mass of material released is computed to be proportional to the amount of material suspended in the headspace times the volume fraction of headspace gases that must vent to reduce the pressure back to the original value. The panel appears to be consistent in their analyses for how much material may be suspended in a tank headspace by a combustion event that does not fail the dome. The results shown in Figures 4 and 5 for the amount of transportable and respirable material suspended, respectively, compares very closely with reported results (DESH 1997) for combustion events in SSTs. Consequence calculations for headspace burns in DSTs are likely to be very similar to those for SSTs when the tank domes are computed to remain intact.

The proposed assumption that all suspended material is released if it is computed that there is gross structural failure of the dome was determined by the panel to be unacceptably conservative. This bounding assumption does not account for suspended waste falling back into the tank or on the ground in the immediate vicinity of the tank, nor does it account for possible coarse filtering of the waste as gases vent through tank overburden. Thus, the panel determined that their uncertainty distributions for the net mass release from a DST conditioned on gross structural failure of the tank dome, caused by a burn in one case or a detonation in another, would provide more accurate estimates of the source term quantities for risk calculations. The results for the mass of transportable and respirable waste released for these two cases are shown in Figures 4 and 5. Interestingly, the distributions for the case of dome collapse caused by a headspace detonation are not significantly different from the distributions for releases from SSTs for dome failure cases where 100% of the suspended material is assumed to be released. This means that the "worst case" consequences for DSTs will be very comparable to those computed for SSTs, even though the DST analysis includes consideration of more details. The uncertainty distribution for mass of material released from a DST when a headspace deflagration causes structural failure of the dome is very comparable to that for the material suspended in an SST headspace when the combustion event cracks the dome. The accident consequences computed for these two scenarios should be very similar.

Figure 4. Mass of Transportable Waste Suspended in the Headspace of (For No Dome Failure Cases), or Released From (For Dome Failure Cases), a Double-Shell Tank by a Headspace Combustion Event.

Figure 5. Mass of Respirable Waste Suspended in the Headspace of (For No Dome Failure Cases), or Released From (For Dome Failure Cases), a Double-Shell Tank by a Headspace Combustion Event.

Duration of a buoyant displacement-type GRE. The rate at which gases are released into a tank headspace will affect the peak concentration of gases in the headspace. The longer the duration of a GRE, the more effective ventilation systems may be at preventing the formation of flammable conditions. Figure 6 shows the aggregate uncertainty distributions for the duration of buoyant displacement-type GREs. The duration of small and medium efficiency releases are determined to be centered around 10^4 seconds (~2.5 hours), with a range of ~0.25 hours to 10 hours. Large efficiency GREs were determined to occur more rapidly, with an average duration of ~40 minutes and a range from a few minutes to ~5 hours. For a ventilation rate of 500 cfm, a little more than one hour is required to ventilate a volume of gas equal to that of the headspace. Large efficiency GREs release the largest amount of gas over a time that is generally less than the characteristic headspace exchange time for tanks filled near capacity. Therefore, the computed results will likely indicate that ventilation systems must be much higher capacity (at least several times larger) than currently operating systems before they may be effective at preventing flammable conditions from occurring in DST headspaces when a tank exhibits buoyant displacement-type GREs.

Figure 6. Duration of a Buoyant Displacement-Type Gas Release Event.

Probability of an ignition source in a DST caused by an earthquake. The panel reviewed the differences between SSTs and DSTs and concluded that the larger amounts of operating equipment on DSTs may affect the potential for a seismic-induced ignition source compared to SSTs. Figure 7 shows the uncertainty distributions associated with 100-year, 1,000-year, and 10,000-year earthquakes. About 80% of the range of results for a 10,000-year earthquake falls in the range of a 1 in 100 chance or higher of a seismic-initiated ignition source and about 50% of the range is for a chance of 1 in 2 or better. If the seismic event initiates a GRE, the GRE has a potential to induce a second ignition source. The ignition probability for 10,000-year earthquakes is thus very high. For 100-year earthquakes, the potential for a seismic-induced ignition source is generally 2 to 3 orders of magnitude less likely. The results shown in Figure 7 are very close to those reported for SSTs (DESH 1997). The conclusion is that a few panel members may have determined that DSTs were more susceptible to seismic-induced ignition sources than SSTs, but the panel as a whole did not determine there is a substantial difference between the two types of tanks.

Figure 7. Probability of a Seismic-Induced Ignition Source in a Double-Shell Tank.

Probability of a seismic-induced GRE in a tank with a deep supernatant layer. The panel considered whether the presence of a deep supernatant layer that can potentially slosh around in a tank during an earthquake would affect the probability of a seismic-induced GRE compared to tanks without a deep liquid layer. Figure 8 shows the aggregate distributions conditioned on the magnitude of the seismic event (100-, 1,000-, or 10,000-year earthquake) and the efficiency of release (small, medium, or large). With the exception of large efficiency releases induced by a 100-year earthquake, the distributions fall mostly within the range of a 1 in 10 chance or higher that the seismic event induces a GRE, and nearly half of the results fall within the range of 1 in 2 or higher. The clear conclusion of the flammable gas expert panel is that the probability of a seismic-induced GRE for all efficiencies of release and magnitudes of seismic event is very high when a deep supernatant layer is present.

Figure 8. Probability of a Seismic-Induced Gas Release Event in a Tank With a Deep Layer of Supernatant.

Probability of a seismic-induced GRE in an SST. Salt well pumping has been proposed as a practical control for reducing the flammable gas risk associated with seismic-induced GREs. For the May 1997 results (DESH 1997), the panel was not asked to condition their uncertainty distributions for the probability of a seismic-induced GRE in an SST on whether a tank had been salt well pumped. Therefore, during the second set of panel workshops, the experts who had provided uncertainty distributions for this parameter were asked to review their previous analyses and quantify how knowledge of a tank's pump status would affect their uncertainty distributions, if at all. By clarifying the impact of salt well pumping on the probability of seismic-induced GREs in an SST, the AF will be able to more accurately model the impact of pumping as a control for the risk from seismic-induced GREs.

The results are shown in Figures 9 through 14. Because of the large number of uncertainty distributions that result from the several conditioning factors (3 earthquake magnitudes $\times$ 3 release efficiencies $\times$ 2 pumping states $\times$ 2 Facility Group designations = 36 different combinations of conditioning factors), the distributions for this parameter are presented in these six figures to help facilitate cross-comparisons of the influence of different conditioning factors.

Two experts determined that, within their uncertainty, a tank's pumping status had no effect on the probability of a seismic-induced GRE. The remaining experts concluded there was an effect for at least some of the conditioning cases. It is difficult to compare the results presented in

Figures 9 through 14 with the reported results (DESH 1997) and draw clear conclusions by inspection because the previous results are for a different set of conditioning factors. The numerical impact of the added resolution for the impact of salt well pumping on the risk from seismic-induced GREs can only be satisfactorily quantified by using the AT.

Figure 9. Probability of a 100-Year Earthquake-Induced Gas Release Event in a Single-Shell Tank.

Figure 10. Probability of a 1,000-Year Earthquake-Induced Gas Release Event in a Single-Shell Tank.

Figure 11. Probability of a 10,000-Year Earthquake-Induced Gas Release Event in a Single-Shell Tank.

Figure 12. Probability of a Seismic-Induced Small Efficiency Gas Release Event in a Single-Shell Tank.

Figure 13. Probability of a Seismic-Induced Medium Efficiency Gas Release Event in a Single-Shell Tank.

Figure 14. Probability of a Seismic-Induced Large Efficiency Gas Release Event in a Single Shell Tank.

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APPENDIX A
REPORTS OF EXPERT PANELISTS'
UNCERTAINTY DISTRIBUTIONS

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APPENDIX A.1
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

S. F. Agnew

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events per Year
Cond: a. Small efficiency release

Normal

Mean 2

Std.Dev. 0.83

1 3

0.415 1.245

General Comments:

use spontaneous GRE distributions for FII group SSTs from SCOPE elicitation

Specific Comments about Fractiles:

x	F(x)	Rationale
2	0.5	see comments
0.5	0.05	see comments
3	0.9	see comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events per Year
Cond: b. Medium efficiency release

Log-Normal

Mean -5.738

Std.Dev. 0.69

-2.869 -8.607

0.345 1.035

General Comments:

use spontaneous GRE distributions for FII group SSTs from SCOPE elicitation

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.95	see comments
0.003	0.5	see comments
0.001	0.05	see comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events per Year
Cond: c. Large efficiency release

Log-Normal

Mean -9.236

Std.Dev. 1.4

-4.618 -13.854

0.7 2.1

General Comments:

use spontaneous GRE distributions for FII group SSTs from SCOPE elicitation

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.95	see comments
0.0001	0.5	see comments
0.00001	0.05	see comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 3.Total mass of transportable waste material suspended
 Units: Kilograms
 Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal
 Mean -13.764
 Std.Dev. 1.41
 -12 -18
 0.5 1.5

General Comments:

no HEPA failure will limit the particle emission substantially;
 based judgments mainly on three factors: dome volume (780 cubic meters), aerosol
 density (0.001 kg per cubic meter), release factor (1e-6)
 for more details see expert's document

Specific Comments about Fractiles:

x	F(x)	Rationale
1E-07	0.05	high efficiency filters generally have small emission characteristics; that small amount of material will be captured
0.000001	0.5	order of magnitude higher than 5th, order of magnitude lower than 95th percentile
0.00001	0.95	small masses, even at upper end

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Weibull
 Alpha 1.287
 Beta 21.402
 0.5 1.5
 9 27

General Comments:

for cases where the HEPA filter broke, the main considerations are:
 - the material gets into the headspace (spall);
 - turbulence in headspace is sufficient to keep material suspended.

Specific Comments about Fractiles:

x	F(x)	Rationale
2	0.05	is about 10/35 (based on psig) lower than corresponding fractile for >20 psi condition
16	0.5	calculations based on dome volume 1300 (at STP), aerosol density of 0.02 kg per cubic meter (low turbulence) and release factor of 0.6
50	0.95	is about 10/35 (based on psig) lower than corresponding fractile for >20 psi condition

General Comments (cont.):

Looked back at estimates given in SST elicitation and realized that his judgments were relatively high compared to other experts and other reports on that topic (which didn't consider spall);
 expert calculated a pressure differential across the surface (average velocity is 0.5m/s); for sound speed, a value of 50m/s was taken as a good average for the type of material;
 therefore, the differential is exceeding the yield of the material and makes spall possible;
 the median of the uncertainty distribution was derived by parameterizing the dome volume, aerosol density and release factor (spall serves as an additional source term which will increase values)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 3.Total mass of transportable waste material suspended
 Units: Kilograms
 Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Normal

Mean 130

Std.Dev. 61.62

65 195

30 90

General Comments:

see general remarks in 3b

Specific Comments about Fractiles:

x	F(x)	Rationale
10	0.05	calculations based on 0.7 release factor, 0.07kg per cubic meter aerosol density and 2600 cubic meter dome volume
130	0.5	based on rescaling the median of the detonation condition, which served as an upper end
200	0.95	see remarks above

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Normal

Mean 130

Std.Dev. 61.62

65 195

30 90

General Comments:

- see general remarks in 3b;
- use same distribution function as in 3c because there are compensating factors (relative to judgments in 3c):
- increased pressure means more aerosol density and more vented volume;
- on the other hand, vent paths increased subs

Specific Comments about Fractiles:

x	F(x)	Rationale
10	0.05	see general comments
130	0.5	see general comments
200	0.95	see general comments

General Remarks (cont.)

- used same distribution function as in 3c because there are compensating factors (relative to judgments in 3c):
- increase pressure means more aerosol density and more vented volume;
- on the other hand, vent paths increased substantially and are filtered by the soil overburden;
- therefore, on balance this two competing factors led the expert to using the same distribution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Log-Normal

Mean 5.324

Std.Dev. 1.344

4 8

0 2

General Comments:

see general remarks in 3b;

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.05	due to the uncertainty with the extent and specific nature of the detonation, expert wanted to go an order of magnitude below the median
200	0.5	median was based on calculations explained in general comments
2000	0.95	due to the uncertainty with the extent and specific nature of the detonation, expert wanted to go an order of magnitude above the median

General Remarks (cont.):

use a "maximum" aerosol density of 0.1, combined with 3380 dome volume and a relatively high release factor of 0.6 (some filtering associated with soil overburden), but higher release factor compared to 3d because of higher turbulences due to detonation

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 4. Total mass of respirable waste material suspended
 Units: Kilograms
 Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean -16.11
 Std.Dev. 1.41
 -7.5 -22.5
 0.705 2.115

General Comments:

in general: will use a given factor to be applied to distributions from variable 3

Specific Comments about Fractiles:

x	F(x)	Rationale
1E-08	0.05	0.1 times corresponding fractile from 3a
1E-07	0.5	0.1 times corresponding fractile from 3a
0.000001	0.95	0.1 times corresponding fractile from 3a

General Comments (cont.):

not a lot of information about particle sizes; some documents (Herting and other documents referenced in expert's write-up) suggest that 80% of the total mass of PARTICLES is respirable (less than 10 micron diameter);
 but: only about 60% of the total mass is actually particles; even the amount that this would suggest is still too high for a median since these measurements "teased apart" the particles (leading at an overestimate of the real respirable fraction);

expert suggested that there is enough uncertainty expressed in the distributions for variable 3 such that it is not necessary to assess an uncertainty distribution of percent respirable;
 rather, a given factor should be applied to distributions from variable 3 (with corresponding changes in parameters of fitted distributions)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Weibull

Alpha 1.291

Beta 2.117

0.5 1.5

0.5 4

General Comments:

see comments for 4a; did not think that increased pressure and associated turbulence would impact the fraction of respirable material

Specific Comments about Fractiles:

x	F(x)	Rationale
0.2	0.05	0.1 times corresponding fractile of 3b
1.6	0.5	0.1 times corresponding fractile of 3b
5	0.95	0.1 times corresponding fractile of 3b

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Normal

Mean 13

Std.Dev. 6.162

6.5 19.5

3.081 9.243

General Comments:

see comments for 4a; did not think that increased pressure and associated turbulence would impact the fraction of respirable material

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.05	0.1 times corresponding fractile from 3c
13	0.5	0.1 times corresponding fractile from 3c
20	0.95	0.1 times corresponding fractile from 3c

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 4. Total mass of respirable waste material released
 Units: Kilograms
 Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Normal
 Mean 52
 Std.Dev. 24.648
 26 78
 12.324 36.972

General Comments:

see comments for 4a; felt that in case of dome failure, venting rate increases, but more importantly the suddenness of the event and increased turbulence (higher shear forces) provide physical mechanism to break up the particles;

Specific Comments about Fractiles:

x	F(x)	Rationale
4	0.05	0.4 times corresponding fractile from 3d (fraction of respirable should be considerably higher than conditions a-c, but less than 0.5)
52	0.5	0.4 times corresponding fractile from 3d (fraction of respirable should be considerably higher than conditions a-c, but less than 0.5)
80	0.95	0.4 times corresponding fractile from 3d (fraction of respirable should be considerably higher than conditions a-c, but less than 0.5)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Log-Normal
 Mean 4.81
 Std.Dev. 1.344
 4 5
 0.672 2.016

General Comments:

see comments to case 4d, but with detonation we have the ability to not only break up the agglomerates, but also to break up larger particles

Specific Comments about Fractiles:

x	F(x)	Rationale
12	0.05	0.6 times corresponding fractile from 3e (could go above 0.5 respirable fraction due to reasons mentioned in general comments)
120	0.5	0.6 times corresponding fractile from 3e (could go above 0.5 respirable fraction due to reasons mentioned in general comments)
1200	0.95	0.6 times corresponding fractile from 3e (could go above 0.5 respirable fraction due to reasons mentioned in general comments)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 5. Duration of Buoyant Displacement Gas Release Event
 Units: Minutes
 Cond: a. Small efficiency release

Weibull

Alpha 1.358

Beta 13.18

0.5 1.5

5 15

General Comments:

reasonable data (SHMS monitoring data from DST, e.g., Wilkins et al., Stewart presentation) for small GREs and large GREs
 small BD GREs lasted from 1 to 20 minutes (with some skew to the right)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.05	based on range given in SHMS measurement
10	0.5	based on SHMS data and assuming that the distribution is not symmetrical but has a skew to the right
30	0.95	based on range given in SHMS measurement

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 5. Duration of Buoyant Displacement Gas Release Event
 Units: Minutes
 Cond: b. Medium efficiency release

Weibull

Alpha 1.052

Beta 243.3

0.5 1.5

150 450

General Comments:

less data for medium BD GREs; therefore the fractiles were "scaled" to fall roughly half-way between the corresponding ones for small and large GREs

Specific Comments about Fractiles:

x	F(x)	Rationale
10	0.05	based on range given in SHMS measurement
200	0.5	based on SHMS data and assuming that the distribution is not symmetrical but has a skew to the right
600	0.95	based on range given in SHMS measurement

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 5. Duration of Buoyant Displacement Gas Release Event
 Units: Minutes
 Cond: c. Large efficiency release

Weibull

Alpha 1.001

Beta 455.6

0.5 1.5

200 600

General Comments:

reasonable data (SHMS monitoring data from DST, e.g., Wilkins et al., Stewart presentation) for small GREs and large GREs
 large GREs tend to be coupled and "clustered" running between 20 minutes and 1400 minutes, with more weight given to the lower end f

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.05	based on range given in SHMS measurement
400	0.5	based on SHMS data and assuming that the distribution is not symmetrical but has a skew to the right
1400	0.95	based on range given in SHMS measurement

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
 Units: Probability (dimensionless)
 Cond: 1a. 1E-2 /year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta	
Alpha	0.8
Beta	0.36
	0.4 1.2
	0.18 0.54

General Comments:

use the medium GRE condition for 1e-3 earthquake to scale down

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	see general comments
0.8	0.5	see general comments
0.99	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Weibull

Alpha 1.979

Beta 0.3492

0.5 2

0.1 0.5

General Comments:

using the large GRE from 1e-3 earthquake to scale down would make this a little bit too frequent; scaled it down a bit further

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.05	see general comments
0.3	0.5	see general comments
0.5	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. $1E-2$ / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 1.19

Beta 0.1402

0.5 1.5

0.1 0.3

General Comments:

wanted to make this unlikely but not impossible

Specific Comments about Fractiles:

x	F(x)	Rationale
0.005	0.05	wanted to allow for a wide range
0.1	0.5	unlikely to happen
0.35	0.95	wanted to allow for a wide range

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 0.95
 Beta 0.25
 0.475 1.425
 0.125 0.375

General Comments:

documentation on the design base earthquake characteristics (Weiner et al, Reid et al; see expert's write-up) differ by a factor of 3

Specific Comments about Fractiles:

x	F(x)	Rationale
0.25	0.05	wanted to go down to account for the fact that earthquake induced movements can be quite irregular and not lead to the 4-5 waves assumed for median
0.9	0.5	see general comments; very likely to get a small GRE under this scenario
0.999	0.99	close to one

General Comments (cont.)

Reid et al. used 0.4g earthquake for 1e-3 earthquake and calculated a displacement of 4-5 inches (roughly equivalent to a Richter 8 100km from epicenter); San Francisco earthquake was 8.25; not a lot of information about other earthquakes; under these conditions, a small GRE is very likely

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of seismic induced GRE
Units: Probability
Cond: 1e. 1E-3 earthquake; medium GRE; thick liquid layer

Beta	
Alpha	0.8
Beta	0.36
	0.4
	0.18
	1.2
	0.54

General Comments:

same documents as for 61d; used 0.99 as an upper end and thought that median and lower end need to be scaled down quite a bit compared to small GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	see general comments
0.8	0.5	see general comments
0.99	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Beta
 Alpha 2.525
 Beta 4
 0.5 3
 0.5 4

General Comments:

mainly depends on how waves in the liquid amplify and break up the rest of the waste and release it; for more than 25% of the tank to be affected by such an earthquake, the median would be about "even odds"

Specific Comments about Fractiles:

x	F(x)	Rationale
0.025	0.05	wanted to allow for a wide range
0.4	0.5	slightly less than "even odds"
0.65	0.95	wanted to allow for a wide range

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 19.3
 Beta 2.25
 2.5 20
 0 3

General Comments:

for an earthquake of that size, a small GRE is almost certain

Specific Comments about Fractiles:

x	F(x)	Rationale
0.75	0.05	wanted to go down to account for the fact that earthquake induced movements can be quite irregular and not lead to the 4-5 waves assumed for median
0.95	0.5	see general comments; very likely to get a small GRE under this scenario
0.9995	0.95	close to one

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/98
 Expert: Steve Agnew
 Analyst: Thomas Eppel
 Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
 Units: Probability (dimensionless)
 Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta
 Alpha 0.95
 Beta 0.25
 0.475 1.425
 0.125 0.375

General Comments:

scaled from 1e-3 earthquake; used the small GRE distribution from that condition

Specific Comments about Fractiles:

x	F(x)	Rationale
0.25	0.05	see general comments
0.9	0.5	see general comments
0.999	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Steve Agnew
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. $1E-4$ / year return frequency earthquake, large efficiency gas release, thick liquid layer

Beta
 Alpha 0.8
 Beta 0.36
 0.4 1.2
 0.18 0.54

General Comments:

used medium GRE from $1e-3$ earthquake scenario

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	see comments
0.8	0.5	see comments
0.99	0.95	see comments

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APPENDIX A.2
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

E. C. Beahm

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SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD-GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Weibull
Alpha 2.28
Beta 9.375
 1 3
 2.5 15

General Comments:

> 1m will not be around for too long. SSTs in worse shape than DSTs. Probability of DST will be lower than from SSTs. Small releases - same mechanism (changes in atmospheric pressure).

Specific Comments about Fractiles:

x	F(x)	Rationale
8	0.5	4-10 atmospheric pressure drops/year plus Ogden data
15	0.95	Physical limitation, don't generate more gas than that, truncate!
1	0.05	
0.5	0.01	Almost certainly above that

General Comments (cont.):

Revisited SSTs for small releases. S 111 data (Ogden), 8 small GRE.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Ed Beahm
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD-GRE behavior
Units: Events / Year
Cond: b. Medium GRE

Log-Normal

Mean -4.502

Std.Dev. 1.156

-4 -5

0.5 1.5

General Comments:

Based on information supplied by Beahm after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.5	
0.2	0.99	
0.002	0.05	
0.1	0.95	
0.001	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD-GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Weibull

Alpha 1.79

Beta 0.00063

0.5 2

0.0005 0.0015

General Comments:

In SST evaluation, large were similar to 1b for DSTs. No leaks in DSTs and no structural integrity problems. Very improbable.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0005	0.5	Subjective, 1 in 2000 years, compare to other events, e.g. core meltdowns.
0.002	0.99	
0.0001	0.05	
0.001	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement GREs
Units: Minutes
Cond: a. Small efficiency release

Weibull

Alpha	0.914
Beta	260
0.5	2
50	400

General Comments:

Blain Barton provided analysis on 3/4/98, plots generated by Ed. Ed adopted his approach. Blain contacted Nick Kirch who supplied info for large events (SY 101). Median of 17min for the large event from Nick.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.01	truncate, some finite period required
2880	0.99	truncate, highest data point, two days, after that it is simply a gradual release
137	0.5	
510	0.75	
85	0.25	
40	0.1	

Use same distribution for 5b

General Comments (cont.):

Ed estimated median of 20 min based on tapes (for large release). Ed created scatterplot and found no corr between peak H2 and time. Longest time (for five tanks) for A1W 101, but there was no clear mechanism to separate out the tanks. AN tanks were somewhat lower. Created cumulative using Barton's data. For large GREs used Kirch, but restricted to one tank (SY 101).

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 5. Duration of Buoyant Displacement GREs
 Units: Minutes
 Cond: b. Medium efficiency release

Weibull
 Alpha 0.914
 Beta 260
 0.5 2
 50 400

General Comments:

Blain Barton provided analysis on 3/4/98, plots generated by Ed. Ed adopted his approach. Blain contacted Nick Kirch who supplied info for large events (SY 101). Median of 17min for the large event from Nick.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.01	truncate, some finite period required
2880	0.99	truncate, highest data point, two days, after that it is simply a gradual release
137	0.5	
510	0.75	
85	0.25	
40	0.1	

General Comments (cont.):

Ed estimated median of 20 min based on tapes (for large release). Ed created scatterplot and found no corr between peak H2 and time. Longest time (for five tanks) for AW 101, but there was no clear mechanism to separate out the tanks. AN tanks were somewhat lower. Created cumulative using Barton's data. For large GREs used Kirch, but restricted to one tank (SY 101).

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement GREs
Units: Minutes
Cond: c. Large efficiency release

Weibull

Alpha 1.36

Beta 21.5

1 3

12.5 37.5

General Comments:

Blain Barton provided analysis on 3/4/98, plots generated by Ed. Ed adopted his approach. Blain contacted Nick Kirch who supplied info for large events (SY 101). Median of 17min for the large event from Nick.

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.5	SY 101 plus data from Nick Kirch
120	0.99	truncate, largest in SY 101 was 96 min
1	0.01	must take some time
7	0.25	two seven minute events

General Comments (cont.):

Ed estimated median of 20 min based on tapes (for large release). Ed created scatterplot and found no corr between peak H2 and time. Longest time (for five tanks) for AW 101, but there was no clear mechanism to separate out the tanks. AN tanks were somewhat lower. Created cumulative using Barton's data. For large GREs used Kirch, but restricted to one tank (SY 101).

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in SSTs
Units: Probability (dimensionless)
Cond: 2a. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
	100%	
		100 year earthquake must be at least as waste disturbing as one inch of merc. barometric pressure.
		FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
		Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
		Started with 10(-3) with medium, unpumped.
		Adjusted to include non-mobilized waste.
		Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2b. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Weibull
 Alpha 7.7
 Beta 0.7875
 0.5 8
 0.375 1.125

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.75	0.5	Unpumped, 10(-3) was 100%, a little less than that.
0.9	0.95	truncate at 1
0.5	0.05	

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped.

Adjusted to include non-mobilized waste.

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2c. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Normal

Mean 0.6

Std.Dev. 0.118

0.3 0.9

0.05 0.15

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.6	0.5	Unpumped, 10(-3) was 100%, a little less than that.
0.8	0.95	truncate at 1
0.4	0.05	

50% probability for the pumped, large
 75% probability for the unpumped, medium
 Bounds the unpumped, large

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
 Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
 Adjusted to include non-mobilized waste.
 Large release extends beyond mobilized plus unpumped.

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2d. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 2

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
		100%, see previous reasoning for Variable 63.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2e. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Weibull
Alpha 7.7
Beta 0.7875
0.5 8
0.375 1.125

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
0.5	0.05	same as for unpumped 62b&h
0.75	0.5	
0.9	0.95	

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2f. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Normal

Mean 0.6

Std.Dev. 0.118

0.3 0.9

0.05 0.15

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.4	0.05	same as 62c&l
0.6	0.5	100%
0.8	0.95	

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 2g. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
	100%.	
		100 year earthquake must be at least as waste disturbing as one inch of merc. barometric pressure.
		FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
		Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
		Started with 10(-3) with medium, unpumped.
		Adjusted to include non-mobilized waste.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2h. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 3

Weibull

Alpha	7.7
Beta	0.7875
0.5	8
0.375	1.125

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.75	0.5	Unpumped, 10(-3) was 100%, a little less than that.
0.9	0.95	truncate at 1
0.5	0.05	

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped.

Adjusted to include non-mobilized waste.

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Normal

Mean	0.6
Std.Dev.	0.118
	0.3 0.9
	0.05 0.15

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.6	0.5	Unpumped, 10(-3) was 100%, a little less than that.
0.8	0.95	truncate at 1
0.4	0.05	

50% probability for the pumped, large
 75% probability for the unpumped, medium
 Bounds the unpumped, large

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
 Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
 Adjusted to include non-mobilized waste.
 Large release extends beyond mobilized plus unpumped.

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2j. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 3

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
		100%, see previous reasoning for Variable 63.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2k. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Weibull

Alpha 7.73

Beta 0.7875

0.5 8

0.375 1.125

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
0.5	0.05	same as for unpumped 62b&h
0.75	0.5	
0.9	0.95	

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2I. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Normal

Mean 0.6

Std.Dev. 0.118

0.3 0.9

0.05 0.15

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
0.4	0.05	same as 62c&l
0.6	0.5	100%
0.8	0.95	

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahrn
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3a. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% for small, based on Chuck's analyses leading to medium releases at 10(-3)

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped. 63a=63g = 100%.

Adjusted to include non-mobilized waste.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 3b. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% because Chuck's analysis were based on pumped version.
		Definitely occurs with unpumped.
		FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
		Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
		Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
		Adjusted to include non-mobilized waste.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3c. 1E-3/year return frequency earthquake, large efficiency GRE, unpumped, FG 2

Normal

Mean 0.95

Std.Dev. 0.02

0.475 1.425

0.01 0.03

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.95	0.5	Similar to Chuck's SST with liquid layer, quite probable.
0.9	0.05	
1	1	Natural bound, truncate at 1.0!

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range.

Started with 10(-3) with medium, unpumped. 63a=63g = 100%.

Adjusted to include non-mobilized waste.

Large release extends beyond mobilized plus unpumped.

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3d. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 2

General Comments:

Specific Comments about Fractiles:

x 	F(x) 	Rationale 100% based on same reasoning as 63a&g
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FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped. 63a=63g = 100%.

Adjusted to include non-mobilized waste.

Large release extends beyond mobilized plus unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3e. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% based on same reasoning as 63b&h

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
 Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
 Adjusted to include non-mobilized waste.
 Large release extends beyond mobilized plus unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3f. 1E-3/year return frequency earthquake; large efficiency gas release, pumped, FG 2

Weibull

Alpha 7.881

Beta 0.7875

1 8
0.375 1.125

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.75	0.5	More gas released than Chuck's medium release.
0.5	0.05	
0.9	0.95	truncate at 1.0.

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped.

Adjusted to include non-mobilized waste.

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3g. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% for small, based on Chuck's analyses leading to medium releases at 10(-3)
		FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
		Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
		Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
		Adjusted to include non-mobilized waste.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 3h. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% because Chuck's analysis were based on pumped version.
		Definitely occurs with unpumped.
		FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
		Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
		Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
		Adjusted to include non-mobilized waste.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3i. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Normal

Mean 0.95

Std.Dev. 0.02

0.475 1.425

0.01 0.03

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.95	0.5	Similar to Chuck's SST with liquid layer, quite probable.
0.9	0.05	
1	1	Natural bound, truncate at 1.0!

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped. 63a=63g = 100%.

Adjusted to include non-mobilized waste.

Large release extends beyond mobilized plus unpumped.

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3j. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% based on same reasoning as 63a&g

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
 Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
 Adjusted to include non-mobilized waste.
 Large release extends beyond mobilized plus unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3k. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		100% based on same reasoning as 63b&h

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range
 Started with 10(-3) with medium, unpumped. 63a=63g = 100%.
 Adjusted to include non-mobilized waste.
 Large release extends beyond mobilized plus unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3l. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Weibull

Alpha 7.881

Beta 0.7875

1 8

0.375 1.125

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.75	0.5	More gas released than Chuck's medium release.
0.5	0.05	
0.9	0.95	truncate at 1.0.

FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.

Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range

Started with 10(-3) with medium, unpumped.

Adjusted to include non-mobilized waste.

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4a. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x **F(x)** **Rationale**
 All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4b. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x **F(x)** **Rationale**
 All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4c. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x **F(x)** **Rationale**
 All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 4d. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 2

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x F(x) **Rationale**
 All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4e. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x **F(x)** **Rationale**
 All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4f. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 2

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x	F(x)	Rationale All probabilities are 100%. Based on Chuck's unpumped case at 10(-3) generated medium GRE. 10(-4) must then create small, medium, and large release for both pumped and unpumped.
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Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4g. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x F(x)

Rationale

All probabilities are 100%.

Based on Chuck's unpumped case at 10(-3) generated medium GRE.

10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4h. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x	F(x)	Rationale All probabilities are 100%. Based on Chuck's unpumped case at 10(-3) generated medium GRE. 10(-4) must then create small, medium, and large release for both pumped and unpumped.
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Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 4i. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x F(x)

Rationale

All probabilities are 100%.

Based on Chuck's unpumped case at 10(-3) generated medium GRE.

10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/1998
Expert: Ed Beahm
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4j. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 3

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x F(x)

Rationale

All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 4k. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x F(x) **Rationale**

All probabilities are 100%.
 Based on Chuck's unpumped case at 10(-3) generated medium GRE.
 10(-4) must then create small, medium, and large release for both pumped and unpumped.

Probability = 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/9/98
 Expert: Ed Beahm
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Units: Probability (dimensionless)
 Cond: 4I. 1E-4/year-return frequency earthquake, large efficiency gas release, pumped, FG 3

General Comments FG 2 and 3 separation questioned. FG2=FG3. Template of FG2.
 Based on Chuck Stewart's analyses, 10(-3) events. 5%-13% release at 10(-3) in medium range. Adjusted to include non-mobilized waste.
 Started with 10(-3) with medium, unpumped.
 Large release extends beyond mobilized plus unpumped.

Specific Comments about Fractiles:

x	F(x)	Rationale All probabilities are 100%. Based on Chuck's unpumped case at 10(-3) generated medium GRE. 10(-4) must then create small, medium, and large release for both pumped and unpumped.
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Probability = 1.0

APPENDIX A.3
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

P. D. d'Entremont

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SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD-GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Log-Normal
 Mean -6.1841
 Std.Dev. 2.71
 -4.355 -13.065
 1.355 4.065

General Comments:

Use 1 b&c. Frequencies are ten times higher.

Specific Comments about Fractiles:

x	F(x)	Rationale
10	1	
1	0.99	
7.6E-06	0.025	150 tank-years without burp in tanks that do not pass roll-over test.
0.36	0.975	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD-GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Log-Normal

Mean -8.71

Std.Dev. 2.71

-4.355 -13.065

1.355 4.065

General Comments:

b=c, no physical basis, some unknown process, can't distinguish between medium and large. Large uncertainty band, different types of tanks. 150 tank-years with no burps.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.1	0.99	
7.6E-07	0.025	150 tank-years without burp in tanks that do not pass roll-over test.
0.036	0.975	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD-GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Log-Normal

Mean -8.71

Std.Dev. 2.71

-4.355 -13.065

1.355 4.065

General Comments:

b=c, no physical basis, some unknown process, can't distinguish between medium and large. Large uncertainty band, different types of tanks. 150 tank-years with no burps.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.1	0.99	
7.6E-07	0.025	150 tank-years without burp in tanks that do not pass roll-over test.
0.036	0.975	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -7.56

Std.Dev. 1.36

-3.5 -10.5

0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	1	
0.005	0.95	shifted by 1/100 from c
0.0005	0.5	
0.00005	0.05	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean -5.32

Std.Dev. 1.35

-3.5 -10.5

0.5 1.5

General Comments:

b: multiply all fractiles by .1, less turbulence in tanks

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	1	
0.05	0.95	divide by 10 from c
0.005	0.5	
0.0005	0.05	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -2.97

Std.Dev. 1.35

-1.5 -4.5

0.5 1.5

General Comments:

Narrow distribution, computed median based on 11 roll-over events w/o ignition

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.5	0.95	
0.05	0.5	
0.005	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

Custom Curve

General Comments:

Use Chuck Stewart's data, DST roll over tanks except 101SY

Specific Comments about Fractiles:

x	F(x)	Rationale
86	0	Shortest time recorded, from total in 25, medium releases have to take some time around 1h or above
1128	1	Upper bound in data
218	0.5	
485	0.75	
115	0.25	

Use shifted exponential to start at 86.

Don't worry about upper tail

USE: $F(x)=1-\exp(-0.00322*(x-86))$

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
 Expert: Paul d'Entremont
 Analyst: Detlof von Winterfeldt
 Variable: 5. Duration of Buoyant Displacement Gas Release Event
 Units: Minutes
 Cond: b. Medium efficiency release

Custom Curve

General Comments:

Use Chuck Stewart's data, DST roll over tanks except 101SY

Specific Comments about Fractiles:

x	F(x)	Rationale
86	0	Shortest time recorded, from total in 25, medium releases have to take some time around 1h or above
1128	1	Upper bound in data
218	0.5	
485	0.75	
115	0.25	

Use shifted exponential to start at 86.
 Don't worry about upper tail

USE: $F(x) = 1 - \exp(-.00322 \cdot (x - 86))$

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Exponential
 Lambda 0.0282
 0
 0.01 0.15

General Comments:

Use Chuck Stewart's data. Use medium plot and divide fractile by 10. 101SY had release times in "minutes".

Specific Comments about Fractiles:

x	F(x)	Rationale
4	0	Faster release from tapes
112.8	1	
21.8	0.5	All numbers from medium divided by 10.
48.5	0.75	
11.5	0.25	

Can go to zero. Middle part of curve is most important.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
 Expert: Paul D'Entremont
 Analyst: Detlof von Winterfeldt
 Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
 Units: Probability (dimensionless)
 Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Normal

Mean	0.5
Std.Dev.	0.266
	0.25 0.75
	0.1 0.3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	If a tank might undergo BD even a small earthquake can kick of a small release with certainty
0.5	0.5	
0.01	0.05	Longer left tail

Truncate at 1, but not at lower end.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Weibull

Alpha 0.77

Beta 0.086

0.5 1.5

0.05 0.15

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	1	1/10 but adjusted
0.05	0.5	1/10 of the 1000 year earthquake fractiles
0.001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 0.64

Beta 0.01945

0.5 1.5

0.005 0.02

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	1	"Ripe" tanks might go with 50% chance
0.01	0.5	1/10 th of 1000 year earthquake
0.0002	0.05	same as above

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Small releases will definitely occur with a 1000 year earthquake.

Probability=1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Normal

Mean	0.5
Std.Dev.	0.2
0.25	0.75
0.1	0.3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	If a tank is "ripe" for a BD, it will do so even with a 10(-3) earthquake
0.5	0.5	
0.01	0.05	Long tail expected for tanks that are not "ripe"

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 0.73

Beta 0.167

0.5 1.5

0.05 0.2

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	Tank ripe for BD
0.1	0.5	If a tank is not ripe, earthquake has to supply all energy to liquefy waste, pretty unlikely
0.002	0.05	

Truncate at 1.0

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

0.05 0.15

General Comments:

Specific Comments about Fractiles:

x 	F(x) 	Rationale With the 10000 year earthquake you will at least kick of a medium and definitely a small gas release
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Probability=1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

0.05 0.15

General Comments:

Specific Comments about Fractiles:

x 	F(x) 	Rationale With the 10000 year earthquake you will at least kick of a medium and definitely a small gas release
----------------------	-------------------------	--

Probability=1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Paul D'Entremont
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. 1E-4 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Normal

Mean 0.5

Std.Dev. 0.2495

0.25 0.75

0.1 0.75

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	"Ripe" tanks can have a very high p of large GRE
0.5	0.5	If not ripe - 10000 year earthquake can liquefy all waste
0.01	0.05	

Truncate at 1.0!!!

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: a. $1E-2$ / year return frequency earthquake

Log-Normal

Mean -5.3

Std.Dev. 1.3

-2.65 -7.95

0.65 1.95

General Comments:

Probability is high for 100 year earthquake.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	1	
0.005	0.5	Divide by 10 from 7b
0.0005	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: b. 1E-3 /year return frequency earthquake

Log-Normal
 Mean -3
 Std.Dev. 1.3
 -1.5 -4.5
 0.65 1.95

General Comments:

Probability is high for 1000 year earthquake.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.05	0.5	
0.005	0.05	

For the tanks with the air lift circulators = probability is 1.0
 For other tanks = use probability distribution

Truncate at 1.0 and don't worry about left tail.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Paul d'Entremont
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: c. $1E-4$ / year return frequency earthquake

Normal
 Mean 0.5
 Std.Dev. 0.19373
 0.25 0.75
 0.01 0.2

General Comments:

Probability is high for 10000 year earthquake.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.5	0.5	Midpoint of curve selected by SST panelists
0.05	0.05	

For the tanks with the air lift circulators = probability is 1.0

For other tanks = use probability distribution

Truncate at 1.0 and don't worry about left tail.

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APPENDIX A.4
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

C. Easterly

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -9.12

Std.Dev. 1.34

-6 -18

1 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-04	0.5	based on p(ignition) of many different events and tank characteristics
1.00E-06	0.05	
1.00E-03	0.95	
1	1	Truncate at 1.0

Reviewed ignition sources in DSTs

All systems rated as high hazard for electrical spark have been removed
 Assuming normal operations and conditions
 Operating procedures for DSTs are quite stringent

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean -7.56

Std.Dev. 1.4

-6 -18

1 3

General Comments Scaled up from small by a factor of 5

Specific Comments about Fractiles:

x	F(x)	Rationale
5.00E-04	0.5	based on p(ignition) of many different events and tank characteristics
5.00E-06	0.05	
5.00E-03	0.95	
1	1	Truncate at 1.0

Reviewed ignition sources in DSTs

All systems rated as high hazard for electrical spark have been removed

Assuming normal operations and conditions

Operating procedures for DSTs are quite stringent

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -6.8

Std.Dev. 1.32

-4 -18

1 3

General Comments Scaled up from medium by a factor of 2 (factor of 10 from small)

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-03	0.5	based on p(ignition) of many different events and tank characteristics
1.00E-05	0.05	
1.00E-02	0.95	
1	1	Truncate at 1.0 Reviewed ignition sources in DSTs

All systems rated as high hazard for electrical spark have been removed
 Assuming normal operations and conditions
 Operating procedures for DSTs are quite stringent

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 2.115

Beta 0.0478

0.5 10

0.01 0.1

General Comments Eval based on air loading capacities for dust;
 Nominal vol of 4000 m3 to start

Specific Comments about Fractiles:

x	F(x)	Rationale
4.00E-02	0.5	median transportable material is .04 kg (4000 times .00001)
4.00E-03	0.05	factor of 10 less than median
8.00E-02	0.95	factor of 2 greater than median

Maximum of .00001 kg/m3 to start; will stay in headspace for hours

No Decrease in capacity because no settling; will stay suspended

median material suspended is .04 kg (4000 times .00001)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Weibull

Alpha 2.115

Beta 0.244

0.5 10

0.1 1

General Comments Eval based on air loading capacities for dust;
Nominal vol of 4000 m3 to start

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E-01	0.5	median transportable material is .2 kg (4000 times .00005)
2.00E-02	0.05	factor of 10 less than median
4.00E-01	0.95	factor of 2 greater than median

Maximum of .001 kg/m3 to start; will stay in headspace for a long time
Decrease in capacity by factor of 20 in settling process, .00005 kg/m3

median material suspended is .2 kg (4000 times .00005)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Weibull

Alpha 2.21

Beta 0.487

0.5 10

0.1 1

General Comments Eval based on air loading capacities for dust;
Nominal vol of 4000 m³ to start

Specific Comments about Fractiles:

x	F(x)	Rationale
4.00E-01	0.5	median transportable material is .4 kg (4000 times .0001)
4.00E-02	0.05	factor of 10 less than median
8.00E-01	0.95	factor of 2 greater than median

Maximum of .01 kg/m³ to start; will stay in headspace for a while
Decrease in capacity by factor of 100 in settling process, .0001 kg/m³

median material suspended is .4 kg (4000 times .0001)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull

Alpha 2.21

Beta 0.487

0.5 10

0.1 1

General Comments Eval based on air loading capacities for dust;
 Nominal vol of 4000 m3 to start

Specific Comments about Fractiles:

x	F(x)	Rationale
4.00E-01	0.5	median material loss is .4 kg (4000 times .0001)
4.00E-02	0.05	factor of 10 less than median
8.00E-01	0.95	factor of 2 greater than median

Maximum of .1kg/m3 to start

Decrease in capacity by factor of 100 in exit process, .001 kg/m3

Fast moving air will hit stagnant pool of air

Decrease in capacity by factor of 10 once outside tank, .0001 kg/m3

median material loss is .4 kg (4000 times .0001)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 2.115

Beta 2.4

0.5 10

0.5 10

General Comments Eval based on air loading capacities for dust;
Nominal vol of 4000 m3 to start

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E+00	0.5	median material loss is 2 kg (4000 times .0005)
2.00E-01	0.05	factor of 10 less than median
4.00E+00	0.95	factor of 2 greater than median

Maximum of 1kg/m3 to start

Decrease in capacity by factor of 100 in exit process, .01 kg/m3

Fast moving air will hit stagnant pool of air

Decrease in capacity by factor of 20 once outside tank,.0005 kg/m3

median material loss is 2 kg (4000 times .0005)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 5/11/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter
 Convolved total*respirable factor

Weibull

Alpha 1.64

Beta 0.0262

0.5 2

1.00E-02 0.1

General Comments Product of transportable waste (3a) and Respirable Fraction of Mass, Beta(2.55,2.04)
 Fractiles calc using @Risk (Latin hypercube sampling, 1000 iterations)

Specific Comments about Fractiles:

x	F(x)	Rationale
4.80E-03	0.05	5% Perc =
6.65E-03	0.1	10% Perc =
8.44E-03	0.15	15% Perc =
1.03E-02	0.2	20% Perc =
1.18E-02	0.25	25% Perc =
1.32E-02	0.3	30% Perc =
1.65E-02	0.4	40% Perc =
2.00E-02	0.5	50% Perc =
2.43E-02	0.6	60% Perc =
2.89E-02	0.7	70% Perc =
3.25E-02	0.75	75% Perc =
3.50E-02	0.8	80% Perc =
3.90E-02	0.85	85% Perc =
4.49E-02	0.9	90% Perc =
5.25E-02	0.95	95% Perc =

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 5/11/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.
 Convolved total*respirable factor

Weibull

Alpha 1.5545

Beta 0.13573

0.5 2

1.00E-03 0.5

General Comments Product of transportable waste (3b) and Respirable Fraction of Mass, Beta(2.55,2.04)
 Fractiles calc using @Risk (Latin hypercube sampling, 1000 iterations)

Specific Comments about Fractiles:

x	F(x)	Rationale
2.14E-02	0.05	5% Perc =
3.29E-02	0.1	10% Perc =
4.03E-02	0.15	15% Perc =
5.08E-02	0.2	20% Perc =
5.85E-02	0.25	25% Perc =
7.04E-02	0.3	30% Perc =
8.64E-02	0.4	40% Perc =
1.05E-01	0.5	50% Perc =
1.26E-01	0.6	60% Perc =
1.48E-01	0.7	70% Perc =
1.65E-01	0.75	75% Perc =
1.83E-01	0.8	80% Perc =
2.07E-01	0.85	85% Perc =
2.43E-01	0.9	90% Perc =
2.72E-01	0.95	95% Perc =

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 5/11/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome
 Convolved total*respirable factor

Weibull

Alpha 1.595

Beta 0.2773

0.5 2

1.00E-02 1

General Comments Product of transportable waste (3c) and Respirable Fraction of Mass, Beta(2.55,2.04)
 Fractiles calc using @Risk (Latin hypercube sampling, 1000 iterations)

Specific Comments about Fractiles:

x	F(x)	Rationale
4.27E-02	0.05	5% Perc =
6.77E-02	0.1	10% Perc =
8.80E-02	0.15	15% Perc =
1.08E-01	0.2	20% Perc =
1.26E-01	0.25	25% Perc =
1.41E-01	0.3	30% Perc =
1.74E-01	0.4	40% Perc =
2.11E-01	0.5	50% Perc =
2.53E-01	0.6	60% Perc =
3.01E-01	0.7	70% Perc =
3.25E-01	0.75	75% Perc =
3.65E-01	0.8	80% Perc =
4.13E-01	0.85	85% Perc =
4.57E-01	0.9	90% Perc =
5.31E-01	0.95	95% Perc =

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 5/11/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 4. Total mass of respirable waste material released
Units: kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome
 Convolved total*respirable factor

Weibull

Alpha 1.58021

Beta 0.27829

0.001 2

1.00E-02 1

General Comments Product of transportable waste (3d) and Respirable Fraction of Mass, Beta(2.55,2.04)
 Fractiles calc using @Risk (Latin hypercube sampling, 1000 iterations)

Specific Comments about Fractiles:

x	F(x)	Rationale
4.62E-02	0.05	5% Perc =
6.62E-02	0.1	10% Perc =
8.67E-02	0.15	15% Perc =
1.02E-01	0.2	20% Perc =
1.19E-01	0.25	25% Perc =
1.36E-01	0.3	30% Perc =
1.74E-01	0.4	40% Perc =
2.12E-01	0.5	50% Perc =
2.53E-01	0.6	60% Perc =
2.96E-01	0.7	70% Perc =
3.28E-01	0.75	75% Perc =
3.63E-01	0.8	80% Perc =
4.12E-01	0.85	85% Perc =
4.64E-01	0.9	90% Perc =
5.36E-01	0.95	95% Perc =

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 5/11/1998
 Expert: Clay Easterly
 Analyst: Richard John
 Variable: 4. Total mass of respirable waste material released
 Units: kilograms
 Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome
 Convolved total*respirable factor

Weibull

Alpha 1.61

Beta 1.35

0.5 2

1.00E+00 2

General Comments Product of transportable waste (3e) and Respirable Fraction of Mass, Beta(2.55,2.04)
 Fractiles calc using @Risk (Latin hypercube sampling, 1000 iterations)

Specific Comments about Fractiles:

x	F(x)	Rationale
2.06E-01	0.05	5% Perc =
3.29E-01	0.1	10% Perc =
4.15E-01	0.15	15% Perc =
4.89E-01	0.2	20% Perc =
5.81E-01	0.25	25% Perc =
6.90E-01	0.3	30% Perc =
8.69E-01	0.4	40% Perc =
1.05E+00	0.5	50% Perc =
1.23E+00	0.6	60% Perc =
1.48E+00	0.7	70% Perc =
1.62E+00	0.75	75% Perc =
1.81E+00	0.8	80% Perc =
2.00E+00	0.85	85% Perc =
2.24E+00	0.9	90% Perc =
2.63E+00	0.95	95% Perc =

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2a. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Beta
 Alpha 0.792
 Beta 0.965
 0.396 1.188
 0.4825 1.4475

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
3.60E-01	0.5	see general comments
7.20E-01	0.8	see general comments
3.60E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2b. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Log-Normal

Mean -2.538

Std.Dev. 0.953

-1.269 -3.807

0.4765 1.4295

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
1.60E-01	0.8	see general comments
8.00E-02	0.5	see general comments
8.00E-03	0.01	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2c. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Weibull

Alpha 0.98

Beta 0.086

0.49 1.47

0.043 0.129

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
1.20E-01	0.8	see general comments
6.00E-02	0.5	see general comments
6.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2d. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 2
 (note: not conditioned on nonoccurrence of large or medium GRE)

Log-Normal

Mean -3.3

Std.Dev. 0.83

-3 -9

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 10 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
3.60E-02	0.5	Important points to fit are .5 and .8 fractiles
7.20E-02	0.8	
3.60E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system

Deibler ref says 10 to 100 times less likely for dry

More difficult to disturb mass when dry

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2e. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal
Mean -4.8
Std.Dev. 0.78
-3 -9
0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 10 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
8.00E-03	0.5	Important points to fit are .5 and .8 fractiles
1.60E-02	0.8	
	0.01	check whether original distribution was for .05 or .01...will not change fitted distributions
8.00E-04		
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system
Deibler ref says 10 to 100 times less likely for dry
More difficult to disturb mass when dry

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2f. 1E-2/year return frequency earthquake, large efficiency gas release, pumped; FG 2

Log-Normal
Mean -5.1
Std.Dev. 0.78
-3 -9
0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 10 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
6.00E-03	0.5	Important points to fit are .5 and .8 fractiles
1.20E-02	0.8	
6.00E-04	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system
 Deibler ref says 10 to 100 times less likely for dry
 More difficult to disturb mass when dry

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2g. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Beta
 Alpha 0.792
 Beta 0.965
 0.396 1.188
 0.4825 1.4475

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
3.60E-01	0.5	see general comments
7.20E-01	0.8	see general comments
3.60E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2h. 1E-2/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Log-Normal

Mean -2.538

Std.Dev. 0.953

-1.269 -3.807

0.4765 1.4295

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
1.60E-01	0.8	see general comments
8.00E-02	0.5	see general comments
8.00E-03	0.01	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Weibull

Alpha 0.98

Beta 0.086

0.49 1.47

0.043 0.129

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
1.20E-01	0.8	see general comments
6.00E-02	0.5	see general comments
6.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2j. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 3
 (note: not conditioned on nonoccurrence of large or medium GRE)

Log-Normal

Mean -3.3
 Std.Dev. 0.83
 -3 -9
 0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 10 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
3.60E-02	0.5	Important points to fit are .5 and .8 fractiles
7.20E-02	0.8	
3.60E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system
 Deibler ref says 10 to 100 times less likely for dry
 More difficult to disturb mass when dry

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2k. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal

Mean -4.8

Std.Dev. 0.78

-3 -9

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 10 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
8.00E-03	0.5	Important points to fit are .5 and .8 fractiles
1.60E-02	0.8	
	0.01	check whether original distribution was for .05 or .01...will not change fitted distributions
8.00E-04		
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system

Deibler ref says 10 to 100 times less likely for dry

More difficult to disturb mass when dry

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 21. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal

Mean	-5.1
Std.Dev.	0.78
	-3 -9
	0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 10 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
6.00E-03	0.5	Important points to fit are .5 and .8 fractiles
1.20E-02	0.8	
6.00E-04	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system
 Deibler ref says 10 to 100 times less likely for dry
 More difficult to disturb mass when dry

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3a. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Beta
 Alpha 0.829
 Beta 1.433
 0.4145 1.2435
 0.7165 2.1495

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
6.00E-01	0.8	see general comments
3.00E-01	0.5	see general comments
3.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3b. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Weibull

Alpha 1.103

Beta 0.10593

0.5515 1.6545

0.052965 0.1589

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
1.50E-01	0.8	see general comments
7.50E-02	0.5	see general comments
7.50E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3c. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Weibull

Alpha 1.116

Beta 0.17418

0.558 1.674

0.08709 0.26127

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
2.50E-01	0.8	see general comments
1.25E-01	0.5	see general comments
1.25E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3d. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 2
 (note: not conditioned on nonoccurrence of large or medium GRE)

Log-Normal
 Mean -2.77
 Std.Dev. 0.78
 -2 -9
 0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 5 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
6.00E-02	0.5	Important points to fit are .5 and .8 fractiles
1.20E-01	0.8	
6.00E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system
 PNL 10198 report studied changes in rheological
 More difficult to disturb mass when dry
 stirring moves from viscous material to less viscous
 2 times decrease in yield stress with dilution
 decreases in strength due to slight increases in temp
 1000 yr quake will create similar mixing to dilution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3e. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal

Mean -4.2

Std.Dev. 0.86

-4 -5

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 5 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
1.50E-02	0.5	Important points to fit are .5 and .8 fractiles
3.00E-02	0.8	
1.50E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

1000 yr quake will create similar mixing to dilution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3f. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Log-Normal

Mean -3.82

Std.Dev. 0.82

-3 -5

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 5 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
2.20E-02	0.5	Important points to fit are .5 and .8 fractiles
4.40E-02	0.8	
2.20E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

1000 yr. quake will create similar mixing to dilution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3g. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Beta
 Alpha 0.829
 Beta 1.433
 0.4145 1.2435
 0.7165 2.1495

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
6.00E-01	0.8	see general comments
3.00E-01	0.5	see general comments
3.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3h. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Weibull

Alpha 1.103

Beta 0.10593

0.5515 1.6545

0.052965 0.1589

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
1.50E-01	0.8	see general comments
7.50E-02	0.5	see general comments
7.50E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3i. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Weibull

Alpha 1.116

Beta 0.17418

0.558 1.674

0.08709 0.26127

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
2.50E-01	0.8	see general comments
1.25E-01	0.5	see general comments
1.25E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3j. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 3
 (note: not conditioned on nonoccurrence of large or medium GRE)

Log-Normal

Mean -2.77

Std.Dev. 0.78

-2 -9

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 5 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
6.00E-02	0.5	Important points to fit are .5 and .8 fractiles
1.20E-01	0.8	
6.00E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

1000 yr quake will create similar mixing to dilution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3k. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal

Mean -4.2

Std.Dev. 0.86

-4 -5

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 5 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
1.50E-02	0.5	Important points to fit are .5 and .8 fractiles
3.00E-02	0.8	
1.50E-03	0.05	
1.00E+00	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

1000 yr quake will create similar mixing to dilution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3I. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal

Mean -3.82
 Std.Dev. 0.82
 -3 -5
 0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 5 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
2.20E-02	0.5	Important points to fit are .5 and .8 fractiles
4.40E-02	0.8	
2.20E-03	0.05	
1.00E+00	1	Truncate at 1.0

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 PNL 10198 report studied changes in rheological
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 decreases in strength due to slight increases in temp
 1000 yr quake will create similar mixing to dilution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4a. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Weibull

Alpha 1.316

Beta 0.31458

0.658 1.974

0.15729 0.47187

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
4.50E-01	0.8	see general comments
2.25E-01	0.5	see general comments
2.25E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4b. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Weibull

Alpha 1.211

Beta 0.15858

0.6055 1.8165

0.07929 0.23787

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	1	see general comments
2.30E-01	0.8	see general comments
1.15E-01	0.5	see general comments
1.15E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4c. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Weibull

Alpha 1.211

Beta 0.22683

0.6055 1.8165

0.113415 0.34025

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.32	0.8	see general comments
0.16	0.5	see general comments
0.016	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
 Probability (dimensionless)
Units:
Cond: 4d. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 2
 (note: not conditioned on nonoccurrence of large or medium GRE)

Log-Normal

Mean -2.18

Std.Dev. 0.79

-1 -3

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 2 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
0.11	0.5	Important points to fit are .5 and .8 fractiles
0.22	0.8	
0.011	0.05	
1	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

10000 yr Quake will liquefy solids, only take factor of 2 smaller for pumping

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4e. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal

Mean -2.86

Std.Dev. 0.92

-1 -3

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 2 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
0.057	0.5	Important points to fit are .5 and .8 fractiles
0.12	0.8	
0.0057	0.05	
1	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

10000 yr Quake will liquefy solids, only take factor of 2 smaller for pumping

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4f. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Log-Normal

Mean -2.52

Std.Dev. 0.8

-1 -3

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 2 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
0.08	0.5	Important points to fit are .5 and .8 fractiles
0.16	0.8	
0.008	0.05	
1	1	Truncate at 1.0

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More difficult to disturb mass when dry

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2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

10000 yr Quake will liquify solids, only take factor of 2 smaller for pumping

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4g. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Weibull

Alpha 1.316

Beta 0.31458

0.658 1.974

0.15729 0.47187

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.45	0.8	see general comments
0.225	0.5	see general comments
0.0225	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4h. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Weibull

Alpha 1.211

Beta 0.15858

0.6055 1.8165

0.07929 0.23787

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.23	0.8	see general comments
0.115	0.5	see general comments
0.0115	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4i. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Weibull

Alpha 1.211

Beta 0.22683

0.6055 1.8165

0.113415 0.34025

General Comments used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.32	0.8	see general comments
0.16	0.5	see general comments
0.016	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4j. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 3
 (note: not conditioned on nonoccurrence of large or medium GRE)

Log-Normal

Mean -2.18

Std.Dev. 0.79

-1 -3

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 2 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
0.11	0.5	Important points to fit are .5 and .8 fractiles
0.22	0.8	
0.011	0.05	
1	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

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decreases in strength due to slight increases in temp

10000 yr Quake will liquefy solids, only take factor of 2 smaller for pumping

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4k. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal

Mean -2.86

Std.Dev. 0.92

-1 -3

0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 2 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
0.057	0.5	Important points to fit are .5 and .8 fractiles
0.12	0.8	
0.0057	0.05	
1	1	Truncate at 1.0

More difficult to put energy into dry system

PNL 10198 report studied changes in rheological

More difficult to disturb mass when dry

stirring moves from viscous material to less viscous

2 times decrease in yield stress with dilution

decreases in strength due to slight increases in temp

10000 yr Quake will liquefy solids, only take factor of 2 smaller for pumping

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4I. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal

Mean -2.52
 Std.Dev. 0.8
 -1 -3
 0.5 1.5

General Comments FG2 = FG3

Fractiles are a factor of 2 smaller than for unpumped

Specific Comments about Fractiles:

x	F(x)	Rationale
0.08	0.5	Important points to fit are .5 and .8 fractiles
0.16	0.8	
0.008	0.05	
1	1	Truncate at 1.0

More difficult to put energy into dry system
 PNL 10198 report studied changes in rheological
 More difficult to disturb mass when dry
 stirring moves from viscous material to less viscous
 2 times decrease in yield stress with dilution
 decreases in strength due to slight increases in temp
 10000 yr Quake will liquefy solids, only take factor of 2 smaller for pumping

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in DST
Units: probability (dimensionless)
Cond: a. 1E-2 / year return frequency earthquake

Log-Normal

Mean -9.18

Std.Dev. 1.32

-4 -18

1 3

General Comments Same logic as small eff BD-GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.5	based on p(ignition) of many different events and tank characteristics
0.000001	0.05	
0.001	0.95	
1	1	Truncate at 1.0 Reviewed ignition sources in DSTs

All systems rated as high hazard for electrical spark have been removed
 Assuming normal operations and conditions
 Operating procedures for DSTs are quite stringent

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in DST
Units: probability (dimensionless)
Cond: b. 1E-3 / year return frequency earthquake

Log-Normal

Mean -6.8

Std.Dev. 1.34

-4 -18
1 3

General Comments Scaled up from 100 yr eq by factor of 10
 Energy not 10 times greater, but responses to energy not linear in energy

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.5	based on p(ignition) of many different events and tank characteristics
0.00001	0.05	
0.01	0.95	
1	1	Truncate at 1.0

Reviewed ignition sources in DSTs

All systems rated as high hazard for electrical spark have been removed
 Assuming normal operations and conditions
 Operating procedures for DSTs are quite stringent

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Clay Easterly
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in DST
Units: probability (dimensionless)
Cond: c. 1E-4 / year return frequency earthquake

Log-Normal

Mean -4.56

Std.Dev. 1.36

-2 -6

1 3

General Comments Scaled up from 1000 yr eq by factor of 10
 Energy not 10 times greater, but responses to energy not linear in energy

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-02	0.5	based on p(ignition) of many different events and tank characteristics
1.00E-04	0.05	
1.00E-01	0.95	
1	1	Truncate at 1.0

Reviewed ignition sources in DSTs

All systems rated as high hazard for electrical spark have been removed
 Assuming normal operations and conditions
 Operating procedures for DSTs are quite stringent

APPENDIX A.5
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

M. Epstein

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Log-Normal
Mean -7.91
Std.Dev. 1.5
 -3.5 -10.5
 0.5 1.5

General Comments Stiff waste layer on the bottom...low freq rollover they haven't seen yet
 Should act like other rollovers...prev rollovers showed no functional depth on size of release eff

Specific Comments about Fractiles:

x	F(x)	Rationale
3.60E-04	0.5	about 4 in 10 thousand
1.20E-04	0.05	
4.70E-03	0.95	
0.01	1	

Upper bound
 12 DST w/thick layer of supernate of 1 meter and stiff nonconvective layer on bottom have been watch for 12 years with no burping
 Upper bound based on 12 X 12 tank years (144 tank years)
 Used a model of different type tanks....got a formula that makes freq is directly prop to gas generation rate and inversely prop to void fraction that must be reached in nonconvective layer
 Uncertainty arises from the different parameters for these parameters...range over about 2 orders of magnitude...gas gen rate and void fract.

9.40E-05 0

Min from model

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Log-Normal

Mean -7.91
 Std.Dev. 1.5
 -3.5 -10.5
 0.5 1.5

General Comments Stiff waste layer on the bottom...low freq rollover they haven't seen yet
 Should act like other rollovers...prev rollovers showed no functional depth on size of release eff

Specific Comments about Fractiles:

x	F(x)	Rationale
3.60E-04	0.5	about 4 in 10 thousand
1.20E-04	0.05	
4.70E-03	0.95	
0.01	1	Upper bound

12 DST w/thick layer of supernate of 1 meter and stiff nonconvective layer on bottom have been watch for 12 years with no burping
 Upper bound based on 12 X 12 tank years (144 tank years)
 Used a model of different type tanks....got a formula that makes freq is directly prop to gas generation rate and inversely prop to void fraction that must be reached in nonconvective layer
 Uncertainty arises from the different parameters for these parameters...range over about 2 orders of magnitude...gas gen rate and void fract.

9.40E-05 0

Min from model

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Log-Normal

Mean -7.91

Std.Dev. 1.5

-3.5 -10.5

0.5 1.5

General Comments Stiff waste layer on the bottom...low freq rollover they haven't seen yet
Should act like other rollovers...prev rollovers showed no functional depth on size of release eff

Specific Comments about Fractiles:

x	F(x)	Rationale
3.60E-04	0.5	about 4 in 10 thousand
1.20E-04	0.05	
4.70E-03	0.95	
0.01	1	Upper bound 12 DST w/thick layer of supernate of 1 meter and stiff nonconvective layer on bottom have been watch for 12 years with no burping Upper bound based on 12 X 12 tank years (144 tank years) Used a model of different type tanks....got a formula that makes freq is directly prop to gas generation rate and inversely prop to void fraction that must be reached in nonconvective layer Uncertainty arises from the different parameters for these parameters....range over about 2 orders of magnitude...gas gen rate and void fract.
9.40E-05	0	Min from model

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal
 Mean -11.4
 Std.Dev. 0.936
 -6 -18
 0.5 1.5

General Comments Base case...Motion is very trivial in small release case...

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-05	0.5	p=1 in 100,000 because risk is slight (see below)
1.00E-06	0	Lower bound 1 in a million
1.00E-04	1	Upper bound of 1 in 10,000

p(motion) = .001
 p(spark)=.01
 p(motion and spark) = .00001

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean	-9.18
Std.Dev.	1.36
-4.5	-13.5
0.5	1.5

General Comments Motion is factor of 10 larger than small, spark p is the same

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-04	0.5	
1.00E-05	0.05	Lower bound 1 in a million
1.00E-03	0.95	Upper bound of 1 in 10,000

$$p(\text{motion}) = .01$$

$$p(\text{spark}) = .01$$

$$p(\text{motion and spark}) = .0001$$

about 111 BD-GREs with no ignition gives us upper bound p of .01 for spark

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -6.84

Std.Dev. 1.36

-3 -9

0.5 1.5

General Comments Motion p is same as medium (.01), spark p 10 times med and small

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-03	0.5	
1.00E-04	0.05	
1.00E-02	0.95	
0.05	1	20 large releases with no ignition...upper bound at .05 p(motion) = .01 p(spark) = .1 p(motion and spark) = .001

20 large releases with no ignition...upper bound at .05

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean -8.5

Std.Dev. 2.9

-5 -15

1 3

General Comments Used more sophisticated model for mass variable;

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E-04	0.5	best est k times best est U (2.0 times .0001)
1.90E-08	0.05	best estimate flame speed U times low value of k coeff (1.9 10 ⁻⁸)
2.40E-02	0.95	highest value of k times best estimate of burnspeed (2.4 times .01)
0.22	1	upper bound value of k and u
1.70E-09	0	lower bound is product of lower bounds of both

Mechanism is areodynamic in burn wave...lots of experimental data on entrainment of solid particles in air streams...and entrainment law...entrainment rate is proportional to the cube of velocity of air stream...prop coeff varies over 5 or 6 orders of magnitude
 uncertainties:
 prop coef (5 to 6 orders of mag)
 velocity of air equiv to burn wave..factor of 10 of 3 to 30 meters per sec (when cubed 27 to 27e3)
 burn wave starts at the center of the tank and is circ working way to walls of tank...equation to relate mass sus to max press achieved and headspace not as easy to pull part off of wet surface as dry surface...entrainment constant reduced by 10 for moist surface
 product of entrainment constant (k) and square of wave speed (U)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Log-Normal

Mean -3.42

Std.Dev. 1.8

-3 -9

1 3

General Comments Used more sophisticated model for mass variable;
assume full 20 psi (upper end of condition)

Specific Comments about Fractiles:

x	F(x)	Rationale
3.20E-02	0.5	solid part entrained and bubble bursting...best ests of due only to bubble bursting
3.20E-03	0.05	solid part entrained and bubble bursting...3.2e-3 due only to bubble bursting, one order of mag lower than best est of entrainment coeff
6.30E-01	0.95	equally divided between sold and liq; solid plus liq w/1 order of mag greater than best est of prop constant
3.2	1	upper bound solid particles dominate
2.20E-08	0	lower bound is 2.2e-8 (no bubble bursting, same as 3a) 150 cu meter of gas (equiv to 20 psi) 3 mechanisms...1. is the same as for 3a (used same equation, max press now 20 psi rather than 1.5 psi) 2 new mechanisms 2.burn wave can tear liquid drops off liquid surface, but flame speed is not enough for this to apply 3. As bubbles burst at surface, get aerosol from liquid burst...amt is prop to the vol of the gas coming to the surface....prop constant that relates amount of gas to aerosol liq 1 discussed earlier, 2 is a no nevermind 2 orders of magnitude either direction (4 total) on the prop constant)...only uncertainty

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal
Mean -2.4
Std.Dev. 1.62
-1.5 -4.5
1 3

General Comments: Used more sophisticated model for mass variable;
 same meth as for 3b, increased pressure from 20 psi to 50 psi

Specific Comments about Fractiles:

x	F(x)	Rationale
8.60E-02	0.5	best estimates of everything, bubble bursting dominates
8.00E-03	0.05	bubble bursting, 1 order of mag less than median est of entrainment coeff
1.60E+00	0.95	equal contributions from solid and bubble bursting (see 3b meth)
7.7	1	Solid dominates, see 3a for model
5.30E-08	0	only solid part entrainment

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
 Expert: Mike Epstein
 Analyst: Richard John
 Variable: 3. Total mass of transportable waste material released
 Units: Kilograms
 Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal

Mean	5.4
Std.Dev.	1.5
	9
	3

General Comments: Used more sophisticated model for mass variable; assumes pressure rise of 85 psi to fail dome, 2500 cu m of headspace (upper bound vol of burping vol)

Specific Comments about Fractiles:

x	F(x)	Rationale
2.30E+02	0.5	#4 dominates for .5 and above fractiles...rad of opening 6 ft, best guess of velocity
1.30E-02	0.05	bubble bursting dominates
2.70E+03	0.95	radius of 8.5 opening assumed
6700	1	opening assumed to be twice median (r=8.5 ft) with 75% rainout
8.90E-06	0	no bubble bursting, only solid part

4 possible entrainment mechanisms

1. liquid aerosol from bubble bursting at surface
2. Aerodynamic entrainment from solids
3. Aerodynamic entrainment of liquids at surface after solid layer is gone
4. KEY (dominates) entrainment of waste as from headspace venting...vel will entrain large quantities of transportable waste....

most likely rupture opening is 6 ft...used as best guess for 5, 50, and 95 fractiles
upper bound used assumption of 8.5 ft opening

for mech #1 and #2 (bubbles and solids), same model as in 3a-c
assume gas release of 625 cu meters to get 85 psi

#3 only important for upper bound estimates...trivial compared to #4 even for upper bound (#3 never really comes into play)

#4 model dev in 50s by Taylor and students at Las Alamos, dev for mixing gases also accurate for predicting liquid picked up w/parallel flow of gas
uncertainty arises from speed of the gas flow, assumes entrainment coeff of .1 (plus or minus 50%, did not vary this coeff)

model is integrated over entire surface area of waste...rupture is at the center of the tank
dev formula to relate amt of waste pulled out to velocity of gas flow
area of rupture opening is most important determinant of waste pulled off
used 6 ft opening for all fractiles except upper bound and .95 frac

Rain out fraction90% of material would fall to ground and not be taken by wind
used 90% for all but upper bound, used 75% for upper bound

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Log-Normal
 Mean 5.94
 Std.Dev. 1.28
 3 9
 1 3

General Comments: Used more sophisticated model for mass variable;
 assumes pressure rise of 85 psi to fail dome, 2500 cu m of headspace (upper
 bound vol of burping vol)

Specific Comments about Fractiles:

x	F(x)	Rationale
3.70E+02	0.5	det wave dominates other mechused median viscosity of 2e-2 pa.s.(140 kg) , 90% liq rainout frac; also 230 kg liq entrained by venting (same as 3d); other solid mech minor...
9.10E+01	0.05	det wave dominates (lower bnd viscosity of 3e-3 pa.s.); rainout frac of was 90%
3.20E+03	0.95	dominated by venting process...2700 kg; 220 due to detonation wave, 90% rainout
8000	1	upper bound most dom by venting (6700 kg); 900 kg due to detonation wave
1.00E-03	0	lower bound is zero det wave dominates (lower bnd viscosity of 3e-3 pa.s.) deflagration wave is modify entrainment coef from defl wave diff set of entrainment coeffs, moved value of k (entrainment coeff for solid part pickup) downward to make more reasonable (not take off several centimeters of waste) used median value for dry to represent highest possible value for entrainment coeff best estimate k is the lower bound value of k for dry powder 5 orders of mag uncertainty for k uncertainty due to defl wave speed...1000 m/sec up to 2000 m/sec median value of 1500 m/sec used same formula for detonation as for deflagration for purpose of calc how much solid is picked up mass picked up is a function of surface area wave travels (assumed to be full surface area of tank, 10 meter diameter, 80% of waste surface) viscosity is important factor in determining entrainment get a factor of 20 variation in viscosity of tank waste.... mass entrained is linear with viscosity

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean -10

Std.Dev. 2.9

-5 -15

1.45 4.35

General Comments respirable fraction times total trans waste; used 2 samples of actual data

averaged to fraction of .60, but revised downward based on methodology, to about a third or .20 (used distr for SSTs with median of .05, range from .005 to .25)

Specific Comments about Fractiles:

x	F(x)	Rationale
4.00E-05	0.5	best est k times best est U (2.0 times .0001)
3.80E-09	0.05	best estimate flame speed U times low value of k coeff (1.9 10 ⁻⁸)
4.80E-03	0.95	highest value of k times best estimate of burn speed (2.4 times .01)
0.044	1	upper bound value of k and u
3.40E-10	0	lower bound is product of lower bounds of both

Mechanism is aerodynamic in burn wave...lots of experimental data on entrainment of solid particles in air streams..and entrainment law...entrainment rate is proportional to the cube of velocity of air stream...prop coeff varies over 5 or 6 orders of magnitude
 uncertainties:
 prop coef (5 to 6 orders of mag)
 velocity of air equiv to burn wave factor of 10 of 3 to 30 meters per sec (when cubed 27 to 27e3)
 burn wave starts at the center of the tank and is circ working way to walls of tank...equation to relate mass sus to max press achieved and headspace not as easy to pull part off of wet surface as dry surface...entrainment constant reduced by 10 for moist surface
 product of entrainment constant (k) and square of wave speed (U)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Log-Normal

Mean -3.42

Std.Dev. 1.52

-3 -9

1 3

solid * .2 + bubble

General Comments multiply solid trans by .2 as for 4a
 all trans waste mass from bubbles is respirable

Specific Comments about Fractiles:

x	F(x)	Rationale
3.30E-02	0.5	solid part entrained and bubble bursting...best ests of due only to bubble bursting
3.20E-03	0.05	solid part entrained and bubble bursting...3.2e-3 due only to bubble bursting, one order of mag lower than best est of entrainment coeff
3.80E-01	0.95	equally divided between sold and liq; solid plus liq w/1 order of mag greater than best est of prop constant
0.9	1	upper bound solid particles dominate
4.40E-09	0	lower bound is 2.2e-8 (no bubble bursting, same as 3a) 150 cu meter of gas (equiv to 20 psi) 3 mechanisms...1. is the same as for 3a (used same equation, max press now 20 psi rather than 1.5 psi) 2 new mechanisms 2.burn wave can tear liquid drops off liquid surface, but flame speed is not enough for this to apply 3. As bubbles burst at surface, get aerosol from liquid burst...amt is prop to the vol. of the gas coming to the surface....prop constant that relates amount of gas to aerosol liq 1 discussed earlier, 2 is a no nevermind 2 orders of magnitude either direction (4 total) on the prop constant)...only uncertainty

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean -2.4

Std.Dev. 1.4

-1.5 -4.5

1 3

solid * .2 + bubble

General Comments: multiply solid trans by .2 as for 4a
 all trans waste mass from bubbles is respirable

Specific Comments about Fractiles:

x	F(x)	Rationale
8.10E-02	0.5	best estimates of everything, bubble bursting dominates
8.00E-03	0.05	bubble bursting, 1 order of mag less than median est of entrainment coeff
9.60E-01	0.95	equal contributions from solid and bubble bursting (see 3b meth)
2.2	1	Solid dominates, see 3a for model
1.10E-08	0	only solid part entrainment

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
 Expert: Mike Epstein
 Analyst: Richard John
 Variable: 4. Total mass of respirable waste material released
 Units: kilograms
 Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal

Mean 0.7
 Std.Dev. 1.4
 0.5 1.5
 0.5 1.5

solid multiplied by .2; bubble is all; all liquid mass multiplied by 8.1e-3 as follows

General Comments: used weber number criteria (between 10 and 12); used 12 (very little uncertainty)

to predict average diameter of drops as they pass thru headspace and leave rupture opening; used newtons law and potential flow theory

Specific Comments results in formula to get avg droplet diameter of 53 microns; assumed a lognormal distribution with mean of 53 microns and sd taken from literature (avg of 40 microns in lit), sd varied from 1.3 to 1.5 microns, used sd of 2.0 resulting in fraction that i

x	F(x)	Rationale
2.00E+00	0.5	#4 dominates for .5 and above fractiles...rad of opening 6 ft, best guess of velocity
1.30E-02	0.05	bubble bursting dominates
2.30E+01	0.95	radius of 8.5 opening assumed
58	1	opening assumed to be twice median (r=8.5 ft) with 75% rainout
1.80E-08	0	no bubble bursting, only solid part

4 possible entrainment mechanisms

1. liquid aerosol from bubble bursting at surface
2. Aerodynamic entrainment from solids
3. Aerodynamic entrainment of liquids at surface after solid layer is gone
4. KEY (dominates) entrainment of waste as from headspace venting...vel will entrain large quantities of transportable waste....

most likely rupture opening is 6 ft...used as best guess for 5, 50, and 95 fractiles
upper bound used assumption of 8.5 ft opening

for mech #1 and #2 (bubbles and solids), same model as in 3a-c

assume gas release of 625 cu meters to get 85 psi

#3 only important for upper bound estimates...trivial compared to #4 even for upper bound (#3 never really comes into play)

#4 model dev in 50s by Taylor and students at Las Alamos, dev for mixing gases also accurate for predicting liquid picked up w/parallel flow of gas
uncertainty arises from speed of the gas flow, assumes entrainment coeff of .1 (plus or minus 50%, did not vary this coeff)

model is integrated over entire surface area of waste..rupture is at the center of the tank
dev formula to relate amt of waste pulled out to velocity of gas flow
area of rupture opening is most important determinant of waste pulled off
used 6 ft opening for all fractiles except upper bound and .95 frac

Rain out fraction ...90% of material would fall to ground and not be taken by wind
used 90% for all but upper bound, used 75% for upper bound

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Log-Normal
Mean 1.1
Std.Dev. 1.888
0.5 1.5
1 3

General Comments: Methodology is same as for 4d, also pick up more liquid
solids*.2+bubbles+liq*.8.1e-3

Specific Comments about Fractiles:

x	F(x)	Rationale
3.10E+00	0.5	det wave dominates other mechused median viscosity of 2e-2 pa.s.(140 kg) , 90% liq rainout frac; also 230 kg liq entrained by venting (same as 3d); other solid mech minor...
7.40E-01	0.05	det wave dominates (lower bnd viscosity of 3e-3 pa.s.); rainout frac of was 90%
8.60E+01	0.95	dominated by venting process...2700 kg; 220 due to detonation wave, 90% rainout
150	1	upper bound most dom by venting (6700 kg); 900 kg due to detonation wave
2.00E-04	0	lower bound is zero det wave dominates (lower bnd viscosity of 3e-3 pa.s.) deflagration wave is modify entrainment coef from defl wave diff set of entrainment coeffs, moved value of k (entrainment coeff for solid part pickup) downward to make more reasonable (not take off several centimeters of waste) used median value for dry to represent highest possible value for entrainment coeff best estimate k is the lower bound value of k for dry powder 5 orders of mag uncertainty for k uncertainty due to defl wave speed...1000 m/sec up to 2000 m/sec median value of 1500 m/sec used same formula for detonation as for deflagration for purpose of calc how much solid is picked up mass picked up is a function of surface area wave travels (assumed to be full surface area of tank, 10 meter diameter, 80% of waste surface) viscosity is important factor in determining entrainment get a factor of 20 variation in viscosity of tank waste.... mass entrained is linear with viscosity

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

Log-Normal

Mean 5.4

Std.Dev. 0.52

3 9

0.5 1.5

General Comments: Chuck Stewart made cumulative from available data taken from all BD-GREs (n=aprox 50 in sample)
 Small, Medium, and Large efficiency release all equivalent
 data suggests no relationship between size and duration of release

Specific Comments about Fractiles:

x	F(x)	Rationale
2.18E+02	0.5	from Stewart
9.60E+01	0.05	from Stewart
8.40E+02	0.95	from Stewart
5700	1	upper bound assumes that waste is weak but in tact; bubbles must migrate through; used Stokes law with much higher viscosity than lower; used Meyer estimate of viscosity, viscosity varies linearly with depth in tank; high end of viscosity 2e4 from Meyer
2.20E+00	0	lower bound based on time for bubbles to rise (Stokes law for bubble rise) diameter of bubbles based on experiments showing mean bubble size of 1 mm

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

Log-Normal
 Mean 5.4
 Std.Dev. 0.52
 3 9
 0.5 1.5

General Comments: Chuck Stewart made cumulative from available data taken from all BD-GREs (n=aprox 50 in sample)

Specific Comments about Fractiles:

x	F(x)	Rationale
2.18E+02	0.5	from Stewart
9.60E+01	0.05	from Stewart
8.40E+02	0.95	from Stewart
5700	1	upper bound assumes that waste is weak but in fact; bubbles must migrate through; used Stokes law with much higher viscosity than lower; used Meyer estimate of viscosity, viscosity varies linearly with depth in tank; high end of viscosity 2e4 from Meyer
2.20E+00	0	lower bound based on time for bubbles to rise (Stokes law for bubble rise) diameter of bubbles based on experiments showing mean bubble size of 1 mm

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
 Expert: Mike Epstein
 Analyst: Richard John
 Variable: 5. Duration of Buoyant Displacement Gas Release Event
 Units: Minutes
 Cond: c. Large efficiency release

Log-Normal
 Mean 5.4
 Std.Dev. 0.52
 3 9
 0.5 1.5

General Comments: Chuck Stewart made cumulative from available data taken from all BD-GREs (n=aprox 50 in sample)

Specific Comments about Fractiles:

x	F(x)	Rationale
2.18E+02	0.5	from Stewart
9.60E+01	0.05	from Stewart
8.40E+02	0.95	from Stewart
5700	1	upper bound assumes that waste is weak but in fact; bubbles must migrate through; used Stokes law with much higher viscosity than lower; used Meyer estimate of viscosity, viscosity varies linearly with depth in tank; high end of viscosity 2e4 from Meyer
2.20E+00	0	lower bound based on time for bubbles to rise (Stokes law for bubble rise) diameter of bubbles based on experiments showing mean bubble size of 1 mm

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2a. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Log-Normal

Mean -4.68

Std.Dev. 1.43

-4 -5

0.5 3

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.99	
0.1	0.95	
0.01	0.5	
0.0001	0.01	
0.001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2b. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Log-Normal

Mean -6.86

Std.Dev. 1.466

-5 -10

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.99	
0.01	0.95	
0.001	0.5	
0.00001	0.01	
0.0001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2c. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Log-Normal

Mean -9.188

Std.Dev. 1.565

-8 -12

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.005	0.99	
0.001	0.95	
0.0001	0.5	
0.000001	0.01	
0.000001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2d. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Log-Normal
 Mean -4.68
 Std.Dev. 1.43
 -4 -5
 0.5 3

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.99	
0.1	0.95	
0.01	0.5	
0.0001	0.01	
0.001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2e. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal

Mean -6.86

Std.Dev. 1.466

-5 -10

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.99	
0.01	0.95	
0.001	0.5	
0.00001	0.01	
0.0001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2f. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Log-Normal

Mean -9.188

Std.Dev. 1.565

-8 -12

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.005	0.99	
0.001	0.95	
0.0001	0.5	
0.000001	0.01	
0.00001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2g. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Log-Normal

Mean -4.68

Std.Dev. 1.43

-4 -5

0.5 3

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.99	
0.1	0.95	
0.01	0.5	
0.0001	0.01	
0.001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2h. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 3

Log-Normal

Mean -6.86

Std.Dev. 1.466

-5 -10

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.99	
0.01	0.95	
0.001	0.5	
0.00001	0.01	
0.0001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Log-Normal

Mean -9.188

Std.Dev. 1.565

-8 -12

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.005	0.99	
0.001	0.95	
0.0001	0.5	
0.000001	0.01	
0.000001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2j. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Log-Normal

Mean -4.68

Std.Dev. 1.43

-4 -5

0.5 3

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.99	
0.1	0.95	
0.01	0.5	
0.0001	0.01	
0.001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2k. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal

Mean -6.86

Std.Dev. 1.466

-5 -10

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.99	
0.01	0.95	
0.001	0.5	
0.00001	0.01	
0.0001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2I. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal
 Mean -9.188
 Std.Dev. 1.565
 -8 -12
 0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.005	0.99	
0.001	0.95	
0.0001	0.5	
0.000001	0.01	
0.00001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3a. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Weibull

Alpha 0.71

Beta 0.0875

0.355 1.065

0.04375 0.13125

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3b. 1E-3/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Log-Normal

Mean -4.58

Std.Dev. 1.466

-1 -5

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.01	
0.001	0.05	
0.01	0.5	
0.1	0.95	
0.5	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3c. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Log-Normal

Mean -6.872

Std.Dev. 1.565

-6 -8

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.00001	0.01	
0.0001	0.05	
0.001	0.5	
0.01	0.95	
0.05	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3d. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Weibull

Alpha 0.71
 Beta 0.0875
 0.355 1.065
 0.04375 0.13125

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3e. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal

Mean -4.58

Std.Dev. 1.466

-1 -5

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.01	
0.001	0.05	
0.01	0.5	
0.1	0.95	
0.5	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3f. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Log-Normal

Mean -6.872

Std.Dev. 1.565

-6 -8

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.00001	0.01	
0.0001	0.05	
0.001	0.5	
0.01	0.95	
0.05	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3g. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Weibull
 Alpha 0.71
 Beta 0.0875
 0.355 1.065
 0.04375 0.13125

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3h. 1E-3/year return frequency earthquake, medium efficiency GRE, unpumped, FG 3

Log-Normal

Mean -4.58

Std.Dev. 1.466

-1 -5

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.01	
0.001	0.05	
0.01	0.5	
0.1	0.95	
0.5	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3i. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Log-Normal

Mean -6.872

Std.Dev. 1.565

-6 -8

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.00001	0.01	
0.0001	0.05	
0.001	0.5	
0.01	0.95	
0.05	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3j. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Weibull

Alpha 0.71
 Beta 0.0875
 0.355 1.065
 0.04375 0.13125

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3k. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal

Mean -4.58

Std.Dev. 1.466

-1 -5

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.01	
0.001	0.05	
0.01	0.5	
0.1	0.95	
0.5	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3I. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal

Mean -6.872

Std.Dev. 1.565

-6 -8

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.00001	0.01	
0.0001	0.05	
0.001	0.5	
0.01	0.95	
0.05	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4a. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Weibull

Alpha 0.83

Beta 0.16

0.415 1.245

0.08 0.24

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
1.00E+00	0.95	see general comments
1.00E-01	0.5	see general comments
0.001	0.01	see general comments
1.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4b. 1E-4/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Weibull

Alpha 0.7872

Beta 0.0837

0.41 1.23

0.06 0.09

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4c. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Weibull

Alpha 0.83

Beta 0.0158

0.415 1.245

0.0079 0.0237

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-01	0.99	see general comments
5.00E-02	0.95	see general comments
5.00E-03	0.5	see general comments
0.0005	0.05	see general comments
5.00E-05	0.01	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4d. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Weibull

Alpha 0.83

Beta 0.16

0.415 1.245

0.08 0.24

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
1.00E+00	0.95	see general comments
1.00E-01	0.5	see general comments
0.001	0.01	see general comments
1.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4e. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Weibull

Alpha 0.7872

Beta 0.0837

0.41 1.23

0.06 0.09

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4f. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Weibull

Alpha 0.83
 Beta 0.0158
 0.415 1.245
 0.0079 0.0237

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-01	0.99	see general comments
5.00E-02	0.95	see general comments
5.00E-03	0.5	see general comments
0.0005	0.05	see general comments
5.00E-05	0.01	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4g. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Weibull

Alpha 0.83

Beta 0.16

0.415 1.245

0.08 0.24

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
1.00E+00	0.95	see general comments
1.00E-01	0.5	see general comments
0.001	0.01	see general comments
1.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4h. 1E-4/year return frequency earthquake, medium efficiency GRE, unpumped, FG 3

Weibull

Alpha 0.7872

Beta 0.0837

0.41 1.23

0.06 0.09

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4i. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Weibull

Alpha 0.83

Beta 0.0158

0.415 1.245

0.0079 0.0237

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-01	0.99	see general comments
5.00E-02	0.95	see general comments
5.00E-03	0.5	see general comments
0.0005	0.05	see general comments
5.00E-05	0.01	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4j. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Weibull

Alpha 0.83

Beta 0.16

0.415 1.245

0.08 0.24

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
1.00E+00	0.95	see general comments
1.00E-01	0.5	see general comments
0.001	0.01	see general comments
1.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4k. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Weibull
Alpha 0.7872
Beta 0.0837
 0.41 1.23
 0.06 0.09

General Comments:
 used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E+00	0.99	see general comments
5.00E-01	0.95	see general comments
5.00E-02	0.5	see general comments
0.0005	0.01	see general comments
5.00E-03	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4I. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Weibull

Alpha 0.83

Beta 0.0158

0.415 1.245

0.0079 0.0237

General Comments:

used last year's distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-01	0.99	see general comments
5.00E-02	0.95	see general comments
5.00E-03	0.5	see general comments
0.0005	0.05	see general comments
5.00E-05	0.01	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: a. $1E-2$ / year return frequency earthquake

Log-Normal

Mean -6.872

Std.Dev. 1.439

-6 -8

0.5 2

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.5	
0.01	0.95	
0.0001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mike Epstein
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
 probability (dimensionless)
Units:
Cond: b. 1E-3 / year return frequency earthquake

Log-Normal

Mean -2.3

Std.Dev. 1

-1.15 -3.45

0.5 1.5

General Comments:

used last year's elicitations

Specific Comments about Fractiles:

x	F(x)	Rationale
1.00E-01	0.5	see general comments
5.00E-01	0.95	see general comments
2.00E-02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
Expert: Mike Epstein
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
 probability (dimensionless)
Units:
Cond: c. $1E-4$ / year return frequency earthquake

Beta
 Alpha 4
 Beta 3.9965
 0.5 4
 0.5 4

General Comments:

Based on information supplied by Epstein after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	
1	0.95	
0.25	0.05	

APPENDIX A.6
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

P. A. Gauglitz

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Log-Normal

Mean -2.34

Std.Dev. 2.54

-1.5 -4.5

1 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	Releases of this size will certainly occur
1.00E-03	0.05	
5	0.95	

Fractiles 100 times Medium Release on low end and median

Tanks that could have many releases per year would have tested positive for BD-GRE within the Meyer Model (includes gas generation rate); High gas generation rate would lead to BD-GRE and not this mechanism for spontaneous GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Log-Normal

Mean -6.85

Std.Dev. 2.8

-2.5 -7.5

1 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.5	variety of mechanisms plausible, including that tests missed medium BD-GRE
1.00E-05	0.05	
0.1	0.95	

Fractiles 100 times Large Release

Unlikely since BD would have already kicked in prior

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Log-Normal

Mean -11.5

Std.Dev. 2.8

-5 -15

1 3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.00001	0.5	Unlikely for tests to miss potential BD-GRE of this magnitude
1.00E-07	0.05	
0.001	0.95	plausible for tests to miss potential BD-GRE

Uncertainty is greater due to unreliability of tests

Only one tank that came up this bad.....plus or minus 2 orders of mag

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -6.9

Std.Dev. 1.4

-3 -9

0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.5	Twice the independent ignition frequency
1.00E-04	0.05	10 fold smaller
0.01	0.95	10 fold larger
Truncate at 0 and 0.1		

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean -3
 Std.Dev. 1.4
 -1.5 -4.5
 0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.5	approx 1 in 20 releases cause equipment motion because waste motion occurs near equipment and motion causes spark
5.00E-03	0.05	10 fold smaller
0.5	0.95	10 fold larger
		Truncate at 0 and 1
		5 fold larger than SST

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Normal

Mean 0.5

Std.Dev. 0.252

0.25 0.75

0.15 0.45

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	Large GRE will cause sparks, but perhaps not every time, 50-50
5.00E-02	0.05	
1	1	

Truncate at 0 and 1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: minutes
Cond: a. Small efficiency release

Log-Normal

Mean 5.35

Std.Dev. 0.92

2.5 7.5

0.5 1.5

General Comments Small and Medium Releases are the same distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
200	0.5	from Stewart summary
5.00E+01	0.05	Smaller than Stewart summary, this reflects a broader distribution
1000	0.95	from Stewart summary
10	0	Lower bound is 10 minutes
		Truncate at 10 minute below

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: minutes
Cond: b. Medium efficiency release

Log-Normal

Mean 5.35

Std.Dev. 0.92

2.5 7.5

0.5 1.5

General Comments Small and Medium Releases are the same distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
200	0.5	from Stewart summary
5.00E+01	0.05	Smaller than Stewart summary, this reflects a broader distribution
1000	0.95	from Stewart summary
10	0	Lower bound is 10 minutes

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: minutes
Cond: c. Large efficiency release

Weibull

Alpha 0.88

Beta 19.8

0.5 1.5

15 45

General Comments NOTE: Distribution Plotted for Duration minus 4 minutes (absolute minimum duration)

Specific Comments about Fractiles:

x-4	F(x)	Rationale
11	0.5	from Barton summary
1.00E+00	0.05	slightly shorter than the lower bound of 7 min in the data, because this gives a broader distribution
96	0.95	upper bound on Barton data
		hard to believe anything faster, bubbles need to minimum time to rise
		Truncate at 4 minutes

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Weibull

Alpha 6.006

Beta 0.848

3.3 9.9

0.4 1.2

General Comments Small GRE 100 yr = Medium GRE 1000 yr = Large GRE 10000 yr

Specific Comments about Fractiles:

x	F(x)	Rationale
0.8	0.5	
5.00E-01	0.05	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1b. $1E-2$ / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Normal

Mean 0.49

Std.Dev. 0.26

0.25 0.75

0.1 0.3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	given a 100 yr quake, it is expected that medium releases will occur
5.00E-02	0.05	
	0.95	
1	1	Must truncate at 1.0

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Log-Normal

Mean -3

Std.Dev. 1.4

-1.5 -4.5

0.7 2.1

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.5	given a 100 yr quake, 1 in 20 tanks will have a large release
5.00E-03	0.05	
0.5	0.95	Truncate all probabilities at 0 and 1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 24.94
 Beta 1
 14.5 43.5
 0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.5	
9.00E-01	0.05	fewer than 1 in 20 tanks will not have a small release for a 1000 year quake
1	0.95	upper bound is 1.0...Truncate at 1.0

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Weibull

Alpha 6.582

Beta 0.837

3 9

0.45 1.35

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.8	0.5	
5.00E-01	0.05	10 fold larger than large release
1	0.95	upper bound is 1.0...Truncate at 1.0

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Normal

Mean 0.5

Std.Dev. 0.27

0.25 0.75

0.1 0.3

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	This is the starting point from Stewart and Reid and Deibler, and is the most defensible estimate
5.00E-02	0.05	Given 20 tanks, at least one would have large release
1	1	upper bound is 1.0...Truncate at 1.0

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 1000
 Beta 1
 500 1500
 0.5 1.5

General Comments Probability = 1

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.5	
1.00E+00	0.05	Certain to have a small release
1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta	
Alpha	25
Beta	1
12.5	37.5
0.5	1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.5	
9.00E-01	0.05	Almost certain to have a medium release
1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a DST
Units: Probability (dimensionless)
Cond: 1i. 1E-4 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha	6.052
Beta	0.84
	3.4 10.2
	0.4 1.2

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.8	0.5	a large GRE was fully expect (0.5) for a 1000 yr quake, so this is certainly going to happen
5.00E-01	0.05	fewer than 1 in 20 tanks will not have a small release for a 1000 year quake
1	0.95	upper bound is 1.0...Truncate at 1.0

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2a. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Log-Normal
 Mean -2.32
 Std.Dev. 1
 -1.16 -3.48
 0.5 1.5

Use previously elicited SST distributions

General Comments No diff between pumped and unpumped
 No diff between FG2 and FG3;
 USE LAST YEAR'S DISTRIBUTIONS

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

Pumped vs unpumped:

Forces that retain bubbles are eliminated or weakened with eq.....

Waste is stronger after eq

These effects act in opposite directions....magnitude estimated to be approx equal

FG2 vs. FG3

Waste is not that different in properties that retain bubbles

Efficiencies of release would not be that different for FG2 vs. FG3

This is a significant factor for spontaneous releases, but not for induced

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2b. 1E-2/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Log-Normal

Mean -4.56

Std.Dev. 1.38

-2.28 -6.84

0.69 2.07

General Comments:

use last year's elicitations (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2c. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Log-Normal

Mean -6.93

Std.Dev. 1.41

-3.465 -10.395

0.705 2.115

General Comments:

use last year's elicitations (see general remarks in 62adj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.05	
1.00E-03	0.5	
0.01	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2d. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Log-Normal

Mean	-2.32
Std.Dev.	1
	-1.16 -3.48
	0.5 1.5

Use previously elicited SST distributions

General Comments No diff between pumped and unpumped
 No diff between FG2 and FG3;
 USE LAST YEAR'S DISTRIBUTIONS

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

Pumped vs unpumped:

Forces that retain bubbles are eliminated or weakened with eq.....

Waste is stronger after eq

These effects act in opposite directions.....magnitude estimated to be approx equal

FG2 vs. FG3

Waste is not that different in properties that retain bubbles

Efficiencies of release would not be that different for FG2 vs. FG3

This is a significant factor for spontaneous releases, but not for induced

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gagliuzi
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2e. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal

Mean -4.56

Std.Dev. 1.38

-2.28 -6.84

0.69 2.07

General Comments:

use last year's elicitations (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2f. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Log-Normal

Mean -6.93

Std.Dev. 1.41

-3.465 -10.395

0.705 2.115

General Comments:

use last year's elicitations (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.05	
1.00E-03	0.5	
0.01	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2g. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Log-Normal
 Mean -2.32
 Std.Dev. 1
 -1.16 -3.48
 0.5 1.5

Use previously elicited SST distributions

General Comments No diff between pumped and unpumped
 No diff between FG2 and FG3;
 USE LAST YEAR'S DISTRIBUTIONS

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

Pumped vs unpumped:

Forces that retain bubbles are eliminated or weakened with eq.....

Waste is stronger after eq

These effects act in opposite directions....magnitude estimated to be approx equal

FG2 vs. FG3

Waste is not that different in properties that retain bubbles

Efficiencies of release would not be that different for FG2 vs. FG3

This is a significant factor for spontaneous releases, but not for induced

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2h. 1E-2/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Log-Normal

Mean	-4.56
Std.Dev.	1.38
-2.28	-6.84
0.69	2.07

General Comments:

use last year's elicitations (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Log-Normal

Mean -6.93

Std.Dev. 1.41

-3.465 -10.395

0.705 2.115

General Comments:

use last year's elicitations (see general remarks in 62adgi)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.05	
1.00E-03	0.5	
0.01	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2j. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Log-Normal

Mean -2.32

Std.Dev. 1

-1.16 -3.48

0.5 1.5

Use previously elicited SST distributions

General Comments No diff between pumped and unpumped

No diff between FG2 and FG3;

USE LAST YEAR'S DISTRIBUTIONS

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

Pumped vs unpumped:

Forces that retain bubbles are eliminated or weakened with eq.....

Waste is stronger after eq

These effects act in opposite directions....magnitude estimated to be approx equal

FG2 vs. FG3

Waste is not that different in properties that retain bubbles

Efficiencies of release would not be that different for FG2 vs. FG3

This is a significant factor for spontaneous releases, but not for induced

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2k. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal
 Mean -4.56
 Std.Dev. 1.38
 -2.28 -6.84
 0.69 2.07

General Comments:

use last year's elicitations (see general remarks in 62adgi)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal

Mean -6.93

Std.Dev. 1.41

-3.465 -10.395

0.705 2.115

General Comments:

use last year's elicitations (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.05	
1.00E-03	0.5	
0.01	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3a. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Weibull

Alpha 2.25

Beta 0.6

1.125 3.375

0.3 0.9

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
5.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3b. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Log-Normal

Mean -2.28

Std.Dev. 1.16

-1.14 -3.42

0.58 1.74

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3c. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Log-Normal

Mean -4.6

Std.Dev. 1.5

-2.3 -6.9

0.75 2.25

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3d. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Weibull
 Alpha 2.25
 Beta 0.6
 1.125 3.375
 0.3 0.9

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
5.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3e. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Log-Normal

Mean -2.28

Std.Dev. 1.16

-1.14 -3.42

0.58 1.74

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3f. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Log-Normal

Mean -4.6
 Std.Dev. 1.5
 -2.3 -6.9
 0.75 2.25

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3g. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Weibull

Alpha 2.25

Beta 0.6

1.125 3.375

0.3 0.9

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
5.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3h. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Log-Normal

Mean -2.28

Std.Dev. 1.16

-1.14 -3.42

0.58 1.74

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3i. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Log-Normal

Mean -4.6

Std.Dev. 1.5

-2.3 -6.9

0.75 2.25

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3j. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Weibull

Alpha 2.25

Beta 0.6

1.125 3.375

0.3 0.9

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adg)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
5.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3k. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Log-Normal

Mean -2.28

Std.Dev. 1.16

-1.14 -3.42

0.58 1.74

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
1.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3I. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Log-Normal

Mean -4.6

Std.Dev. 1.5

-2.3 -6.9

0.75 2.25

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	
1.00E-02	0.5	
0.1	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gagliuzi
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4a. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Log-Normal

Mean -0.22

Std.Dev. 0.125

-0.11 -0.33

0.0625 0.1875

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.6	0.05	
8.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4b. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Normal

Mean 0.4

Std.Dev. 0.2

0.2 0.6

0.1 0.3

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4c. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Weibull

Alpha 1.5

Beta 0.464

0.75 2.25

0.232 0.696

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4d. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Log-Normal
 Mean -0.22
 Std.Dev. 0.125
 -0.11 -0.33
 0.0625 0.1875

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgi)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.6	0.05	
8.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4e. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Normal

Mean	0.4
Std.Dev.	0.2
	0.6
	0.1
	0.3

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adg)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4f. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Weibull

Alpha 1.5

Beta 0.464

0.75 2.25

0.232 0.696

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4g. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Log-Normal
 Mean -0.22
 Std.Dev. 0.125
 -0.11 -0.33
 0.0625 0.1875

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.6	0.05	
8.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4h. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Normal

Mean 0.4

Std.Dev. 0.2

0.2 0.6

0.1 0.3

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4i. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Weibull

Alpha	1.5
Beta	0.464
0.75	2.25
0.232	0.696

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gagliuzi
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4j. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Log-Normal

Mean -0.22
 Std.Dev. 0.125
 -0.11 -0.33
 0.0625 0.1875

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.6	0.05	
8.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gaultitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4k. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Normal

Mean 0.4

Std.Dev. 0.2

0.2 0.6

0.1 0.3

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 4I. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Weibull

Alpha	1.5
Beta	0.464
	0.75 2.25
	0.232 0.696

General Comments:

USE LAST YEAR'S ELICITATIONS (see general remarks in 62adgj)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	
4.00E-01	0.5	
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in DST
Units: probability (dimensionless)
Cond: a. 1E-2 / year return frequency earthquake

Log-Normal

Mean -3
 Std.Dev. 1.4
 -1.5 -4.5
 0.7 2.1

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.5	10 fold less energy and waste motion than 1000 yr quake. Roughly 1 in 20 tanks will have sufficient waste and equipment motion to spark
5.00E-03	0.05	10 fold less
0.5	0.95	
1	1	Truncate probabilities at 0 and 1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in DST
Units: probability (dimensionless)
Cond: b. 1E-3 / year return frequency earthquake

Normal

Mean 0.5

Std.Dev. 0.25

0.25 0.75

0.125 0.375

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	This is the primary point. A 1000 yr quake provides sufficient equipment motion to cause sparks, but perhaps not every time.
5.00E-02	0.05	
	0.95	
1	1	Truncate probabilities at 0 and 1

1000 yr eq equivalent motion to that caused by large GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Phil Gauglitz
Analyst: Richard John
Variable: 7. Probability of seismic induced ignition source in DST
Units: probability (dimensionless)
Cond: c. 1E-4 / year return frequency earthquake

Weibull

Alpha 6

Beta 0.84

3 9

0.42 1.26

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.8	0.5	Generally get sparks
5.00E-01	0.05	Unusual not to get a spark for this event
	0.95	
1	1	

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This document was too large to scan as a single document; therefore, it has been divided into smaller sections.

Section 2 of 3

Document Information			
Document #	HNF-2577	Revision	0
Title	FLAMMABLE GAS PROJECT EXPERT ELICITATION RESULTS FOR HANFORD SITE DOUBLE-SHELL TANKS		
Date	07/09/1998		
Originator	D.R. BRATZEL	Originator Co.	DESH
Recipient		Recipient Co.	
References	EDT-613765		
Keywords			
Projects	TFARM		
Other Information	CONTAINS APPENDIX A.7-1 THROUGH A.14-28		

APPENDIX A.7
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

J. Havens

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Log-Normal

Mean -4.08

Std.Dev. 0.422

-2 -6

0.1 1.5

General Comments Small eff distribution is 100 times more likely than large eff distr

Specific Comments about Fractiles:

x	F(x)	Rationale
0.016667	0.5	see below
0.006667	0.05	
0.033333	0.95	

1

If thick liq layer present but rollover is not indicated,
then small eff releases are more likely than large eff releases

30 tanks times 10 years is 300 tank years, perhaps 5 large eff BD-GREs (1/60)

Spontaneous non BD is 100 times less likely than BD, so 1/6000

Calc max freq assuming 10 large ef BD-GREs (1/30)

Calc min freq assuming 2 large eff BD-GREs (1/15000)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Log-Normal

Mean -6.4
 Std.Dev. 0.422
 -5 -15
 0.1 1.5

General Comments Medium distribution is 10 times more likely than large eff distr

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001667	0.5	see below
0.000667	0.05	
0.003333	0.95	

1

If thick liq layer present but rollover is not indicated,
then small eff releases are more likely than large eff releases

30 tanks times 10 years is 300 tank years, perhaps 5 large eff BD-GREs (1/60)
 Spontaneous non BD is 100 times less likely than BD, so 1/6000
 Calc max freq assuming 10 large ef BD-GREs (1/30)
 Calc min freq assuming 2 large eff BD-GREs (1/15000)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
 Expert: Jerry Havens
 Analyst: Richard John
 Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
 Units: Events / Year
 Cond: c. Large efficiency release

Log-Normal
 Mean -8.7
 Std.Dev. 0.422
 -5 -15
 0.1 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.000167	0.5	see below
6.67E-05	0.05	
0.000333	0.95	

1

If thick liq layer present but rollover is not indicated,
then small eff releases are more likely than large eff releases

30 tanks times 10 years is 300 tank years, perhaps 5 large eff BD-GREs (1/60)
 Spontaneous non BD is 100 times less likely than BD, so 1/6000
 Calc max freq assuming 10 large ef BD-GREs (1/30)
 Calc min freq assuming 2 large eff BD-GREs (1/15000)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -4.945

Std.Dev. 1.34

-1.5 -8

0.5 1.5

General Comments GRE event is the cause of the ignition source; min energy for H₂ is low
 Prob for energy event to cause an ignition is greater for large eff compared to med or low eff releases; roughly proportional to eff of release

Specific Comments about Fractiles:

x	F(x)	Rationale
0.007143	0.5	0.1 prob of min energy event
0.000714	0.05	0.01
0.064286	0.95	0.9
1	1	Must truncate probability at 1.0

since ignition energy required is so low, prob that min energy will be exceeded
 Assuming that min energy is very likely, but that spark does not occur with gas
 Source of uncertainty is the location of the spark

Co-location of spark and gas same as large

Ratio of large to medium Prob (ignition source) is prop to ratio of energy of large
 to medium and is prop to ratio of vol of gas of large to medium

Ratio of large to medium vols is 35:2.5, so medium is large * 1/14ths

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean -3.15

Std.Dev. 1.34

-1.5 -4.5

0.5 1.5

General Comments GRE event is the cause of the ignition source; min energy for H₂ is low
 Prob for energy event to cause an ignition is greater for large eff compared to med
 or low eff releases; roughly proportional to eff of release

Specific Comments about Fractiles:

x	F(x)	Rationale
0.042857	0.5	0.1 prob of min energy event
0.004286	0.05	0.01
0.385714	0.95	0.9
1	1	

Must truncate probability at 1.0

since ignition energy required is so low, prob that min energy will be exceeded

Assuming that min energy is very likely, but that spark does not occur with gas

Source of uncertainty is the location of the spark

Co-location of spark and gas same as large

Ratio of large to medium Prob (ignition source) is prop to ratio of energy of large to medium and is prop to ratio of vol of gas of large to medium

Ratio of large to medium vols is 35:15, so medium is large * 3/7ths

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -2.31
 Std.Dev. 1.34
 -1.5 -4.5
 0.5 1.5

General Comments GRE event is the cause of the ignition source; min energy for H₂ is low
 Prob for energy event to cause an ignition is greater for large eff compared to med
 or low eff releases; roughly proportional to eff of release

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	0.1 prob of min energy event
0.01	0.05	0.01
0.9	0.95	0.9
1	1	Must truncate probability at 1.0

since ignition energy required is so low, prob that min energy will be exceeded
 Assuming that min energy is very likely, but that spark does not occur with gas
 Source of uncertainty is the location of the spark

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean	-3.33
Std.Dev.	0.5
	-1.5 -4.5
	0.5 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments about Fractiles:

x	F(x)	Rationale
0.035	0.5	from data for 1 psi pressure
0.015909	0.05	median/2.2
0.077	0.95	median*2.2

Pressure → H₂ burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H₂ burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminor flame vel for O₂/H₂ mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Weibull
Alpha 1.19
Beta 0.195
0.5 1.5
0 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
Estimated flow velocities that tank surfaces would be subjected to

Specific Comments about Fractiles:

x	F(x)	Rationale
0.144	0.5	from data for 10 psi
0.022273	0.05	data for 2 psi (0.049) and divided by 2.2
0.4774	0.95	data for 20 psi (0.217) and mult by 2.2

Pressure → H₂ burned and energy rel → flow vel → entrainment
Used data to derive entrainment flux as a function of flow velocities
Associated pressure increase with the amount of energy release from H₂ burn
Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
Assume the char vel of scouring is the max value of the laminor flame vel for O₂/H₂ mixtures
also assumes negligible turbulence in the tank headspace
Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
Uncertainty associated with flow vel to entrainment data

Calc values of mass suspended at 2, 10 and 20 psi and associated each with 5%, 50%, and 95% fractiles

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
 Expert: Jerry Havens
 Analyst: Richard John
 Variable: 3.Total mass of transportable waste material suspended
 Units: Kilograms
 Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal
 Mean -1.28
 Std.Dev. 0.59
 -0.5 -1.5
 0.5 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments about Fractiles:

x	F(x)	Rationale
0.277	0.5	from data for 33.5 psi
0.103636	0.05	data for 22 psi (0.228) and divided by 2.2
0.6974	0.95	data for 47 psi (0.317) and mult by 2.2

Pressure → H₂ burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H₂ burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminor flame vel for O₂/H₂ mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

Calc values of mass suspended at 22, 33.5 and 47 psi and associated each with 5%, 50%, and 95% fractiles

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Jerry Havens
Analyst: Richard John
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal

Mean -3.69

Std.Dev. 1.2

-1.5 -4.5

0.5 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments about Fractiles:

x	F(x)	Rationale
0.024872	0.5	from data for 68 psi (.359 kg) times filtering factor of .07 [= sqrt(0.2*0.024)]
0.003535	0.05	data for 50 psi (0.324), divided by 2.2 [= .147], multiplied by filtering factor of .024
0.16984	0.95	data for 86 psi (0.386), mult by 2.2 [0.85], multiplied by filtering factor of 0.2

Pressure → H2 burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H2 burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminor flame vel for O /H2 mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

Calc values of mass suspended at 50, 68 and 86 psi and associated each with 5%, 50%, and 95% fractiles
 2.2 factor used for 5th and 95th fractiles captures uncertainty in entrainment data

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
 Expert: Jerry Havens
 Analyst: Richard John
 Variable: 3.Total mass of transportable waste material released
 Units: Kilograms
 Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 2.02

Beta 475.5

0.5 10

300 2250

General Comments Assume for detonation that transportable and respirable are the same
 Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments about Fractiles:

x	F(x)	Rationale
400	0.5	$1200 * 2/3$ (nonstoichiometric) * .5 (TNT equiv to mass ratio)
80	0.05	median /5 (using 0.1 TNT equiv to mass ratio)
800	0.95	median *2 (using 1.0 TNT equiv to mass ratio)

Correlation in data suggested for transportable waste and TNT equiv of explosion
 Get 1 kg of respirable/transportable for each kg of TNT equiv. (Ref?)
 (may be high by as much as one order of magnitude) .1 to 1 kg
 Assume 60 kcal per mole of H₂ burned and used factor of 1.1 kcal per gram of TNT
 Assume headspace of half a million gal, resulting moles of H₂ burned = 23000
 Assumes stoichiometric mixture
 1200 kgram multiply by 2/3 factor since gas is not perfectly stoichiometric
 For detonation, assume that all material released escapes and is respirable
 Uncertainty arises from TNT equiv

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean -3.6

Std.Dev. 0.408

-1.5 -4.5

0.1 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments Multiply transportable masses by .8

x	F(x)	Rationale
0.028	0.5	from data for 1 psi pressure
0.012727	0.05	median/2.2
0.04928	0.95	median*2.2

Pressure → H₂ burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H₂ burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminar flame vel for O₂/H₂ mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Weibull

Alpha 1.31

Beta 0.16

0.5 1.5

0 0.2

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments Multiply transportable by .8 to get respirable

x	F(x)	Rationale
0.1152	0.5	from data for 10 psi
0.017818	0.05	data for 2 psi (0.049) and divided by 2.2
0.38192	0.95	data for 20 psi (0.217) and mult by 2.2

Pressure → H₂ burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H₂ burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminar flame vel for O₂/H₂ mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

Calc values of mass suspended at 2, 10 and 20 psi and associated each with 5%, 50%, and 95% fractiles

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal
Mean -1.505
Std.Dev. 0.59
 -0.5 -2
 0.5 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments Multiply transportable by .8 to get respirable mass

x	F(x)	Rationale
0.2216	0.5	from data for 33.5 psi
0.082909	0.05	data for 22 psi (0.228) and divided by 2.2
0.55792	0.95	data for 47 psi (0.317) and mult by 2.2

Pressure → H₂ burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H₂ burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminar flame vel for O₂/H₂ mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

Calc values of mass suspended at 22, 33.5 and 47 psi and associated each with 5%, 50%, and 95% fractiles

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Jerry Havens
Analyst: Richard John
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the DST dome

Log-Normal

Mean -3.9

Std.Dev. 1.2

-1.5 -4.5

0.5 1.5

General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments Multiply transportable by .8 to get respirable mass

x	F(x)	Rationale
0.019898	0.5	from data for 68 psi (.359 kg) times filtering factor of .07 [= sqrt(0.2*0.024)]
0.002828	0.05	data for 50 psi (0.324), divided by 2.2 [= .147], multiplied by filtering factor of .024
0.135872	0.95	data for 86 psi (0.386), mult by 2.2 [0.85], multiplied by filtering factor of 0.2

Pressure → H2 burned and energy rel → flow vel → entrainment
 Used data to derive entrainment flux as a function of flow velocities
 Associated pressure increase with the amount of energy release from H2 burn
 Could then derive area of tank for entrainment from the area of the tank subjected to flow velocities (scouring)
 Assume the char vel of scouring is the max value of the laminor flame vel for O/H2 mixtures
 also assumes negligible turbulence in the tank headspace
 Can calculate vel and time periods assoc with velocities, then utilized entrainment data (Fr...),
 Uncertainty associated with flow vel to entrainment data

Calc values of mass suspended at 50, 68 and 86 psi and associated each with 5%, 50%, and 95% fractiles
 2.2 factor used for 5th and 95th fractiles captures uncertainty in entrainment data

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
 Expert: Jerry Havens
 Analyst: Richard John
 Variable: 4. Total mass of respirable waste material released
 Units: Kilograms
 Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 2.02

Beta 475.5

0.5 10

300 2250

Assume for detonation that transportable and respirable are the same
 General Comments Assume mech for susp waste is solid entrainment from tank surfaces
 Estimated flow velocities that tank surfaces would be subjected to

Specific Comments about Fractiles:

x	F(x)	Rationale
400	0.5	1200 * 2/3 (nonstoichiometric) * .5 (TNT equiv to mass ratio)
80	0.05	median /5 (using 0.1 TNT equiv to mass ratio)
800	0.95	median *2 (using 1.0 TNT equiv to mass ratio)

Correlation in data suggested for transportable waste and TNT equiv of explosion
 Get 1 kg of respirable/transportable for each kg of TNT equiv. (Ref?)
 (may be high by as much as one order of magnitude) .1 to 1 kg
 Assume 60 kcal per mole of H₂ burned and used factor of 1.1 kcal per gram of TNT
 Assume headspace of half a million gal, resulting moles of H₂ burned = 23000
 Assumes stoichiometric mixture
 1200 kgram multiply by 2/3 factor since gas is not perfectly stoichiometric
 For detonation, assume that all material released escapes and is respirable
 Uncertainty arises from TNT equiv

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 4/22/1998
 Expert: Jerry Havens
 Analyst: Thomas Eppel
 Variable: 5: Duration of BD GRE
 Units: Minutes
 Cond: a. Small GRE

Weibull

Alpha 1.118

Beta 48.79

0.5 1.5

17.5 52.5

General Comments:

Based on information supplied by Havens after original elicitation session.

Specific Comments about Fractiles:

x	F(x)	Rationale
34.5	0.5	
2.3	0.05	
115	0.95	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

Weibull

Alpha	1.2
Beta	78
0.5	1.5
50	150

General Comments Estimates based on analysis of dataset provided; H2 concentration data for 6 BD-GRE events

Utilized agreed defn of duration as the time for the H2 concentration in the headspace to achieve 95% of peak value; est from conc data time for 6 events

Specific Comments about Fractiles:

x	F(x)	Rationale
57	0.5	rounded mean of data
3.8	0.05	only small chance of less than 5 min due to physical constraints; half of min
190	0.95	based on adjusting max of observed data (173 min)
1		

6 times: 173, 86, 10, 29, 115, 29 min

Mean= 73.7 min; sd=57.4 min

duration = time of rollover

For any release, can calc a char velocity scale = depth of rollover cell/duration

ratio of large to medium = ratio of depth of rollovers of large to medium

Ratio of Large to Medium rollover deths = .76 (see report for derivation)

Multiply large durations times .76 to get medium durations

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/1998
Expert: Jerry Havens
Analyst: Richard John
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Weibull

Alpha	1.17
Beta	102
0.5	1.5
50	150

General Comments Estimates based on analysis of dataset provided; H2 concentration data for 6 BD-GRE events

Utilized agreed defn of duration as the time for the H2 concentration in the headspace to achieve 95% of peak value; est from conc data time for 6 events

Specific Comments about Fractiles:

x	F(x)	Rationale
75	0.5	rounded mean of data
5	0.05	only small chance of less than 5 min due to physical constraints; half of min
250	0.95	based on adjusting max of observed data (173 min)
1		

6 times: 173, 86, 10, 29, 115, 29 min

Mean= 73.7 min; sd=57.4 min

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APPENDIX A.8
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

M. Kazimi

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Weibull

Alpha 0.907

Beta 0.0447

0.5 1.5

0 0.15

General Comments:

Some resemblance to the corresponding frequency of FGII unpumped SST, except that the smaller events are less likely to occur in DSTs since they have a better gas retention; for the same reason, medium GREs might be more likely than in SSTs

Specific Comments about Fractiles:

x	F(x)	Rationale
0.003	0.1	order of magnitude less than median
0.01	0.2	
0.03	0.5	started with 0.37 as the median of observed small GREs in FGII SSTs; used a factor of about 10 to reflect - better retention in DSTs - no observed spontaneous releases - no observed releases from intrusive events in DSTs (Barton's presentation)
0.1	0.9	
0.3	0.99	close to observed frequency in SSTs, but since there were no observed events in DSTs, this was taken as the upper bound

General Comments (cont.):

there is no observed evidence for either medium or large GREs in DSTs; based judgments with the changes mentioned above on the observed GRE data from FGII SSTs (WHC-SC-WM-TI-797 and presentation by B. Barton, April 29, 1997)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/1/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Weibull

Alpha 0.883

Beta 0.01425

0.5 1.5

0 0.15

General Comments:

see general comments in 1a

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.1	about an order of magnitude less than median, but wants to leave a non-negligent chance that you're actually lower than that, since there were no observed medium GREs
0.003	0.2	
0.01	0.5	increased the observed frequency from SSTs by about 50%, but then decreased the result by a factor of about 4 to account for the fact that there were no observed medium GREs in DSTs
0.03	0.9	
0.1	0.99	about an order of magnitude higher than median, serves as upper bound since no observed medium GREs in DSTs

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
 Expert: Mujid Kazimi
 Analyst: Thomas Eppel
 Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
 Units: Events / Year
 Cond: c. Large efficiency release

Weibull

Alpha 0.474

Beta 2.2E-05

0 1.5

0.000005 0.0001

General Comments:

no observed large GREs that are not BD in either SSTs or DSTs

Specific Comments about Fractiles:

x	F(x)	Rationale
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0.000001	0.2	starting with the frequencies from the SST elicitation, expert divided the cumulative probabilities by about a factor of two, shifting the distribution to the right, making this event more likely for DSTs than for SSTs
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0.00001	0.5	see above
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0.0001	0.9	see above
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0.001	0.99	see above
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Gram
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean 1.336

Std.Dev. 1.079

0.5 4.5

0.5 1.5

General Comments:

there are always some aerosols in the headspace and there will be some splashing from the waste; for this condition these are the two major sources of material

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0	
1	0.1	doesn't believe that there is much chance that it will be less than 1g given the fact that there is always some aerosols in the headspace; therefore the cumulative of 0.1 could actually be lower
3	0.5	assumed that median in headspace at all times is about 2g (based on headspace measurements; see expert's report); splash effect might contribute another gram
10	0.75	
100	0.99	there are some estimates for "intense" activities (e.g., drilling) from Los Alamos that reach 350g; but this is really like an upper bound
1000	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Gram
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Log-Normal

Mean 3.084

Std.Dev. 1.301

0.5 4.5

0.5 1.5

General Comments:

entrainment is added as another factor that will increase the amount of mass in the headspace by a few grams

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0	
3	0.05	aerosol mass in the headspace under normal conditions
20	0.5	due to entrainment, about 15 grams could be added to the aerosol mass that is already in the headspace
100	0.9	see below
1000	0.99	due to low pressure, it is hard to imagine that hundreds of grams of aerosols are added to the headspace given this slow burn
10000	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Gram
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean 4.813

Std.Dev. 1.655

3 10

0.5 2

General Comments:

no additional mechanism, but higher energies will increase the amount of mass suspended

Specific Comments about Fractiles:

x	F(x)	Rationale
3	0	
10	0.05	see reasoning for median
100	0.5	effect of entrainment is assumed to increase quadratically as a function of pressure; pressure increased by a factor of about 2.5
1000	0.9	see reasoning for median
10000	0.99	see reasoning for median

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Gram
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal

Mean 6.94

Std.Dev. 1.43

5 10

1 2

General Comments:

in addition to the mechanisms considered in cases 3a-3c, no the impact of the debris from the dome collapse falling onto the waste, suspends additional material, but the soil also adds as a filter for the additional material

Specific Comments about Fractiles:

x	F(x)	Rationale
100	0.05	somewhat lower than the smallest value reported in Los Alamos report (see comments about median)
400	0.2	
1000	0.5	estimates from Delphi group discussion have ranged from about 200 g to about 10.8 kg in risk assessment by Los Alamos (LA-UR-95-1900); the median is taken to be the product of the two square roots
4000	0.8	
10000	0.95	taken from the Los Alamos report (see comments about median)
100000	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
 Expert: Mujid Kazimi
 Analyst: Thomas Eppel
 Variable: 3.Total mass of transportable waste material released
 Units: Gram
 Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 1.0875

Beta 5000

0 1.5

3000 8000

General Comments:

no new mechanism; increased energy and dynamic effects will increase the amount of mass suspended by entrainment and hence available for transportation

Specific Comments about Fractiles:

x	F(x)	Rationale
100	0.02	somewhat lower than the 200 g report in Delphi group
400	0.1	
1000	0.2	
4000	0.5	
10000	0.9	based on calculations considering surface area of waste, impact of falling debris and filtration due to soil; see expert's report for more details
100000	1	using the 10.8 kg upper bound reported in Los Alamos study, the increased energy assumed in this scenario led the expert to give a 10% chance of the variable being above this value

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Gram
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Log-Normal

Mean 0.693

Std.Dev. 1.181

0 4.5

0.5 1.5

General Comments:

for the cases where the dome did not collapse, the percentage of respirable material was about 50% of the total mass of transportable aerosols (from variable 3)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0	50% of corresponding value in 3a
0.5	0.1	50% of corresponding value in 3a
1.5	0.5	50% of corresponding value in 3a
5	0.75	50% of corresponding value in 3a
50	0.99	50% of corresponding value in 3a
500	1	50% of corresponding value in 3a

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Gram
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Log-Normal

Mean 2.444

Std.Dev. 1.301

0.5 4.5

0.5 1.5

General Comments:

use 50% of the corresponding fractiles in 3b

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0	see general comments
1.5	0.05	see general comments
10	0.5	see general comments
50	0.9	see general comments
500	0.99	see general comments
5000	1	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Gram
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean 4.043

Std.Dev. 1.655

3 10

0.5 2

General Comments:

use 50% of the corresponding fractiles in 3c

Specific Comments about Fractiles:

x	F(x)	Rationale
1.5	0	see general comments
5	0.05	see general comments
50	0.5	see general comments
500	0.9	see general comments
5000	0.99	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Gram
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal
 Mean 5.315
 Std.Dev. 1.4
 5 10
 1 2

General Comments:

use 20% of the corresponding fractiles in 3d; filtering through the soil will collect a high fraction of particles above 5micrometers (diameter);

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.05	see above
80	0.2	see above
200	0.5	see above
800	0.8	see above
2000	0.95	see above
20000	1	see above

General Comments (cont.):

therefore, the percentage of respirable material is considerably less in case there is a dome failure compared to where the dome stays intact

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Gram
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 0.9345

Beta 1115.3

0 1.5

50 8000

General Comments:

use 20% of corresponding fractiles in 3e; see comments in 4d

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.02	see general comments
80	0.1	see general comments
200	0.2	see general comments
800	0.5	see general comments
2000	0.9	see general comments
20000	1	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

NOTE: Expert gave formula to derive distribution conditioned on height of non-convective layer

Log-Normal (assuming height of 4m for non-convective layer)

Mean 5.24

Std.Dev. 0.5785

4 6

0.5 1

General Comments:

modeled the duration of a BD GRE as a function of the height of the non-convective layer, using the following formula (see details in expert's report):

Duration (minutes) = $3000/(\text{Height}^2)$ where height is in meters;

Specific Comments about Fractiles:

x	F(x)	Rationale
46.9	0.01	see general comments
93.8	0.1	see general comments
187.5	0.5	see general comments
375	0.9	see general comments
750	0.99	see general comments

General Comments (cont.):

The fractiles above assume a height of 4m and illustrate how the distribution can be derived; need to input specific tank information to derive duration

The formula above is taken as the median; fractiles are obtained by scaling up or down by successive factors of two (e.g., 10th percentile = median/2; 1st percentile = median/4 etc.);

Model was developed using data presented for example in PNNL-11296 and PNNL-11536 Rev. 1 (see details in expert's report)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

NOTE: Expert gave formula to derive distribution conditioned on height of non-convective layer

Log-Normal (assuming height of 4m for non-convective layer)

Mean 5.24

Std.Dev. 0.5785

4	6
0.5	1

General Comments:

modeled the duration of a BD GRE as a function of the height of the non-convective layer, using the following formula (see details in expert's report):
 Duration (minutes) = $3000/(\text{Height}^2)$ where height is in meters;

Specific Comments about Fractiles:

x	F(x)	Rationale
46.9	0.01	see general comments
93.8	0.1	see general comments
187.5	0.5	see general comments
375	0.9	see general comments
750	0.99	see general comments

General Comments (cont.):

The fractiles above assume a height of 4m and illustrate how the distribution can be derived; need to input specific tank information to derive duration

The formula above is taken as the median; fractiles are obtained by scaling up or down by successive factors of two (e.g., 10th percentile = median/2; 1st percentile = median/4 etc.);

Model was developed using data presented for example in PNNL-11296 and PNNL-11536 Rev. 1 (see details in expert's report)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

NOTE: Expert gave formula to derive distribution conditioned on height of non-convective layer

Log-Normal (assuming height of 4m for non-convective layer)

Mean 5.24

Std.Dev. 0.5785

4	6
0.5	1

General Comments:

modeled the duration of a BD GRE as a function of the height of the non-convective layer, using the following formula (see details in expert's report):
 $\text{Duration (minutes)} = 3000/(\text{Height}^2)$ where height is in meters;

Specific Comments about Fractiles:

x	F(x)	Rationale
46.9	0.01	see general comments
93.8	0.1	see general comments
187.5	0.5	see general comments
375	0.9	see general comments
750	0.99	see general comments

General Comments (cont.):

The fractiles above assume a height of 4m and illustrate how the distribution can be derived; need to input specific tank information to derive duration

The formula above is taken as the median; fractiles are obtained by scaling up or down by successive factors of two (e.g., 10th percentile = median/2; 1st percentile = median/4 etc.);

Model was developed using data presented for example in PNNL-11296 and PNNL-11536 Rev. 1 (see details in expert's report)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/1/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.01
Maximum	1
0.0005	0.01
0.5	1.5

General Comments:

see remarks in 61f, same distribution as 1E-3 large GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/1//98
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
 Probability (dimensionless)
Units:
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.003
Maximum	0.3
0.0005	0.003
0.5	0.3

General Comments:

see remarks in 61f about using a uniform in logs; range was adjusted by about a factor of 3 from the small GRE, including shifting the maximum from unity to 0.3

Specific Comments about Fractiles:

x	F(x)	Rationale
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/1/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.001
Maximum	0.1
0.0005	0.001
0.5	0.1

General Comments:

see remarks in 61f about using a uniform in logs; range was adjusted by an order of magnitude from the small GRE, including shifting the maximum from unity to 0.1

Specific Comments about Fractiles:

x	F(x)	Rationale
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/1/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.2
Maximum	1
0.0005	0.2
0.5	1

General Comments:

see general rule about using log-uniform in 61f; minimum was adjusted such that median of this variable is about 0.5

Specific Comments about Fractiles:

x	F(x)	Rationale
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.04
Maximum	1
0.0005	0.04
0.5	1

General Comments:

see general rule about using log-uniform in 61f; minimum was adjusted such that median of this variable is about 0.2

Specific Comments about Fractiles:

x	F(x)	Rationale
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.01
Maximum	1
0.0005	0.01
0.5	1.5

General Comments:

1E-3 earthquake shows potential of straining the waste indicating substantial release potential (PNNL-11668);

Specific Comments about Fractiles:

x	F(x)	Rationale
		based on Stewart's presentation which suggested that 1E-3 earthquake would in all likelihood release about 50% of the retained gas, expert adjusted the "rule" to make the distribution uniform in logs such that the median of this distribution is about 0.1;

implications of this rule and assumption about median were checked on a linear scale which shows the large skew to the right

General Comments (cont.):

several factors (like double-walls in DSTs; assuming perfectly plastic behavior at 5% strain, no account of gas content for damping of waves, higher viscosity of multi-particle systems) were not taken into account in that report; therefore the probabilities have to be scaled down by at least an order of magnitude;

based on this report and the adjustments just mentioned, expert established a range for the probability of a seismic-induced GRE in DSTs; uncertainty distributions will be uniform in log-space over that range

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Degenerate Probability Distribution at 1

Minimum	1
Maximum	1
0.0005	1
0.5	1

General Comments:

for a 1E-4 earthquake, a small GRE will certainly happen

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
 Probability (dimensionless)
Units:
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.5
Maximum	1
0.0005	0.5
0.5	1

General Comments:

see general description in 61f; minimum was shifted to 0.5 and median of about 0.7 that this induces corresponds to expert's reasoning

Specific Comments about Fractiles:

x	F(x)	Rationale
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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Mujid Kazimi
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. $1E-4$ / year return frequency earthquake, large efficiency gas release, thick liquid layer

Uniform in Logs

Minimum	0.2
Maximum	1
0.0005	0.2
0.5	1

General Comments:

same as $1E-3$ distribution for small GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
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APPENDIX A.9
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

N. W. Kirch

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Weibull

Alpha 1.208

Beta 1.32

0.5 1.5

0.5 1.5

General Comments:

basics: there is always some generation and retention of gas;
 small releases are similar enough to steady state to assume that they could be quite frequent;
 looked at data for inventory and generation rate of tanks other than the 6 BD GRE tanks

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.01	really like a lower bound
0.1	0.05	even with low generation rates you might get 1 small release in 10 years
1	0.5	with 3 being almost like an upper bound, about 1 event per year is a reasonable estimate of the median (consistent with data)
3	0.95	assumed that about 3 events per year is the limit for low-generation events (see expert's report for definition of low generation rate)
10	0.99	really like an upper bound

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Log-Normal

Mean -4.552

Std.Dev. 1.394

-4 -5

0.5 1.5

General Comments:

assumed that for medium GREs the gas release volume for these tanks is about 10 to several hundred times the daily generation volume, which makes this event quite unlikely since it would require a mechanism of retention and release that is hard to imagine

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	order of magnitude lower than median
0.01	0.5	you have about 300 tank years of data for which there is really no indication of a medium GRE; to allow for the possibility of a medium GRE 1/100 was taken as the median estimate
0.1	0.95	order of magnitude higher than median

General Comments (cont.):

releases of that size would also lead to a level drop which hasn't been observed

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Log-Normal

Mean -11.53
 Std.Dev. 1.415
 -10 -15
 0.5 1.5

General Comments:

given the size of the events it would require 30 to 1000 times the daily generation rate, representing a 2-5 inch level drop, which is far outside the range of observed tank behavior (which makes this event really unlikely)

Specific Comments about Fractiles:

x	F(x)	Rationale
	0.01	
0.000001	0.05	three orders of magnitude less than medium GRE
0.00001	0.5	three orders of magnitude less than medium GRE
0.0001	0.95	three orders of magnitude less than medium GRE
	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -11.53

Std.Dev. 1.415

-10 -15

0.5 1.5

General Comments:

there must be some significant waste movement (move and damage tank-intrusive equipment) for the BD GRE to cause an ignition source;

Specific Comments about Fractiles:

x F(x) Rationale

0.000001 0.05 order of magnitude lower than median

0.00001 0.5 one of the reports gave a 4e-4 probability for one device (FIC); expert believes that for this variable the probability is even lower than that

0.0001 0.95 order of magnitude higher than median

General Comments (cont.):

the sequence of energetic release - movement of equipment - damage of equipment - spark was folded into expert's judgment about the likelihood of this event;

looked at references (see expert's report) of ignition source studies; there is little waste movement induced by a small BD GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal
 Mean -7.571
 Std.Dev. 1.397
 -7 -8
 0.5 1.5

General Comments:

see general remarks for 2a; medium release makes an ignition source under these conditions more likely compared to small GREs, but it is still very unlikely to occur; approximately that same as the FIC failure probability (see expert's write-up)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.00005	0.05	order of magnitude lower than median
0.0005	0.5	4e-4 was probability in FIC report;
0.005	0.95	order of magnitude higher than median

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Weibull

Alpha 0.5685

Beta 0.00969

0 1.5

0.0005 0.01

General Comments:

observed large GREs often led to equipment movement; however, the relative motion in large GREs is quite varied;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.05	about an order of magnitude lower than the original 1e-3 for the median
0.005	0.5	started out with 1e-3; changed it to 5e-3 after acknowledging that large GREs are really different from medium GREs; should be about an order of magnitude more likely
0.1	0.95	there are really no data that would justify that you get more than 1 in 10 events that lead to an ignition source

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

Weibull

Alpha 0.644

Beta 160

0.5 1.5

50 160

General Comments:

looked at 6 tanks that showed past GRE behavior (see list in expert's report); 5 of those showed small and medium efficiency releases, with SY101 being the exception of showing a large GRE;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.05	a bit shorter than the shortest duration observed
90	0.5	actual median of data was 88
720	0.95	longer than observed longest release (which was about 500 minutes); expert assumes that you could get 12 hour releases before they go over to "steady state"
3600	0.99	after 2.5 days the characteristics of the release is really "steady state"

General Comments (cont.):

there were a total of 4 small GREs, 11 medium GREs and 7 large GREs (see list in expert's report); small and medium GREs data show no difference in behavior so that expert did not discern between these two types of events; will use same distribution for both;

data, which included information about duration, was interpreted as representing the 90% credible interval for this variable

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

Weibull

Alpha	0.644
Beta	160
	0.5 1.5
	50 160

General Comments:

same as small GRE since expert did not differentiate; see general comments in 5a

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.05	see 5a
90	0.5	see 5a
720	0.95	see 5a
3600	0.99	see 5a

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Log-Normal
 Mean 2.7
 Std.Dev. 1.27
 1 3
 0.5 1.5

General Comments:

looked at data set specific to SY101 (see expert's report); for other tanks that showed large GREs, there was no gas monitoring data available during those releases;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	0.01	
2	0.05	
15	0.5	based on December 1991 event; expert looked at video and pressure data to form this judgment
120	0.95	17 minutes was the median of actual data set
		largest in data set was 96 minutes; thought that a large release could last somewhat longer than that
1440	0.99	

General Comments (cont.):

in general, one would expect shorter durations for these types of releases due to increased energy;
 the right tail of the distribution is therefore "constrained" since there just might not be enough retained gas to support this type of release over a long period of time

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. $1E-2$ / year return frequency earthquake, small efficiency gas release, thick liquid layer

Weibull

Alpha 1.055

Beta 0.144

0.5275 1.5825

0.072 0.216

General Comments:

this condition is harder to judge since C. Stewart's presentation is less applicable for this lower energy seismic event; had to find data about energy for this type of earthquake (see report);

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	about as likely as large GREs for higher energy quakes ($1e-3$ and $1e-4$)
0.1	0.5	about as likely as large GREs for higher energy quakes ($1e-3$ and $1e-4$)
0.5	0.95	about as likely as large GREs for higher energy quakes ($1e-3$ and $1e-4$)

General Comments (cont.):

went to USGS to find description of magnitude 5 earthquake; thought that small GREs are somewhat likely, but medium and large GREs are unlikely under this scenario

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Log-Normal

Mean -4.53

Std.Dev. 1.38

-2.5 -7.5

0.5 1.5

General Comments:

the DOE terms "likely" for the upper end and "unlikely" for the lower end bracket the expert's uncertainty distribution for this scenario;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	see general comments
0.01	0.5	see general comments
0.1	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Log-Normal

Mean -6.84

Std.Dev. 1.391

-5 -7

0.5 1.5

General Comments:

since a large GRE would require higher energies to occur, expert judged this probability to be about an order of magnitude less than the corresponding probabilities for a medium GRE for this low energy scenario

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.05	see general comments
0.001	0.5	see general comments
0.01	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 2.4
 Beta 2.675
 1.2 3.6
 1.3375 4.0125

General Comments:

based on C. Stewart's presentation (PNNL report) at February workshop, a 1E-3 earthquake would in all likelihood release about 50% of the retained gas;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	wants to be broad in his range of probability since there is considerable uncertainty about tank inventory which would impact the probability of a GRE
0.5	0.5	based on Stewart's presentation, an earthquake of that size would make GREs of any size quite likely; however, there are some tanks that don't have enough inventory to lead to GREs; therefore 0.5 was taken as the median
0.8	0.95	judgment that takes into account conservatism in the analysis presented by Stewart

General Comments (cont.):

therefore, a small GRE is very likely (assuming that a large and medium have not occurred; see NOTE in definition of variables);
 however, since this variable does not distinguish between BD-type tanks and non BD-type tanks, the probability is not unity

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Weibull

Alpha 1.055

Beta 0.144

0.5 1.5

0.05 0.15

General Comments:

see general remarks in 6d; medium GREs under this condition should be less likely than small GREs

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	wants to create a relatively large range to account for uncertainty about waste composition and gas inventory
0.1	0.5	scaled down from the small GRE probability by a factor of about 5
0.5	0.95	wants to create a relatively large range to account for uncertainty about waste composition and gas inventory

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismo-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 1.055

Beta 0.144

0.5275 1.5825

0.072 0.216

General Comments:

use same distribution as for medium GRE (6e); cannot really distinguish whether this scenario leads to a large rather than a medium GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	same as medium GRE
0.1	0.5	same as medium GRE
0.5	0.95	same as medium GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 2.4
 Beta 2.675
 1.2 3.6
 1.3375 4.0125

General Comments:

similar to the reasoning explained for 1e-3 earthquakes (see general comments in 6d), expert believes that given C. Stewart's presentation, this is very likely;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	same as 1e-3 earthquake
0.5	0.5	same as 1e-3 earthquake
0.8	0.95	same as 1e-3 earthquake

General Comments (cont.):

however, due to the fact that not all tanks might have enough gas retained, this probability is not unity and its range should reflect the uncertainty about waste composition;
 expert did not distinguish between 1E-3 and 1E-4 earthquakes for this case

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta
 Alpha 2.4
 Beta 2.675
 1.2 3.6
 1.3375 4.0125

General Comments:

given the increased energy from a 1e-4 earthquake, this scenarios makes medium GREs about as likely as small GREs; again, however, expert wants to reflect uncertainty about waste composition for both median and range of probability distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.05	same as small GRE condition
0.5	0.5	same as small GRE condition
0.8	0.95	same as small GRE condition

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/1998
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. 1E-4 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 1.055

Beta 0.144

0.5275 1.5825

0.072 0.216

General Comments:

large GREs are less likely than small and medium GREs; the increased energy from a 1e-4 earthquake does not change expert's uncertainty distribution compared to the 1e-3 condition (probability of GRE is limited by waste composition)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.05	same as 1e-3 large GRE condition
0.1	0.5	same as 1e-3 large GRE condition
0.5	0.95	same as 1e-3 large GRE condition

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/98
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: a. 1E-2 / year return frequency earthquake

Log-Normal

Mean -13.8

Std.Dev. 1.387

-7.5 -22.5

0.5 1.5

General Comments:

1e-2 earthquake has peak acceleration of 0.03g; under this scenario, the liner would hold, making a non-GRE induced ignition source extremely unlikely (bordering on "incredible" - , 1e-6; there is essentially no damage to the tank)

Specific Comments about Fractiles:

x	F(x)	Rationale
1E-07	0.05	see general comments
0.000001	0.5	see general comments
0.00001	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/98
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
 probability (dimensionless)
Units:
Cond: b. 1E-3 / year return frequency earthquake

Log-Normal

Mean -13.8

Std.Dev. 1.387

-7.5 -22.5

0.5 1.5

General Comments:

1e-3 earthquake has peak acceleration of 0.18g (see PNNL report referenced in expert's report); this is still well below the 0.8g that is required to cause damage to the tank;

Specific Comments about Fractiles:

x	F(x)	Rationale
1E-07	0.05	see general comments
0.000001	0.5	see general comments
0.00001	0.95	see general comments

General Comments (cont.):

therefore, expert does not distinguish between 1E-3 and 1E-2 earthquakes in terms of probability of inducing a non-GRE related ignition source

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/10/98
Expert: Nick Kirch
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: c. $1E-4$ / year return frequency earthquake

Log-Normal
 Mean -11.525
 Std.Dev. 1.407
 -10 -15
 0.5 1.5

General Comments:

$1e-4$ earthquake has peak acceleration of 0.39g (see PNNL report referenced in expert's report); this is approaching the 0.8g threshold to cause damage in the tank; increased probabilities by an order of magnitude compared to $1e-3$ earthquake;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.000001	0.05	see general comments
0.00001	0.5	see general comments
0.0001	0.95	see general comments

General Comments (cont.):

expert did acknowledge the fact that for a $1E-5$ earthquake you are probably above the 0.8 threshold, which would make an ignition source certain;
 in other words: this damage threshold makes that probability of a non-GRE ignition source almost like a step function of earthquake magnitude

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APPENDIX A.10
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

G. Paulson

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Log-Normal

Mean -5.57

Std.Dev. 1.4

-5 -6

0.5 1.5

General Comments:

assumes that the likelihood of having detected a small GRE is 10 times less than the corresponding likelihood of detecting a medium or large GRE; therefore, scale up the fractiles from 1b and 1c by an order of magnitude

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	1	DISTRIBUTION NEEDS TO BE TRUNCATED AT 0.1!!!!!!
0.038	0.95	see above
0.0038	0.5	see above
0.00038	0.05	see above

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Log-Normal

Mean -7.875

Std.Dev. 1.38

-1.5 -10

0.5 1.5

General Comments:

expert assumes that the sensitivity of detecting a medium GRE had there been one is the same as for a large GRE; therefore use the same fractiles and distribution (INCLUDING TRUNCATION) as in 1c

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	1	DISTRIBUTION NEEDS TO BE TRUNCATED AT 0.01!!!!!!
0.0038	0.95	see above
0.00038	0.5	see above
0.000038	0.05	see above

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Log-Normal

Mean	-7.875
Std.Dev.	1.38
	-1.5 -10
	0.5 1.5

General Comments:

assumed that the condition meant that we're talking about tanks where there were no observations of a BD-GRE; they could still have a thick layer of liquid; he refers to 22 tanks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	1	DISTRIBUTION NEEDS TO BE TRUNCATED AT 0.01!!!!!!
0.0038	0.95	upper bound is defined by assuming that there has been one undetected large GRE over the 264 history of tank years
0.00038	0.5	one order of magnitude less than 0.95 fractile
0.000038	0.05	one order of magnitude less than median

General Comments (cont.)

also assumes that had there be a large BD GRE, it would have been observed; assumes that, on average, each tanks has a 12 year history (which translates into 264 tank years with no observed BD GRE of large efficiency)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -9.18

Std.Dev. 1.83

-6 -12

0.5 10

General Comments:

expects lower chance of an ignition source for a small BD-GRE compared to a medium and large BD-GRE; therefore the fractiles will be scaled down

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	TRUNCATE AT 1!!!
0.1	1	TRUNCATE AT 1!!!
0.01	0.98	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a small BD-GRE is less likely to induce an ignition source
0.001	0.89	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a small BD-GRE is less likely to induce an ignition source
0.0001	0.5	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a small BD-GRE is less likely to induce an ignition source
0.00001	0.1	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a small BD-GRE is less likely to induce an ignition source

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean -6.9

Std.Dev. 1.97

-6 -8

0.5 2

General Comments:

expects lower chance of an ignition source for a medium BD-GRE compared to a large BD-GRE; therefore the fractiles will be scaled down

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	TRUNCATE AT 1!!!
0.1	0.99	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a medium BD-GRE is less likely to induce an ignition source
0.01	0.9	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a medium BD-GRE is less likely to induce an ignition source
0.001	0.5	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a medium BD-GRE is less likely to induce an ignition source
0.0001	0.1	fractiles went by orders of magnitude; scaled up the cumulative probabilities to reflect his reasoning that a medium BD-GRE is less likely to induce an ignition source

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -4.55

Std.Dev. 1.38

0 -5

0.5 1.5

General Comments:

use the same type of reasoning as was used to express his uncertainties about this variable for SSTs;
 qualitatively, there is an increased likelihood of having an ignition source in DSTs, particularly for BD-GREs and more in-tank equipment;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	TRUNCATE AT 1!!!
0.1	0.95	went by orders of magnitude; implications of the fractiles for the probability of an ignition source under this scenario were discussed and expert agreed with the implications
0.01	0.5	went by orders of magnitude; implications of the fractiles for the probability of an ignition source under this scenario were discussed and expert agreed with the implications
0.001	0.05	went by orders of magnitude; implications of the fractiles for the probability of an ignition source under this scenario were discussed and expert agreed with the implications

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 0.69

Beta 0.68

0.5 1.5

0 2

General Comments:

since this is a much less energetic scenario, masses from 3b will be scaled down by a factor of 5; a factor of 10 is too high

Specific Comments about Fractiles:

x	F(x)	Rationale
3.6	0.95	see general comments
1.8	0.9	see general comments
0.4	0.5	see general comments
0.08	0.2	see general comments
0.008	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Weibull

Alpha 0.69

Beta 3.52

0.5 1.5

1 10

General Comments:

since this is a much less energetic scenario, masses from 3d and 3c will be scaled down by a factor of 5; a factor of 10 is too high

Specific Comments about Fractiles:

x	F(x)	Rationale
18	0.95	see general comments
9	0.9	see general comments
2	0.5	see general comments
0.4	0.2	see general comments
0.04	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Weibull

Alpha 0.69

Beta 17.2

0.5 1.5

10 100

General Comments:

even though this scenario does not lead to a dome failure, expert believes that there is still enough pressure to use the same distribution as was used for case 3d

Specific Comments about Fractiles:

x	F(x)	Rationale
88.4	0.95	see general comments
44	0.9	see general comments
10	0.5	see general comments
2	0.2	see general comments
0.2	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/98
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull

Alpha 0.69

Beta 17.2

0.5 1.5

10 100

General Comments:

compared to detonation (3e), a deflagration is less energetic, therefore less mass will be suspended

Specific Comments about Fractiles:

x	F(x)	Rationale
88.4	0.95	a factor of 5 less than the corresponding fractile in 3e (a factor of 10 would have been too dramatic)
44	0.9	see general comments
10	0.5	see general comments
2	0.2	see general comments
0.2	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/98
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 0.69

Beta 84.7

0.5 1.5

10 100

General Comments:

newly presented material did not provide any information that led expert to change his basic reasoning that he applied in the SST elicitation for the corresponding parameter; therefore fractiles from elicitation of 14c was used (on point added at lower)

Specific Comments about Fractiles:

x	F(x)	Rationale
442	0.95	see general comments
221	0.9	see general comments
50	0.5	see general comments
10	0.2	see general comments
1	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenin Paulson
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 0.69

Beta 0.34

0.5 1.5

0 2

General Comments:

expert did not change his reasoning from corresponding SST elicitation from last year; used a fraction of 0.5 of the total mass of transportable material to calculate the mass of respirable material;
 this factor of 0.5 does not change for other conditions

Specific Comments about Fractiles:

x	F(x)	Rationale
1.8	0.95	see general comments
0.9	0.9	see general comments
0.2	0.5	see general comments
0.04	0.2	see general comments
0.004	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Weibull

Alpha 0.69

Beta 1.72

0.5 1.5

1 10

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
9	0.95	see general comments
4.5	0.9	see general comments
1	0.5	see general comments
0.2	0.2	see general comments
0.02	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Weibull

Alpha 0.69

Beta 8.6

0.5 1.5

8 8.6

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
44.2	0.95	see general comments
22	0.9	see general comments
5	0.5	see general comments
1	0.2	see general comments
0.1	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/98
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull
Alpha 0.69
Beta 8.6
 0.5 1.5
 8 8.6

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
44.2	0.95	a factor of 5 less than the corresponding fractile in 3e (a factor of 10 would have been too dramatic)
22	0.9	see general comments
5	0.5	see general comments
1	0.2	see general comments
0.1	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/98
 Expert: Glenn Paulson
 Analyst: Thomas Eppel
 Variable: 4. Total mass of respirable waste material released
 Units: Kilograms
 Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 0.69

Beta 42.4

0.5 1.5

10 100

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
221	0.95	see general comments
110	0.9	see general comments
25	0.5	see general comments
5	0.2	see general comments
0.5	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

Weibull

Alpha	1
Beta	1512.5
	0.5 1.5
	50 2000

General Comments:

based on data that was sent to expert on the day of the elicitation (this is actually re-elicited); the data refer to time to peak hydrogen concentration for 5 DSTs equipped with SHMs since 1995 (Blaine Barton)

Specific Comments about Fractiles:

x	F(x)	Rationale
10000	1	based on empirical distribution mentioned in general comments
3000	0.95	based on empirical distribution mentioned in general comments
1000	0.5	based on empirical distribution mentioned in general comments
100	0.05	based on empirical distribution mentioned in general comments
1	0	based on empirical distribution mentioned in general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

Weibull

Alpha 0.8865

Beta 612

0 1.5

300 2250

General Comments:

see general comments in 5a

Specific Comments about Fractiles:

x	F(x)	Rationale
10000	1	based on empirical distribution
3000	0.95	based on empirical distribution
1000	0.88	based on empirical distribution
500	0.5	based on empirical distribution
10	0.05	based on empirical distribution
1	0	based on empirical distribution

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Log-Normal
Mean 4.7
Std.Dev. 0.91
3 5
0.5 1.5

General Comments:

see general comments in 5a

Specific Comments about Fractiles:

x	F(x)	Rationale
1000	1	
500	0.95	
100	0.5	
50	0.05	
10	0	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Degenerate at 1
 Minimum 0
 Maximum 0
 0 0
 0 6

General Comments:

used same reasoning that was used in SST elicitation last year; a new report (see expert's write-up) and presentation by C. Stewart buttresses his reasoning

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	for an earthquake of that size, a small GRE is bound to occur (assuming that neither a large or a medium GRE has occurred)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. $1E-2$ / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Uniform

Minimum 0.9

Maximum 1

0.45 1.35

0.5 1.5

General Comments:

for a $1E-2$ earthquake, a medium GRE (assuming that a large GRE has not occurred) is extremely likely to occur but not guaranteed

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.99	0.9	see general comments
0.95	0.5	see general comments
0.9	0	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Uniform
 Minimum 0.8
 Maximum 1
 0.4 1.2
 0.5 1.5

General Comments:

for a 1E-2 earthquake, a large GRE is very likely to occur but not guaranteed and somewhat less likely than a medium GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.98	0.9	see general comments
0.9	0.5	see general comments
0.8	0	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Degenerate at 1

Minimum	0
Maximum	0
0	0
0	6

General Comments:

used same reasoning that was used in SST elicitation last year; a new report (see expert's write-up) and presentation by C. Stewart buttresses his reasoning

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	for an earthquake of that size, a large GRE is bound to occur; if a large GRE does not occur, a medium GRE is bound to occur; if neither a large or a medium GRE occur, a small GRE is bound to occur

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Degenerate at 1

Minimum	0
Maximum	0
0	0
0	6

General Comments:

used same reasoning that was used in SST elicitation last year; a new report (see expert's write-up) and presentation by C. Stewart buttresses his reasoning

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	for an earthquake of that size, a large GRE is bound to occur; if a large GRE does not occur, a medium GRE is bound to occur; if neither a large or a medium GRE occur, a small GRE is bound to occur

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Degenerate at 1

Minimum	0
Maximum	0
0	0
0	6

General Comments:

used same reasoning that was used in SST elicitation last year; a new report (see expert's write-up) and presentation by C. Stewart buttresses his reasoning

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	for an earthquake of that size, a large GRE is bound to occur; if a large GRE does not occur, a medium GRE is bound to occur; if neither a large or a medium GRE occur, a small GRE is bound to occur

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Degenerate at 1

Minimum	0
Maximum	0
	0
	6

General Comments:

since expert believes that a GRE is bound to occur for a 1E-3 earthquake, it is bound to occur for a 1E-4 earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Degenerate at 1

Minimum	0
Maximum	0
	0
	6

General Comments:

since expert believes that a GRE is bound to occur for a 1E-3 earthquake, it is bound to occur for a 1E-4 earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. 1E-4 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Degenerate at 1

Minimum	0
Maximum	0
	0
	0
	6

General Comments:

since expert believes that a GRE is bound to occur for a 1E-3 earthquake, it is bound to occur for a 1E-4 earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2a. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Beta
 Alpha 0.803
 Beta 4.26
 0.5 1.5
 3 9

General Comments:

distinction between pumped vs. unpumped is an important distinction (not reflected by other conditioning factors like FGs) since unpumped tanks could have a liquid layer;
 all distributions were derived (scaled) from the 1E-4 earthquake, pumped, small GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general comments
0.5	0.95	see general comments
0.1	0.5	see general comments
0.01	0.05	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2b. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Weibull

Alpha 0.98

Beta 0.0303

0.5 1.5

0.03 0.04

General Comments:

see comments in 62a

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.1	0.95	scale down by a factor of 5 from 62a
0.02	0.5	scale down by a factor of 5 from 62a
0.002	0.05	scale down by a factor of 5 from 62a

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2c. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Weibull

Alpha 0.98

Beta 0.006

0.5 1.5

0 0.04

General Comments:

see comments in 62a

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.02	0.95	scale down by a factor of 5 from 62b
0.004	0.5	scale down by a factor of 5 from 62a
0.0004	0.05	scale down by a factor of 5 from 62a

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2d. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Uniform
 Minimum 0
 Maximum 0.1
 0 0
 0.05 0.15

General Comments:

same as 63d

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.1	1	for pumped, the probability of having a small GRE under this conditions is bound to be less than 0.1
0.05	0.5	
0.01	0.05	
0.005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2e. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Uniform
 Minimum 0
 Maximum 0.01
 0 0
 0.005 0.015

General Comments:

see comments in 62a

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.01	1	a factor of 10 less likely than 62d
0.005	0.5	
0.001	0.05	
0.0005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2f. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Uniform
 Minimum 0.
 Maximum 0.001
 0 0
 0.0005 0.0015

General Comments:

see comments in 62a

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.001	1	a factor of 10 less likely than 62e
0.0005	0.5	
0.0001	0.05	
0.00005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2g. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Uniform
 Minimum 0
 Maximum 0.001
 0 0
 0.0005 0.0015

General Comments:

same as 62f

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.001	1	
0.0005	0.5	
0.0001	0.05	
0.00005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2h. 1E-2/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Uniform
 Minimum 0
 Maximum 0.0002
 0 0
 0.0001 0.0003

General Comments:

scale down by a factor of 5 from 62g

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.0002	1	
0.0001	0.5	
0.00002	0.05	
0.00001	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Uniform
 Minimum 0
 Maximum 0.00004
 0 0
 0.00002 0.00006

General Comments:

scale down by a factor of 5 from 62h

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	logical upper bound
0.00004	1	
0.00002	0.5	
0.000004	0.05	
0.000002	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2j. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Degenerate at 0

Minimum 0

Maximum 0

0 0

0 0.00006

General Comments:

for pumped tanks under these conditions, there won't be a gas release of any size

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2k. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Degenerate at 0
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for pumped tanks under these conditions, there won't be a gas release of any size

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 2l. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Degenerate at 0
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for pumped tanks under these conditions, there won't be a gas release of any size

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3a. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Degenerate at 1

Minimum	0
Maximum	0
0	0
0	0.00006

General Comments:

for a 1E-4 earthquake under this conditions (unpumped), a release of any size is bound to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

General Comments (cont.)

in the SST elicitation last year, expert used this type of distribution only for 1E-4 earthquakes, since back then he didn't distinguish between pumped vs. unpumped status;

since unpumped allows for the presence of a liquid layer, expert believes that even a 1E-3 earthquake is bound to induce a GRE of any size
also, there are new modeling data (C. Stewart's presentation) that confirm this type of reasoning

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3b. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Degenerate at 1
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for a 1E-4 earthquake under this conditions (unpumped), a release of any size is bound to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

General Comments (cont.)

in the SST elicitation last year, expert used this type of distribution only for 1E-4 earthquakes, since back then he didn't distinguish between pumped vs. unpumped status;
 since unpumped allows for the presence of a liquid layer, expert believes that even a 1E-3 earthquake is bound to induce a GRE of any size
 also, there are new modeling data (C. Stewart's presentation) that confirm this type of reasoning

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3c. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG2

Degenerate at 1
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for a 1E-4 earthquake under this conditions (unpumped), a release of any size is bound to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

General Comments (cont.)

in the SST elicitation last year, expert used this type of distribution only for 1E-4 earthquakes, since back then he didn't distinguish between pumped vs. unpumped status;
 since unpumped allows for the presence of a liquid layer, expert believes that even a 1E-3 earthquake is bound to induce a GRE of any size
 also, there are new modeling data (C. Stewart's presentation) that confirm this type of reasoning

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3d. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Uniform
 Minimum 0
 Maximum 0.1
 0 0
 0.05 0.15

General Comments:

(almost) same distribution as last year for any GRE size under this condition;
 however, now wants this distribution only to be applied to small GREs

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.1	1	
0.05	0.5	
0.01	0.05	
0.005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3e. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG2

Uniform
 Minimum 0
 Maximum 0.01
 0 0
 0.005 0.015

General Comments:

same distribution as 62e

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.01	1	
0.005	0.5	
0.001	0.05	
0.0005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Cond: 3f. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Uniform
 Minimum 0
 Maximum 0.001
 0 0
 0.0005 0.0015

General Comments:

same distribution as 62f

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.001	1	
0.0005	0.5	
0.0001	0.05	
0.00005	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 3g. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Uniform

Minimum 0.001

Maximum 0.01

0.0005 0.0015

0.005 0.015

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.01	1	63d divided by 10 to account for pumped status
0.005	0.5	
0.001	0	cannot be less than 0.001

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 3h. 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Uniform

Minimum 0.0001

Maximum 0.001

0.00005 0.00015

0.0005 0.0015

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.001	1	take 63g and divide by 10
0.0005	0.5	
0.0001	0	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 3i. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Uniform

Minimum 0.00001

Maximum 0.0001

0.000005 1.5E-05

0.00005 0.00015

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.0001	1	take 63h and divide by 10
0.00005	0.5	
0.00001	0	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 3j. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Degenerate at 0
 Minimum 0
 Maximum 0
 0 1.5E-05
 0 0.00015

General Comments:

pumped status makes a release of any size impossible under this scenario

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 3k. 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Degenerate at 0
 Minimum 0
 Maximum 0
 0 1.5E-05
 0 0.00015

General Comments:

pumped status makes a release of any size impossible under this scenario

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 3I. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Degenerate at 0
 Minimum 0
 Maximum 0
 0 1.5E-05
 0 0.00015

General Comments:

pumped status makes a release of any size impossible under this scenario

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/98
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4a. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Degenerate at 1
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for a 1E-4 earthquake under this conditions (unpumped), a release of any size is bound to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4b. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 2

Degenerate at 1
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for a 1E-4 earthquake under this conditions (unpumped), a release of any size is bound to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4c. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Degenerate at 1
 Minimum 0
 Maximum 0
 0 0
 0 0.00006

General Comments:

for a 1E-4 earthquake under this conditions (unpumped), a release of any size is bound to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4d. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Uniform
 Minimum 0.01
 Maximum 1
 0.005 0.015
 0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.5	0.5	
0.1	0.05	
0.01	0	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4e. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Uniform

Minimum 0.001

Maximum 0.1

0.0005 0.0015

0.05 0.15

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	1	
0.05	0.5	take 64d and divide by 10
0.01	0.05	
0.001	0	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4f. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Uniform

Minimum 0.0001

Maximum 0.01

0.00005 0.00015

0.005 0.015

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	1	
0.005	0.5	take 64e and divide by 10
0.001	0.05	
0.0001	0	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4g. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Degenerate at 1

Minimum 0

Maximum 0

0 0.00015

0 0.015

General Comments:

see 64a-c

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4h. 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG 3

Degenerate at 1

Minimum 0

Maximum 0

0 0.00015

0 0.015

General Comments:

see 64a-c

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4i. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Degenerate at 1

Minimum 0

Maximum 0

0 0.00015

0 0.015

General Comments:

see 64a-c

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4j. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Degenerate at 0

Minimum 0

Maximum 0

0 0.00015

0 0.015

General Comments:

even for 1E-4, pumped tanks under these conditions will not show a release of any size

Specific Comments about Fractiles:

x	F(x)	Rationale
---	------	-----------

0	1	
---	---	--

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4k. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Degenerate at 0

Minimum 0

Maximum 0

0 0.00015

0 0.015

General Comments:

even for 1E-4, pumped tanks under these conditions will not show a release of any size

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 6: Probability of a seismic-induced GRE in SSTs
Units: Probability (dimensionless)
Cond: 4I. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Degenerate at 0

Minimum 0

Maximum 0

0 0.00015

0 0.015

General Comments:

even for 1E-4, pumped tanks under these conditions will not show a release of any size

Specific Comments about Fractiles:

x	F(x)	Rationale
---	------	-----------

0	1	
---	---	--

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 7: Probability of an ignition source in a DST caused by an earthquake
Units: probability (dimensionless)
Cond: a. 1E-2 / year return frequency earthquake

Weibull

Alpha 0.849

Beta 0.01826

0.5 1.5

0.005 0.2

General Comments:

this is the same distribution that was used last year for SSTs; doesn't see any reason why this should be different for DSTs

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	
0.1	0.95	
0.01	0.5	
0.001	0.05	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/98
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 7: Probability of an ignition source in a DST caused by an earthquake
Units: probability (dimensionless)
Cond: b. 1E-3 / year return frequency earthquake

Degenerate at 1

Alpha 0
 Beta 0
 0 1.5
 0 0.2

General Comments:

earthquake of that size (1E-3 or 1E-4) will definitely lead to an ignition source

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/12/1998
Expert: Glenn Paulson
Analyst: Thomas Eppel
Variable: 7: Probability of an ignition source in a DST caused by an earthquake
Units: probability (dimensionless)
Cond: c. 1E-4 / year return frequency earthquake

Degenerate at 1

Alpha	0
Beta	0
0	1.5
0	0.2

General Comments:

earthquake of that size (1E-3 or 1E-4) will definitely lead to an ignition source.

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	

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APPENDIX A.11
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

A. K. Postma

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Weibull

Alpha 1.52

Beta 0.0395

0.5 2

0.025 0.075

General Comments:

Multiple medium by factor of 10

Specific Comments about Fractiles:

x	F(x)	Rationale
0.03	0.5	
0.12	0.99	
0.003	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Weibull

Alpha 1.42

Beta 0.00395

0.5 1.5

0.0025 0.0075

General Comments:

Based on tank experience

Specific Comments about Fractiles:

x	F(x)	Rationale
0.003	0.5	Data: 1 undetected GRE during 20 years, use # tanks
0.012	0.99	Only a one percent chance of 4 medium GREs in 17 tanks for 20 years
0.0003	0.01	order of magnitude

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Weibull

Alpha 1.67

Beta 0.001

0.5 2

0.0005 0.0015

General Comments:

Chance of not having detected a large release of not having detected a large release is very low

Specific Comments about Fractiles:

x	F(x)	Rationale
7.50E-04	0.5	
3.00E-03	0.99	use same shape as 1b
7.50E-05	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: a. Small efficiency buoyant displacement gas release event

Log-Normal

Mean -10.8

Std.Dev. 0.7

-6 -18

0.5 1.5

General Comments:

Less energetic waste motions, smaller volumes reaching concentrations

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E-05	0.5	Tank experience, 400 GREs w/o ignitions, 1:10 chance of ignition, adjusted by 10
6.00E-06	0.05	
2.00E-06	0.01	
6.00E-05	0.95	
2.00E-04	0.99	off by factor of 10

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal

Mean -8.48

Std.Dev. 0.67

-4 -12

0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E-04	0.5	Tank experience, 400 GREs w/o ignitions, 1:10 chance of ignition
6.00E-05	0.05	
2.00E-05	0.01	
6.00E-04	0.95	
2.00E-03	0.99	off by factor of 10

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -7.08

Std.Dev. 0.68

-3 -9

0.5 1.5

General Comments:

Larger waste motions, larger volumes

Specific Comments about Fractiles:

x F(x) Rationale

8.00E-04 0.5 Tank experience, 400 GREs w/o ignitions, 1:10 chance of ignition, adjusted by multiple of 4 from case b

2.40E-04 0.05

8.00E-05 0.01

2.40E-03 0.95

8.00E-03 0.99 off by factor of 10

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
---	------	-----------

		Degenerate distribution at 0 mass.
--	--	------------------------------------

Probability (0) = 1

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Log-Normal

Mean -2.48

Std.Dev. 0.72

-1 -3

0.5 1.5

General Comments:

Scaled study of aerosol generation by hydrogen burns (Fox et al., 1993)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.08	0.5	
0.25	0.95	
0.8	0.99	all in kg.
0.025	0.05	
0.008	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean -1.16

Std.Dev. 0.72

-0.5 -1.5

0.5 1.5

General Comments:

Scaled study of aerosol generation by hydrogen burns (Fox et al., 1993)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.3	0.5	
1	0.95	
3	0.99	all in kg.
0.1	0.05	
0.03	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/98
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal

Mean 0.455

Std.Dev. 0.75

0.25 0.75

0.5 1.5

General Comments:

Fox data to estimate what's air borne, vet out during depressurization (rapid).

Specific Comments about Fractiles:

x	F(x)	Rationale
1.5	0.5	
5	.95	
15	0.99	all in kg.
0.5	0.05	
0.15	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/98
 Expert: Arlin Postma
 Analyst: Detlof von Winterfeldt
 Variable: 3.Total mass of transportable waste material released
 Units: Kilograms
 Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Log-Normal

Mean 0.455

Std.Dev. 0.75

0.25 0.75

0.5 1.5

General Comments:

Very extreme, should not be considered, but use 3d

Specific Comments about Fractiles:

x	F(x)	Rationale
1.5	0.5	
5	0.95	
15	0.99	use 3d
0.5	0.05	
0.15	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

0
0

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
---	------	-----------

Probability (0) = 1

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Log-Normal

Mean -3.19

Std.Dev. 0.75

-1 -4

0.75 2.25

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.004	0.01	
0.013	0.05	
0.040	0.5	see Table 4.4 of Postma's rationale
0.130	0.95	
0.400	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean -1.84

Std.Dev. 0.75

2 -2

0.75 2.25

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.015	0.01	
0.050	0.05	
0.150	0.5	see Table 4.4 of Postma's rationale
0.500	0.95	
1.500	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Log-Normal
 Mean -0.3
 Std.Dev. 0.825
 -1 0
 0.75 2.25

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.075	0.01	
0.250	0.05	
0.750	0.5	see Table 4.4 of Postma's rationale
2.500	0.95	
7.500	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Log-Normal
 Mean -0.3
 Std.Dev. 0.825
 -1 0
 0.75 2.25

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.075	0.01	
0.250	0.05	
0.750	0.5	see Table 4.4 of Postma's rationale
2.500	0.95	
7.500	0.99	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

Weibull

Alpha 3

Beta 230

1 3

125 375

General Comments:

Small release data, Chuck Stewart

Specific Comments about Fractiles:

x	F(x)	Rationale
200	0.5	Average release = 227 min.
400	0.95	
800	0.99	
100	0.05	
50	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

Weibull
 Alpha 2.06
 Beta 435
 1 3
 250 750

General Comments:

Small release data, Chuck Stewart

Specific Comments about Fractiles:

x	F(x)	Rationale
360	0.5	Average release = 367 min.
800	0.95	
1600	0.99	
100	0.05	
50	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Weibull

Alpha 2.28

Beta 48.6

1 3

30 90

General Comments:

101 SY data

Specific Comments about Fractiles:

x	F(x)	Rationale
40	0.5	Average release = 40.8 min.
100	0.95	
200	0.99	
15	0.05	
5	0.01	
2	0	Lower bound

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Log-Normal

Mean -1.59

Std.Dev. 0.5

-1.5 -4.5

0.5 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.2	0.5	
0.5	0.95	
0.8	0.99	Exactly same as medium GRE for 1000
0.1	0.05	
0.05	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Log-Normal

Mean -2.28

Std.Dev. 0.421

-2 -6

0.2 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	
0.2	0.95	
0.4	0.99	Almost the same as large GRE for 1000 year earthquake
0.05	0.05	
0.02	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Log-Normal

Mean -2.97

Std.Dev. 0.336

-2.25 -6.75

0.3 1.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.5	
0.1	0.95	
0.2	0.99	Factor of 2 from medium for 100 years
0.03	0.05	
0.01	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Weibull

Alpha 2.84

Beta 0.565

1 3

0.25 0.75

General Comments:

Liquid layer, strain, and 100 earthquake size, good probability of release

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	
0.8	0.95	
0.9	0.99	Adjustments from 61e upward
0.2	0.05	
0.1	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Log-Normal

Mean -1.59

Std.Dev. 0.5

-0.75 -2.25

0.5 1.5

General Comments:

Liquid layer, strain, and 1000 earthquake size, good probability of release

Specific Comments about Fractiles:

x	F(x)	Rationale
0.2	0.5	Best guess, probably mobilize several tanks
0.5	0.95	
0.8	0.99	
0.1	0.05	
0.05	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Log-Normal

Mean -2.28

Std.Dev. 0.421

-1.5 -4.5

0.2 1.5

General Comments:

Liquid layer, strain, and 1000 earthquake size, good probability of release

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	
0.2	0.95	
0.5	0.99	Adjusted from 6e downward
0.05	0.05	
0.02	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Weibull

Alpha 5.285

Beta 0.752

0.5 15

0.4 1.2

General Comments:

Very likely to get a small release with a 10,000 year earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
0.7	0.5	More than likely to have a small release at 10,000 year earthquake
0.9	0.95	
1	0.99	
0.4	0.05	
0.2	0.01	

Weibull truncated at 1.0

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Weibull

Alpha 3.02

Beta 0.565

0.5 4

0.25 0.75

General Comments:

Very likely to get a small release with a 10,000 year earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	
0.8	0.95	
0.9	0.99	Scaled down from small GREs
0.2	0.05	
0.1	0.01	

SCOPE: Probability Elicitation Protocol

Date: 3/11/1998
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. $1E-4$ / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 2.285

Beta 0.354

0.5 4

0.15 0.45

General Comments:

Very likely to get a small release with a 10,000 year earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
0.3	0.5	
0.6	0.95	
0.8	0.99	Scaled down from medium GREs
0.1	0.05	
0.05	0.01	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: a. 1E-2 / year return frequency earthquake

Log-Normal

Mean -8.46

Std.Dev. 1.34

-4.5 -13.5

0.5 1.5

General Comments:

Need flammable pockets and likelihood of ignition source.

Fold release size into probability distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E-04	0.5	Volume of flammable region as compared to whole headspace, and assumed probability of .1 of ignition in any one location
2.00E-03	0.95	
2.00E-02	0.99	order of magnitude changes
6.00E-05	0.05	
2.00E-05	0.01	

Fit upper points, because they are risk relevant, don't worry about lower end.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
 probability (dimensionless)
Units:
Cond: b. 1E-3 / year return frequency earthquake

Log-Normal

Mean -6.12

Std.Dev. 1.5

-3 -9

0.75 2.25

General Comments:

Need flammable pockets and likelihood of ignition source.

Fold release size into probability distribution

Specific Comments about Fractiles:

x	F(x)	Rationale
2.00E-03	0.5	
2.00E-02	0.95	
2.00E-01	0.99	
6.00E-04	0.05	
2.00E-04	0.01	

Scaled up using volumes of flammable gas by factor of 10

Fit upper points, because they are risk relevant, don't worry about lower end.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/11/98
Expert: Arlin Postma
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: c. $1\text{E-}4$ / year return frequency earthquake

Log-Normal

Mean -2.96

Std.Dev. 1.41

-1 -3

0.75 2.25

General Comments:

Need flammable pockets and likelihood of ignition source.

Fold release size into probability distribution

Specific Comments about Fractiles:

x F(x) Rationale

5.00E-02 0.5

5.00E-01 0.95

8.00E-01 0.99

5.00E-03 0.05

5.00E-04 0.01

Scaled up from $10^{(-3)}$ based on fraction of headspace which would be flammable
plus greater p of ignition source

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APPENDIX A.12
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

C. W. Stewart

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SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

0
0

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
---	------	-----------

		Zero probability to all conditions
		No release mechanism other than buoyant displacement
		No observations

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

0
0

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
---	------	-----------

		Zero probability to all conditions
		No release mechanism other than buoyant displacement
		No observations

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

0
0

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
---	------	-----------

Zero probability to all conditions

No release mechanism other than buoyant displacement

No observations

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
 Expert: Chuck Stewart
 Analyst: Detlof von Winterfeldt
 Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
 Units: Probability (dimensionless)
 Cond: a. Small efficiency buoyant displacement gas release event

0
0

General Comments:

Zero to a and b. a: Waste motion is not credible. b: Waste motion, if any is almost certain to occur before flammability.

Specific Comments about Fractiles:

x F(x) Rationale

a: zero probability
 b: zero probability

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
 Expert: Chuck Stewart
 Analyst: Detlof von Winterfeldt
 Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
 Units: Probability (dimensionless)
 Cond: b. Medium efficiency buoyant displacement gas release event

0
0

General Comments:

Zero to a and b. a: Waste motion is not credible. b: Waste motion, if any is almost certain to occur before flammability.

Specific Comments about Fractiles:

x	F(x)	Rationale
---	------	-----------

a:	zero probability	
b:	zero probability	

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Log-Normal

Mean -6.84

Std.Dev. 1.73

-3 -9

0.5 2

General Comments:

Zero to a and b. a: Waste motion is not credible. b: Waste motion, if any is almost certain to occur before flammability.

Specific Comments about Fractiles:

x	F(x)	Rationale
0.3	1	absolute upper limit. Three events in 101 SY known to be flammable, but not ignited. Truncate at .30.
0.03	0.99	No ignitions in about 30 large GREs, flammable or not.
0.001	0.5	Unlikely
0.0001	0.1	order of magnitude
0.01	0.9	order of magnitude

a: zero probability

b: zero probability

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
 Expert: Chuck Stewart
 Analyst: Detlof von Winterfeldt
 Variable: 5. Duration of Buoyant Displacement Gas Release Event
 Units: Hours
 Cond: a. Small efficiency release

Weibull

Alpha 2.1

Beta 4.45

0.75 2.25

2.5 7.5

General Comments:

a=b, buoyant displacement happens in short time, not like small release in SSTs (over days).

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.99	Data from Gas Chromatograph for AN 103,104,105,AW 101, SY 103
10	0.9	all medium releases
3.6	0.5	More important to catch bottom, upper times may reflect different processes.
1.5	0.1	
1	0.01	

Note: Fit intentionally better on lower time periods, data show kink at about 7 minutes, possibly indicating two different release processes

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Hours
Cond: b. Medium efficiency release

Weibull

Alpha 2.1

Beta 4.45

0.75 2.25

2.5 7.5

General Comments:

a=b, buoyant displacement happens in short time, not like small release in SSTs (over days).

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.99	Data from Gas Chromatograph for AN 103,104,105,AW 101, SY 103
10	0.9	all medium releases
3.6	0.5	More important to catch bottom, upper times may reflect different processes.
1.5	0.1	
1	0.01	

Note: Fit intentionally better on lower time periods, data show kink at about 7 minutes, possibly indicating two different release processes

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Weibull

Alpha 1.26

Beta 10.75

0.75 2.25

2.5 15

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
8	0.5	SY 101 SHMS data by Blain Barton.
55	0.99	only one data point over one hour in whole set, but medium, not large release
20	0.9	
2	0.1	
0.5	0	lower bound time to move around dome space.

Truncate at 0.5

SCOPE: Probability Elicitation Protocol

Date: Chuck Stewart
Expert: 10-Mar-98
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. $1E-2$ / year return frequency earthquake, small efficiency gas release, thick liquid layer

0
0

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Zero probability of small release, since any $10(-2)$ /year seismic event will produce a release that will be larger than small

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. $1E-2$ / year return frequency earthquake, medium efficiency gas release, thick liquid layer

0
0

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
		The Probability of a Medium Efficiency GRE is 1.0 for a $1E-2$ / y earthquake

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 2.1

Beta 4.45

0.75 2.25

2.5 7.5

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
		Zero Probability of a large release since a 1E-3 / y earthquake will produce a medium gas release

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: Chuck Stewart
Expert: 10-Mar-98
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

0
0

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Zero probability of small release since a 1E-3 / y earthquake will produce a release that will be greater than small

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

0
0

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Zero probability of a medium release since a 1E-3 / y earthquake will produce a gas release greater than medium

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. $1E-3$ / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 2.1

Beta 4.45

0.75 2.25

2.5 7.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Probability of a large efficiency GRE is 1.0 for a $1E-3$ / y earthquake

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: Chuck Stewart
Expert: 10-Mar-98
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

0
0

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Zero probability of small release since a 1E-4 / y earthquake will produce a gas release greater than small

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

0
0

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
		Zero probability of a medium release since a 1E-4/year earthquake will produce a gas release greater than medium

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. 1E-4 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Weibull

Alpha 2.1

Beta 4.45

0.75 2.25

2.5 7.5

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
		Probability of a large efficiency GRE is 1.0 for a 1E-4 year earthquake

Note: All degenerate distributions

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2a. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2b. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2c. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2d. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2e. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GRES impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2f. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2g. 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	impossible for Fac. Group III for earthquakes of that size

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2h. 1E-2/year return frequency earthquake, medium efficiency GRE, unpumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	impossible for Fac. Group III for earthquakes of that size

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2i. 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	impossible for Fac. Group III for earthquakes of that size

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2j. 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2k. 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 2l. 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GRES impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3a. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3b. 1E-3/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3c. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3d. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3e: 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3f. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3g. 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3h. 1E-3/year return frequency earthquake, medium efficiency GRE, unpumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3i. 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3j. 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3k: 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 3l. 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks;

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	GREs impossible for these tanks for these earthquakes

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4a. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4b. 1E-4/year return frequency earthquake, medium efficiency GRE, unpumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4c. 1E-4/year frequency earthquake, large efficiency gas release, unpumped, FG 2

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4d. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4e. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4f. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 2

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4g. 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4h. 1E-4/year return frequency earthquake, medium efficiency GRE, unpumped; FG 3

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4i. 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG 3

Fitted Distribution: Degenerate at 0.

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4j. 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 1

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see general remarks and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4k. 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general comments and expert's document

SCOPE: Probability Elicitation Protocol

Date: 5/20/97
Expert: Chuck Stewart
Analyst: Thomas Eppel
Variable: 6. Probability of a seismic-induced Gas Release Events in Single Shell Tanks
Units: Probability (dimensionless)
Conditions: 4I. 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG 3

Fitted Distribution: Degenerate at 0

General Comments: see general remarks; only one type of GRE per scenario (leading to degenerate distributions)

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	see general comments and expert's document

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: a. $1E-2$ / year return frequency earthquake

Log-Normal

Mean -8.78294

Std.Dev. 1.72304

-4.39147 -13.1744

0.86152 2.58456

General Comments:**Specific Comments about Fractiles:**

x	F(x)	Rationale
0.00001	0.05	Same as SSTs. Waste motion is more likely in DST, but seismic induced
0.0003	0.65	ignition probabilities are already one order of magnitude higher than
0.003	0.95	buoyant induced GRE probabilities.

Use SST elicitations.

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: b. 1E-3 / year return frequency earthquake

Log-Normal

Mean -4.05

Std.Dev. 1.76

-2.025 -6.075

0.88 2.64

General Comments:

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.05	Same as SSTs. Waste motion is more likely in DST, but seismic induced
0.03	0.65	ignition probabilities are already one order of magnitude higher than
0.3	0.95	buoyant induced GRE probabilities.

Use SST elicitations.

SCOPE: Probability Elicitation Protocol

Date: 3/10/98
Expert: Chuck Stewart
Analyst: Detlof von Winterfeldt
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: c. $1E-4$ / year return frequency earthquake

General Comments:

Specific Comments about Fractiles:

x 	F(x) 	Rationale Ignition probability = 1 See also SST rationale
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Use SST elicitations.

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APPENDIX A.13
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

J. K. Thomas

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
 Expert: Kelly Thomas
 Analyst: Thomas Eppel
 Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
 Units: Probability (dimensionless)
 Cond: a. Small efficiency buoyant displacement gas release event

Weibull

Alpha 1.267

Beta 0.00051

0.5 1.5

0 0.0015

General Comments:

based on your impression of the potential of the involved waste motions and other phenomena to provide an ignition source under this scenario; in general, expert thinks that this is very unlikely to happen;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0004	0.5	same as 5th percentile of median GRE; wants to reflect that this is a very unlikely event, but not impossible; should be about 1 to 2 orders of magnitude less than median of medium GRE
0.00001	0.05	close to zero
0.001	0.95	order or magnitude lower than corresponding fractile from medium GRE; five times higher than median estimate is reasonable for an upper bound; can't imagine that there is a likely scenario that would drive the probability above 1/1000

General Comments (cont.):

in addition, location and timing of the ignition source have to be very specific

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: b. Medium efficiency buoyant displacement gas release event

Log-Normal
 Mean -6.1835
 Std.Dev. 1
 -1.5 -10
 0.5 1.5

General Comments:

see general comments in 2a; this time however, exceeding 10% of the LFL was used as a criterion to define the sample space of medium GREs

Specific Comments about Fractiles:

x	F(x)	Rationale
0.002	0.5	based on rare event theory (n = 210; 21 observed GREs, multiplied by 10 to take into account possible unobserved GREs of that size); this is consistent with expert's judgment about phenomenology
0.0004	0.05	same as the median estimate of small GRE
0.01	0.95	order or magnitude lower than corresponding fractile from large GRE; five times higher than median estimate is reasonable for an upper bound

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 2. Probability of Buoyant Displacement Gas Release Event induced ignition source
Units: Probability (dimensionless)
Cond: c. Large efficiency buoyant displacement gas release event

Weibull

Alpha 1.2625

Beta 0.0411

0.5 3

0 0.15

General Comments:

in general, one can use hydrogen measurements from SHMS to estimate this probability;
 used rare event theory to take the limited number of large GREs (above LFL) with no ignition to develop this probability (use $(0.5)/(n+1)$ where n is the number of occur

Specific Comments about Fractiles:

x	F(x)	Rationale
0.03	0.5	based on rare event theory ($n = 15$; 3 observed GREs, multiplied by 5 to take into account possible unobserved GREs of that size); is within a factor of 2 of the expert's judgment based on phenomenological considerations, which made him feel more comfortable
0.005	0.05	considering the possible phenomena that would lead to an ignition source under this scenario, expert thinks that the probability is unlikely to be less than $5E-3$
0.1	0.95	doubling the best estimate of 0.05 from looking at phenomenology; provides a reasonable upper bound for this probability

General Comments (cont.):

used rare event theory to take the limited number of large GREs (above LFL) with no ignition to develop this probability (use $(0.5)/(n+1)$ where n is the number of occurrences of a GRE with no ignition);
 another approach is to use the phenomenology that would produce an ignition source (e.g., damage equipment, etc.)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 0.317

Beta 0.00047

0.1 1.5

0.0001 0.001

General Comments:

started with respirable distribution (see 4a)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.5	no change compared to 4a, because such low levels of agitation prior to the event will not suspend large particles;
1E-07	0.05	see comments for median
0.02	0.95	assume that you have higher levels of agitation prior to event; therefore, it is possible to get non-respirable mass suspend in addition to the respirable mass elicited for 4a; scale up by an order of magnitude
0.1	0.99	see comment about 0.95 fractile

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
 Expert: Kelly Thomas
 Analyst: Thomas Eppel
 Variable: 3.Total mass of transportable waste material suspended
 Units: Kilograms
 Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Log-Normal
 Mean -2.96
 Std.Dev. 1.07
 -2 -6
 0.5 1.5

General Comments:

based on respirable mass and now scaled up depending on the specific phenomena and mechanisms that were used to produce the corresponding fractiles

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.5	about a factor of 5 higher than respirable (get into situations where one might add substantial amounts of non-respirable mass)
1E-07	0.01	really the lower bound, since it was based on "stagnant" waste scenario
0.02	0.05	order of magnitude higher than respirable
0.2	0.95	same type of reasoning as for median; increase by an order of magnitude from median
2	0.99	order of magnitude higher than 0.95

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean 3.033

Std.Dev. 0.775

2.5 3.5

0.5 1.5

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
20	0.5	order of magnitude higher than respirable because mechanisms involved produce a large fraction of non-respirable material
0.1	0.01	order of magnitude higher than respirable because mechanisms involved produce a large fraction of non-respirable material
5	0.05	order of magnitude higher than respirable because mechanisms involved produce a large fraction of non-respirable material
50	0.95	increase of a factor of 5 compared to 4c to take into account that the type of mechanisms used to generate these fractiles are more efficient in producing respirable materials (compared to mechanisms used for median and lower bounds)
100	0.99	increase of a factor of 5 compared to 4c to take into account that the type of mechanisms used to generate these fractiles are more efficient in producing respirable materials (compared to mechanisms used for median and lower bounds)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull

Alpha 1.9575

Beta 59.405

0.5 3

5 70

General Comments:

see general comments in 3c

Specific Comments about Fractiles:

x	F(x)	Rationale
50	0.5	about a factor of 5 higher to take into account that these mechanisms lead to a higher fraction of respirable material (compared to lower bounds)
10	0.01	order of magnitude higher than corresponding fractile of respirable mass
20	0.05	order of magnitude higher than corresponding fractile of respirable mass
100	0.95	about a factor of 5 higher to take into account that these mechanisms lead to a higher fraction of respirable material (compared to lower bounds)
200	0.99	about a factor of 2 higher to take into account that these mechanisms lead to a higher fraction of respirable material (compared to lower bounds)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 1.5325

Beta 332

0.5 3

300 500

General Comments:

see general remarks in 3d

Specific Comments about Fractiles:

x	F(x)	Rationale
250	0.5	a factor of about 5 higher than 4e
25	0.01	a factor of about 5 higher than 4e
50	0.05	a factor of about 5 higher than 4e
500	0.95	a factor of about 5 higher than 4e
2000	0.99	a factor of about 5 higher than 4e

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 0.38

Beta 0.00028

0.1 1.5

0.0001 0.001

General Comments:

started with respirable mass since most of the experimental data that expert used were concerned with respirable mass;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0001	0.5	pre-existing aerosols is really the only credible mechanism in this low-pressure case; took value that is in the "middle" of the range for data reported for waste transfer (Gelbard presentation)
1E-07	0.05	"stagnant" waste condition is representative for the lower bound for this low-pressure scenario
0.002	0.95	upper range reported in studies about waste transfers
0.01	0.99	getting close to physical limits according to the way expert conceptualizes this scenario

General comments (cont.):

mechanisms that would lead to source terms considered include:

- pre-existing aerosols in headspace;
- potential for solids entrainment due to flame front;
- potential for liquids and solids entrainment due to tank blow-down;
- potential for solids combustion for rapid boiling of liquid;
- impact of structural elements on the waste surface;
- shock-wave impact.

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Log-Normal
 Mean -4.68
 Std.Dev. 1.42
 -2 -6
 0.5 1.5

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
0.01	0.5	entrainment might add respirable mass (only significant if one assumes upper range of pressure); but the amount added from these mechanisms is still very small relative to the values reported in SARs
1E-07	0.01	as a first approximation for lower bounds, assume that pre-existing aerosols is the dominant mechanism to provide respirable mass; use 5th fractile from distribution for 4a; hard to imagine that you would get below that
0.002	0.05	take 95th percentile from 4a
0.1	0.95	same type of reasoning as for median; increase by an order of magnitude from median
1	0.99	order of magnitude higher than 0.95

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Log-Normal

Mean 0.72

Std.Dev. 1

0.5 1.5

0.5 1.5

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
2	0.5	entrainment and boiling might add respirable mass (only significant if one assumes upper range of pressure); some chance of solid combustion; still doesn't expect to be close to the SAR numbers
0.01	0.01	mainly entrainment, not any of the other mechanisms that would require higher energies were used to develop lower bounds
0.5	0.05	mainly entrainment, not any of the other mechanisms that would require higher energies were used to develop lower bounds
10	0.95	wants to be somewhat lower than the SAR numbers
20	0.99	wants to be somewhat lower than the SAR numbers

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull

Alpha 1.6825

Beta 13.97

0.5 3

5 15

General Comments:

see general comments in 4a;

Specific Comments about Fractiles:

x	F(x)	Rationale
10	0.5	same as 95th for 4c
1	0.01	for this scenario, one would expect to get at least 1 kg
2	0.05	same as 50th for 4c
20	0.95	see general comments, take less extreme estimates for same phenomena to develop 99th
100	0.99	see general comments; reflecting severe entrainment will provide upper bound for this condition with some significant contribution from structural impact

General Comments (cont.):

based on presentation on structural response to deflagration and the conclusions reached by Delphi committee, expert considered some impact from falling debris (but assumed relatively small opening near the center of the dome; "can-opener");

doesn't expect to be close to SAR results which would suggest 100s of kg

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 1.4325

Beta 60.71

0.5 3

50 80

General Comments:

see general comments in 4d; two changes induced by detonation are:

- aerosolization due to shock wave loading;
- potential for more damaging tank failure mode.

In general, one gets closer to the SAR type of numbers

Specific Comments about Fractiles:

x	F(x)	Rationale
50	0.5	a factor of about 5 higher than 4d
5	0.01	a factor of about 5 higher than 4d
10	0.05	a factor of about 5 higher than 4d
100	0.95	a factor of about 5 higher than 4d
400	0.99	a factor of about 5 higher than 4d, but not 500

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 2.875
 Beta 0.543
 0.5 3
 0.4 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
0.9	0.5	similar to reasoning for median; relatively sure that you would get small GRE under this scenario; it is not guaranteed, however
0.5	0.05	hard to imagine that probability is going to drop below 0.5 under this scenario
1	0.95	close to one

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta
 Alpha 1.73
 Beta 0.77
 0.5 2
 0.5 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
0.75	0.5	roughly a factor of 3 less energy compared to the 1E-3 event; therefore it is reasonable to assume that one would not get 100% mobilization and that the release fractions would resemble "normal" BD-GREs; as a first approximation, scaled mobilized region according to energy (by a factor of 3 down from 1E-3) and took 1/4 to 1/2 release fraction from the mobilized region; this leads to a "good" chance of having a medium GRE
0.25	0.05	hard to imagine that probability is going to drop below 0.25 under this scenario
0.95	0.95	getting close to unity, but some evidence that you would get low release fractions under this scenario

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Log-Normal

Mean -1.38

Std.Dev. 0.4108

-1

0.1 -2

0.1 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
0.25	0.5	see comments about median in 61b; a large release is less likely to occur; less than 50-50
0.1	0.05	hard to imagine that probability is going to be lower than 0.1 (thought of it as the "floor" of the distribution)
0.5	0.95	hard to imagine that probability is going to be higher than "even"

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Degenerate at 1

Alpha	0
Beta	0
	0 1.5
	0 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	given the reasoning for large and medium GREs, a small GRE is bound to occur for a 1E-3 earthquake

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta
 Alpha 2.41
 Beta 0.30495
 0.5 3
 0.1093 0.3279

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
0.95	0.5	if there is a high likelihood for a large GRE, there is an even higher chance to get a medium GRE
0.5	0.05	hard to imagine that probability is going to drop below 0.5 given the reasoning used to develop the median estimate
1	1	even the simulant shake tests now indicate a very high probability of inducing a medium GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Beta
 Alpha 1.16
 Beta 0.308
 0.5 1.5
 0.01 1.5

General Comments:

ANSYS analysis (code-based) served as most important basis for developing estimates (since one of the cases is reflective of the rheology of the DSTs);

Specific Comments about Fractiles:

x	F(x)	Rationale
0.9	0.5	based on ANSYS and "insensitivity" of results to mobilization criteria (SEDL) and the effects that were not reflected in ANSYS analysis, expert expects near 100% mobilization;
0.25	0.05	for the region that is mobilized you expect more than 50% release (based on one hard to imagine that probability is going to drop below 0.25 given the reasoning used to develop the median estimate
0.95	0.95	close to unity; some evidence (shaking tests of simulants) that there are some physical considerations that would make a large GRE difficult

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Degenerate at 1
 Alpha 0
 Beta 0
 0 1.5
 0 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	if a small GRE is bound to occur in a 1E-3 earthquake, it is bound to occur in a 1E-4 earthquake

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Uniform
 Minimum 0.9393
 Maximum 1
 0.465 1.395
 0.5 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	based on discussion for 1E-3 earthquakes and considering a threefold increase in energy, that scenario gives us more mobilization and a more dramatic loss of strength and retention capability
0.95	0.05	there might be some combinations of waste rheology and levels that resist mobilization and release

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. $1E-4$ / year return frequency earthquake, large efficiency gas release, thick liquid layer

Uniform
 Minimum 0.73
 Maximum 1
 0.365 1.095
 0.5 1.5

General Comments:

see general comments in 61f

Specific Comments about Fractiles:

x	F(x)	Rationale
1	1	see comments in 61h
0.75	0.05	see comments in 61h, except that now expert wants to give more "room" for the combinations of waste rheology and level since we are talking about a large release

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: a. 1E-2 / year return frequency earthquake

Log-Normal

Mean -6.88

Std.Dev. 1.38

-4 -12

0.5 1.5

General Comments:

see general comments in 7c;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.001	0.5	should be more than an order of magnitude less than median for 1E-3 earthquake
0.0001	0.05	order of magnitude less than median
0.01	0.95	order of magnitude higher than median

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: b. 1E-3 / year return frequency earthquake

Log-Normal
 Mean -3
 Std.Dev. 1
 -1.5 -4.5
 0.5 1.5

General Comments:

see general comments in 7c; however, 1E-3 earthquake is much less energetic

Specific Comments about Fractiles:

x	F(x)	Rationale
0.05	0.5	scale down by an order of magnitude from 1E-4 earthquake
0.01	0.05	probability is not zero, but very small
0.25	0.95	increased the median estimate such that the upper bound is consistent with the expert's judgment about the phenomenology involved

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Kelly Thomas
Analyst: Thomas Eppel
Variable: 7. Probability of seismic induced ignition source in Double Shell Tank
Units: probability (dimensionless)
Cond: c. 1E-4 / year return frequency earthquake

Beta
 Alpha 1.352
 Beta 1.35
 0.5 1.5
 0.5 1.5

General Comments:

looked at previous safety analysis concerned with equipment damage due to seismic activity;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	see general comments
0.1	0.05	wants to make sure that this distribution is rather wide to reflect his level of uncertainty about this parameter
0.9	0.95	wants to make sure that this distribution is rather wide to reflect his level of uncertainty about this parameter

General Comments (cont.):

given that the equipment is damaged, expert then considered the chance of getting an ignition due to damage and combined that with how many pieces of equipment one would typically have;
 this consideration alone would get about a 0.15 probability of having an ignition source;

expert also considered the increase in violence in BD-GREs due to seismic activity that is not reflected in non-seismic BD-GREs as a factor in his probability;

since there are some other mechanisms (banging of equipment; static discharge, etc.) of providing an ignition source with a probability of about 0.15, expert thought that the combined probability is about 0.5

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APPENDIX A.14
REPORT OF EXPERT PANELISTS' UNCERTAINTY DISTRIBUTIONS

M. Yost

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GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: a. Small efficiency release

Weibull

Alpha 1.975

Beta 0.062

0.5 3

0.05 0.2

General Comments:

no available data that might suggest a mechanism other than BD that would lead to a GRE; there is about 80 tank-years of available that did not show any significant non-BD release; medium and large GREs are therefore not likely to occur;

Specific Comments about Fractiles:

x	F(x)	Rationale
0.0125	0.05	used a Poisson process to model this phenomena with a lambda of 0.05
0.05	0.5	see general comments; believes that about 4 events could have been missed and could find explanations for about 4; 10 would be way to high for median
0.1	0.95	used a Poisson process to model this phenomena with a lambda of 0.05

General Comments (cont.):

for small GREs, there are some mechanisms that might lead to a small GRE; also there is the possibility that these small events have not been detected

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: b. Medium efficiency release

Degenerate at 0

Alpha 0

Beta 0

0 3

0 0.2

General Comments:

see comments to 1a; does not believe that you can get medium or large GREs other than BD-type GREs

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 1. Frequency of GREs in DSTs that fail tests for potential BD GRE behavior
Units: Events / Year
Cond: c. Large efficiency release

Degenerate at 0

Alpha	0
Beta	0
0	3
0	0.2

General Comments:

see comments to 1a; does not believe that you can get medium or large GREs other than BD-type GREs

Specific Comments about Fractiles:

x	F(x)	Rationale
0	1	

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 0.74

Beta 0.043

0.5 1.5

0.005 0.1

General Comments:

based on presentation by Gelbard, decided to concentrate on studies that dealt with transient air-flows rather than steady-state type of flows; need estimates of airspeed (ranging from 10 to 40), surface area (fraction of total tank diameter being involve

Specific Comments about Fractiles:

x	F(x)	Rationale
0.025	0.5	for this low energy event, expert used low airspeed and entrainment and assumed that affect tank area could be up to 0.3 of the tank diameter
0.0009	0.05	see comment for median; affect tank area is restricted to be 0.1 of the diameter
0.2	0.95	see comment for median; affected tank area is restricted to be 0.6 of tank diameter

General Comments (cont.):

need estimates of airspeed (ranging from 10 to 40), surface area (fraction of total tank diameter being involved in process; ranging from 10% to 100%); based on these two factors you can calculate mass (through some intermediate steps)

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter

Weibull

Alpha 0.766

Beta 0.4826

0.5 1.5

0.005 1

General Comments:

see general comments in 3a

Specific Comments about Fractiles:

x	F(x)	Rationale
0.3	0.5	expert used medium airspeed and entrainment and assumed that affected tank area could be up to 0.4 of the tank diameter
0.005	0.05	see comment for median; affect tank area is restricted to be 0.1 of the diameter
1.6	0.95	see comment for median; affected tank area is restricted to be 0.7 of tank diameter

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Weibull

Alpha 0.828

Beta 3.5015

0.5 1.5

0.005 5

General Comments:

see general comments in 3a

Specific Comments about Fractiles:

x	F(x)	Rationale
2.25	0.5	expert used high airspeed and entrainment and assumed that affected tank area could be up to 0.4 of the tank diameter
0.035	0.05	see comment for median; affect tank area is restricted to be 0.1 of the diameter
12	0.95	see comment for median; affected tank area is restricted to be 0.7 of tank diameter

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull
 Alpha 0.918
 Beta 7.0015
 0.5 1.5
 0.005 10

General Comments:

see general comments in 3a; in addition, there is some filtering effect from overburden and from local cloud of material; picked low filtering efficiency for detonation and higher filtering efficiency for deflagration;

Specific Comments about Fractiles:

x	F(x)	Rationale
4.6	0.5	expert used high airspeed and entrainment and assumed that affected tank area could be up to 0.6 of the tank diameter, plus higher efficiency filtering effects
0.17	0.05	see comment for median; affect tank area is restricted to be 0.2 of the diameter
21	0.95	see comment for median; assumed that the whole tank area is affected

General Comments (cont.):

either case is not terrifically efficient; high efficiency: 0.4, low efficiency: 0.1;
 penetration is 1 - filter efficiency;
 also, let the range of the affected tank area go from 0.2 of tank diameter to 100% of tank diameter

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 3.Total mass of transportable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 0.878

Beta 9.90005

0.5 1.5

0.005 10

General Comments:

see general comments in 3d; used the lower filtering efficiency

Specific Comments about Fractiles:

x	F(x)	Rationale
6.8	0.5	expert used high airspeed and entrainment and assumed that affected tank area could be up to 0.6 of the tank diameter, plus higher efficiency filtering effects
0.25	0.05	see comment for median; affect tank area is restricted to be 0.2 of the diameter
32	0.95	see comment for median; assumed that the whole tank area is affected

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: a. A headspace burn of insufficient pressure to fail the HEPA filter

Weibull

Alpha 0.76

Beta 0.00847

0.5 1.5

0.001 0.01

General Comments:

for low-energy events (less than 20 psi), expert assumes that the respirable fraction is relatively low (about 0.2)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.005	0.5	0.2 of corresponding fractile of transportable
0.0002	0.05	0.2 of corresponding fractile of transportable
0.04	0.95	0.2 of corresponding fractile of transportable

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: b. A headspace burn of less than 20 psi that fails the HEPA filter.

Weibull

Alpha 0.756

Beta 0.09455

0.5 1.5

0.005 1

General Comments:

see general comments in 4a

Specific Comments about Fractiles:

x	F(x)	Rationale
0.06	0.5	0.2 of corresponding fractile in 3b
0.001	0.05	0.2 of corresponding fractile in 3b
0.32	0.95	0.2 of corresponding fractile in 3b

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material suspended
Units: Kilograms
Cond: c. A headspace burn of more than 20 psi that does not fail the Double Shell Tank dome

Weibull

Alpha 0.761

Beta 2.56244

0.5 1.5
0.005 5

General Comments:

for situations with more than 20 psi; assumed that you can never go higher than the respirable fraction of the waste itself; took 0.7 as the respirable fraction (somewhat lower than Gelbards average for the tank waste, to concentrate on the surface)

Specific Comments about Fractiles:

x	F(x)	Rationale
1.6	0.5	0.7 of the corresponding fractile in 3c
0.02	0.05	0.7 of the corresponding fractile in 3c
8.5	0.95	0.7 of the corresponding fractile in 3c

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: d. A headspace deflagration of sufficient pressure to fail the Double Shell Tank dome

Weibull

Alpha 0.918

Beta 4.6027

0.5 1.5

0.005 10

General Comments:

see general comments in 3c; did not adjust the filtering efficiency

Specific Comments about Fractiles:

x	F(x)	Rationale
3.2	0.5	0.7 of corresponding fractile in 3d
0.1	0.05	0.7 of corresponding fractile in 3d
14.8	0.95	0.7 of corresponding fractile in 3d

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 4. Total mass of respirable waste material released
Units: Kilograms
Cond: e. A headspace detonation sufficient to fail the Double Shell Tank dome

Weibull

Alpha 0.888

Beta 7.0015

0.5 1.5

0.005 10

General Comments:

see general comments in 4d

Specific Comments about Fractiles:

x	F(x)	Rationale
4.8	0.5	0.7 of corresponding fractile in 3e
0.18	0.05	0.7 of corresponding fractile in 3e
22.2	0.95	0.7 of corresponding fractile in 3e

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: a. Small efficiency release

Log-Normal

Mean 5.35

Std.Dev. 0.71

5 6

0.5 1.5

General Comments:

looked at data presented by C. Stewart and SHMS monitoring data dealing with time to peak hydrogen concentration;

Specific Comments about Fractiles:

x	F(x)	Rationale
75	0.05	see general comments
210	0.5	see general comments
675	0.95	see general comments

General Comments (cont.):

concluded that there is no good evidence to treat medium GREs differently from small GREs (correlation between normalized size of release and time to peak is virtually zero);

used a polynomial to fit the data and based fractiles on that

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: b. Medium efficiency release

Log-Normal
 Mean 5.35
 Std.Dev. 0.71
 5 6
 0.5 1.5

General Comments:

looked at data presented by C. Stewart and SHMS monitoring data dealing with time to peak hydrogen concentration;

Specific Comments about Fractiles:

x	F(x)	Rationale
75	0.05	see general comments
210	0.5	see general comments
675	0.95	see general comments

General Comments (cont.):

concluded that there is no good evidence to treat medium GREs differently from small GREs (correlation between normalized size of release and time to peak is virtually zero);
 used a polynomial to fit the data and based fractiles on that

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 5. Duration of Buoyant Displacement Gas Release Event
Units: Minutes
Cond: c. Large efficiency release

Log-Normal

Mean 3.18

Std.Dev. 1.26

3 4

0.5 1.5

General Comments:

looked mainly at data from SY101; release time was in the 10 minute range; limited data since you can't rely on the most recent measurements (because of mixer pump installation)

Specific Comments about Fractiles:

x	F(x)	Rationale
3	0.05	scaled down based on power-log fit to data
24	0.5	feels most comfortable about median since this is the one supported by data
120	0.95	scaled down based on power-log fit to data

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1a. 1E-2 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Log-Normal

Mean -2.28
 Std.Dev. 0.94
 -1.14 -3.42
 0.47 1.41

General Comments:

based on scaling from 1E-3 earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	same as 61b
0.02	0.05	same as 61b (was changed)
0.5	0.95	same as 61b

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1b. 1E-2 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Log-Normal

Mean	-2.28
Std.Dev.	0.94
	-1.5 -4.5
	0.5 1.5

General Comments:

see general comments in 61c

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	by 0.2 lower than median for large GRE
0.05	0.05	same as corresponding fractile for large GRE; could actually be lower
0.5	0.95	about 0.2 lower than corresponding fractile for large GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1c. 1E-2 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Beta
 Alpha 1.9425
 Beta 4.1
 0.5 3
 0.5 8

General Comments:

based on scaling from 1E-3 earthquake

Specific Comments about Fractiles:

x	F(x)	Rationale
0.3	0.5	same as 61d
0.05	0.05	same as 61d
0.7	0.95	higher than twice the median

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1d. 1E-3 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Beta
 Alpha 1.835
 Beta 4
 0.9175 2.7525
 2 6

General Comments:

used two reports as the primary data sources ("Gas Retention Behavior ..." see expert's report); most information is available for 1E-3 earthquake; 1E-3 earthquake is likely to produce a large GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
0.3	0.5	0.4 less than corresponding fractile for large GRE
0.05	0.05	scaled down from large GRE; scaling not quite as extreme as for median
0.5	0.95	upper end should not be more than about twice the median

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1e. 1E-3 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta	
Alpha	2.604
Beta	2.835
1.5	4.5
1.5	4.5

General Comments:

used two reports as the primary data sources ("Gas Retention Behavior ..." see expert's report); most information is available for 1E-3 earthquake; 1E-3 earthquake is likely to produce a large GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
0.5	0.5	0.2 higher than small GRE
0.1	0.05	about twice as corresponding fractile for small GRE
0.95	0.95	wants to spread out the distribution towards the upper end, so that at least the upper part of the distribution gets closer to the large GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1f. 1E-3 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Beta
 Alpha 3
 Beta 1.45
 0.5 3
 0.5 1.5

General Comments:

used two reports as the primary data sources ("Gas Retention Behavior ..." see expert's report); most information is available for 1E-3 earthquake; 1E-3 earthquake is likely to produce a large GRE

Specific Comments about Fractiles:

x	F(x)	Rationale
0.7	0.5	large GRE is quite likely; how likely mainly depends on the crust; median should be higher than "even odds"
0.3	0.05	1E-3 earthquakes are energetic enough that probability shouldn't be less than about 0.3
0.95	0.95	wants to spread out the distribution towards the upper end, so that at least the upper part of the distribution gets closer to the large GRE

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1g. 1E-4 / year return frequency earthquake, small efficiency gas release, thick liquid layer

Log-Normal

Mean -2.28

Std.Dev. 0.95

-1	-3
0.5	1.5

General Comments:

a small GRE is unlikely for this scenario (assuming that if the tank waste did not respond to the earthquake in the form of producing a large or a medium GRE, it is unlikely to respond in form of a small GRE)

Specific Comments about Fractiles:

x	F(x)	Rationale
0.1	0.5	see general comments
0.02	0.05	see general comments
0.5	0.95	see general comments

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1h. 1E-4 / year return frequency earthquake, medium efficiency gas release, thick liquid layer

Beta	
Alpha	4.605
Beta	2.33
	0 15
	0 5

General Comments:

based on scaling up from the 1E-3 earthquake; much higher probability

Specific Comments about Fractiles:

x	F(x)	Rationale
0.7	0.5	about 0.2 higher than corresponding fractile for 1E-3
0.3	0.05	about 0.2 higher than corresponding fractile for 1E-3
0.95	0.95	same as 1E-3 fractile

GAS RELEASE EVENT SAFETY ANALYSIS

Date: 3/13/98
Expert: Michael Yost
Analyst: Thomas Eppel
Variable: 6. Probability of a Seismic-Induced Gas Release Event in a Double Shell Tank
Units: Probability (dimensionless)
Cond: 1i. 1E-4 / year return frequency earthquake, large efficiency gas release, thick liquid layer

Beta	
Alpha	5.77
Beta	1.07
	5
	0
	5

General Comments:

based on scaling up from the 1E-3 earthquake; much higher probability

Specific Comments about Fractiles:

x	F(x)	Rationale
0.9	0.5	about 0.2 higher than corresponding fractile for 1E-3
0.5	0.05	about 0.2 higher than corresponding fractile for 1E-3
0.98	0.95	higher than corresponding fractile of 1E-3 earthquake

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**This document was too large to scan
as a single document; therefore, it has
been divided into smaller sections.**

Section 3 of 3

Document Information			
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APPENDIX B

RATIONALE REPORTS

The expert panel rationale reports in Appendix B are included as received from the individual authors. No technical editing has been performed on the reports (inclusive of misspelled words) in order to maintain the quality assurance requirements of the expert elicitation process.

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APPENDIX B.1
RATIONALE REPORTS

S. F. Agnew

May 1998

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1.0 INTRODUCTION

When confronted with very difficult and complex problems, we all have a tendency to adopt one of two world views. In one world view, we presume that there exists some deterministic solution to the problem and when sufficient resources are applied to the problem, a solution will become readily apparent. In this view, smarter and more highly trained people will find a solution most effectively.

In a second world view, it is assumed that there already exists a technical solution to a given problem and there are factors beyond technical (i.e. cost, political, etc.) that preclude that technical solution. In this view, the decision makers are often viewed as obstacles to problem resolution. Decision makers who are either do not believe or are unwilling to accept the risk that has been communicated to them by their technical people will often defer or simply not make an appropriate decision. In this world view, technical people then assume that this is a "packaging" problem and their primary task is to more effectively package the solution that is already available in such a way as to better communicate the level of risk to the decision makers.

In reality, solutions to most complex problems require strategies that are mixtures of these two world views. The decision maker always performs some complicated series of tradeoffs among a set of potential outcomes. These tradeoffs basically come down to achievement of a desired outcome traded off against the impact of an undesirable outcome such as an elevated level of risk. If the achievement of the desirable outcome is somehow denigrated or not especially critical, the corresponding acceptable risk level will be that much lower. That is, given a completely trivial outcome (i.e., one of no benefit), a decision maker will naturally tend to take on only a very low risk.

The Expert Elicitation process for the GRE Safety Analysis is just such an attempt to both incorporate technical analysis as well as to better communicate its realization as a comprehensive analysis framework to DOE decision makers. Once the level of risk has been communicated to a decision maker, that person then determines if the level of risk is acceptable for producing a desirable outcome.

2.0 TRADITIONAL SAFETY ANALYSES AT HANFORD

Traditional safety analysis methodology at Hanford has used bounding accident approaches to define safety envelopes for operations. This traditional approach is usually quite conservative because of the nature of the bounding assumptions that are often used, one on top of another. Often, a bounding safety analysis is more than adequate to determine the safe operating envelope and allow the decision makers to make the tradeoff between the risk and benefit of operations.

The presence of flammable gas in the dome space and equipment associated with Hanford waste tanks has produced a rather complicated problem that is not easily resolved by bounding safety analyses. This is because the presence of significant amounts of flammable gas with radioactive and often chemically toxic waste materials implies that there necessarily exists a greater risk with waste operations. If tank domes reach flammable conditions and if the dome would ignite, the resulting dome pressurization would lead to some release of waste material to the environment.

In industrial environments, flammable conditions are often mitigated by a combination of controls that depend on the nature of the hazard. Certainly ventilation, inerting, and spark controls all figure prominently into NFPA standards for flammable environments. However, Hanford waste tanks were never engineered for such controls and it is highly unlikely that they can ever be adequately implemented given the diverse nature of operations and the limited resources available. Therefore, the flammable gas issue presents a conundrum for tank operations.

3.0 TWO POINTS OF VIEW

Two opposing views on this issue emerge analogous to the two world views noted above. First is a view that there exists some straightforward solution to this problem. Some examples of solutions are inerting dome spaces with nitrogen gas, increasing tank ventilation, or exclusive use of safety class equipment for NFPA Class 1, Division 1 flammable environments. All of these solutions have been considered and all are possible, given enough money and resources. However, it is clear that resources for these kinds of mitigation are limited. Inerting two tanks at Savannah River was projected to cost \$30 million and has significantly impacted operations for In Tank Processing. In fact, the ITP program was just recently canceled as a result of these and other problems. Inerting Hanford tanks would presumably cost a similar amount of money.

A second view suggests that there is a fifty-year operating history with these waste tanks at Hanford without a single known ignition event. Therefore, this operating history alone suggests a very minimal hazard with flammable gas for past practice operations. This later view is a very prominent with those who tend to view the flammable gas safety analyses with a large amount of skepticism. However, history has shown us repeatedly that it is often complacency that leads to unexpectedly severe accidents in nuclear facilities. Moreover, the risk that the decision makers (DOE, Ecology, Congress, public) are willing to take for tank operations is quite low, much lower than corresponding risks in non-nuclear flammable gas environments. That is, the risks that were acceptable in 1945 are clearly no longer acceptable in 1998.

The flammable gas problem at Hanford originated with the slurry growth noted in 1975 with the influx of complexant (i.e., soluble organic salts like EDTA) bearing wastes to the tank farms. Thus, the GRE flammable-gas problem actually only dates to 1975. Slurry growth was first noted in SSTs during operation of 242-T evaporator in TX Farm, then in later operations of 242-S and 242-A evaporators in S, SX, U, A, and AX Farms. When the SSTs were closed out in 1981, SST

liquids were moved to DSTs and the slurry growth problem with its flammable gas moved with the waste to the DSTs. Two DSTs in West Area, SY-101 and SY-103 began showing rather extreme GRE behavior in 1981 and following a final DSS campaign in 1988, other DSTs AN-103, AN-104, AN-105, and AW-101 followed suit. These six tanks comprise the extent of the DST GRE problem today. Thus, Hanford site does not have operating experience with flammable gas GREs for 177 tanks spanning fifty years, but only some 20 years with SY-101 and SY-103, and ten years with AN-103, AN-104, AN-105, and AW-101.

Compounding the difficulty of using operating history or past practice operations to justify continued operation is that once these six DSTs were filled, there were only very few operations needed for these tanks after that time. The paucity of operations naturally limits spark sources or waste perturbations, both operations of which are expected to increase the hazard of ignition. Hanford is coming into an era, however, where operations will dramatically increase with these tanks as they become feed for the final disposal of defense nuclear waste at Hanford. Therefore, it is especially critical that the nature of the GRE flammable gas risk in these tanks be defined in order to preclude any delay for tank operations in support of waste disposal.

4.0 NATURE OF EXPERT ELICITATION AND THE ANALYSIS FRAMEWORK

If the GRE flammable gas safety problem were amenable to a deterministic solution, that solution should be adopted. On the other hand, if human judgement is key in providing a basis for risk determination, then the expert elicitation process provides a framework to suitably capture a diversity of expert judgement. One must be ever vigilant about safety analyses that rely on "best engineering judgement" for risk determination in complex problems. The Expert Elicitation process represents a significant improvement over use of "best engineering judgement." In particular, the areas where Expert Elicitation is a distinct improvement over best engineering judgement are:

1. All stages of Expert Judgement are captured as elicited parameters
2. Uncertainty distributions are explicitly defined for all elicited parameters
3. Experts are required to provide rationales for all elicitations
4. Diversity of Expert Judgement is captured in process of aggregation of uncertainty distributions.

Expert Elicitation is an approach that appears to effectively define and communicate the level of risk inherent in tank operations that are necessary to support disposal. To argue that operational risk associated with GRE flammable gas is not present within Hanford tanks is simply untenable. However, one can effectively argue that a defined risk is acceptable given the benefit of waste

disposal. With permanent waste disposal, Hanford is trading interim storage short-term risks for long-term IHLW and ILAW disposal risks. Note that with either interim storage or long-term disposal, the radioactivity of the waste persists for the same time. Therefore, with long-term disposal Hanford is not trading short-term risk for zero risk, but rather is trading short-term risk for long-term risk.

In the absence of long-term disposal benefits, only very minimal risks are acceptable for short operations. This is simply human nature. With zero benefit only zero risk is acceptable. Therefore, it is very critical to include the benefit of waste disposal along with the consideration of the risk of those operations.

The Analysis Framework provides a methodology whereby probabilistic risk and frequency results are calculated based on two sets of parameters: measured and elicited. The role of the expert panel is twofold: First, to review, modify, and approve the analysis framework and second, to provide probability density functions and their rationales for the elicited parameter set. The very definition of complex problems means that there are factors or parameters that are difficult if not impossible to measure. For solving complex problems, these parameters represent the limit of where determinism fails and human judgement must take over.

5.0 SPECIFIC COMMENTS ON DST FLAMMABLE GAS GRE SAFETY ANALYSIS

I have had much more difficulty with the DST GRE SA than with the SST analysis. The reason is that there is much more determinism with the DST conditions and safety issues in general and therefore much less room for error. I believe that my elicitations would be much better given more time for analysis for DSTs. The large uncertainties associated with SST conditions did not justify the added effort for those tanks.

For DST GREs, there may be a big payoff in an improved analysis of elicitation parameters. However, such an improved analysis is beyond the workscope of the elicitation process. Serious consideration should be given to improving analyses should the safety envelope for DST operations need to be improved still further.

6.0 ELICITATION PARAMETER RATIONALES

5A. Mass of transportable material suspended and released from a DST [$< \text{HEPA}$, <20 , >20 , $>\text{dome}$, detonation]:

There are two significant questions to address with the material ejected as a result of headspace burns. First, is the pressure differential between the waste surface and headspace during pressure release sufficient to spall material from the surface? Second, is there sufficient turbulence in the dome space to keep that material suspended for the time of release? My previous estimate for the SST material suspended was 3100 kg at the mean (0.5 cm of waste surface), which suggested an aerosol density of 3100 kg per 2310 m³ (a half-filled tank at 1.4 atm), or 1.3 kg/m³. This amount was significantly greater than those proposed by other estimates, which have assumed ranges of 0.001 to 1 kg/m³. However, most other estimates do not seem to consider the effects of spall.

Entrainment of waste as a result of surface turbulence is only one mechanism for suspending material. Spall of material from the surface as a result of rapid depressurization is an additional mechanism. Note that in fluidized bed engineering, it is quite easy to transport 10-50 kg/m³ given a sufficiently large flow velocity. Therefore I will use 1 kg/m³ aerosol for the extreme 95% CI for detonation and 0.01 kg/m³ for the 5% CI, with a mean value of 0.1 kg/m³. For the DSTs, I will scale the aerosol density with burn pressure and assume that turbulence scales linearly with burn pressure until dome failure. At this point, depressurization rate will increase substantially because of the increase in leak paths through dome cracks. However, these leak paths will be into the soil column and therefore will filter the aerosol.

Table 1. Mass (kg) Suspended and Released from DST During Headspace Burns.

Fractiles	No HEPA Failure	<20 psig	>20 psig	$>\text{Dome Failure}$ (~ 50 psig)	Detonation
0.05	1E-7	2	10	10	20
0.50	1E-6	16	130	130	200
0.95	1E-5	50	200	200	2000
Release factor	1E-6	0.6	0.7	0.4	0.6
Aerosol density, kg/m ³	0.001	0.02	0.07	0.1	0.1
Dome volume m ³ at STP	780	1300	2600	3380	3380

A typical dome exchange rate ($T_{1/2}$) is 10 minutes at -2 in. water dome pressure differential. Scaling this to a pressure differential of 1.4 atm results in a $T_{1/2}$ of 3 s. Given a waste cross section of 410 m² and venting of 1,000 m³ at STP, an average linear velocity at the waste surface during this 3 s is ~ 0.5 m/s. Bubbly liquids have very low sound speeds, on the order of 50 m/s, and the pressure differential is equal to the ratio of the surface velocity to the sound speed times

pressure, or $0.5/50 \times 0.7 \text{ atm} \sim 1000 \text{ Pa}$ differential. Therefore, there is sufficient pressure differential to spall material from the surface into the dome if the waste yield point is less than 1000 Pa.

The amount of material released from the tank is affected by the falling back of spalled waste as well as reduced by filtering of the soil column over the waste tank. The venting of the dome space pressure through the soil column would substantially capture all of that suspended material. The other pathways to the surface, most notably through the various risers and other penetrations into the dome space. I suggest that the most important aspect of complete dome failure is the increased depressurization rate and therefore increased amount of material suspended.

With regards to detonation, I expect the local effects of particle suspension for detonation will be substantially greater than for deflagration. However, it is correspondingly less likely that detonation will affect more than about 20% of the waste surface. Therefore, the resultant material suspended will not be substantially greater than for a burn that fails the tank dome.

References:

Han, F.C.; Leach, L. "Delphi Expert Panel Evaluation of Hanford High Level Waste Tank Failure Modes and Release Quantities," WHC-SD-TWR-RPT-003 Rev. 0, September 1996.

Perry, R.T. "Aerosol Mass in the Dome," LANL Calc Note TSA6-CN-WT-SA-TH-093, December 1993.

5B. Mass of respirable material suspended and released from a DST [$< \text{HEPA}$, <20 , >20 , $>\text{dome failure, detonation}$]:

Consideration of the amount of respirable mass begins with the particle size distribution of the waste. However, much of the waste will exist as agglomerates of these small particles and so these particle size distributions will not be exactly the same as those in the headspace.

Another factor in the determination of respirable material will be the amount of charge that can accumulate on these particles and therefore stabilize the aerosol against agglomeration. Accumulation of charge for particles in such an environment can be quite complicated. Basically, self-charging mechanisms can occur when either larger particles rub against smaller particles of similar material or when particles of dissimilar materials rub against each other. These frictional charging mechanisms all result in providing a coulombic repulsion between particles that provides a barrier to agglomeration.

Therefore I have chosen to inflate the fraction respirable with increasing turbulence associated with increasing headspace burns. Despite that fact that particle size determinations show 80 wt% of particles less than 10 microns, these particle size determinations do not account for the fact that most ejected and entrained mass will be agglomerated into much larger particles. Only with increasing shear (i.e., turbulence) will there be significant amounts of respirable particles.

Table 2. Fraction Respirable.

No HEPA Failure	<20 psig	>20 psig	>Dome Failure (~50 psig)	Detonation
0.1	0.1	0.1	0.4	0.6

References:

Herting, et al., WHC-SD-WM-DTR-026, 1992.

Herting, D.L.; Welsh, T.L.; Lambie, R.W.; Tran, T.T. "Tank Characterization Report for Double-Shell Tank 241-SY-101," WHC-SD-WM-ER-409 Rev. 0, July 1995.

7. Duration of BD GRE (time to 95% of peak headspace concentration) [small, medium, large]:

The amount of time for BD GREs is assumed to be represented by the set of SHMS data coupled with the more visual information that dates from videotapes of eruptions for SY-101 prior to its mitigation with a mixing pump. Larger GREs appear to be successive eruptions over large areas as opposed to single localized releases. I will use the visual results from SY-101 to establish the duration for large GREs, the SHMS data to establish the duration of small ones, and interpolate these results for intermediate sized releases.

Ranges for small GREs are 1-20 minutes and I will use this range as a 5-95% interval. There are occasional much longer events, but they do not represent of a significant part of the risk and therefore not worth that much consideration.

Ranges for large GREs have been from 20 minutes to 24 hours.

Table 3. Time in minutes to 95% Final Headspace Concentration.

Fractiles	Small (<5%) Min.	Medium (5-25%)	Large (>25%)
0.05	1	10	20
0.50	10	200	400
0.95	30	600	1400

References:

Wilkins, N.E.; Bauer, R.E.; Ogden, D.M. "Results of Vapor Space Monitoring of Flammable Gas Watch List Tanks," HNF-SD-WM-TI-797 Rev. 2, September 1997.

Stewart, C., spreadsheet synopsis of data from Wilkins, et al.

8a. Probability of earthquake-induced GRE in DST [small, medium, large][100-, 1000-, 10,000-year]:

It is clear that low frequency vibrations such as those associated with earthquakes can dramatically alter the gas retention of wastes. Given the g forces for each of these earthquakes at {0.04, 0.4, 4} I will use these numbers to anchor my elicitations.

It is highly likely that small GREs will occur in all three earthquakes. Ranges of acceleration for 1000-year earthquakes have been variously reported as 0.4 g at 10 Hz or as 0.1-0.3 g range (5 to 95% CIs) depending on the source and type of analysis. A 0.4 g earthquake is reported [Reid and Deibler] to produce displacements of 4-5 inches. Note that a displacement of four inches (100 mm) is equivalent to an 8.0 Richter earthquake (log[microns displacement] 100 km from epicenter). The San Francisco earthquake was an 8.25 on the Richter scale.

This 4 in. displacement of the tank walls will liquefy waste near the walls. The remaining waste solids will "slosh" within that liquefied waste pool, amplifying the wave pressure and increasing the amount of waste that is mobilized. These effects will occur even if the resultant pressure wave does not exceed the waste yield point of ~500 Pa. The duration of a 1000-year earthquake suggests about 5-10 waves of sufficient amplitude to fail waste at the wall. Assuming that each wave will fail about 4 in. of waste, 10 waves will fail 40 in. disc of waste, which is about 17% of the waste. Thus, I will set a medium GRE at a high likelihood, 95% with a 1000-year earthquake.

Table 4. Probability (0 to 1) of 100-year earthquake induced GREs.

Fractiles	Small (<5%) Min.	Medium (5-25%)	Large (>25%)
0.05	0.10	0.05	0.005
0.50	0.80	0.30	0.10
0.95	0.99	0.5	0.35

Table 5. Probability (0 to 1) of 1,000-year earthquake induced GREs.

Fractiles	Small (<5%) Min.	Medium (5-25%)	Large (>25%)
0.05	0.25	0.1	0.025
0.50	0.90	0.8	0.40
0.95	0.999	0.99	0.65

Table 6. Probability (0 to 1) of 10,000-year earthquake induced GREs.

Fractiles	Small (<5%) Min.	Medium (5-25%)	Large (>25%)
0.05	0.75	0.25	0.10
0.50	0.95	0.90	0.80
0.95	0.9995	0.999	0.99

References:

Weiner, E.O.; Rohay, A.C. "Design Basis Earthquake Time Histories of 1992 SDC-4.1, Rev. 12," WHC-SD-GN-30018, 1992.

Ried, H.C.; Deibler, J.E. "Seismic Event-Induced Waste Response and Gas Mobilization Predictions for Typical Hanford Waste Tank Configurations," PNNL-11668, September 1997.

"Hanford Tank Waste Remediation System Basis for Interim Operation," HNF-SD-WM-BIO-001 Rev. 0, Add. 1, 1997.

11. Frequency of spontaneous GREs in DSTs when thick (>1m) liquid layer is present but criteria of potential GREs are not met [small, medium, large]:

The mechanism of BD GREs is incorporated into the AF for the AT applied to DSTs. It has been suggested that those DSTs that are not subject to BD GREs have a risk that is similar to most SSTs in FGII. In FGII for SSTs, there are a series of tanks that have compositions that fall within the Na/Al/NO₂ guidelines for the AF.

In the SST deliberations, I included FGII and FGIII tanks in my elicitation thinking for spontaneous GREs. With the compositional guidelines for BD GREs, we must now only consider tanks that have otherwise rather minimal risk for spontaneous GREs. I will assign those DSTs to have identical probabilities of spontaneous GREs for SSTs.

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**APPENDIX B.2
RATIONALE REPORTS**

E. C. Beahm

May 1998

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1.0 INTRODUCTION

The elicitation was carried out on March 9, 1998 with Detlov von Winterfeldt as the elicitor.

Phase I waste treatment will process waste primarily from Hanford Double-Shell Tanks (DSTs). All of the DSTs that have had Buoyant Displacement Gas Release Events (BD GREs) will be involved in this campaign that runs from 2000 to 2008. All or part of the waste in 14 DSTs will be sent to a private subcontractor for processing that varies from cesium removal to vitrification. Waste in tanks AN-105, AN-104, AN-103, and AW-101 will be mixed, slurried, and diluted with water before being transferred to contractor storage tanks. This is scheduled for 2001–2003. Waste from AZ-101 and AZ-102 will be mixed, settled, and the supernate (convective layer) will be removed. This will leave ~10 inches of liquid above the solids. This is scheduled for 2004. A similar sequence of mixing, settling, and decanting of supernate is scheduled for tanks AN-107, AN-102, AN-106, SY-101, and SY-103 in the years 2005–2008. Waste in tank AZ-101 will be washed with water containing 0.1 molar sodium hydroxide and 0.01 molar sodium nitrite and possibly leached with 3 molar sodium hydroxide before being transferred to contractor storage tanks in the years 2000–2003. Waste in AZ-102 will undergo a similar wash and leach sequence in 2002–2005, and material in AY-102 will have the same treatment in 2005–2008.⁽¹⁾

Thus, in the next two to ten years the amount, type, and configuration of waste in the DSTs will change. In subsequent treatment the DSTs will be used as staging tanks for Single-Shell Tank (SST) waste. The removal of supernate and the treatment requirement that all waste will have a density <1.4 means that BD GREs will not occur. With all of the movement of waste that will take place it seems that gas release during global waste disturbances should be the primary concern. In this regard it is reasonable to assume that any waste that is mobilized will release any gas that it has retained.

1.1 REFERENCES

1. R. A. Kirkbride, G. K. Allen, P. J. Certa, A. F. Manuel, R. M. Orine, L. W. Shelton, E. J. Slaathang, R. S. Wittman, G. T. MacLean, and D. L. Penwell, *Tank Waste Remediation System Operation and Utilization Plan*, HNF-SD-WM-SP-012, Rev. 0, Volumes I and II, September 15, 1997.

2.0 ELICITATION PARAMETER RATIONALES

2.1 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LAYER OF LIQUID (>1 M), BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BUOYANT DISPLACEMENT-TYPE GRES

2.1.1 Background

In Phase I and Phase II waste treatment the DSTs will be used as staging tanks and for in-tank pretreatment. In some cases there will be a thick layer of liquid, but very little solids. The requirements for Phase I Envelope A stipulate <5 wt % solids.⁽¹⁾ It isn't clear how the analysis framework will deal with situations where a DST is nearly full, but the nonconvective layer is negligible. In such cases there would be continual release of flammable gases from the convective layer and what might be construed as GREs from global waste disturbances. However, since gas retention in aqueous solutions is not very large, the amount of gas released in a GRE would be small. For this elicitation we assume that there is >1 meter of a convective layer above a significant depth of a nonconvective layer.

Assume a similar waste configuration in a DST and in a SST. Would we expect the frequency of spontaneous gas releases to be the same? Only if we think that the tanks or the conditions of the tanks play no role in spontaneous GREs. The single-shell tanks are older and they have lost integrity with regard to leakage. They all either leak or will leak in the near future. The welds were not stress relieved and they have cracked. Some of them were heated to the extent that the steel baseplate buckled. The extent to which material can transfer from and to the tanks and the surrounding media is not clearly defined. In the sense of chemical thermodynamics they are an open system with regard to mass transfer. It is not too much of an exaggeration to say that the tanks themselves have become part of the waste. Given all of these factors it is more likely for waste in a SST to respond to environmental changes. They may also be more susceptible to changes in waste configuration by events such as subsidence or failure of the metal or concrete components. Also, the DSTs are instrumented better than the SSTs so it is more likely that GREs or events that could lead to GREs would be detected. Because of differences in the tanks themselves we will assign somewhat lower frequencies for medium and large GREs to DSTs than those given previously for SSTs.

2.1.2 Small Spontaneous GREs

Small GREs, especially those associated with low pressure fronts, are likely to occur. A handwritten evaluation transmitted by D. M. Odgen⁽²⁾ showed 8 GREs from 10–18–95 to 2–9–97 for tank S-111, a SST. The hydrogen release ranged from 12 ft^3 to 70 ft^3 . Excluding what was called the bad data from summer months, there were 12 months of data.

The rate of small GREs should be related to the frequency of low pressure fronts. There will be a limitation over the long term due to the gas generation rate. Blaine Barton⁽³⁾ presented steady state gas generation rates for 13 tanks. The values ranged from 0.2 ft³/day to 6 ft³/day. These values were thought to be accurate within a factor of 2–3. Five of the values given were 2 ft³/day and the others were evenly distributed above and below this value. Assuming that an average small GRE has ~1 M³ (35 ft³) of H₂, this is ½ of the de minimus value given in the Analysis Framework, Rev. 1. Using a generation rate of 2 ft³/day ~18 days would be required to generate enough hydrogen for a small GRE. From this ~20 small GREs per year are a reasonable estimate for the maximum sustainable rate.

A plot of barometric pressure data for the Yakima air terminal in 1995 gives 4 pressure drops of ~1 in. Hg or more and ~10 pressure drops of ~½ in. Hg. In general, this rate of pressure drops is consistent with a plot of barometric pressure for Hanford for January 1994–March 1997.

Based on this we assign a 5 percentile frequency for a small GRE of 1 and a 50 percentile of 8. This was arrived at by assuming that there is a 100% chance of a small GRE for pressure drops of ≥1 in. Hg that do not occur in the same month, and a 50% chance that a pressure drop of ~½ in. Hg will produce a small GRE. The 95 percentile is taken as 15 which is close to the maximum sustainable value. The 1 percentile is taken as 0.5 because it is felt barometric pressure changes will result in a frequency at least this large, especially in tanks with >1 M of convective layer.

2.1.3 Medium and Large GREs

Frequencies for medium and large GREs are assigned values that are somewhat lower than those for SSTs for the reasons that were given in Section 2.1.1. For large spontaneous GREs we assign a 50 percentile of 5×10^{-4} (1 every 2000 years), a 95 percentile of 10^{-3} , a 5 percentile of 10^{-4} , and a 99 percentile of 2×10^{-3} . This was based on a subjective evaluation of events with low frequencies. On the one hand it does not appear to be credible to assign a frequency of zero because no mechanism for a large spontaneous GRE can be identified. On the other hand, integrity of the DSTs should limit their frequency. A paper by Niehaus and Lederman⁽⁴⁾ gave core melt frequencies for 22 nuclear reactors in the United States. These frequencies varied from 1×10^{-6} /year to 2×10^{-3} /year. Obviously, there is no direct relation between GREs and core melts, but a great deal of effort has gone into evaluating severe reactor accidents and the frequencies and range of frequencies is useful for estimating the range of frequencies for rare events.

For medium GREs a 50 percentile of 0.01/year, a 5 percentile of 0.002/year, a 1 percentile of 0.001/year, a 95 percentile of 0.1/year, and a 99 percentile of 0.2/year are assigned. The breadth of this frequency range indicates the uncertainty in the assigned values. The frequency values assigned to medium GREs are similar to those assigned to large spontaneous GREs in SSTs.

NOTE: The fractiles for the medium GRE are those listed here. The plots provided by the elicitor had the large and medium fractiles the same. I regret this mix-up.

2.1.4 References

2. D. M. Ogden, handwritten information received May 2, 1997.
3. W. B. Barton, "Field Estimated Gas Generation Rates," Second SCOPE Panel Meeting, April 28, 1997.
4. F. Niehaus and L. Lederman, "PSA As a Tool for Decision Making," Nuclear Eng. and Design, **93**, 349 (1986).

2.2 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

2.2.1 Background

Small buoyant displacement gas release events (BD GREs) may be manifested as continuous releases. This would occur if gas is trapped by the floating crust layer and released over a period of weeks.⁽⁹⁾ Such protracted sequences are of no interest in evaluating gas release events.

The time to peak data that was provided in an e-mail from Blaine Barton⁽⁶⁾ on 3-4-98 should be used directly in the Analysis Framework. It includes a total of 41 BD GREs that occurred in DSTs AW-101, SY-103, AN-103, AN-104, and AN-105, as well as data on 7 large BD GREs in SY-101. The rationale for the starting point and time to peak, as well as uncertainties, are clearly stated. The data was evaluated by Blaine Barton and Nick Kirch.

2.2.2 Small and Medium BD GREs

Data provided by Blaine Barton was plotted to see if there was any apparent correlation between the peak hydrogen concentration and BD GRE duration. The scatter of the data indicated that it would not be useful to try to establish such a correlation. The data for time to peak for 41 events in tanks AW-101, SY-103, AN-103, AN-104, and AN-105 were then arranged into percentiles and the percentiles were plotted against time to peak. The data used in this evaluation is listed in Table 2. This data and plot provided the basis for the elicitation on small and medium BD GREs.

The tabulated data shows that the durations of ≥ 200 minutes are dominated by BD GREs from tank AW-101. However, this tank also had a BD GRE with a time to peak of 40 minutes and tank SY-103 has also had some relatively long events. The percentile values were selected based on the tabulated percentiles without regard to tank. The 50 percentile was 137 minutes, the 75 percentile was 510 minutes, and the 25 percentile was 85 minutes. The 99 percentile was

2880 minutes, which was the longest duration of the 41 events. The distribution was truncated at this point because small or even medium GREs longer than 2 days are in the realm of continuous release rather than GREs. The 1 percentile was 1 minute, the shortest time of the 41 events. This was also truncated.

2.2.3 Large GREs

Data for large BD GREs is restricted to events in tank SY-101 before the use of a mixer pump. Data for 7 BD GREs that occurred from 4-19-90 to 2-26-93 were evaluated by Nick Kirch and reported by Blaine Barton.⁽⁶⁾ Videos of BD GREs in SY-101 were viewed on the TWINS Internet site.⁽⁷⁾ Both the videos and the data from Nick Kirch support a 50 percentile of 20 minutes for a large BD GRE. In Kirch's data there was a duration of 20 minutes and one of 17 minutes. There were 3 events with durations less than these and 2 that were longer. The 99 percentile was adopted as 120 minutes and truncated. The longest duration given by Kirch was 96 minutes. The 25 percentile was 7 minutes, and there were 2 events with this duration. The 1 percentile was 1 minute and truncated.

2.2.4 References

5. C. W. Stewart, presentation "Stage II Expert's Panel Elicitation Workshop #1," January 19-23, 1998, PNNL-SA-29606.
6. W. B. Barton, e-mail dated 3-4-98.
7. Site address: <http://twins.pnl.gov:8001/TWINS/main/docs/video.html>.

2.3 PROBABILITY OF A SEISMIC-INDUCED GRE IN SSTs

2.3.1 Background

The assignments of SSTs to Facility Groups II and III were based on a two part test.⁽⁸⁾ First, a releasable gas volume of 7.35% was assumed along with release of a gas containing 97% hydrogen and 0.22 M³ of ammonia. If the well mixed concentration was <25% of the Lower Flammability Limit (LFL) the tank passed the evaluation and was considered to be in Facility Group III. This "quick screen" clearly favors those tanks with relatively little waste. The second test for tanks that did not pass the "quick screen" involves the estimation of retained gas by surface level growth and by barometric pressure variations with truncation to 30% void fraction for those tanks that indicated >30%.

The designation into Facility Group II or Facility Group III based on these tests results in some anomalies. Three tanks which are on the flammable gas watch list, SX-104, AX-101, and AX-103, are in Facility Group III. Also, tank C-103 which had the highest percentage of the LFL (13%) of any of the passively vented SSTs is in Facility Group III.⁽⁹⁾ A tabulation of the results of vapor phase sampling of the passively ventilated SSTs included 56 tanks with an LFL percentage greater than zero. Of these 56 tanks 24 are in Facility Group II and 32 are in Facility Group III. The assignment of SSTs to Facility Group II or Facility Group III may be useful for some purposes, but it doesn't appear to have any merit in the evaluation of seismic-induced GREs. In this elicitation no distinction was made between Facility Group II and Facility Group III.

Chuck Stewart evaluated waste mobilization by a 10^{-3} /year earthquake.⁽¹⁰⁾ For homogeneous SST waste with no liquid depth the volume mobilized was 5% with a solids depth of 150 inches and 13% with a solids depth of 300 inches. It was noted that a liquid layer would strongly amplify the effect of surface waves on a solids layer. The solid yield stress assumed in Stewart's evaluation was 300 Pa. An earlier evaluation by Stewart⁽¹¹⁾ indicated that a 10^{-3} /year frequency earthquake and a yield stress of 1000 ± 500 Pa would release >50% of retained gas. It was noted that the earlier evaluation was a conservative "ballpark" estimate. The evaluation reported by Reid and Deibler⁽¹²⁾ showed significant differences in gas mobilization between homogeneous solid waste and liquid over solid waste with much more mobilization in the latter case.

It is likely that gas release will occur from mobilized waste. However, gas release may not be limited to the mobilized fraction. Volumes surrounding the mobilized material will be subject to motion and stress as well.

2.3.2 Earthquakes With a 10^{-4} /Year Return Frequency

Evaluations of seismic events have centered around the 10^{-3} /year events. This has obvious utility in being the intermediate event frequency. From the evaluation of Stewart⁽¹⁰⁾ the fraction mobilized in A-101 with a 300 inch solids depth with no liquid overburden was 13%. It may be anticipated that a 10^{-4} /year seismic event would mobilize at least twice as much waste and result in a large GRE. This would represent a case in a tank that had been saltwell pumped. A liquid layer on top of the solids would only enhance the fraction mobilized. As a result of this assessment, a probability of 1.0 is assigned for large gas releases, medium gas releases, and small gas releases in a 10^{-4} /year seismic event, with or without saltwell pumping.

2.3.3 Earthquakes With a 10^{-3} /Year Return Frequency

The evaluation of Stewart⁽¹⁰⁾ gave a mobilized fraction of 13% for 300 inches of solid in tank A-101 with no depth of water. We consider this to represent a saltwell pumped condition. Based on this a probability of 1.0 is assigned for both a medium and a small GRE. It is likely that gas will be released in volumes adjacent to the mobilized material making it likely that a large

GRE would also occur. We assign a 50 percentile probability of 0.75 for a large GRE, a 5 percentile of 0.5, and a 95 percentile of 0.90. In tanks that are not saltwell pumped following Stewart's assessment for A-101 with 198 inches of liquid over 165 inches of solids that gave a mobilized volume of 68% we assign very high probabilities for a large GRE: a 50 percentile of 0.95, a 5 percentile of 0.90, and a 1.0 for the natural limit near 100 percentile. The probability for small and medium GREs in unpumped tanks is 1.0, i.e., a 10^{-3} /year seismic event will result in at least a medium GRE.

2.3.4 Earthquakes With a 10^{-2} /Year Return Frequency

Assigning GRE probabilities in this case is more problematic than in the 10^{-3} /year and 10^{-4} /year return events. It is certainly at least as likely that a 10^{-2} /year frequency earthquake would induce a small GRE as a change in barometric pressure of 1 in. Hg. Previously, in Section 2.1.2, we assigned a small GRE for every such change in barometric pressure. Thus, we assign a probability of 1.0 that a 10^{-2} /year earthquake would result in a small GRE. For medium GREs a 50 percentile of 0.75, a 5 percentile of 0.50, and a 95 percentile of 0.90 is assigned to both pumped and unpumped tanks. For large GREs a 50 percentile of 0.60, a 5 percentile of 0.40, and a 95 percentile of 0.80 is adopted.

2.3.5 References

8. J. M. Grigsby, memo "SCOPE Expert Panel – Action From Workshop 2," May 5, 1997.
9. N. E. Wilkins, *Results of Vapor Space Monitoring of Flammable Gas Watch List Tanks*, SD-WM-TI-797, January 20, 1997.
10. C. W. Stewart, "Seismic Response of DST Waste," Expert Elicitation Workshop #1, January 19–23, 1998.
11. C. W. Stewart, M. E. Brewster, P. A. Gauglitz, L. A. Mahoney, P. A. Meyer, K. P. Recknagle, and H. C. Reid, *Gas Retention and Release Behavior in Hanford Single-Shell Waste Tanks*, PNNL-11391, December 1996.
12. H. Reid and J. Deibler, "Waste Tank Seismic Event Potential Gas Mobilization and Release Analysis for Flammable Gas Program," Second SCOPE Panel Meeting, May 1, 1997.

3.0 COMMENTS

In the next 2 to 10 years Phase I treatment will process waste from all of the DSTs that have had BD GREs. Concern about GREs in DSTs will be directed at what have been called global waste disturbances as the waste is mixed, retrieved, and transferred. In contrast, treatment of waste in

SSTs other than C-106 will occur later. This means that the potential for GREs in the aged and leaky SSTs will extend into the future. In the long term, the Analysis Framework will be more important in assessing GREs in the SSTs than in the DSTs unless more specific models are included to deal with waste processing. Additional models would have to consider water or caustic addition in tank or in-line, as well as mixing and the use of equipment such as floating suction pumps. In-line mixing of waste and water could result in gas release in the receiving tank. In addition, the temperature of the waste will change during processing. All of these factors would have to be taken into account if the Analysis Framework is to be used for assessing GREs resulting from waste treatment. Simply using the models in place for global waste disturbances wouldn't capture the events that would occur in processing.

Table 1. Frequency of Spontaneous GREs in DSTs
With >1 M Convective Layer.

Percentile	
Small (1a)	
1	0.5/year
5	1/year
50	8/year
95	15/year
Medium (1b)	
1	0.001/year
5	0.002/year
50	0.01/year
95	0.1/year
99	0.2/year
Large (1c)	
5	1×10^{-4} /year
50	5×10^{-4} /year
95	1×10^{-3} /year
99	2×10^{-3} /year

Table 2. Time to Peak for Small and Medium GREs Arranged by Percentile.

DST	ppm H2	Minutes	Percent
AW-101	1830	2880	100.00%
AW-101	1820	960	97.50%
AW-101	1800	840	95.00%
AW-101	1180	720	92.50%
AW-101	1000	600	90.00%
AW-101	5000	540	80.00%
AW-101	4900	540	80.00%
AW-101	2000	540	80.00%
AW-101	1800	540	80.00%
SY-103	1770	512	77.50%
AW-101	1400	510	75.00%
AW-101	2800	480	72.50%
AW-101	1600	450	70.00%
AW-101	900	420	67.50%
AW-101	4400	315	62.50%
AW-101	6000	315	62.50%
SY-103	1140	255	60.00%
AW-101	2800	250	57.50%
AW-101	6200	180	55.00%
SY-103	900	147	52.50%
SY-103	640	137	50.00%
AN-103	1600	120	45.00%
AN-105	1030	120	45.00%
AN-105	6980	115	42.50%
AN-104	2000	111	40.00%
AN-105	3900	102	37.50%
SY-103	960	100	35.00%
AN-104	2850	96	32.50%
AN-104	2250	88	27.50%
SY-103	2200	88	27.50%
AN-104	5900	85	25.00%
SY-103	1290	84	22.50%
AN-105	14500	73	20.00%
SY-103	5030	71	17.50%
SY-103	1330	56	15.00%
SY-103	1830	51	12.50%
AW-101	3500	40	10.00%
SY-103	1980	33	7.50%
AN-104	2000	31	5.00%
AN-105	16000	4	2.50%
AN-104	1000	1	.00%

Table 3. Elicitation Values for Duration of a
Buoyant Displacement-Type GRE.

Percentile	Time (minutes)
Small (5a)	
1	1 Truncate
10	40
25	85
50	137
75	510
99	2880 Truncate
Medium (5b)	
1	1 Truncate
10	40
25	85
50	137
75	510
99	2880 Truncate
Large (5c)	
1	1 Truncate
25	7
50	20
99	120 Truncate

Table 4. Probability of Seismic-Induced GREs – Frequency of Induced GREs.

1.) 10^{-2} /Year Earthquake

Unpumped	Small	Medium	Large
	(62a) (62g)	(62b) (62h)	(62c) (62i)
5	1.0	0.50	0.40
50	1.0	0.75	0.60
95	1.0	0.90	0.80
		(truncate at 1.0)	(truncate at 1.0)
Pumped	Small	Medium	Large
	(62d) (62j)	(62e) (62k)	(62f) (62l)
5	1.0	0.50	0.40
50	1.0	0.75	0.60
95	1.0	0.90	0.80
		(truncate at 1.0)	(truncate at 1.0)

2.) 10^{-3} /Year Earthquake

Unpumped	Small	Medium	Large
	(63a) (63g)	(63b) (63h)	(63c) (63i)
5	1.0	1.0	0.90
50	1.0	1.0	0.95
95	1.0	1.0	0.99
			(truncate at 1.0)
Pumped	Small	Medium	Large
	(63d) (63j)	(63e) (63k)	(63f) (63l)
5	1.0	1.0	0.50
50	1.0	1.0	0.75
95	1.0	1.0	0.90

3.) 10^{-4} /Year Earthquake

Unpumped	Small	Medium	Large
	(64a) (64g)	(64b) (64h)	(64c) (64i)
5	1.0	1.0	1.0
50	1.0	1.0	1.0
95	1.0	1.0	1.0
Pumped	Small	Medium	Large
	(64d) (64j)	(64e) (64k)	(64f) (64l)
5	1.0	1.0	1.0
50	1.0	1.0	1.0
95	1.0	1.0	1.0

References

1. R. A. Kirkbride, G. K. Allen, P. J. Certa, A. F. Manuel, R. M. Orine, L. W. Shelton, E. J. Slaathang, R. S. Wittman, G. T. MacLean, and D. L. Penwell, *Tank Waste Remediation System Operation and Utilization Plan*, HNF-SD-WM-SP-012, Rev. 0, Volumes I and II, September 15, 1997.
2. D. M. Ogden, handwritten information received May 2, 1997.
3. W. B. Barton, "Field Estimated Gas Generation Rates," Second SCOPE Panel Meeting, April 28, 1997.
4. F. Niehaus and L. Lederman, "PSA As a Tool for Decision Making," *Nuclear Eng. and Design*, **93**, 349 (1986).
5. C. W. Stewart, presentation "Stage II Expert's Panel Elicitation Workshop #1," January 19–23, 1998, PNNL-SA-29606.
6. W. B. Barton, e-mail dated 3–4–98.
7. Site address: <http://twins.pnl.gov:8001/TWINS/main/docs/video.html>.
8. J. M. Grigsby, memo "SCOPE Expert Panel – Action From Workshop 2," May 5, 1997.
9. N. E. Wilkins, *Results of Vapor Space Monitoring of Flammable Gas Watch List Tanks*, SD-WM-TI-797, January 20, 1997.
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11. C. W. Stewart, M. E. Brewster, P. A. Gauglitz, L. A. Mahoney, P. A. Meyer, K. P. Recknagle, and H. C. Reid, *Gas Retention and Release Behavior in Hanford Single-Shell Waste Tanks*, PNNL-11391, December 1996.
12. H. Reid and J. Deibler, "Waste Tank Seismic Event Potential Gas Mobilization and Release Analysis for Flammable Gas Program," Second SCOPE Panel Meeting, May 1, 1997.

**APPENDIX B.3
RATIONALE REPORTS**

P. D. d'Entremont

May 1998

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1.0 INTRODUCTION

On 11 March 1998, Detlof von Winterfeldt elicited my input to the Stage II Gas Release Event Safety Analysis Project. The elicitation took place at the Hampton Inn in Richland, Washington from 8:00-11:00 a.m. Richard Johns, an associate of Dr. Winterfeldt, attended the elicitation as an observer and also participated in some of the discussions.

During this elicitation I gave my input to five parameters that will be used in the Analysis Framework. The Analysis Framework is a computational model generated as part of the Gas Release Event (GRE) Safety Analysis Project. This model will be used to predict the risk of operating double-shell tanks at Hanford (Slezak, Gelbard, and Cheng). Six of these tanks have experienced gas release events in which flammable gas was suddenly released from the waste, so it is important to determine the risk posed by these tanks and possible controls that could be implemented to reduce the risk.

The Analysis Framework relies primarily on experimental data and generally recognized mathematical and engineering models, for example flammable gas models and diffusion models. However, there are some parameters for which no generally recognized model exists, for example the probability of a ignition source in a double shell tank. For these parameters, the GRE Project sought the input of expert judgement.

I was hired by Sandia National Laboratory to be one of the expert panelists for this project (Forest). The expert panelists met during the weeks of 19-23 January 1998 and 9-13 February 1998 for a review of the Analysis Framework and available data. During the week of 9-13 March, each panelist was interviewed one-on-one by an expert elicitor to determine the panelist's input to the Analysis Framework. The input of all the panelists on each parameter will be aggregated to develop a probability distribution for each parameter that will be used in the Analysis Framework.

The five parameters I was elicited on (and two parameters I was not elicited on) were determined by Scott Slezak, the technical leader of the GRE Project, and communicated to the panel in an E-mail message (Slezak 1998a). Slezak's E-mail message specified the exact wording of each parameter and how it would be used in the Analysis framework.

This report documents my rationale for the input I gave to Dr. Winterfeldt in the elicitation interview. Each parameter, and the detailed rationale for it, is described in the pages that follow. The numbers for each parameter and the wording of the parameter are as determined by Slezak.

References for Introduction

Forest, Barbara J., approver, Integrated Contractor Order between Sandia Corporation and Westinghouse Savannah River Company, Document Number AY-5319, 17 November 1997, Sandia National Laboratories, 1515 Eubank Blvd. S.E., Albuquerque, NM 87123

Slezak, 1998a: Slezak, Scott E., "Final DST parameter list and descriptions," Electronic Mail Message from sesleza@sandia.gov to GRE Safety Analysis Panelists, 19 February 1998, 5:41 p.m.

Slezak, Scott E.; Gelbard, Fred; Cheng, Wu-Ching "Enhanced Safety Analysis Methodology for Flammable Gas Risk Assessment In Hanford Site Tanks; Proposed Part II: Double Shell Tanks," HNF-SD-WM-ES-410, 5 January 1998

2.0 1. FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LAYER OF LIQUID (>1M) BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BUOYANT DISPLACEMENT-TYPE GRES

2.1 1a. SMALL EFFICIENCY RELEASE

For this parameter, I used a similar distribution as for b & c, except that the median was shifted so that all the frequencies were ten times higher. This fit my intuition that small efficiency releases ought to occur more frequently than medium and large releases. For the development of the distributions for b & c, see the next section.

The distribution I recommend for conditioning factor "a" is as follows:

Log-normal distribution

Median= 0.001649

Std. Dev. = 15

Ln(Median) = -6.401

Ln(Std. Dev.) = 2.70805

2.2 1b & c. MEDIUM AND LARGE EFFICIENCY RELEASES

For these conditioning factors, I developed a complete log-normal distribution. I set the median of this distribution so that the probability of a burp being detected in 150 tank-years is even (i.e., 50% chance of one burp being detected, 50% chance of no burps being detected).

I chose to combine both large and medium efficiency releases into one distribution because I have no rational basis for distinguishing between medium and large releases (small releases might not be detected, so I chose to handle these separately and assign them a higher frequency—see the previous section).

One of the difficulties of developing a distribution for this parameter is that there is no physical basis for spontaneous GRES. Per Slezak's instructions, the spontaneous GRE parameter excludes tanks that pass the test for rollovers, excludes earthquakes, excludes disturbances of the waste,

and so on. In other words, the scope of this parameter has been restricted to those tanks for which there is no reason to expect a release. Therefore, I chose to combine both parameters and set the distribution based on the available data.

My rationale for the basis of 150 tanks-years without a detected burp is as follows: there are 28 double-shell tanks, of which only six have burped or pass the tests for burping proposed at the second workshop of the Stage II panel, 9-13 February (Slezak 1998b). This means that no burping has been observed in 22 tanks. To help put this into perspective I consulted with C. W. (Chuck) Stewart of PNNL, who is quite familiar with the GRE history of Hanford tanks and the methods of detecting them (Stewart et. al 1996a). According to Stewart, excluding the tanks from which burps have been detected, about 15 double-shell tanks have instrumentation that is probably sufficient to detect a large efficiency release and any medium efficiency releases large enough to represent a safety risk. Stewart wasn't sure exactly how long each tank had this instrumentation, but his judgement was that it was probably reasonable to assume that each of these tanks has had this instrumentation for an average of 10 years.

Thus, a reasonable assumption is that 150 tanks years (15 tanks times 10 years) have been experienced without a detectable spontaneous burp in these tanks. This statement would perhaps miss some medium efficiency releases in tanks that have a small enough gas volume so that a medium release isn't large enough to detect, but in such tanks a medium efficiency release is risk insignificant, so I chose to neglect this.

To develop the distribution, I made the following assumptions:

1. The real probability distribution is quite large. If I walk up to a particular tank and know nothing about it's condition, this tank might be "ripe" for a buoyant displacement, i.e., it might have a lot of gas in an unstable configuration. On the other hand, the tank conditions might be such that it couldn't have a spontaneous release in a million years. I believe some tanks would be found in the Hanford Tank farm throughout this range. A span of five orders of magnitude at the 95% confidence level seemed about right to me. This spans the range of E-01 per year (which seems reasonable considering each tank that has had instruments for ten years) to E-06 per year, which is the threshold accepted as being incredible.
2. The parameter is log-normally distributed.
3. The median of the range should be set so that the probability of not having a burp in 150 years is about 50%.

I computed the distribution as follows:

- Using Microsoft Excel, I developed a spreadsheet with a range of Cumulative Probabilities (CPs) and a Probability of Burp in a particular year (P-burp) associated with each. I tried to sample the entire range of CPs by dividing the range of 0 to 100%

into 150 segments, (representing years 1 through 150), and sampled the midpoint for each one. For example, the first Cumulative Probability, CP_1 , was $1/150 - 1/300 = 0.00333$. CP_2 was $2/150 - 1/300$, and so on.

- For each CP, P-burp was computed using the Microsoft Excel Loginv function, which returns a log-normal function value for a given Cumulative Probability. To start things off I put in dummy values for the mean and the standard deviation of the distribution.
- For each point, I then computed the probability of not burping in a particular year, which is simply $(1 - P_{burp})$.
- To compute the probability of not burping over 150 years, I took the product of all the probabilities of not burping. Algebraically, this can be expressed

$$\text{Probability of not burping in 150 years} = \prod_{i=1}^{150} (1 - P_{burp}(CP_i))$$

I then adjusted the mean and standard deviation of the distribution with the goal of having it span five orders of magnitude at 95% confidence and having the probability of not burping in 150 years to be 50%. This is an even chance of burping or not burping. If the probability were higher than 50%, it seemed likely that a burp would have been detected in these 150 tank years. With a probability less than 50%, it seemed reasonable that none has been detected.

The distribution I computed was as follows:

Log-normal distribution

Mean = 0.0001649

$\text{Ln}(\text{Mean}) = -8.7099$

Std. Dev. = 15

$\text{Ln}(\text{Std. Dev.}) = 2.70805$

Cum. Prob. of Spontaneous non-BD GRE

The first ten rows and the last ten rows of my spreadsheet are reproduced below. I do not show the middle rows in the interest of saving paper. The rightmost column is the cumulative product shown above for rows 1 through n. Note that at year 150, the cumulative product is approximately 0.5. Also, note that the span at 95% confidence is about 0.5E-05, which I decided was close enough to E-05, which was the span that I was shooting for.

Calculation of Probability Distribution for Parameter 1, Conditioning Factors b & c

Year	Cumulative Probability	Probability of burp, P_{burp} (per year)	Probability of no burp, $(1 - P_{\text{burp}})$ (per year)	Product of $(1 - P_{\text{burp}})$ Rows 1 through n
1	0.0033333	1.06E-07	1	1
2	0.01	3.03E-07	1	1
3	0.0166667	5.18E-07	0.999999	0.999999
4	0.0233333	7.55E-07	0.999999	0.999998
5	0.03	1.01E-06	0.999999	0.999997
6	0.0366667	1.29E-06	0.999999	0.999996
7	0.0433333	1.59E-06	0.999998	0.999994
8	0.05	1.92E-06	0.999998	0.999993
9	0.0566667	2.27E-06	0.999998	0.99999
10	0.0633333	2.64E-06	0.999997	0.999988

Year	Cumulative Probability	Probability of burp, P_{burp} (per year)	Probability of no burp, $(1 - P_{\text{burp}})$ (per year)	Product of $(1 - P_{\text{burp}})$ Rows 1 through n
Values for years 11 through 140 are not shown				
141	0.9366667	0.01032	0.98968	0.886369
142	0.9433333	0.01201	0.98799	0.875724
143	0.95	0.014185	0.985815	0.863302
144	0.9566667	0.017072	0.982928	0.848563
145	0.9633333	0.021058	0.978942	0.830694
146	0.97	0.026873	0.973127	0.808371
147	0.9766667	0.036054	0.963946	0.779226
148	0.9833333	0.052495	0.947505	0.738321
149	0.99	0.089811	0.910189	0.672011
150	0.9966667	0.255944	0.744056	0.500014

References for Parameter 1

Slezak 1998b; Slezak, Scott E., "electronic copy of workshop flipcharts," Electronic mail message from sesleza@sandia.gov to GRE Project panelists, 2 March 1998, 2:01 p.m.

Stewart et. al. 1996a, "Gas Retention and Release Behavior in Hanford Single-Shell Waste Tanks," PNNL-11391, UC-2030, December 1996

3.0 2. PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

During a buoyant displacement GRE, devices that have a pipe sticking into the waste could have the pipe bend and strike the side of the riser, causing a spark. This appears likely because there are many items sticking into the waste that have risers not much bigger than the pipe sticking into the top of the tank (for example a three-inch pipe sticking down through a four-inch hole in the riser).

3.1 2a. SMALL EFFICIENCY RELEASES

Probability of ignition source from BD GRE

Small Efficiency Release

Multiply all probabilities for Large Efficiency Releases by 0.01

It seems reasonable that small releases will have a much lower frequency of ignition than large releases, because much less of the tank is being disturbed, and the velocities of liquid in the tank will be much lower. I assumed that the small releases would have probabilities that were 100 times less than a large efficiency release. Small releases will probably not be very risk significant, so I didn't worry about setting this factor carefully. See section 2c for the development of the curve for large efficiency releases.

3.2 2b. MEDIUM EFFICIENCY RELEASES

Probability of ignition source from BD GRE

Medium Efficiency Release

Multiply all probabilities for Large Efficiency Releases by 0.1

It seems reasonable that medium releases will have a lower frequency of ignition than large releases, because less of the tank is being disturbed, and the velocities of liquid in the tank will be lower. I assumed that the medium releases would have probabilities that were 10 times less than a large efficiency release. Medium releases will be less risk significant than large releases, so I felt that judging a factor of ten was reasonable. See section 2c for the development of the curve for large efficiency releases.

3.3 2c. LARGE EFFICIENCY RELEASES

Probability of ignition source from BD GRE

Large Efficiency Release

Cumulative Probability	Probability of ignition source (no units)	Rationale
Upper Bound	1.0	Maximum probability. Seems likely that in a large release many things could break, electrical components could come loose and create sparks
95%	0.5	10 times the median. Seems reasonable that the 90% confidence limits should span about a factor of 100.
50%	0.05	Most DSTs have similar configurations of equipment, so I believe the real distribution is fairly narrow, although I don't know what it is. Therefore, I'm accounting for knowledge uncertainty, but I'll assume that this probability is really a single point, and I'm trying to make a best estimate of what the number is.

Cumulative Probability	Probability of ignition source (no units)	Rationale
50% (continued)		I can compute what that single point is by noting that three rollovers have occurred in 241-SY-101 with hydrogen concentrations in the general dome space greater than flammable (greater than 40,000 ppm). (Stewart 1998a). In eight other rollover events (six in 241-SY-101 and two in AN-105) the general dome space was greater than 10,000 ppm, suggesting that some part of the vapor space was above flammable. In these 11 events, no deflagrations occurred, suggesting that the risk of ignition is less than about 0.05 per event (0.94 to the 11 th power is about 0.5, suggesting that with a probability of 0.06 per event, the chances of having a deflagration after 11 events (with flammable hydrogen) is about even).
5%	0.005	A factor of 10 below median. Not very risk significant.
Lower Bound		The lower tail is risk insignificant.

References for Parameter 2

Stewart 1998a: Stewart, C. W., "Presentations by Chuck Stewart to GRE Safety Analysis Panel," PNNL-SA-29606, First Presentation, entitled, "GRE History of Hanford DSTs," 20 January 1998

4.0 5. DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

4.1 5a & b. SMALL AND MEDIUM EFFICIENCY RELEASES

In my opinion, of all the parameters I was elicited on, this is the parameter for which we have the best data, so I chose to simply use the data for my distribution rather than developing a distribution based on my own judgement. Chuck Stewart has analyzed the data for small and medium efficiency releases, and this data was provided to the panel by Slezak (Slezak 1998c). Based on a phone conversation with Chuck, I believe his reduction of the data is appropriate. His data is the time to the peak concentration in the tank headspace, which the panel agreed is the right time to use for this parameter (See Slezak 1998a). Since actual data on this parameter is available, I believe this is the best way of constructing a "best estimate" probability distribution.

Here is the data developed by Stewart:

I chose to provide one distribution for both small and medium efficiency because I had no good basis for developing two different distributions from this same set of data. There is some evidence that small efficiency releases happen slower than medium efficiency, but small releases of long duration would be risk insignificant, so I chose to neglect this difference.

Stewart compiled the data into an Microsoft Excel spreadsheet, which I printed out and used in my elicitation. In my elicitation on 11 March 1998, Dr. Winterfeldt asked me to pick off fractiles to develop a distribution. I interpolated the following points from a copy Stewart's spreadsheet:

Cumulative Probability	Time of release (minutes)	Rationale
Upper Bound	1128	This is the longest release shown on Stewart's spreadsheet. I considered lengthening the time to account for other variables, but couldn't come up with any defensible reason for increasing it, and long times are insignificant anyway. Therefore, I chose to simply use the data.
75%	485	I interpolated this point from the data on Stewart's spreadsheet.
50%	218	I interpolated this point from the data on Stewart's spreadsheet.
25%	115	I interpolated this point from the data on Stewart's spreadsheet.

Cumulative Probability	Time of release (minutes)	Rationale
Lower Bound	86	This is the shortest release shown on Stewart's spreadsheet. I considered shortening the time to account for other variables, but the actual data seems to come to a very abrupt point, suggesting that the curve does not have tail in this region. Therefore, I chose to simply use the data rather than trying to develop a reason for a tail.

4.2 5c. LARGE EFFICIENCY RELEASES

For a large efficiency release, the data is not as clear as for small and medium efficiency releases. The only large efficiency releases which have been observed were in Tank 101-SY before the installation of the mixer pump in 1993. There are two problems with estimating the time of these releases:

- These releases occurred before good gas measuring devices, such as SHMS, were installed in the tank
- The releases from Tank 101-SY were quite fast. Even if a SHMS were installed when the releases occurred, one would have to account for mixing in the headspace, how close the monitoring equipment was to the release point, and other similar factors.

I chose to set my distribution at 10 times as fast as small and medium releases. In other words, both distributions have the same shape, but the large efficiency release distribution has a median of one-tenth the small and medium distributions.

I based the factor of ten on my estimate that GREs in Tank 101-SY lasted an average of 20 minutes, if one uses the same basis agreed to by the panel of the time to peak gas concentration. Twenty minutes is about one-tenth the median release time of 218 minutes in Stewart's spreadsheet (for small and medium releases). The data is quite sketchy, and I had to exercise considerable judgement to come up with an estimate of 20 minutes. My judgement was as follows:

- During one of the panel workshops I observed a videotape of a rollover of Tank 101-SY. My recollection is that the tank rolled over in a few minutes, but there was movement and continued bubbling for some time after the rollover. Twenty minutes seems a reasonable time for the bubbling to subside (I should note that I did not go back and carefully view the videotape again with this question in mind).
- One reference (Ashby et. al.) shows that three GREs in Tank 101-SY caused the tank to go to positive pressure, and that the average release in 101-SY (for all large releases,

including the three that caused the tank to go positive) was about 5000 cubic feet. The fact that the tank went to positive pressure suggests that the peak release rate was greater than 500 cfm, the ventilation rate for the tank. If one assumes the average release rate for the duration of the release was half of that (250 cfm), this is a release time of 20 minutes for a 5000 cubic-foot release. It seems reasonable that the average rate should be much less than the peak (i.e., an average release rate of 500 cfm, corresponding to a 10-minute release, seems too high).

- One reference (Stewart et. al. 1996b) reports that the time for rollover of tank 101-SY was “a few minutes.” No report that I could find attempted to quantify the release time precisely. Therefore, I was left with the approximate rollover time of “a few minutes” combined with some judgement factor for how long gas would continue to vent after the initial rollover. Based on the previous arguments, an average release time of 20 minutes sounded reasonable.

Time of Release for a large efficiency release

Cumulative Probability	Time of release (minutes)	Rationale
75%	48.5	This is a factor of 10 less than the time for a medium release.
50%	21.8	This is a factor of 10 less than the time for a medium release.
25%	11.5	This is a factor of 10 less than the time for a medium release.
Lower Bound	4	Based on discussions with the panelists and my memory of the videotapes, this seems to be the fastest that the tank could rollover and release most of its gas. At times shorter than 5-10 minutes, the actual value is not risk significant, anyway, because the release happens so fast as to approximate a instantaneous release.

Reference for Parameter 5

Ashby, E.C.; Jonah, C.; Meisel, D.; Pederson, L.R.; and Strachan, D.M., “Gas Generation and Retention in Tank 101-SY: A Summary of Laboratory Studies, Tank Data, and Information Needs,” PNL-8124, AD-940, June 1992

Slezak, 1998a: Slezak, Scott E., “Final DST parameter list and descriptions,” Electronic Mail Message from sesleza@sandia.gov to GRE Safety Analysis Panelists, 19 February 1998, 5:41 p.m.

Slezak 1998c: Slezak, Scott E., “SHMS GRE data from Chuck Stewart,” Electronic Mail Message from sesleza@sandia.gov to GRE panelists, 18 February 1998, 11:58 a.m.

Stewart et. al. 1996b: Stewart, C.W.; Alzheimer, J.M.; Brewster, M.E.; Chen, G.; Mendoz, R.E.; Reid, H.C.; Shepard, C.L.; and Terrones, G., "In Situ Rheology and Gas Volume in Hanford Double-Shell Tanks," PNNL-11296, UC-2030, September 1996

5.0 6B. PROBABILITY OF A SEISMIC-INDUCED GRE IN A DST

5.1 61a. 100-YEAR EARTHQUAKE, SMALL EFFICIENCY

Probability of seismic induced GRE in a DST
100-year earthquake (Small earthquake)
Small Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	1.0	If tank is "ripe" for a buoyant displacement (i.e., has gas in an unstable configuration), even a small earthquake may kick off some release.
50%	0.5	Even a small earthquake seems likely to mobilize some small fraction of the waste, enough to cause a gas release event of less than 5%. Not very risk significant.
5%	0.01	Seems like this distribution ought to have a long tail because there will be some tanks in which conditions are not ripe for seismic-induced GRE. A factor of 50 below the median feels about right.

5.2 61b. 100-YEAR EARTHQUAKE, MEDIUM EFFICIENCY

Probability of seismic induced GRE in a DST

100-year earthquake (Small earthquake)

Medium Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	0.5	If tank is "ripe" for a buoyant displacement (i.e., has gas in an unstable configuration), even a small earthquake may kick off a medium release.
50%	0.05	Factor of 10 less than 1000-year earthquake for a medium efficiency release. In a small earthquake, much less waste would be mobilized than by medium earthquake. Reduction by a factor of 10 seems reasonable and is not very risk significant
5%	0.001	Factor of 10 less than 1000-year earthquake for a medium efficiency release.

5.3 61c. 100-YEAR EARTHQUAKE, LARGE EFFICIENCY

Probability of seismic induced GRE in a DST

100-year earthquake (Small earthquake)

Large Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	0.5	If tank is "ripe" for a buoyant displacement (i.e., has gas in an unstable configuration), even a small earthquake has a significant change of kicking off a large release.
50%	0.01	Factor of 10 less than 1000-year earthquake for a large efficiency release. In a small earthquake, much less waste would be mobilized than by medium earthquake. Reduction by a factor of 10 seems reasonable and is not very risk significant
5%	0.0002	Factor of 10 less than 1000-year earthquake for a large efficiency release.

5.4 61d. 1000-YEAR EARTHQUAKE, SMALL EFFICIENCY

Probability of seismic induced GRE in a DST
 1,000-year earthquake (Medium earthquake)
 Small Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
All points	1.00	All large earthquakes will release some gas. Based on work reported by Chuck Stewart (Stewart, 1998b), a 1,000-year earthquake will mobilize most of the waste. Therefore, it seems a virtual certainty that both a 1,000-year earthquake and a 10,000-year earthquake will always induce a small efficiency release (less than 5% of gas released) or larger.

5.5 61e. 1000-YEAR EARTHQUAKE, MEDIUM EFFICIENCY

Probability of seismic induced GRE in a DST
 1,000-year earthquake (Medium earthquake)
 Medium Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	1.0	If tank might undergo buoyant displacement, even a small earthquake may kick off a release.
50%	0.5	Based on work reported by Stewart, it is likely that a 1000-year earthquake will mobilize most of the waste in the tank. If the tank is subject to BD GRE and has a high gas inventory, a BD GRE will "kick off." Otherwise a medium efficiency release seems fairly likely. A median probability of 50% seem reasonable.
5%	0.01	Seems like this distribution ought to have a long tail because there will be some tanks in which conditions are not ripe for seismic-induced GRE. A factor of 50 below the median feels about right.

In my elicitation with Dr. Winterfeldt on 11 March 1998, I incorrectly gave him a probability of 0.001 for the 5% percentile. This was a mistake in my notes that I noticed after the elicitation. The elicitation distribution recorded by Dr. Winterfeldt should be corrected to reflect the correct value of 0.01.

5.6 61f. 1000-YEAR EARTHQUAKE, LARGE EFFICIENCY

Probability of seismic induced GRE in a DST

1,000-year earthquake (Medium earthquake)

Large Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	1.0	If tank might undergo buoyant displacement, even a small earthquake may kick off a release.
50%	0.1	If the tank is not ripe for buoyant displacement, then the earthquake has to supply all the energy to liquify the waste and keep it mobilized long enough for the gas to escape (i.e., a pocket of gas might shake loose, move a few inches, and then stay put when the waste settles down). In an event that did liquify all the waste, it seems that more than 25% would be released. However, most earthquakes would only mobilize portions of the tank. The waste is Bingham plastic, like peanut butter. Although your knife moving through peanut butter will move it, most of the peanut butter doesn't liquify (for example, the gob of peanut butter ahead of the knife moves but sticks together as a gob). It seems unlikely that a medium earthquake will liquify all of the waste.
5%	0.002	A factor of 50 less than the median. Not very risk significant.

5.7 61g. 10,000-YEAR EARTHQUAKE, SMALL EFFICIENCY

Probability of seismic induced GRE in a DST

10,000-year earthquake (Large earthquake)

Small Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
All points	1.00	All large earthquakes will release some gas. Based on work reported by Chuck Stewart (Stewart, 1998b), a 1,000-year earthquake will mobilize most of the waste. Therefore, it seems a virtual certainty that both a 1,000-year earthquake and a 10,000-year earthquake will always induce a small efficiency release (less than 5% of gas released) or larger.

5.8 61h. 10,000-YEAR EARTHQUAKE, MEDIUM EFFICIENCY

Probability of seismic induced GRE in a DST

10,000-year earthquake (Large earthquake)

Medium Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
All points	1.0	All large earthquakes will release some gas. Based on work reported by Chuck Stewart (Stewart, 1998b), a 1,000-year earthquake will mobilize most of the waste. Therefore, it seems a virtual certainty that a 1,000-year earthquake will induce at least a small efficiency release, and also a certainty that a 10,000-year earthquake will induce a medium efficiency release or larger.

5.9 61i. 10,000-YEAR EARTHQUAKE, LARGE EFFICIENCY

Probability of seismic induced GRE in a DST

10,000-year earthquake (Large earthquake)

Large Efficiency Release

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	1.0	If a tank is "ripe" for buoyant displacement, a large earthquake will certainly kick it off.
50%	0.5	If the tank is not ripe for buoyant displacement, then the earthquake has to supply all the energy to liquify the waste and keep it mobilized long enough for the gas to escape (i.e., gas might shake loose, move a few inches, and then stay put when the waste settles down). In an event that did liquify most of the waste, seems that more than 25% would be released. In a large earthquake it seems that there's a good chance this will happen (my judgement is 50% of the time).
5%	0.01	Factor of 10 below the median.

References for Parameter 6B

Stewart, 1998b: Stewart, C. W, Presentations by Chuck Stewart to GRE Safety Analysis Panel, PNNL-SA-29606, Last Presentation, entitled, "Seismic Response of DST Waste"

6.0 7. PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

A presentation by Chuck Stewart (Stewart 1998b) shows that in a 1000-year earthquake (medium size earthquake), most of the material in a DST with liquid over solid will be mobilized. He reported movements of 80 to 100% of the tank contents. In this kind of earthquake, many of the items sticking into the tank, such as the pumps, tapes, and air-lift circulators (in tanks that have them) will move. Devices that have a pipe sticking into the waste could have the pipe bend and strike the side of the riser, causing a spark. This appears likely because there are many items sticking into the waste that have risers not much bigger than the pipe sticking into the top of the tank (for example a three-inch pipe sticking down through a four-inch hole in the riser).

According to Scaief (Scaief), most DSTs have some kind of transfer pump installed. A few tanks have air-lift circulators, which, because of their large surface area sticking down into the waste, seem likely to move significantly during a seismic event. For the purpose of my elicitation I assumed 4 tanks out of 28 DSTs had the air-lift circulators and are almost sure to spark during an earthquake. Most tanks also have things like instrument probes, which can produce sparks by the same mechanism.

In the elicitation interview, Dr. Winterfeldt and I discussed the possibility of introducing the additional conditioning factor of "Tank has air-lift circulators." This idea was attractive to me. I believe that tanks with circulators will have a higher probability of an ignition source than other tanks because there are many circulators in each tank, and they have a large cross-section, which means the force imparted on the circulator by a moving fluid will be higher than the force on other pieces of tank equipment, such as pumps. Thus, tanks with circulators will likely experience much more banging of metal on metal than tanks that only have equipment like pumps and thermowells. I believe this means more potential for sparks.

However, I chose not to insist that Dr. Winterfeldt establish a new conditioning factor just for me. Since the probabilities of ignition are large fractions of one anyway, especially for a large earthquake, ignoring this conditioning factor doesn't make much difference in the calculation.

Another source of ignition sources is the ventilation system. For example, T. B. Powers & G. R. Sawtelle report that a possible ignition source would be an out-of-balance fan blade striking the fan housing and producing sparks. Such an imbalance seems likely to happen during an earthquake.

6.1 7a. SMALL EARTHQUAKE

Probability of Ignition Source in a DST caused by an earthquake
100-year earthquake (Small Earthquake)

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	0.1	Seems that the shape of this curve should be similar to medium earthquake but with much lower probabilities. I arbitrarily set it a factor of 10 less than a medium earthquake (not very risk significant)
50%	0.005	Factor of 10 below medium earthquake.
5%	0.0005	Factor of 10 below medium earthquake.

6.2 7b. MEDIUM EARTHQUAKE

Probability of Ignition Source in a DST caused by an earthquake
1000-year earthquake (Medium earthquake)

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	1.0	Maximum probability. Seems likely that in a medium earthquake, in which a large fraction of the waste will move, many things would break, electrical components would come loose and create sparks, and there would be much banging of metal against metal.
50%	0.05	<p>Probability should be comparable to the ignition risk of a large rollover event, since the amount of sloshing appears comparable.</p> <p>Three rollovers have occurred in 241-SY-101 with hydrogen concentrations in the general dome space greater than flammable (greater than 40,000 ppm) (Stewart, 1998a). In eight other rollover events (six in 241-SY-101 and two in AN-105) the general dome space was greater than 10,000 ppm, suggesting that some part of the vapor space was above flammable. In these 11 events, no deflagrations occurred, suggesting that the risk of ignition is less than about 0.05 per event (0.94 to the 11th power is about 0.5, suggesting that with a probability of 0.06 per event, the chances of having one deflagration after 11 events is about even. I rounded it to 0.05).</p>

Cumulative Probability	Probability (no units)	Rationale
5%	0.005	A factor of 10 below median. Not very significant.
Lower Bound		The lower tail is risk insignificant.

6.3 7c. LARGE EARTHQUAKE

Probability of Ignition Source in a DST caused by an earthquake
10,000-year earthquake (Large earthquake)

Cumulative Probability	Probability (no units)	Rationale
Upper Bound	1.0	Maximum probability. Seems likely that in a large earthquake many things could break, electrical components could come loose and create sparks, etc.
50%	0.5	This was the median selected by the SST panelists, Figure A-28 (SCOPE panelists). This feels about right to me, a fairly high average probability of ignition for this violent earthquake.
5%	0.05	Factor of 10 less than median. Not very significant.
Lower Bound		Not concerned about the lower tail. Risk insignificant.

References for Parameter 7

Powers, T. B; and Sawtelle, G. R., "Tank Farm Deflagration Rates Due to Various Ignition Sources," SHC-SC-WM-CN-041, Rev. 0, August 1996

Scaief, C.C., "Tank Farm Potential Ignition Sources," WHC-SD-WM-ES-362, Rev. 1, January 1996

SCOPE Panelists, "Safety Controls Optimization by Performance Evaluation (SCOPE) Flammable Gas Expert Elicitation Results for Hanford Site Single-Shell Tanks," July 1997

Stewart 1998a: Stewart, C. W., "Presentations by Chuck Stewart to GRE Safety Analysis Panel," PNNL-SA-29606, First Presentation, entitled, "GRE History of Hanford DSTs," 20 January 1998

Stewart, 1998b: Stewart, C. W., Presentations by Chuck Stewart to GRE Safety Analysis Panel, PNNL-SA-29606, Last Presentation, entitled, "Seismic Response of DST Waste"

7.0 REFERENCES FOR ALL SECTIONS

- Ashby, E.C.; Jonah, C.; Meisel, D.; Pederson, L.R.; and Strachan, D.M., "Gas Generation and Retention in Tank 101-SY: A Summary of Laboratory Studies, Tank Data, and Information Needs," PNL-8124, AD-940, June 1992
- Forest, Barbara J., approver, Integrated Contractor Order between Sandia Corporation and Westinghouse Savannah River Company, Document Number AY-5319, 17 November 1997, Sandia National Laboratories, 1515 Eubank Blvd. S.E., Albuquerque, NM 87123
- Powers, T. B; and Sawtelle, G. R., "Tank Farm Deflagration Rates Due to Various Ignition Sources," SHC-SC-WM-CN-041, Rev. 0, August 1996
- Scaief, C.C., "Tank Farm Potential Ignition Sources," WHC-SD-WM-ES-362, Rev. 1, January 1996
- SCOPE Panelists, "Safety Controls Optimization by Performance Evaluation (SCOPE) Flammable Gas Expert Elicitation Results for Hanford Site Single-Shell Tanks," July 1997
- Slezak, 1998a: Slezak, Scott E., "Final DST parameter list and descriptions," Electronic Mail Message from sesleza@sandia.gov to GRE Safety Analysis Panelists, 19 February 1998, 5:41 p.m.
- Slezak 1998b: Slezak, Scott E., "electronic copy of workshop flipcharts," Electronic mail message from sesleza@sandia.gov to GRE Project panelists, 2 March 1998, 2:01 p.m.
- Slezak 1998c: Slezak, Scott E., "SHMS GRE data from Chuck Stewart," Electronic Mail Message from sesleza@sandia.gov to GRE panelists, 18 February 1998, 11:58 a.m.
- Slezak, Scott E.; Gelbard, Fred; Cheng, Wu-Ching "Enhanced Safety Analysis Methodology for Flammable Gas Risk Assessment In Hanford Site Tanks; Proposed Part II: Double Shell Tanks," HNF-SD-WM-ES-410, 5 January 1998
- Stewart 1998a: Stewart, C. W., "Presentations by Chuck Stewart to GRE Safety Analysis Panel," PNNL-SA-29606, First Presentation, entitled, "GRE History of Hanford DSTs," 20 January 1998
- Stewart, 1998b: Stewart, C. W., Presentations by Chuck Stewart to GRE Safety Analysis Panel, PNNL-SA-29606, Last Presentation, entitled, "Seismic Response of DST Waste"
- Stewart et. al. 1996a, "Gas Retention and Release Behavior in Hanford Single-Shell Waste Tanks," PNNL-11391, UC-2030, December 1996

Stewart et. al. 1996b: Stewart, C.W.; Alzheimer, J.M.; Brewster, M.E.; Chen, G.; Mendoz, R.E.; Reid, H.C.; Shepard, C.L.; and Terrones, G., "In Situ Rheology and Gas Volume in Hanford Double-Shell Tanks," PNNL-11296, UC-2030, September 1996

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**APPENDIX B.4
RATIONALE REPORTS**

C. Easterly

May 1998

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1.0 2. PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

Based on the sources identified in the References below, and others of a similar nature, it was necessary to develop a distribution of ignition probabilities for three sizes of GREs. A small efficiency buoyant event is not considered to be significantly different from normal operations. The basis of the argument will be constructed around normal operation and the resultant probabilities will be modified (scaled) according to the size of the GRE. The lower bound is obtained by realizing that the lowest ignition probability (frequency) associated with the operation of a DST tank farm is in the order of 10^{-5} or 10^{-6} per year. The more potentially dangerous tanks, by and large the DSTs, have been given more attention than the less dangerous ones in terms of equipment selectivity and procedures. Yet, the DSTs generally contain more electrical equipment than the SSTs. Given that a GRE is relatively short by comparison with a year of operation, I choose the value of 10^{-6} /event as the lower bound. This is physically realistic and has no obvious contradictions. It is difficult to envision probabilities much below 10^{-6} /event and this value is taken to represent the 5% subjective probability level.

A physically possible upper bound is 10^0 or 1. But this value is not realistic in the current conditions of the DSTs. A combination of ignition set 2 controls in addition to other carefully applied operational procedures currently in place should reduce the probability of causing a spark ignition to be less than 10^{-3} per operation. We approach the dilemma between the physically possible and the likely by assigning a probability of 0.001 to the 95% subjective probability level.

The remainder of the problem is to identify the middle ground. In his evaluation of hazards during normal conditions, Scaief identifies a number of electrical devices in essentially all DSTs that are capable of being rated as high spark hazard. Scaief has five levels of assignments from the most hazardous to the least. Some of the "high Hazards" are associated with the vent systems and I do not think that the fans and their controllers will be materially affected by GREs because of their locations. However, other non-vent equipment within the tanks is electrically energized. Mechanical sparks, on the basis of the referenced sources and others, are not anticipated to surpass the electrical sources in degree of hazard. Over all, the probability of an ignition source being present at 10^{-4} /event seems to be a reasonably expected operational characteristic of DSTs. This value is adopted for the 50% subjective probability of occurrence of a small GRE.

When scaling for medium and large GREs, I use a multiplier to scale the effects of energy transmitted to the contents of the tanks during the GREs. The 5X multiplier chosen represents the additional energy in the medium and large GREs and the nonlinear effects of additional energy in causing ignitions. This 5X applies to all subjectivity probabilities, 95%, 50% and 5%.

Thus numerical values are:

- 2a. Frequency of Ignition Caused by a Small GRE

95%	1E-3
50%	1E-4
5%	1E-6
- 2b. Frequency of Ignition Caused by a Medium GRE

95%	5E-3
50%	5E-4
5%	5E-6
- 2c. Frequency of Ignition Caused by a Large GRE

95%	1E-2
50%	1E-3
5%	1E-5

References:

A variety of references were reviewed to provide a perspective on mechanisms and electrical sources of ignition. Among the sources are:

Scaief III, C.C. 30 January 1996. "Tank Farm Potential Ignition Sources."
WHC-SD-WM-ES-362-REV-1.

"SST: Potential Flammable Gas Ignition Sources." Presentation to the SCOPE panel.

Powers, Tom B. and Sawtelle, George R. 29 August 1996. "Tank Farm Deflagration Rates Due to Various Sources." WHC-SD-WM-CN-041.

Hamilton, D.W. 4 September 1996. "A Safety Assessment for Rotary Mode Core Sampling in flammable Gas Single Shell Tanks, Hanford Site, Richland, Washington."
WHC-SD-WM-SAD-035-REV-0-a.

Private discussions on 13 March 1997 with Mike Grigsby and Richard Schlosser

2.0 3. TOTAL MASS OF TRANSPORTABLE WASTE SUSPENDED IN HEADSPACE

The mass of waste that can be suspended in the headspace is a function of the magnitude of disturbance that caused the waste to be suspended and the movement of air within the headspace

over the time that the material of interest is considered suspended. These considerations will be addressed from bounding points of view. On the one hand, this author considers that, for the maximum accident considered, a headspace detonation resulting in the dome failing, an upper limit of dust-in-air is about 1 kg/m^3 . On the other hand, the lower limit of accident is so slight that industrial hygiene limits, typically 5 to 10 mg/m^3 , are barely achieved. In between will lie the other concentrations. They will also be modified by estimated losses of material due to settling out over time and mixing with soil fines, in cases that are appropriate, which could be considered a dilution or filtering effect. In addition, for situations in which contaminated gas could be vented at anything but a very low gas velocity, there will be an effect similar to when a fast moving river enters a stagnant lake. There is a deposit of some of the materials that the fast moving water is carrying. A similar phenomenon occurs with high velocity gas entering the relatively stagnant atmosphere. Where appropriate, this phenomenon is factored into the estimates of mass of transportable material suspended.

2.1 3a. MASS OF TRANSPORTABLE WASTE MATERIAL SUSPENDED IN DST HEADSPACE BY BURN: NO HEPA FAILURE

This situation represents the minimum disturbance of the waste. The overpressure created is less than 1 psig, less than adequate to fail the HEPA filter system. Such a condition is expected to provide barely enough air motion to suspend ACGIH typical nuisance dust limits of 5 to 10 mg/m^3 or 10^{-5} kg/m^3 . This material is suspended in an assumed volume of $4,000 \text{ m}^3$. The product of suspended dust concentration and volume provides the 50% estimate of 0.04 kg suspended. The 95% value is considered a factor of two higher at 0.08 kg, and the 5% value is considered to be a factor of ten below the middle estimate, or 0.04 kg. Thus we arrive at the following:

- 95% 0.08 kg
- 50% 0.04 kg
- 0.5% 0.004 kg

2.2 3b. MASS OF TRANSPORTABLE WASTE MATERIAL SUSPENDED IN DST HEADSPACE BY BURN: HEPA FAILS; < 20 PSIG; NO DOME FAILURE

In this event, taken to produce near 20 psig, the HEPA filter is lost but we are assuming that the HEPA loss prevented further path leaks. The initial burn is taken to suspend waste at the surface at a concentration of about 1 g/m^3 . Maintenance of this concentration requires considerable velocity. In the region of the tank near the vent, at early times after the pressurization, high velocities will be obtained adequate to maintain the 1 g/m^3 . But, away from the immediate vent, velocities will be considerably lower and, within a few seconds, the suspended materials will be depositing. Immediately upon entering the atmosphere above the tank, there will also be a change in air motion, going from a very high speed in the vent tube to a few meters per second in the atmosphere. Between the initial suspension at the surface of 1 g/m^3 to outside the tank, I estimate

a reduction in concentration by about a factor of 20, to 50 g/m³. When taken with the original volume of 4.000 m³, the mass suspended is 0.2 kg. This is taken as the 50% central figure. As before the higher and lower concentrations retain their same factor relationships, and the masses are:

- 95% 0.4 kg
- 50% 0.2 kg
- 5% 0.02 kg

2.3 3c. MASS OF TRANSPORTABLE WASTE MATERIAL SUSPENDED IN DST HEADSPACE BY BURN: HEPA FAILS; > 20 PSIG; NO DOME FAILURE

This event is assumed to produce about twice the pressure of the previous elicitation. Much higher gas velocities are anticipated though and approximately 10 g/m³ of suspended waste is estimated to be produced. While a considerably greater density of material is suspended, it also takes a much greater velocity to maintain this suspension. As before, a small quantity of matter at the original concentration will be vented from the tank near the vent hole. However, during the 10-20 seconds of depressurization, most of the tank will not experience velocities anywhere near the air speeds associated with the initial burn. Consequently there will be settling out in the tank at a greater rate than elicitation 3b. Furthermore, immediately upon exiting the HEPA filter box, the suspended waste will encounter a relatively stagnant air mass. It is estimated that the resulting average concentration will be reduced by about a factor of 100 from the initial value. Taking the original volume to be the same, and using the same relationships for the distribution, the masses suspended are:

- 95% 0.8 kg
- 50% 0.4 kg
- 5% 0.04 kg

2.4 3d. MASS OF TRANSPORTABLE WASTE RELEASED FROM DST BY A BURN THAT CAUSES DOME FAILURE

This major deflagration event results in a failed dome. Gas front speeds are expected to produce very high dust loadings, approximately 100 g/m³. This suspended material can vent out of the HEPA duct but it also can vent out of other pathways through other openings forced open by the pressure rise. Having breached the dome, pathways through the soil overburden are also possibilities. It is assumed that there is significantly greater area to vent through the dome crack than the other, unfiltered pathways. By a combination of filtering out contamination and dilution with noncontaminated soil, the pressurized release is taken to have a reduction in concentration by a factor of 100. The remaining gas loading of 1 g/m³ still requires a significant air velocity to maintain and this is not met upon entry of the relatively stagnant air of the atmosphere. We take

an additional factor of 10 reduction immediately upon entry into the atmosphere for a transportable concentration of 100 g/m^3 . Given the same original volume as before the masses suspended are:

- 95% 0.8 kg
- 50% 0.4 kg
- 5% 0.04 kg

2.5 3e. MASS OF TRANSPORTABLE WASTE RELEASED FROM DST BY A DETONATION THAT CAUSES DOME FAILURE

This detonation is considered to result in the upper limit measured for dust-in-air of about 1 kg/m^3 . This high dust loading can only exist for very high speed air movement. Due to the factors discussed in (3d), a factor of 100 decrease is expected by the time this gas enters the stagnant atmosphere. Because of the higher requirement for high air speeds to maintain a high dust loading, the reduction upon entering the atmosphere is increased by a factor of two over that assumed in (3d). This leaves 0.5 g/m^3 to be dispersed downwind of the DST. Given the original volume and relationships between the estimates, the masses released are:

- 95% 4 kg
- 50% 2 kg
- 5% 0.2 kg.

References:

A large number of references were used in developing a perspective about this set of variables:

- L.H. Sullivan et al., "A Safety Assessment for the Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington," Los Alamos National Laboratory report, LA-UR-92-3196, Rev. 14 (March 31, 1995).
- R.T. Perry, "Aerosol Mass in the Dome," Los Alamos National Laboratory Calc-Note TSA6-CN-WT-SA-TH-096 (December 1995).
- K.O. Pasamehmetoglu, "Additional Dome Collapse Calculations for Single-Shell Flammable Watch List Tanks," Los Alamos National Laboratory Calc-Note TSA6-CN-WT-SA-TH-093 (December 1995).
- J.D. Iverson, "Particulate Entrainment by Wind," Department of Aerospace Engineering, Iowa State University report Project 1699, ISU-ERI-Ames-85010, prepared for Los Alamos National Laboratory under Subcontract No. 9-X54-K9610-1 (July 1984).

- D.R. MacFarlane, D.W. Stack, J. Kindinger, R.K. Deremer, S.R. Medhekar, and T.J. Mikschl, "Probabilistic Safety Assessment for Hanford High-Level Waste Tanks," Los Alamos National Laboratory report, LA-UR-95-1900, TSA-11-94-R110 (November 1995).
- W.C. Hinds, "Aerosol Technology, Properties, Behavior, and Measurement of Airborne Particles" (John Wiley and Sons, New York, NY, 1982).
- R.F. Schwab, "Dusts," Chapter 12, Section 3, from A.E. Cote, P.E., Editor-in-Chief, Fire Protection Handbook (National Fire Protection Association, Quincy, Massachusetts, 1992).
- S.L. Sutter, "Accident Generated Particulate Materials and Their Characteristics-A Review of Background Information," Pacific Northwest Laboratory report NUREG/CR-2651, PNL-4154 (May 1982).
- H.R. MacDougall, L.W. Scully, and J.R. Tillerson, "Preliminary Preclosure Radiological Safety Analysis," Appendix F in "Site Characterization Plan Conceptual Design Report," Sandia National Laboratory report SAND84-2641 (1987).
- U.S. Department of Energy, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities," U.S. Department of Energy Handbook DOE-HDBK-3010-94 (October 1994).
- A Safety Assessment for Rotary Mode Core Sampling in Flammable Gas Single Shell Tanks, Hanford Site, Richland, Washington, WHC-SD-WM-SAD-035, Rev. 0-a.
- A Safety Assessment for Salt Well Jet Pumping Operations in Tank 241-A-101: Hanford Site, Richland, Washington, WHC-SD-WM-SAD-036, Rev. 0.
- Flammable Gas Program Topical Report, G.D. Johnson, January 1997, HNF-SP-1193, Rev. 2.

**3.0 4. TOTAL MASS OF RESPIRABLE WASTE MATERIAL SUSPENDED IN
THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE
STRUCTURAL FAILURE OF A DST, OR RELEASED FROM A DST
BY A COMBUSTION EVENT THAT CAUSES STRUCTURAL
FAILURE OF A DST**

The variables for this elicitation derive from a combination of variables from elicitation #3 plus additional information on the percentage of suspended mass that is respirable. The original elicitation was based on the References below with a sampling of about 30 data points. These data points were the respirable fraction of material suspended in an event. Data are available for a

wide variety of events but only those thought to be applicable to the DSTs were used. The elicitation analyst (RSJ) fitted my points and then multiplied the resulting curve with the curves from elicitation #3.

Subsequent to the elicitation, I pursued the matter in a little more detail and assembled 154 points to investigate the robustness of the original findings. The current findings represented in Figure 1 show some small differences, mostly in the lower part of the curve. Thus, the data from this report should be re-analyzed and re-plotted. Original elicitation values and values for this report are:

Subjective Probability	Original Elicitation (Respirable Fraction)	This Final Report (Respirable Fraction)
95%	0.8	0.9
50%	0.52	0.55
5%	0.01	0.18

Figure 1. Current Finding.

References:

- R.T. Perry, "Aerosol Mass in the Dome," Los Alamos National Laboratory Calc-Note TSA6-CN-WT-SA-TH-096 (December 1995).
- K.O. Pasamehmetoglu, "Additional Dome Collapse Calculations for Single-Shell Flammable Watch List Tanks," Los Alamos National Laboratory Calc-Note TSA6-CN-WT-SA-TH-093 (December 1995).
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- W.C. Hinds, "Aerosol Technology, Properties, Behavior, and Measurement of Airborne Particles" (John Wiley and Sons, New York, NY, 1982).
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- Pasamehmetoglu, Kermal O. 20 March 1997. "Overview of Safety Assessments Developed by LANL." Presentation to the SCOPE panel.
- Gelbard, Fred and Brockmann, John E. "Material Aerosolization." Presentation to the SCOPE panel.

4.0 62(d&j, e&k, f&I), 63(d&j, e&k, f&I), 64(d&j, e&k, f&I). PROBABILITY OF SEISMIC INDUCED GRE IN SSTs, CONDITIONED ON PUMPED VS UNPUMPED

This analysis begins with the distributions I developed for the SST SCOPE analysis. They are described in the first set of elicitations #19 entitled *Frequency of Induced Small, Medium & Large GREs for 10^{-2} , 10^{-3} , 10^{-4} Earthquakes*. The initial elicitation considered that the tanks, all SSTs, may be in any condition. Therefore, the condition of unpumped dominated the thinking in terms of potential hazard, and in developing the distribution of frequencies. In the present elicitation, there is an explicit attempt to distinguish between pumped and unpumped SSTs. Because the unpumped case dominated the original elicitation, values in the original elicitation are used for all unpumped conditions.

For the cases involving pumping, the effects of removing the liquid must be considered. Saltwell pumping is used to remove the liquid but this does not result in a complete removal of moisture from the waste. Residual moisture in the waste becomes important in the more infrequent earthquakes, as will be described later. By removing the pumpable water, it will be much more difficult for energy to be transferred from the motion of the earth into the waste because the waste cannot easily respond by developing standing or resonant waves. For low energy earthquakes, the pumped waste will be too stiff for the development of significant wave motion. Thus, with little response to the earth motion, there should be little potential for a GRE. Work by Reid & Deibler, PNNL 11668, 1997 suggest that two separate measures of deformation (volume exceeding strain limit, and volume exceeding strain energy density limit) are reduced by roughly 10 to 100 times for dry versus wet over dry waste for a 1,000 year event. These models support common sense with order of magnitude estimates for level-of-effect.

References used in this elicitation response are the same as for the SSTs except for a few called out references in the following text.

4.1 100 YEAR EVENT

For the 100 year event, the figure of 10X is used to reduce the volume of waste disturbed from that previously presented in the SCOPE analysis, elicitation #19. This reduced volume of waste disturbed is a consequence of the waste being devoid of free standing water, consequently the volume of gas disturbed is reduced. In contrasting the gas released from the pumped versus the unpumped tanks, gas volume is taken to be proportional to waste disturbed, i.e., 10X. Thus for all distributions conditioned on pumped, we reduce the original elicitation quantities (taken to be unpumped) by a factor of 10X. The factor of 10X reduction from the original elicitation variables applies to the Small, Medium and Large GREs for all Facility Groups.

4.2 1,000 YEAR EVENT

A 1,000 year earthquake begins to have significant accelerations and duration. According to private discussions with Phil Gauglitz (panel member), some very stiff waste forms have been observed to rapidly take on a more fluid character upon stirring; reconsolidation to original stiffness may take a long time...up to months. In addition, the report on "The Effects of Heating and Dilution on the Rheological and Physical Properties of Tank 241-SY-101 Waste," PNL-10198 (1994), suggests a significant (approximately 2X) decrease in yield stress with a 10% dilution in NaOH or likewise, a 20°C increase in temperature. Interpreted in a general way, this information suggests substantial decreases in strength with slight changes in physical conditions. The forces of a 1,000 year earthquake will provide some simulation to stirring or agitation of the pumped waste that still contains moisture. The waste is expected to respond to the earth's motion by becoming slightly less stiff and consequently more liquid-like. The greater duration of the event, the more liquid-like the waste will become. Thus, for the pumped cases, we adopt for the 1,000 year case a reduction by a factor of 5X from the unpumped condition. The factor of 5X reduction from the original elicitation variables applies to the Small, Medium and Large GREs for all Facility Groups.

4.3 10,000 YEAR EVENT

In a similar manner, for a 10,000 year earthquake, the waste, even though devoid of liquid on the surface, and incapable of providing free water in salt wells, does contain a significant amount of water. With the forces of a 10,000 year earthquake, which is considered also to be of greater duration than the 1,000 year event, the waste is expected to take on more liquid-like characteristics. This more liquid state is progressive and the more liquid-like it becomes, the more energy that can enter the waste in the form of standing waves. In the case of a pumped waste, under the conditions of a 10,000 year earthquake, the waste is expected to respond similarly to an unpumped waste during the latter stages of a 10,000 year disturbance. Thus we take only a factor of 2X reduction in waste disturbed from the unpumped condition. The factor of 2X reduction from the original elicitation variables applies to the Small, Medium and Large GREs for all Facility Groups.

5.0 7. PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

This variable is treated much the same as *Variable 2, Probability of an Ignition Source Being Induced by a Buoyant Displacement GRE*, however, in place of the motion within the tanks due to the movement of the gas, there will be induced motion because of the earthquakes. The beginning point of this variable is the same distribution as for normal operations. A 100 year event is considered to be small enough to be classed the same as normal operation. In order to

account for the greater energy input into the tanks under earthquake conditions over and above those due to some other mechanism for inducing a GRE as per *Variable 2*, a factor of 10X is given to principle variables for the 1,000 and 10,000 year events. The factor of 10 is greater than the energy increase of about 3x going from 10^{-2} to 10^{-3} to 10^{-4} events, but, this greater multiplier is used to account for the possibility that ignition sources may scale at a higher proportion than energy input alone. The numerical values are:

- 7a. Frequency of Ignition Sources during 10^{-2} Earthquake
 - 95% 1E-3
 - 50% 1E-4
 - 5% 1E-6
- 7b. Frequency of Ignition Sources during 10^{-3} Earthquake
 - 95% 1E-2
 - 50% 1E-3
 - 5% 1E-5
- 7c. Frequency of Ignition Sources during 10^{-4} Earthquake
 - 95% 1E-1
 - 50% 1E-2
 - 5% 1E-4

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**APPENDIX B.5
RATIONALE REPORTS**

M. Epstein

May 1998

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1.0 INTRODUCTION

The elicitation session took place on March 12, 1998. Richard S. John served as the elicitor. The parameters discussed and for which the probability distributions were provided by the expert panelist during the elicitation session are listed below. The numbers assigned to the parameters correspond to the order in which they appear in this report:

1. Frequency of spontaneous gas releases
2. Probability of an ignition source induced by a buoyant displacement gas release event (GRE)
3. Total mass of transportable waste material suspended or released
4. Total mass of respirable waste material suspended or released
5. Duration of a buoyant displacement GRE
6. Probability of a seismic-induced GRE in single shell tanks (SSTs)
7. Probability of an ignition source in a double shell tank (DST) caused by an earthquake.

Mathematical models were constructed to aid in assigning fractile values to Elicitation Parameters 1, 3, 4, and 5. The spread of the cumulative probability distributions derived from each model was based on the known uncertainties in key model parameters. Elicitation Parameter 2 deals with the probability of an ignition source and, of course, a rational model could not be developed for this case. The approach here was to narrow (or bound) the uncertainty band of the expert judgements by appealing to the Hanford cumulative experience of ignition-free gas releases in DSTs. Elicitation Parameters 6 and 7 are essentially the same as those previously addressed for SSTs and it was decided that the probabilities (fractiles) assigned to the SSTs should be similar to and appropriate for the DSTs.

Elicitation Parameters 3 and 4 were the most amenable to the modeling approach of the expert. It is notable that the predicted mass released from a failed DST is considerably larger than the expert's previous predictions of the mass released from an SST headspace following a burn that results in tank failure. This difference is a direct consequence of the breakup of the floating crust in the DST and the exposure of a liquid (supernatant) waste surface to the venting headspace gas. The SY-101 videotape attests to the absence of a protective surface crust during a large GRE. It is the expert's opinion that DST liquid waste entrained by the venting headspace gas produces a higher downwind radiological dose potential than that downwind of an SST with an identical dome-rupture opening.

2.0 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTs THAT HAVE A THICK LAYER OF LIQUID (> 1.0 M) BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BUOYANT DISPLACEMENT-TYPE GRES

Since by definition the subject double shell tanks (DSTs) have a thick, convective layer of liquid overlying the relatively stiff, gas-generating waste (nonconvective) layer, it is this expert's opinion that the potential for a buoyant displacement gas release event (GRE) is far greater than the potential for a spontaneous GRE of the type already assessed for the single shell tanks (SSTs; Epstein, 1997). Therefore, the confidence level values for the frequencies of GRES in the inactive DSTs (non-burpers) are estimated by considering low-frequency buoyant displacement GRES to be in the spontaneous GRE category and, moreover, to be the most likely GRE among all possible spontaneous GRES.

Suppose that the waste chemistry and rheology in a representative non-burper is such that the rate at which the gas concentration (void) in the nonconvective layer increases and approaches the neutral buoyancy void value α_{nb} required for a rollover is so gradual that the time between GRES exceeds the number of years of tank operating or monitoring experience. Slow void buildup implies that the rate at which gas is transported upward and out of the nonconvective layer is only slightly less than the rate at which gas is generated within the layer. Assuming that the gas generation rate G (mole day⁻¹ m⁻³), pressure P_{nc} , temperature T_{nc} and gas void fraction α are spatially uniform within the nonconvective layer we may write the following void conservation equation:

$$\frac{d\alpha}{dt} = \frac{GR_{id}T_{nc}}{P_{nc}} - \frac{u_g}{H_{nc}} \alpha \quad (2-1)$$

In Eq. (2-1) t is time, H_{nc} is the height of the nonconvective layer, R_{id} is the universal gas constant, u_g is the upward gas migration velocity. The product $u_g \alpha$ in Eq. (2-1) is the upward superficial gas velocity and is based on the implicit assumption that upward gas migration in the nonconvective layer can be described by a Stokes-law-type bubble-rise mechanism. Integrating Eq. (2-1) from the initial condition $\alpha = \alpha_0$ at $t = 0$ to the nonconvective layer's neutral buoyancy condition $\alpha = \alpha_{nb}$ at $t = t_p$ gives

$$t_p = \frac{H_{nc}}{u_g} \ln \left[\frac{GR_{id}T_{nc}/P_{nc} - u_g \alpha_0/H_{nc}}{GR_{id}T_{nc}/P_{nc} - u_g \alpha_{nb}/H_{nc}} \right] \quad (2-2)$$

where t_p is identified with the time period between rollover events (i.e., GRES).

*The meanings of all the symbols that appear in this report are summarized in Section 10.0.

At this point it is useful to introduce the symbol ϵ which is defined as the normalized difference between void growth by gas production and void removal by upward gas migration or, in mathematical terms,

$$\epsilon = \frac{GR_{id} T_{nc} / P_{nc} - u_g \alpha_{nb} / H_{nc}}{GR_{id} T_{nc} / P_{nc}} \quad (2-3)$$

In the limit of a very long period t_p between rollover events ($t_p \rightarrow \infty$) the two terms in the right-hand numerator of Eq. (2-3) are very close to one another in magnitude and accordingly the quantity ϵ is very small. Therefore, for purposes of evaluating the u_g 's in the coefficient and in the numerator of the logarithmic term of Eq. (2-2), one may write

$$u_g \approx \frac{H_{nc} GR_{id} T_{nc}}{P_{nc} \alpha_{nb}} \quad (2-4)$$

so that Eq. (2-2) becomes

$$t_p = \frac{P_{nc} \alpha_{nb}}{GR_{id} T_{nc}} [\ln (1 - \alpha_o / \alpha_{nb}) - \ln \epsilon] \quad (2-5)$$

An additional simplification is possible by noting that for low-frequency GREs

$$\ln (1 - \alpha_o / \alpha_{nb}) \ll \ln \left(\frac{1}{\epsilon} \right)$$

since, as will be shown below, $\epsilon \ll 1.0$. Thus Eq. (2-5) becomes

$$t_p \approx \frac{P_{nc} \alpha_{nb}}{GR_{id} T_{nc}} \ln \left(\frac{1}{\epsilon} \right) \quad (2-6)$$

This intuitively expected result simply states that the average time t_p between releases is directly proportional to the neutral buoyancy void fraction α_{nb} and inversely proportion to the gas generation rate G . Of course t_p is also a function of the relative rates of void generation and migration via the parameter ϵ . Presumably ϵ depends very much on the chemistry and rheology of the nonconvective waste layer. It is reasonable to suppose that the waste materials in the non-burping tanks are similar enough to one another that the ϵ for one tank does not vary by more than a few orders of magnitude from the ϵ for another tank. Note from Eq. (2-6) that a variation

in ϵ by, say, 10^3 translates to a variation of about a factor of 7.0 in t_p . This is well within the uncertainty range associated with this parameter (see below) and, accordingly, $\ln(1/\epsilon)$ will be taken to be a constant of proportionality in Eq. (2-6) that applies to all the non-burping tanks. The elicitation parameter of interest is the release frequency f_{rel} , which is simply the inverse of Eq. (2-6), or

$$f_{rel} = \frac{CGR_{id}T_{nc}}{P_{nc} \alpha_{nb}} \quad (2-7)$$

where $1/\ln(1/\epsilon)$ has been replaced by the proportionality coefficient C. The value of C is estimated below using the bounding f_{rel} value.

Construction of the DSTs was completed about 12 years ago. Twenty two of the DSTs have not yet exhibited a rollover. Three of these tanks may be eliminated from consideration because their convective layers are less than 1.0 m in height. The nonconvective layers in seven additional DSTs are too thin (≈ 3.0 cm) to be of any concern with respect to the storage of gas. Thus the upper bound frequency $f_{rel,ub}$ of GREs in the remaining twelve tanks is assessed to be $(1/12)(1/12)$ events per year, or roughly

$$f_{rel,ub} \approx 10^{-2} \text{ events (year)}^{-1} \quad (2-8)$$

The numerical values of the group $GR_{id}T_{nc}/(P_{nc} \alpha_{nb})$ in Eq. (2-7) were calculated for each of the 12 non-burping (but potentially gas releasing) tanks from the information provided by Stewart (1998a). Substituting into Eq. (2-7) the largest value of this group, $GR_{id}T_{nc}/(P_{nc} \alpha_{nb}) = 0.59 \text{ (year)}^{-1}$ for Tank AN-107, together with the upper bound frequency from Eq. (2-8), gives $C = 1.7 \times 10^{-2}$ (or $\epsilon = 2.4 \times 10^{-26}$). Thus the remaining fractiles for f_{rel} are estimated with the relation

$$f_{rel} = 1.33 \times 10^{-2} \frac{GR_{id}T_{nc}}{P_{nc} \alpha_{nb}} \quad (2-9)$$

The twelve calculated values of $GR_{id}T_{nc}/(P_{nc} \alpha_{nb})$ were arranged into a cumulative distribution from which the lower bound, 5th, 50th, and 95th values of $GR_{id}T_{nc}/(P_{nc} \alpha_{nb})$ were determined. These are, respectively, 7.1×10^{-3} , 8.7×10^{-3} , 2.7×10^{-2} , and 0.35, all in units of year^{-1} . From Eq. (2-9) the corresponding fractile values for f_{rel} in units of events per year are 9.4×10^{-5} , 1.2×10^{-4} , 3.6×10^{-4} , and 4.7×10^{-3} .

With regard to the conditioning factors for the frequency of releases, it is noteworthy from the DST gas release histories compiled by Meyer et al. (1997) for the burping tanks that the rollover GRE periods are essentially independent of the size of the release. The GRE period for the small releases observed in Tank AN-103 is, on average, 160 days. The average GRE periods for the

medium releases in Tanks AN-104, AN-105, AW-101 and SY-103 vary between 90 and 220 days. The large releases in Tank SY-101 were separated by about 110 days. Based on this evidence we will assume that the release frequencies for the hypothesized low-frequency rollovers in the non-burping tanks are also independent of the size of the release. The estimated frequencies are listed in Table 2-1.

Table 2-1. Frequency of Small, Medium and Large Spontaneous Gas Releases (Low-Frequency Rollovers) in DSTs with Thick Supernatant Layers But That Do Not Pass Buoyant Displacement Tests.

Fractile	GRE Frequency (year) ⁻¹
Lower Bound	9.4×10^{-5}
5th	1.2×10^{-4}
50th	3.6×10^{-4}
95th	4.7×10^{-3}
Upper Bound	10^{-2}

3.0 PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

The only possible source of ignition caused by a buoyant displacement GRE is an incendive spark. This expert does not believe that GREs are energetic enough to result in electrical equipment failure. Sparking may occur if the supernatant motion is capable of flexing the pipes (instrument tubes) that reach into the waste (from above) to an extent significant enough to cause them to contact one another up in the headspace. There are two reasons why this expert feels that such a GRE-induced ignition source is not a very likely event. First, it is doubtful that the natural frequency of the submerged pipes is close to the natural frequencies of the inertial supernatant oscillations. Far removed from resonance conditions, little of the supernatant wave energy is imparted to the submerged object and repetitive sparking is precluded. Secondly, the motion that is transmitted to the pipes during the GRE will probably subside before a flammable region of significant size has a chance to form in the headspace. It is recognized that gradual bending of tubes inserted into the waste is possible owing, say, to level drop and the concomitant lateral forces imposed by the floating crust, but this is not a likely mechanism of sparking.

3.1 SMALL EFFICIENCY BUOYANT DISPLACEMENT GRE

The small gas release probably occurs through openings in the floating crust. The corresponding motion of the waste is regarded as trivial. We estimate that the combined probability of inserted equipment motion (10^{-3}) and sparking (10^{-2}) in a flammable region of the headspace is near-risk insignificant and assign a probability of 10^{-5} for this case. A two-decade level of uncertainty is associated with this estimate; so that the 5th and 95th fractiles are 10^{-6} and 10^{-4} (see Table 3-1). The upper bound and 95th fractile are taken to be identical.

Table 3-1. Probability of Small GRE-Induced Ignition Source.

Fractile	Probability
5th	10^{-6}
50th	10^{-5}
95th	10^{-4}
Upper Bound	10^{-4}

3.2 MEDIUM EFFICIENCY BUOYANT DISPLACEMENT GRE

Obviously, a medium release is a more energetic event than a small release and the probability of producing a spark in a flammable region is judged to be at about a factor of ten greater than that for a small release. The combined probability of motion-induced sparking and ignition is approximated as one in ten thousand releases with a factor of 100 uncertainty between the 5th and 95th fractiles. These judgements are given in Table 3-2. Note that the upper bound probability in the table was estimated by appealing to the known gas release histories from waste level measurements (Stewart et al., 1996). Approximately 111 buoyant displacement GREs releasing over 5% of the stored gas have occurred but failed to ignite the released gas.

Table 3-2. Probability of Medium GRE-Induced Ignition Source.

Fractile	Probability
5th	10^{-5}
50th	10^{-4}
95th	10^{-3}
Upper Bound	10^{-2}

3.3 LARGE EFFICIENCY BUOYANT DISPLACEMENT GRE

One can bound the probability of an ignition source being induced by a large GRE. Referring once again to Stewart et al. (1996), about 20 large GREs (releasing over 25% of the stored gas) have been recorded in the burping tanks which have not been ignited. Therefore the bounding probability is 0.05. The 95th confidence level value is judged to be about 0.01, or a factor of five less than the bounding value. The 50th fractile is assessed at 10^{-3} and the 5th at 10^{-4} (see Table 3-3).

Table 3-3. Probability of Large GRE-Induced Ignition Source.

Fractile	Probability
5th	10^{-4}
50th	10^{-3}
95th	10^{-2}
Upper Bound	0.05

4.0 TOTAL MASS OF TRANSPORTABLE WASTE MATERIAL (A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (B) RELEASED FROM A DST BY A COMBUSTION EVENT THAT CAUSES STRUCTURAL FAILURE OF A DST

4.1 TOTAL MASS OF TRANSPORTABLE WASTE SUSPENDED IN DST HEADSPACE BY BURN INSUFFICIENT TO FAIL HEPA FILTER

The estimated amount of material suspended in a DST headspace by a small burn (deflagration) is based solely on the mechanism of aerodynamic entrainment of deposited solid-waste particles. The particles exposed to a passing deflagration wave are assumed to be located on the upper surface of the floating crust and/or on the dome or wall of the tank. The dependence of the particle entrainment mass flux $\dot{m}_p''$ (in $\text{kg m}^{-2} \text{s}^{-1}$) on the air (burned gas) velocity U_∞ is assumed to be of the form (see Epstein, 1997)

$$\dot{m}_p'' = k U_\infty^3 \quad (4-1)$$

where k is an empirical constant (in $\text{kg s}^2 \text{m}^{-5}$). The functional form of Eq. (4-1) is suggested by the work of Reynolds and Slinn (1979) and the values of the empirical constant k are inferred from the data reviewed by Gelbard and Brockmann (1997).

Starting with Eq. (4-1), the following relationship between the mass m_p of waste particles suspended and final combustion pressure $P_{\max}$ was derived by Epstein (1997)

$$m_p = \frac{1}{2} k U_{\infty}^2 \left(\frac{V_{hs}}{\rho_u/\rho_b - 1} \right) \left[\left(\frac{P_{\max}}{P_0} \right)^{1/\gamma_b} - 1 \right] \quad (4-2)$$

where ρ_u , ρ_b are the densities of the unburned and burned gases, respectively, γ_b is an effective isentropic exponent of the burned gas, P_0 is the initial headspace pressure, and V_{hs} is the volume of the headspace. For a stoichiometric hydrogen/air mixture, $\rho_u/\rho_b = 6.89$ and $\gamma_b = 1.08$. In deriving Eq. (4-2) it was assumed that the flammable gas region is ignited centrally, the flame front is hemispherical and propagates outward from the ignition location with constant speed U_{∞} , the velocity of the burned gases behind the deflagration wave is spatially uniform and equal to U_{∞} , and that the final pressure at the end of the combustion process can be related to the volume burned V_b (headspace air + released fuel gas) by

$$\frac{P_{\max}}{P_0} = \left[1 + \left(\frac{\rho_u}{\rho_b} - 1 \right) \frac{V_b}{V_{hs}} \right]^{\gamma_b} \quad (4-3)$$

Equation (4-3) follows from the work reported in Epstein et al. (1986).

There is considerable uncertainty as to the value to assign the crucial entrainment constant k in Eq. (4-2). The value of k that, when inserted into Eq. (4-1), bounds from above all the data collected by Gelbard and Brockmann (1997) is $k = 1.25 \times 10^{-4} \text{ kg s}^2 \text{m}^{-5}$. On the other hand, substituting the value $k = 9.5 \times 10^{-11} \text{ kg s}^2 \text{m}^{-5}$ into Eq. (4-1) results in an $\dot{m}_p$ versus U_{∞} relation that bounds all the data from below. The best estimate value of k is taken to be $10^{-6} \text{ kg s}^2 \text{m}^{-5}$ which when substituted into Eq. (4-1) produces an $\dot{m}_p$ versus U_{∞} curve that passes through the "centroid" of the data base in that half the data sets lie above the curve and the remaining half lie below the curve.

It is reasonable to assume that the waste particles on the floating crust or on the inside surface of the dome do not behave as dry powders. Because the waste particles are moist, the forces of adhesion of particles to the substrate surface are considerably larger than the adhesion forces measured for dry particles. It is known from the work of Reynolds and Slinn (1979) that the entrainment rate is reduced from the "dry values" by at least one-order-of-magnitude when the powder is moist. Thus the above estimated values of k are reduced by this amount to get the "working values" summarized in Table 4-1.

Table 4-1. Entrainment Coefficient (k) Values for Waste Particle Entrainment Estimates.

Estimate Type	k (kg s ² m ⁻³)
High	1.25 x 10 ⁻⁵
Best	1.0 x 10 ⁻⁷
Low	9.5 x 10 ⁻¹²

The other parameter in Eq. (4-2) besides k that is subject to considerable uncertainty is the flame speed U_{∞} . The flame speed is related to the turbulent burning velocity S_t by the equation

$$U_{\infty} = \frac{\rho_u}{\rho_b} S_t \quad (4-4)$$

The turbulent burning velocity correlation for hydrogen-air mixtures proposed by Koroll et al. (1993) predicts burning velocities in good agreement with their measured values. The correlation is

$$\frac{S_t}{S_u} = \left[1 + 16.0 \left(\frac{u'}{S_u} \right)^2 \right]^{1/2} + \frac{1}{\sqrt{3}} \left[1 - \exp \left(- \frac{u'}{S_u} \right) \right] \left(\frac{\rho_u}{\rho_b} - 1 \right) \quad (4-5)$$

where S_u is the laminar burning velocity and u' is the effective r.m.s. velocity of the isotropic turbulence in the gas mixture. High turbulence intensities may be produced locally within the headspace during a plume release. The gas velocity within the plume may be estimated with the formula recommended by Blevins (1984)

$$u = 3.5 \left(\frac{Qg}{H} \right)^{1/3} \quad (4-6)$$

where Q is the gas-release rate (in m³ s⁻¹), g is the gravitational constant and H is the height of the headspace. Inserting the representative values $Q = 0.1$ m³ s⁻¹ and $H = 5.0$ m gives $u = 2.0$ m s⁻¹. The r.m.s. velocity u' is typically about 10 percent of the flow velocity so that $u' = 0.2$ m s⁻¹. Substituting this estimate of u' into Eq. (4-5) together with $S_u = 3.5$ m s⁻¹ for a stoichiometric H₂-air mixture we get $S_t = 4.3$ m s⁻¹. We note that the laminar and turbulent burning velocities are not significantly different from one another. From Eq. (4-4) we estimate $U_{\infty} = 30.0$ m s⁻¹.

Now outside the plume flow the r.m.s. velocity fluctuations are relatively low and are determined by the natural convection process that normally drives the headspace air flow. A rough estimate is $u' \approx 0.05 (gH\Delta T/T)^{1/2} \approx 0.029 \text{ m s}^{-1}$, based on a headspace temperature $T \approx 30^\circ\text{C}$ and a waste surface-to-dome temperature difference $\Delta T \approx 2.0^\circ\text{C}$. Also, the hydrogen concentration is likely to be below the stoichiometric value (30 volume percent). Perhaps a more reasonable flame speed value is obtained by considering a 20% hydrogen-air mixture for which $S_t \approx S_u \approx 1.5 \text{ m s}^{-1}$ and, from Eq. (4-4), $U_\infty \approx 10.0 \text{ m s}^{-1}$. A low estimate is assessed to be $U_\infty \approx 3.0 \text{ m s}^{-1}$ by considering $S_t \approx S_u = 0.5 \text{ m s}^{-1}$ for a 12% hydrogen-air mixture. The above-estimated flame speeds are summarized in Table 4-2.

Table 4-2. Flame Speed (U_∞) Values for Waste Particle Entrainment Estimates.

Estimate Type	U_∞ (m s^{-1})
High	30.0
Best	10.0
Low	3.0

We are now in a position to use Eq. (4-2) to estimate the mass of waste suspended by a burn that is insufficient to fail the HEPA filter. The headspace pressure increase required to fail the filter is about 1.5 psi. Thus the pertinent final-to-initial pressure ratio to use in Eq. (4-2) is $P/P_0 = 1.1$. The headspace volume will be assumed to be $V_{hs} = 2500 \text{ m}^3$ and ρ_w/ρ_0 and γ_b will be held fixed at the stoichiometric values 6.89 and 1.08, respectively. The upper bound value of the mass suspended, $m_{p,ub}$, is assessed by identifying kU_∞^2 in Eq. (4-2) with the product of the high k value in Table 4-1 and the square of the high U_∞ value in Table 4-2. The result is $m_{p,ub} = 0.22 \text{ kg}$. The 95th fractile mass suspended $m_{p,95}$ is obtained by, again, using the high value of k in Table 4-1 but multiplying it by the square of the best estimate value of $U_\infty = 10.0 \text{ m s}^{-1}$, giving $m_{p,95} = 0.024 \text{ kg}$. The 50% confidence level value is based on the best estimate values of k and U_∞ listed in Tables 4-1 and 4-2, respectively. The computed suspended mass is $m_{p,50} = 2.0 \times 10^{-4} \text{ kg}$. The low entrainment coefficient value $k = 9.5 \times 10^{-12} \text{ kg s}^{-2} \text{ m}^{-5}$ and the best estimate flame speed $U_\infty = 10.0 \text{ m s}^{-1}$ are substituted into Eq. (4-2) to get the 5th fractile suspended mass $m_{p,5} = 1.9 \times 10^{-8} \text{ kg}$. Finally, the lower bound value of the mass suspended, $m_{p,lb}$, is calculated with the low estimates of k and U_∞ in Tables 4-1 and 4-2 and is $m_{p,lb} = 1.7 \times 10^{-9} \text{ kg}$. The fractile estimates are summarized below in Table 4-3.

Table 4-3. Mass Suspended in DST Headspace by
Burn Insufficient to Fail HEPA.

Fractile	m_p (kg)
Lower Bound	1.7×10^{-9}
5th	1.9×10^{-8}
50th	2.0×10^{-4}
95th	2.4×10^{-2}
Upper Bound	0.22

4.2 TOTAL MASS OF TRANSPORTABLE WASTE SUSPENDED IN DST HEADSPACE BY BURN < 20 PSIG WITH HEPA FAILURE

According to Eq. (4-3), a pure hydrogen gas release sufficient to produce a combustion pressure rise of 20 psi would require about 150 m^3 of hydrogen in a headspace volume $V_{hs} \approx 2500 \text{ m}^3$. This is a fairly substantial GRE and all the visual evidence indicates that such a release would result in the breakup of the surface crust and its submergence below the surface of the liquid supernatant (see video of SY-101 rollover). Thus rather than stripping and entrainment of solid-precipitate floating-crust material we must consider the possibility of entrainment of liquid waste (supernatant) at its exposed surface. The liquid waste can only be "lifted" into the headspace in the wake of a deflagration wave if the gas flow behind the wave is sufficient to suspend the liquid against gravity. The critical gas velocity u_{cr} for droplet fluidization (entrainment) by the gas flow can be estimated by using the Kutateladze (1972) correlation

$$u_{cr} = 3.0 \left(\frac{\sigma g \rho_f}{\rho_g^2} \right)^{1/4} \quad (4-7)$$

where ρ_g and ρ_f are the densities of the gas and liquid waste, respectively, and σ is the surface tension of the liquid waste. Entrainment at the liquid surface by the gas flow induced by the combustion wave becomes hydrodynamically possible when

$$U_{\infty} > u_{cr} \quad (4-8)$$

Now the density of the waste liquid is about $\rho_f = 1400 \text{ kg m}^{-3}$. The density of the burned gas behind the deflagration wave is approximately $\rho_g = 0.3 \text{ kg m}^{-3}$ (at 35 psi and 2700 K). Thus, assuming that the surface tension of the waste liquid is similar to that of water, namely $\sigma = 0.07 \text{ N m}^{-1}$, the entrainment onset velocity inferred from Eq. (4-8) is $u_{cr} = 31.0 \text{ m s}^{-1}$. This

value is just above the range of deflagration wave speeds deemed by this expert to be possible (see Table 4-2). Thus the amount of liquid entrained by the passage of a deflagration is likely to be insignificant.

The gas release event itself can produce liquid aerosol via the bubble bursting process at the liquid-waste surface. Each bubble rises to the liquid surface and forms a dome-shaped lamina that ruptures. There is a considerable literature on the amount of aerosol created by the bursting of bubbles. The results of Tomaides and Whitby (1976) are probably the most pertinent in terms of the present application. They examined aerosol formation when 0.55-cm diameter bubbles burst at the surface of an aqueous solution of NaCl. About 200 droplets of approximately 5.0 μm -mean diameter were observed per bubble burst. This indicates that the ratio of the volume of liquid aerosol V_f to the volume of the bubble (released gas) V_g is

$$\frac{V_f}{V_g} \approx 1.5 \times 10^{-7} \quad (4-9)$$

where the subscript f refers to liquid aerosol produced by bubble bursting. Garner et al. (1954) measured the volume of the aerosol drops produced above bursting bubbles in the 6.0 to 12.0 mm range in water containing a suspension of calcium carbonate. The volume of liquid ejected is approximately represented by Eq. (4-9). From Eq. (4-9) the mass of liquid aerosol generated by the GRE is

$$m_{f,50} = 1.5 \times 10^{-7} \rho_f V_g \quad (4-10)$$

Since the numerical value 1.5×10^{-7} in Eq. (4-9) is derived by cubing the measured mean droplet diameter (Tomaides and Whitby, 1976) it is felt that there is probably a two-order-of-magnitude range of uncertainty associated with this value. Equation (4-10) is regarded as the 50% confidence level estimate of m_f . The 5% and 95% fractiles of m_f are obtained from the relations

$$m_{f,5} = 1.5 \times 10^{-8} \rho_f V_g \quad (4-11)$$

$$m_{f,95} = 1.5 \times 10^{-6} \rho_f V_g \quad (4-12)$$

As mentioned previously the amount of flammable gas (H_2) necessary to produce, upon combustion, a headspace pressure rise of 20 psi is about 150 m^3 . It follows from Eqs. (4-10) to (4-12) that the passage of this amount of gas through the liquid waste surface could conceivably generate a liquid aerosol mass within an uncertainty range given by

$$m_{f,5} \approx 3.2 \times 10^{-3} \text{ kg} \quad , \quad m_{f,50} = 3.2 \times 10^{-2} \text{ kg} \quad , \quad \text{or} \quad m_{f,95} = 0.32 \text{ kg} \quad (4-13)$$

In addition to the aerosol produced by the bursting of the released gas bubbles, a deflagration following the GRE can result in the removal of deposited waste material from the inside surfaces of the tank dome and wall. The solid-particle mass suspended is calculated using Eq. (4-2) and the k and U_o entries in Tables 4-1 and 4-2. The only, but significant difference between the

particle erosion estimates of the previous section and those of the present case is the higher final combustion pressure of $P_{\max} = 14.7 + 20.0 = 34.7$ psi. The fractile estimates listed in Table 4-4 represent the sum of the deflagration-removed solid material (particles) and the aerosol mass generated by bubbles piercing the liquid-waste surface. Note that the lower bound estimate is based on the assumption that the floating crust remains intact during the GRE so that $m_f = 0$ for this case. The upper bound estimate is the sum $m_{p,ub} + m_{f,95}$.

Table 4-4. Mass Suspended in DST Headspace by
Burn < 20 psig with HEPA Failure.

Fractile	$m_p + m_f$ (kg)
Lower Bound	2.2×10^{-8}
5th	3.2×10^{-3}
50th	3.2×10^{-2}
95th	0.63
Upper Bound	3.2

4.3 TOTAL MASS OF TRANSPORTABLE WASTE SUSPENDED IN DST HEADSPACE BY BURN > 20 PSIG BUT NO DOME FAILURE

In assessing this elicitation parameter the combustion pressure was assumed to rise to about 50 psig (65.0 psi). The volume of flammable gas released and burned was estimated from Eq. (4-3) to be 375 m^3 in a 2500 m^3 headspace. The calculations of the mass of transportable waste suspended in the headspace were performed in a manner identical to the calculations of the previous elicitation parameter, 3b. That is, both solid particle entrainment from internal surfaces above the waste swept by the burn wave and aerosol formation by bubble bursting at the liquid-waste surface comprise the estimates presented in Table 4-5.

Table 4-5. Mass Suspended in DST Headspace by
Burn > 20 psig But No Dome Failure.

Fractile	$m_p + m_f$ (kg)
Lower Bound	5.3×10^{-8}
5th	8.0×10^{-3}
50th	8.6×10^{-2}
95th	1.6
Upper Bound	7.7

4.4 TOTAL MASS OF TRANSPORTABLE WASTE RELEASED FROM DST BY BURN THAT CAUSES DOME FAILURE

To assess this elicitation parameter it is assumed that the pressure increase exceeds the dome failure pressure and is, say, 85 psi. The corresponding total pressure at the end of the combustion process is, therefore, 100 psi. The estimated amount of flammable gas released and burned to produce this pressure in a 2500 m³ headspace is $V_g \approx 625$ m³. The likely failure mode from internal tank pressurizations that exceed the DST failure pressure is a 6 ft-radius-"can-opener" flap-type rupture opening in the tank dome (Juryk, 1998). The failure would likely blow out part of the concrete and soil above the 6-ft radius (10.5 m²) opening with limited fall back of debris to the failed portion of the dome. Concrete/debris masses falling from the dome into the liquid waste (supernatant) should be limited by the remaining rebar net and the primary steel liner. The release is assumed to be of sufficient strength to wipe away the floating crust and expose the supernatant to headspace air. Four mechanisms of waste aerosolization are considered: (i) liquid aerosol produced by bubble bursting at the liquid waste surface, (ii) aerodynamic entrainment of solid deposits in the wake of a deflagration wave, (iii) aerodynamic entrainment of liquid waste (supernatant) in the wake of a deflagration wave, and (iv) the entrainment of the supernatant by the venting combustion products/air mixture. An 8.3-ft radius (20 m²) opening having nearly twice the venting area of the likely rupture will be regarded as the bounding dome failure.

Mechanisms (i) and (ii) have already been discussed. Using the methodology outlined in Sections 4.1 and 4.2, but for a combustion pressure of 100 psi and a gas release volume of 625 m³, we obtain the results displayed in Table 4-6. The "lower bound" entry in the table is based on the assumption of an immobile floating crust that protects the supernatant from headspace air motion and suppresses the bubble bursting process.

Table 4-6. Mass Suspended in DST Headspace by Bubble Bursting (Mechanism i) and Solid Deposit Entrainment (Mechanisms ii) During Burn.

Fractile	$m_p + m_r$ (kg)
Lower Bound	8.9×10^{-8}
5th	1.3×10^{-2}
50th	0.14
95th	2.56
Upper Bound	13.0

With regard to mechanism (iii), we have shown in Section 4.2 that the gas velocity behind a deflagration wave is probably not sufficient to aerodynamically entrain the supernatant. However, in that case the headspace pressure rise was 20 psi whereas in the situation considered here the pressure rise is 85 psi. For the strongest deflagration wave considered ($U_w = 30 \text{ m s}^{-1}$, see Table 4-2) the headspace air becomes dense enough toward the end of the burn to begin to strip supernatant from the surface of the waste. This process only contributes to the upper bound estimate of the mass suspended and is likely to be unimportant compared with venting-induced entrainment (mechanism iv), which is the subject of the rest of this subsection.

If the rupture opening in the dome is large enough surface entrainment of the waste liquid by the headspace air is possible via mechanism iv. In order to determine the potential for liquid waste entrainment, knowledge of the rupture-induced gas flow in the headspace of the waste tank is required. To assess the potential for entrainment in liquid-filled storage tanks during venting, Epstein et al. (1989) showed that a single axisymmetric description of the flow is adequate, and they derived the following equation for the critical vent (rupture opening) area A_{cr} above which liquid surface entrainment takes place:

$$A_{cr} = \frac{2\pi H^2 u_{cr}}{U_o} \quad (4-14)$$

where u_{cr} is given by Eq. (4-7), H is the height of the headspace, and U_o is the gas velocity within the entrance plane of the rupture opening. The latter quantity can be estimated using the well-known single-phase compressible flow result for maximum or "choked" flow

$$U_o = C_D \Gamma(\gamma) (R_i T_{hs})^{1/2} \quad (4-15)$$

where C_D is the rupture opening discharge coefficient, R_i is the ideal gas constant of the venting headspace gas, T_{hs} is the instantaneous gas temperature in the headspace and $\Gamma(\gamma)$ is the following function of the specific heat ratio γ of the headspace gas:

$$\Gamma(\gamma) = \gamma^{1/2} \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma+1}{2(\gamma-1)}} \quad (4-16)$$

As a result of the deflagration the waste-tank gas temperature rises to about $T_{hs} = 2700$ K. Based on the headspace gas properties (for air) $\gamma = 1.4$, $\Gamma(1.4) = 0.685$, $R_i = 287.0$ J kg⁻¹ K⁻¹ and a rupture orifice coefficient $C_D = 0.6$, we estimate from Eqs. (4-15) and (4-16) that $U_o = 361$ m s⁻¹. Substituting the supernatant properties $\sigma = 0.07$ N m⁻¹, $\rho_f = 1400$ kg m⁻³ and headspace gas density $\rho_g = 0.88$ kg m⁻³ into Eq. (4-7) gives $u_{cr} = 17.8$ m s⁻¹. The vertical extent of the headspace is about $H = 5.0$ m. Thus Eq. (4-14) reveals that liquid waste entrainment is possibly when the area of the rupture opening exceeds $A_{cr} = 7.7$ m² or, equivalently, when the opening radius exceeds $R_{cr} = 1.6$ m (5.1 ft). The dimensions of the critical rupture opening for incipient entrainment are below those of the most likely failure opening of radius 1.83 m (6.0 ft) and $A = 10.5$ m² (Julyk, 1998); therefore, liquid entrainment due to gas flow to the rupture opening is a mechanism that should be considered.

At this point it should be mentioned that there are two mechanisms by which the venting gas may "pull" liquid to the rupture opening. One mechanism emerges from the well-known fact that wind blowing over a liquid surface generates small (capillary) waves. In regions where the gas flow is parallel to the waste surface droplet formation will occur when the ratio of amplitude to wave length for these waves becomes too large for the crests to remain an integral part of the liquid. This wind-capillary wave mechanism is usually referred to as the Kelvin-Helmholtz (K-H) mechanism. Equation (4-7) for the onset of entrainment is based on the K-H mechanism. The second entrainment mechanism involves the development of a single liquid slug or surge wave just beneath the rupture orifice location. The slug transitions to an upside-down liquid vortex which grows up to and then into the vent. Vortex formation is known to be responsible for entrainment during choked discharges from small scale breaks in piping containing flowing stratified air/water layers (see, e.g., Schrock et al., 1986). Vortex formation is predicted to be possible in a waste tank with a 6-ft radius rupture opening and a headspace height less than approximately 6 m. However, it is this expert's opinion that, given the large liquid surface area within the tank and the short gas discharge time (< 1.0 sec; see below), the potential for vortex formation is low. Here we adopt the K-H mechanism to account for gas-venting-induced entrainment.

In addition to determining the critical rupture area A_{cr} below which entrainment ceases it is useful in calculating the mass suspended to know the critical headspace pressure P_{cr} below which entrainment is cutoff for a fixed rupture area "A". The expression for P_{cr} may be determined by first eliminating u_{cr} between Eqs. (4-7) and (4-14) and then using Eq. (4-15) and the ideal gas law to replace $\rho_g R_i T_{hs}$ by P . These manipulations give

$$P_{cr} = \left(\frac{6\pi H^2}{C_D \Gamma(\gamma) A} \right)^2 (\sigma g p)^{1/2} \quad (4-17)$$

For the most likely rupture-opening-area $A = 10.5 \text{ m}^2$, and Eq. (4-17) indicates that $P_{cr} = 0.37 \text{ MPa}$ (54.0 psi). As mentioned previously, the upper bound rupture opening is assumed to be $A = 20.0 \text{ m}^2$, nearly twice that of the most likely rupture, for which we estimate $P_{cr} = 10.8 \text{ psi}$. This low, non-physical P_{cr} suggests that in the bounding case liquid entrainment off the surface of the waste will persist throughout most of the headspace depressurization transient.

By combining Eq. (4-15) with a mass balance for the headspace, an expression for the gas discharge time t_d through the rupture opening as a function of gas pressure P is obtained:

$$t_d = \frac{2 V_{hs}}{A U_o (\gamma - 1)} \left[\left(\frac{P_{max}}{P} \right)^{\frac{\gamma - 1}{2\gamma}} - 1 \right] \quad (4-18)$$

where P_{max} is the peak tank pressure as a consequence of the deflagration. Strictly speaking, Eqs. (4-17) and (4-18) are not valid for P values down to the ambient pressure P_{∞} because of the transition to a subsonic mass discharge rate. However, for present purposes, the error incurred by letting $P = P_{\infty}$ in Eq. (4-18) can be tolerated.

Returning to the problem of interest, namely headspace volume $V_{hs} = 2500 \text{ m}^3$, $P_{max} = 100 \text{ psi}$, $U_o = 361 \text{ m s}^{-1}$, and $A = 10.5 \text{ m}^2$ for the likely rupture opening, we estimate from Eq. (4-18) that it takes 0.3 s for the headspace gas pressure to be reduced to $P_{cr} = 54.0 \text{ psi}$ at which time entrainment ends. We know from the previous discussion that for the upper bound rupture opening entrainment continues until the tank depressurizes to near-atmospheric pressure. Inserting $A = 20 \text{ m}^2$ and $P = 15 \text{ psi}$ in Eq. (4-18) gives a depressurization time or, equivalently, an entrainment time of 0.55 s.

An expression for the calculation of the liquid entrainment rate, for rupture areas that exceed the critical opening area corresponding to the onset of surface entrainment (see Eq. 4-14), is developed by exploiting the remarkably successful entrainment model (hypothesis) for turbulent jets and boundary layers (Morton et al., 1956; Morton, 1959; and Ricou and Spalding, 1961). According to this semiempirical model, the velocity v_e with which the liquid is swept into the gas flow by entrainment is

$$v_e = \begin{cases} E_o u (\rho_g / \rho_l)^{1/2} & u > u_{cr} \\ 0 & u < u_{cr} \end{cases} \quad (4-19)$$

where u is the local flow velocity parallel to the liquid surface and E_o is the entrainment coefficient ($E_o \approx 0.1$). This expression was first developed for gas-phase mixing problems (see, e.g., Ricou and Spalding, 1961), but was later shown to be applicable to the entrainment of liquid by a gas flow (see, e.g., Weimer et al., 1973).

Let r be the coordinate measured along the surface of the waste liquid from the point on the surface that is located directly below the center of the rupture opening. The horizontal component of the gas velocity $u(r)$ just above the liquid surface and directed toward the opening is zero at $r = 0$ and increases as r increases. The velocity reaches a peak value $u_{\max}$ at some distance $r_{\max}$ between the center of the rupture opening and the tank wall which is assumed here to be located at $r = \infty$. The velocity $u(r)$ then decreases as r is increased beyond $r_{\max}$ and ultimately comes back to zero at the wall (i.e. at $r = \infty$). Liquid entrainment will begin at that location r_{on} ($r_{\max} < r_{\text{on}} < \infty$) where the gas velocity $u(r)$ is equal to the critical gas velocity u_{cr} for the onset of entrainment. Similarly liquid entrainment will cease at that location r_{off} ($r_{\text{off}} \leq r_{\text{on}}$) when the gas velocity falls below u_{cr} . It follows, then, from Eq. (4-19), that the mass of liquid entrained per unit time is

$$\dot{m}_e = \int_{r_{\text{off}}}^{r_{\text{on}}} \rho_f v_e(r) 2\pi r dr = 2\pi E_o (\rho_g \rho_f)^{1/2} \int_{r_{\text{off}}}^{r_{\text{on}}} u(r) r dr \quad (4-20)$$

This expert's experience with axisymmetric potential flows in cylindrical geometries indicates that the exact horizontal velocity component $u(r)$ in Eq. (4-20) may be approximately represented by the piecewise continuous expression

$$u(r) = \begin{cases} \frac{U_o R_o^2 r}{2 H^3} & 0 < r < H \\ \frac{U_o R_o^2}{2 H r} & H < r < \infty \end{cases} \quad (4-21)$$

where R_o is the radius of the rupture opening. The peak gas velocity $u_{\max}$ is reached at the radial location $r_{\max} = H$, at least according to Eq. (4-21). Now r_{on} may be located by using the lower equality in Eq. (4-21) and setting $u(r) = u_{\text{cr}}$ to get

$$r_{\text{on}} = \frac{U_o R_o^2}{2H u_{\text{cr}}} \quad (4-22)$$

Similarly r_{off} is obtained from the upper equality in Eq. (4-21) and is

$$r_{\text{off}} = \frac{2 H^3 u_{\text{cr}}}{U_o R_o^2} \quad (4-23)$$

The condition for incipient waste entrainment is obtained from the condition $r_{\text{on}} = r_{\text{off}}$ from which we recover Eq. (4-14). Thus the incipient entrainment condition proposed by Epstein et al. (1989) and the velocity profile given by Eq. (4-21) are consistent with one another.

Substituting Eq. (4-21) into Eq. (4-20) and carrying out the indicated integration gives, after some algebra,

$$\dot{m}_e = E_o (\rho_g \rho_f)^{1/2} U_o A \left[\frac{A}{A_{\text{cr}}} - \frac{1}{3} \left(\frac{A_{\text{cr}}}{A} \right)^3 - \frac{2}{3} \right] \quad (4-24)$$

To illustrate the use of this result let us reconsider the most likely rupture opening $A = 10.5 \text{ m}^2$ and the previously calculated critical opening $A_{\text{cr}} = 7.7 \text{ m}^2$ based on $U_o = 361 \text{ m s}^{-1}$, $\rho_g = 0.88 \text{ kg m}^{-3}$ and $\rho_f = 1400 \text{ kg m}^{-3}$, and for which the waste surface is subject to entrainment by the venting headspace air for 0.3 s. Introducing these estimates into Eq. (4-24) leads to the result $\dot{m}_e = 7.53 \times 10^3 \text{ kg s}^{-1}$. Assuming that U_o remains fairly constant in time during the venting period, the total mass of liquid entrained and, perhaps, carried through the rupture opening is $m_e = (7.53 \times 10^3) \times 0.3 = 2.3 \times 10^3 \text{ kg}$.

Most of the entrained droplets carried by the gas flow will fall on the ground just outside the rupture opening. To the best of this expert's knowledge there is no information available on the amount of liquid "rainout" from a two-phase air/water critical flow jet ejected upward. Small scale experiments performed by Johnson (1991) on horizontally directed high-pressure (18 to 110 psi) discharges of superheated water indicate a rainout fraction of about 90% for low water superheats (0 to 30 K) and about 55% for high water superheat (80 to 115 K). The superheat of the entrained waste-water drops is at most about 60 K (for $P_{\text{max}} = 100 \text{ psi}$). The corresponding "lower bound" rainout fraction from Johnson's data is about 75%. The most likely rainout fraction is taken to be 90%, owing to calculations that indicate the difficulty of heating the large entrained waste drops ($\sim 1.0 \text{ mm}$) to their boiling point during the short flight time ($\sim 0.2 \text{ s}$) from the waste surface to the rupture opening, and because the headspace pressure and, therefore, the maximum achievable superheat decreases rapidly with time.

The best estimate value of transportable entrained liquid is based on the most likely rainout fraction (90%) and the above-predicted $2.3 \times 10^3 \text{ kg}$ of liquid carried through the most likely rupture opening ($A = 10.8 \text{ m}^2$); i.e., $0.1 \times (2.3 \times 10^3)$, or

$$m_{e,50} = 2.3 \times 10^2 \text{ kg} \quad (4-25)$$

The 95th fractile m_e is estimated from Eq. (4-24) for headspace venting through a 20-m² rupture opening and concomitant liquid entrainment for a period of 0.55 s, resulting in the prediction $m_e = 2.7 \times 10^4$ kg. After accounting for 90% of the ejected liquid falling to the ground just outside the rupture opening, we estimate

$$m_{e,95} = 2.7 \times 10^3 \text{ kg} \quad (4-26)$$

The upper bound m_e is also based on a 20-m² rupture opening, but the lower, 75% rainout fraction is used to estimate the transportable mass, giving

$$m_{e,ub} = 6.7 \times 10^3 \text{ kg} \quad (4-27)$$

The results expressed by Eqs. (4-25) to (4-27) are added to the corresponding fractile entries in Table 4-6 to get the total mass fractiles of transportable waste released from an DST by a burn that causes dome failure. The computed fractiles are presented in Table 4-7. Note that the lower bound $m_{e,lb}$ and the 5th fractile $m_{e,5}$ are both zero because the rupture opening area for these cases is taken to be less than the critical area $A_{cr} = 7.7 \text{ m}^2$ for the onset of entrainment at the liquid-waste surface. For the 50th, 95th and upper bound fractiles the transportable waste produced by solid deposit entrainment and bubble bursting is insignificant compared to the transportable waste generated by the flow of venting headspace air over the exposed surface of the supernatant.

Table 4-7. Total Mass of Transportable Waste Released From a DST by a Burn That Causes Dome Failure.

Fractile	$m_p + m_f + m_e$ (kg)
Lower Bound	8.9×10^{-6}
5th	1.3×10^{-2}
50th	2.3×10^2
95th	2.7×10^3
Upper Bound	6.7×10^3

4.5 TOTAL MASS OF TRANSPORTABLE WASTE RELEASED FROM DST BY DETONATION THAT CAUSES DOME FAILURE

In this expert's opinion the presence of a detonation wave rather than a deflagration wave in the headspace atmosphere changes the elicitation parameter assessments from those summarized in Table 4-7 in three ways. First, the treatment of aerodynamic entrainment of solid particles behind a detonation wave requires the application of entrainment-coefficient- k values that are different from those used for deflagrations and listed in Table 4-1. Second, unlike the deflagration wave, liquid entrainment behind a detonation front that passes over the waste surface is important and should be considered. Finally, the liquid mass entrained by bubble bursting can be ignored compared with the waste material entrained by the aerodynamic mechanisms. On the other hand, the liquid-surface mass entrained by headspace venting through the dome-failure opening following a detonation should be the same as that predicted following a deflagration.

To estimate the mass of solid waste particles entrained behind a detonation wave we will make use of Eq. (4-2), recognizing full well that the characteristic velocity U_0 (2000 m s^{-1} for a stoichiometric H_2 /air mixture) is well above the experimental air flow velocities used to establish the available data base for the entrainment constant k (see Gelbard and Brockmann, 1997). The application of Eq. (4-2) together with the "best" and "high" values of the entrainment coefficients listed in Table 4-1 for detonation speed $U_0 \approx 2000 \text{ m s}^{-1}$ results in predicted exposure and erosion of particles that, in terms of particle layers, were initially deeply buried beneath the surface of the waste "cake". These buried particles are likely to be much more strongly bonded to one another than the waste surface particles. To approximately represent the strong particle adhesion forces we choose a new low-value $k = 10^{-12} \text{ kg s}^2 \text{ m}^{-5}$, as measured by Reynolds and Slinn (1979) for entrainment of fine particulate from moist substrates. Our best estimate of k will be taken to coincide with the value that bounds from below all the dry powder entrainment data, namely $k = 9.5 \times 10^{-11}$. The new, high value of k is the previous best estimate value $k = 10^{-7} \text{ kg s}^2 \text{ m}^{-5}$ for the dry powder data (see Table 4-1). The k values are summarized in Table 4-8.

Table 4-8. Entrainment Coefficient (k) Values for Detonation-Induced Waste Particle Suspension Estimates.

Estimate Type	k ($\text{kg s}^2 \text{ m}^{-5}$)
High	10^{-7}
Best	9.5×10^{-11}
Low	10^{-12}

The lower bound value of the solid particle mass suspended ($m_{p,lb}$) is based on $k = 10^{-12} \text{ kg s}^2 \text{ m}^{-5}$ from Table 4-8 and a detonation speed of 1000 m s^{-1} , which is typically the explosion wave velocity measured in large enclosures (Dorofeev et al., 1996). Upon substitution of these values (along with $V_{hs} = 2500 \text{ m}^3$, $P_{max} = 100 \text{ psi}$, $\rho_v/\rho_b = 6.89$, and $\gamma_b = 1.08$) into Eq. (4-2) we get $m_{p,lb} = 10^{-3} \text{ kg}$. Using $U_\infty = 1500 \text{ m s}^{-1}$ for a 15 vol% H_2/air mixture and, again, $k = 10^{-12} \text{ kg s}^2 \text{ m}^{-5}$, the calculated 5th fractile mass suspended is $m_{p,5} = 2.3 \times 10^{-3} \text{ kg}$. The 50th fractile is calculated from the best estimate $k = 9.5 \times 10^{-11}$ and $U_\infty = 1500 \text{ m s}^{-1}$. This gives $m_{p,50} = 0.22 \text{ kg}$. The 95th fractile $m_{p,95} = 310 \text{ kg}$ is based on $k = 10^{-7} \text{ kg s}^2 \text{ m}^{-5}$ (see Table 4-8) and $U_\infty = 1500 \text{ m s}^{-1}$. The upper bound value $m_{p,ub} = 420 \text{ kg}$ is predicted using $k = 10^{-7} \text{ kg s}^2 \text{ m}^{-5}$ and $U_\infty = 2000 \text{ m s}^{-1}$ (for a stoichiometric H_2/air mixture). These results are summarized in Table 4-9.

Table 4-9. Mass Suspended in DST Headspace by Solid Deposit Entrainment Behind Detonation Wave.

Fractile	m_p (kg)
Lower Bound	10^{-3}
5th	2.3×10^{-3}
50th	0.22
95th	3.1×10^2
Upper Bound	4.2×10^2

For purposes of calculating the liquid-waste entrained in the wake of a detonation wave, it is assumed that the detonation enters the headspace at a central location just above the liquid-waste surface and then propagates radially outward. Thus at time t following the appearance of the detonation the radial location of the detonation front is

$$R_d = U_\infty t \quad (4-28)$$

The instantaneous rate at which supernatant droplets are pulled from the waste surface behind the front is given by the product of the waste area covered by the flowing burned gases (πR_d^2) and the droplet entrainment flux given by Eq. (4-19)

$$\frac{dm_e}{dt} = (\pi R_d^2) \rho_f V_e = \pi E_0 (\rho_f \rho_g)^{1/2} U_\infty^3 t^2 \quad (4-29)$$

Integrating this expression and eliminating t in favor of R_d via Eq. (4-28) gives the following equation for the mass of liquid entrained as a function of the radial distance traveled by the detonation:

$$m_e = \frac{\pi}{3} E_0 (\rho_g \rho_f)^{1/2} R_d^3 \quad (4-30)$$

At very high gas velocities the rate of growth of the wind-driven capillary waves on the waste surface is damped by the effects of liquid viscosity. Thus Eq. (4-30) gives results that are too high. It can be shown that the functional form of Eq. (4-19) can be derived theoretically by interpreting the drop erosion rate as the breaking of infinitesimal-amplitude capillary waves and using Kelvin-Helmholtz (K-H) instability theory for an inviscid gas passing over an inviscid liquid (see e.g., Epstein and Fauske, 1989). Taylor (1963) treated the more complex K-H problem of an inviscid gas flowing over a viscous liquid. Using Taylor's numerical results for the wave number and growth time of the most rapidly growing capillary wave, we find that the entrainment velocity in the presence of viscosity, $v_{e,\mu}$, when normalized by the entrainment velocity v_e for inviscid material pairs, as given by Eq. (4-19), is strictly a function of the capillary number; that is

$$\frac{v_e}{v_{e,\mu}} = f \left[\sqrt{\frac{\rho_g}{\rho_f} \frac{\mu_f U_\infty}{\sigma}} \right] \quad (4-31)$$

where μ_f is the liquid (supernatant) viscosity. Computed values of $v_e/v_{e,\mu}$ as a function of the capillary number are given in Table 4-10. The liquid-waste mass entrained by the detonation, as predicted with Eq. (4-30), should be reduced by the ratio $v_e/v_{e,\mu}$ so that

$$m_e = \frac{\pi}{3} E_0 (\rho_g \rho_f)^{1/2} R_d^3 \cdot \left(\frac{v_e}{v_{e,\mu}} \right) \quad (4-32)$$

Table 4-10. Entrainment Velocity Ratio $v_e/v_{e,\mu}$
Versus Capillary Number.

$\frac{v_e}{v_{e,\mu}}$	$\sqrt{\frac{\rho_g}{\rho_f} \frac{\mu_f U_\infty}{\sigma}}$
1.0	0.00
0.91	0.2
0.82	0.5
0.72	1.0
0.6	2.0
0.5	5.0
0.42	10.0
0.32	20.0
0.24	50.0
0.19	100.0

The viscosity of the supernatant has been reported by Reynolds (1988) to be a function of the supernatant temperature, specific gravity and sodium concentration. The viscosity ranges between about 3.0×10^{-3} and 6.0×10^{-2} $\text{kg m}^{-1} \text{s}^{-1}$, with a mean value of about 2.0×10^{-2} $\text{kg m}^{-1} \text{s}^{-1}$. The corresponding ratios $v_e/v_{e,\mu}$ for the best estimated detonation speed $U_\infty = 1500 \text{ m s}^{-1}$, $\rho_g = 0.88 \text{ kg m}^{-3}$, $\rho_f = 1400 \text{ kg m}^{-3}$, and $\sigma = 0.07 \text{ N m}^{-1}$ are: 0.64, 0.26 and a mean value 0.41. In estimating the fractile values of m_e , we will assume that in all cases the radial distance traveled by the detonation is $R_d = 10 \text{ m}$, which represents about 80 percent of the waste surface. If we ignore the attenuating effects of viscosity on entrainment (i.e., $v_e/v_{e,\mu} = 1.0$), Eq. (4-32) gives the upper bound estimate of entrained liquid of 3500 kg. The three values $v_e/v_{e,\mu} = 0.26, 0.41$ and 0.64 estimated above give the 5th, 50th, and 95th fractile estimates, 910 kg, 1400 kg, and 2200 kg, respectively. Again, the lower bound value of liquid entrained is zero, based on the assumption of an intact floating crust. To convert these calculated fractile values of entrained (suspended) mass to transportable mass we follow the procedure outlined at the end of Section 4.4 to account for liquid rainout and multiply the upper bound value by 0.25 and the 5th, 50th, and 95th fractile masses by 0.1 to get the sought estimates:

$$m_{e,lb} = 0 \quad , \quad m_{e,5} = 91 \text{ kg} \quad , \quad m_{e,50} = 140 \text{ kg} \quad (4-33)$$

$$m_{e,95} = 220 \text{ kg} \quad , \quad m_{e,ub} = 875 \text{ kg} \quad (4-34)$$

Additional liquid will be pulled from the surface by the venting headspace air/combustion product gases. The fractile mass estimates for venting-induced entrainment have already been calculated in Section 4.4 and the values are given by Eqs. (4-25) to (4-27). The total, transportable waste liquid fractiles are summarized in Table 4-11.

Table 4-11. Total Mass of Transportable Liquid Waste Released from a DST by a Detonation That Causes Dome Failure.

Fractile	m_e (kg)
Lower Bound	0.00
5th	91
50th	370
95th	2900
Upper Bound	7600

The total, solid plus liquid transportable waste is obtained by simply adding the entries in Tables 4-9 and 4-11. The results are given in Table 4-12. A comparison of Table 4-7 with Table 4-12 reveals little difference between the transportable masses produced by deflagrations and detonations, at least for the risk significant 50th, 95th and bounding fractile values. This is because liquid waste stripping by headspace gases flowing toward the rupture opening is predicted to be the dominant waste entrainment process.

Table 4-12. Total Mass of Transportable Waste (Solid + Liquid) Released from a DST by a Detonation That Causes Dome Failure.

Fractile	$m_e + m_p$ (kg)
Lower Bound	10^{-3}
5th	91
50th	370
95th	3200
Upper Bound	8000

5.0 TOTAL MASS OF RESPIRABLE WASTE MATERIAL (A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (B) RELEASED FROM A DST BY A COMBUSTION EVENT THAT CAUSES STRUCTURAL FAILURE OF A DST

5.1 TOTAL MASS OF RESPIRABLE WASTE MATERIAL SUSPENDED IN DST HEADSPACE BY BURN INSUFFICIENT TO FAIL HEPA FILTER

During a weak burn only solid particle waste materials are entrained by the headspace air. The particles are removed from the internal surfaces of the dome and tank wall and from the upper surface of an intact floating crust, and the total mass of these particles was estimated in Section 4.1. Owing to the presence of the crust, no liquid waste material is suspended. The respirable material is that fraction of the suspended (transportable) waste particles with diameter $10\text{ }\mu\text{m}$ or less.

The respirable fraction of suspended solids has been estimated by Epstein (1997) to fall within the range 5×10^{-3} to 0.25, based on the waste particle size distribution measurements reported by Gerber (1995), Lenhard (1995), Reynolds (1992) and Herting et al. (1991). For the purpose of converting Table 4-3 entries to respirable suspended mass we will employ a single respirable fraction value of 0.2. This value equals about one-third the arithmetic mean of the respirable fraction values measured for two simulant sludges (Gerber, 1995) and one sludge sample retrieved from Tank SY-101 (Herting, 1992). The one-third factor represents the difficulty of atomizing suspended aggregates of moist surface sludge into primary particles. The respirable mass fractiles $m_{p, \text{res}}$ obtained from multiplying Table 4-3 values by 0.2, are given in Table 5-1.

Table 5-1. Respirable Mass Suspended in DST
Headspace by Burn Insufficient to Fail HEPA.

Fractile	$m_{p, \text{res}}$ (kg)
Lower Bound	3.4×10^{-10}
5th	3.8×10^{-9}
50th	4.0×10^{-5}
95th	4.8×10^{-3}
Upper Bound	4.4×10^{-2}

5.2 TOTAL MASS OF RESPIRABLE WASTE SUSPENDED IN DST HEADSPACE BY BURN < 20 PSIG WITH HEPA FAILURE

Solid particles produced by aerodynamic entrainment and liquid drops generated by the bursting of GRE bubbles comprise the suspended transportable waste (see Table 4-4). The size distribution data (Tomaides and Whitby, 1976) indicate that most of drops produced by bubble bursting are in the respirable range. Thus the bubble bursting component m_f of the fractiles listed in Table 4-4 is identified with respirable mass $m_{f,res}$ and this is added to 0.2 (respirable fraction, see Section 4.1) times the suspended solid particle components m_p in Table 4-4 to get the total respirable mass. The respirable mass results are tabulated below.

Table 5-2. Respirable Mass Suspended in DST Headspace
by Burn < 20 psig with HEPA Failure.

Fractile	$m_{p,res} + m_{f,res}$ (kg)
Lower Bound	4.4×10^{-9}
5th	3.2×10^{-3}
50th	3.3×10^{-2}
95th	0.38
Upper Bound	0.90

5.3 TOTAL MASS OF RESPIRABLE WASTE SUSPENDED IN DST HEADSPACE BY BURN > 20 PSIG BUT NO DOME FAILURE

This case is handled in the same manner as parameter 4b in that, referring to Table 4-5, the solid component m_p is multiplied by 0.2 and the result is added to the bubble bursting component m_f to get the total respirable mass. The estimates are presented in Table 5-3.

Table 5-3. Respirable Mass Suspended in DST Headspace
by Burn > 20 psig But No Dome Failure.

Fractile	$m_{p,res} + m_{f,res}$ (kg)
Lower Bound	1.1×10^{-8}
5th	8.0×10^{-3}
50th	8.1×10^{-2}
95th	0.96
Upper Bound	2.2

5.4 TOTAL MASS OF RESPIRABLE WASTE RELEASED FROM DST BY BURN THAT CAUSES DOME FAILURE

This elicitation parameter involves estimating the respirable fraction of the liquid mass suspended (m_c ; see Table 4-7) via entrainment at the liquid waste surface by the venting headspace air. The entrained liquid-waste drops suspended in the headspace air will undergo further atomization as they are accelerated through the dome rupture opening. A criterion for droplet disintegration in a gas stream can be expressed in terms of the Weber number We defined by

$$We = \frac{\rho_g (u_g - u_d)^2 \bar{d}}{\sigma} \quad (5-1)$$

where $\bar{d}$ is the average (stable) diameter of the drops produced by liquid disintegration in the gas stream; and u_g and u_d are the gas and drop velocities, respectively, along a streamline in the vicinity of the rupture opening. The critical Weber number for droplet shattering in a gas stream is about 10 to 12 for low viscosity liquids (see, e.g., Hass, 1964).

To predict the droplet size from Eq. (5-1), it is necessary to estimate the relative velocity term $u_g - u_d$. The force balance on a droplet accelerated by a gas stream is

$$\frac{4}{3} \pi \left(\frac{\bar{d}}{2} \right)^3 \rho_f \frac{du_d}{dt} = \frac{C_D}{2} \frac{\pi \bar{d}^2}{4} \rho_g (u_g - u_d)^2 \quad (5-2)$$

Here C_D is the drag coefficient and t is time. From the chain rule the acceleration term in the above equation can be rewritten as

$$\frac{du_d}{dt} = u_d \frac{du_d}{ds} \quad (5-3)$$

where ds is the incremental distance traveled by the drop along a stream line. Clearly, the maximum possible relative velocity between gas and liquid is obtained by replacing the drop velocity u_d in the acceleration terms in Eqs. (5-2) and (5-3) with the gas velocity u_g . Moreover, it can be shown from potential flow theory, that the gas acceleration achieves its peak value within the plane of the rupture opening and that the maximum gas acceleration is

$$u_g \left. \frac{du_g}{ds} \right|_{\max} = \frac{U_o^2}{R_o} \quad (5-4)$$

where U_o is the gas velocity within the plane of the rupture opening (see Eq. 4-15) and R_o is the radius of the opening.

Combining Eqs. (5-2) to (5-4) and solving for the maximum relative velocity yields

$$u_g - u_{d\max}^2 = \frac{4 \bar{d} \rho_f U_o^2}{3 C_D \rho_g R_o} \quad (5-5)$$

Eliminating $u_g - u_d$ between Eqs. (5-1) and (5-5) gives the following estimate of the average size of the entrained waste drops as they pass through the rupture opening:

$$\bar{d} = \left[\frac{3 \sigma C_D R_o W_e}{4 \rho_f U_o^2} \right]^{1/2} \quad (5-6)$$

The drag coefficient for a sphere in a high Reynolds number flow is $C_D = 0.44$ (Bird et al., 1962). We will assume that the waste drops behave as rigid spheres and adopt this value for C_D . The gas velocity in the rupture opening has been estimated in Section 4.4 and is $U_o = 361 \text{ m s}^{-1}$. The liquid waste properties are $\sigma = 0.07 \text{ W m}^{-1}$ and $\rho_f = 1400 \text{ kg m}^{-3}$ and the radius of the most likely failure

opening is $R_o = 1.83$ m (see Section 4.4). Inserting these parameter estimates and $W_o = 12$ into Eq. (5-6) results in the predicted, average radius of the supernatant drops that pass through the rupture opening:

$$\bar{d} = 53.0 \text{ } \mu\text{m} \quad (5-7)$$

To determine the fraction of the ejected waste drops that are respirable ($< 10 \text{ } \mu\text{m}$), we note that droplet size distributions for liquid atomization processes are typically described by the log-normal form. The volume percent of lognormally distributed drops with diameters less than diameter d is

$$\text{Vol } \% = 50 \left[1 + \text{erf} \left(\frac{\ln d/\bar{d}}{\sqrt{2} \ln \sigma_g} \right) \right] \quad (5-8)$$

where $\bar{d}$ is the volume mean diameter and σ_g is the geometric standard deviation of the distribution. Assuming that we know $\bar{d}$ based on the result given by Eq. (5-7), what needs to be determined is the geometric spread of the distribution σ_g . Fortunately, data for σ_g exists for both flash (superheated-liquid) and aerodynamic atomization processes. Bettis et al. (1987) estimated $\sigma_g \approx 1.5$ from measurements of the sizes of drops produced by the flashing release of Freon from a 11.5-cm diameter ruptured vessel experiment. Sher and Elata (1977) report values of $\sigma_g = 1.31$ and $\bar{d} \approx 40 \text{ } \mu\text{m}$ based on data collected from flash atomization of Freon and Toluene from a 1.0-mm diameter orifice. The atomization of a water jet by a higher velocity ($\approx 200 \text{ m s}^{-1}$) coaxial stream of air was investigated by Tsai et al. (1996). Their measured drop size distributions can be fit with the log-normal distribution fraction using $\bar{d} = 40 \text{ } \mu\text{m}$ and $\sigma_g = 1.5$. Based on these similar experimental results for very different (admittedly very small) geometries and test conditions, Eq. (5-8) with the reasonable bounding $\sigma_g = 2.0$ will be used to predict the respirable fraction of the entrained waste liquid. Inserting $\bar{d}$ from Eq. (5-7), threshold respirable diameter $d = 10.0 \text{ } \mu\text{m}$ and $\sigma_g = 2.0$ into Eq. (5-8) we get the respirable fraction for the entrained supernatant

$$f_g = \frac{(\text{Vol } \%)_{d=10 \text{ } \mu\text{m}}}{100} = 8.1 \times 10^{-3} \quad (5-9)$$

Owing to evaporation the liquid drops may be converted to solid-residue particles by the time they are carried 100 m downwind of the failed tank. The residue particles are estimated to be about 65% smaller than their parent drops, which leads perhaps to more respirable material than is indicated by Eq. (5-9). However, it is the feeling of this expert that the choice of the bounding standard deviation $\sigma_g = 2$ (relative to $\sigma_g = 1.5$ indicated by the data) more than makes up for the effects of droplet evaporation on f_g . Also this value of σ_g is assumed to cover the possibility that $\bar{d}$ may be as low as $30 \text{ } \mu\text{m}$.

Referring to Table 4-7 of Section 4.4, the total mass of respirable waste released from the failed tank is $0.2 m_p + 8.1 \times 10^{-3} m_e + m_f$ and the results are summarized below in Table 5-4.

Table 5-4. Respirable Mass Released From DST by Burn That Causes Dome Failure.

Fractile	$m_{p,res} + m_{f,res} + m_{e,res}$ (kg)
Lower Bound	1.8×10^{-8}
5th	1.3×10^{-2}
50th	2.0
95th	23.0
Upper Bound	58.0

5.5 TOTAL MASS OF RESPIRABLE WASTE RELEASED FROM DST BY DETONATION THAT CAUSES DOME FAILURE

We proceed here as in Section 4.4, except that the sum $m_e + m_p$ in Table 4-12 is reduced in accord with the prescription $8.1 \times 10^{-3} m_e + 0.2 m_p$. The respirable mass fractiles for the detonation case are given in Table 5-5.

Table 5-5. Respirable Mass Released from DST by Detonation That Causes Dome Failure.

Fractile	$m_{e,res} + m_{p,res}$ (kg)
Lower Bound	2×10^{-4}
5th	0.74
50th	3.10
95th	86.0
Upper Bound	150.0

6.0 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

Stewart (1998b) has tabulated the times from the start of buoyant displacement GREs to the times of peak release gas concentrations in the DST headspaces, as measured by the hydrogen gas monitoring systems. These measurements represent the release durations for five of the six burping tanks. Most of the recorded releases are in the medium category, although a few of the releases in Tank AW-101 and included in Stewart's table may be classified as large. Data on the SY-101 releases are not included in Stewart's table, but he notes that the duration of these large releases are on the order of a few minutes. Information extracted from the SY-101 GRE evaluation reports and interpreted by Kirch (see Barton, 1998) show release times in the range 7 to 96 min and an average release time of 30 min. Stewart plotted the release times as a function of the size (volume) of the releases. This plot clearly reveals that release duration does not correlate very well (if at all) with release size; therefore, identical elicitation distributions will be presented for all gas release sizes. Stewart converted the tabulated data into a cumulative distribution and determined the 5th, 50th, and 95th fractile values of the release time τ_{rel} . These are

$$\tau_{rel,5} = 96 \text{ min} \quad , \quad \tau_{rel,50} = 218 \text{ min} \quad , \quad \tau_{rel,95} = 840 \text{ min} \quad (6-1)$$

In the remainder of this section we attempt to provide the bounding values for the release duration τ_{rel} .

To estimate the lower bound release time, $\tau_{rel,lb}$, it is assumed that the rollover event results in the complete breakup of the nonconvective gas-containing layer as it begins to rise through the convective (supernatant) layer. The release time then is given by the characteristic rise time of the bubble cloud that is suddenly ejected from the disintegrating nonconvective waste layer; namely,

$$\tau_{rel,lb} = \frac{H_{cl}}{u_b} \quad (6-2)$$

where u_b is the terminal rise velocity of the bubbles and H_{cl} is the height of the convective layer. Observations of retained gas in simulant and actual wastes indicate that the average bubble diameter $d_b \approx 10^{-3}$ m (Gauglitz et al., 1996). The viscosity of supernatant liquid is, on average, $\mu_f \approx 2.0 \times 10^{-2}$ Pa-s (Reynolds, 1988; see also Section 4.5). The supernatant density is $\rho_f \approx 1400 \text{ kg m}^{-3}$. For this combination of bubble diameter and liquid viscosity and density, the bubbles remain nearly spherical and rise in approximate accord with Stokes law (Wallis, 1974); thus

$$u_b = \frac{d_b^2 \rho_f g}{18 \mu_f} \quad (6-3)$$

and from Eq. (6-2)

$$\tau_{rel,lb} = \frac{18H_{cl}\mu_f}{d_b^2\rho_fg} \quad (6-4)$$

Assuming a representative supernatant height $H_{cl} \approx 5.0$ m, the lower bound release time estimated from Eq. (6-4) is

$$\tau_{rel,lb} \approx 2.2 \text{ min} \quad (6-5)$$

To determine the upper bound value of τ_{rel} it is assumed that the nonconvective sludge layer rises all the way to the top of the supernatant layer and that the release time is dictated by the bubble migration time through a weakened but essentially intact sludge layer. The upward motion of the gas bubbles through the sludge is assumed to obey Stokes law (Eq. 6-3) so that the upper bound release time $\tau_{rel,ub}$ is

$$\tau_{rel,ub} = \frac{18H_{nc}\mu_{nc}}{d_b^2\rho_{nc}g} \quad (6-6)$$

where the subscript nc refers to the height and physical properties of the nonconvective layer. In this regard Meyer (1998) suggests $H_{nc} \approx 3.0$ m and $\rho_{nc} \approx 1600$ kg m⁻³. The apparent viscosity μ_{nc} of the sludge layer varies with depth (Meyer et al., 1998), from a value of approximately 10² Pa-s at the top of the layer up to about 2 x 10⁴ Pa-s near the bottom of the layer. We will assume that the lower value 10² Pa-s best represents the viscosity of the sludge after it undergoes its buoyant rise to the surface of the waste pool. Thus from Eq. (6-6) $\tau_{rel,ub}$ is estimated to be

$$\tau_{rel,ub} \approx 5.7 \times 10^3 \text{ min} \quad (6-7)$$

The fractile estimates of τ_{rel} given by Eqs. (6-1), (6-5), and (6-7) are summarized in Table 6-1.

Table 6-1. Duration of a Buoyant Displacement-Type Small, Medium or Large GRE.

Fractile	Duration (min)
Lower Bound	2.2
5th	96.0
50th	218.0
95th	840.0
Upper Bound	5700.0

7.0 PROBABILITY OF A SEISMIC-INDUCED GRE IN SSTs

This is the same parameter quantified previously by this expert for SSTs (Epstein, 1997), but without considering the impact of the tank pumping status. After carefully reviewing the previous elicitation rationale and the layers of assumptions and approximations and subjective judgements used to arrive at the fractile values, as well as the wide uncertainty band reflected by these values, it is concluded that it would not be productive for this expert to attempt to distinguish between pumped and unpumped tanks. Also recall that this experts elicitation distributions were based on a single, generic waste type in that Group II versus Group III wastes were not used as conditioning parameters. For the sake of completeness the uncertainty distributions already provided by Epstein (1997) are repeated below unchanged.

Table 7-1. Probability of 100-yr Earthquake-Induced GRE for Unpumped and Pumped, Group II and Group III Tanks.

Fractile	Size of GRE		
	Small	Medium	Large
1st	10^{-4}	10^{-5}	10^{-6}
5th	10^{-3}	10^{-4}	10^{-5}
50th	10^{-2}	10^{-3}	10^{-4}
95th	10^{-1}	10^{-2}	10^{-3}
99th	0.5	5×10^{-2}	5×10^{-3}

Table 7-2. Probability of 1000-yr Earthquake-Induced GRE for Unpumped and Pumped, Group II and Group III Tanks.

Fractile	Size of GRE		
	Small	Medium	Large
1st	5×10^{-4}	10^{-4}	10^{-5}
5th	5×10^{-3}	10^{-3}	10^{-4}
50th	5×10^{-2}	10^{-2}	10^{-3}
95th	0.5	10^{-1}	10^{-2}
99th	1.0	0.5	5×10^{-2}

Table 7-3. Probability of 10,000-yr Earthquake-Induced GRE for Unpumped and Pumped, Group II and Group III Tanks.

Fractile	Size of GRE		
	Small	Medium	Large
1st	10^{-3}	5×10^{-4}	5×10^{-5}
5th	10^{-2}	5×10^{-3}	5×10^{-4}
50th	10^{-1}	5×10^{-2}	5×10^{-3}
95th	1.0	0.5	5×10^{-2}
99th	1.0	1.0	10^{-1}

8.0 PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

There is no information that would allow this expert to conclude that the probability of an ignition source in a DST caused by an earthquake is any different from that of an SST during an earthquake. Because of structural differences the SSTs may show more damage than the DSTs for a given earthquake. However, if the seismic event is severe enough the SSTs and DSTs should be subject to similar in-tank banging of equipment and concomitant electrical failures and spark creation. Thus the available probability results for an earthquake-induced ignition source

for an SST (Epstein, 1997) are inserted in Table 8-1 below to also represent the probability of an earthquake-induced ignition source in a DST.

Table 8-1. Probabilities of Ignition Source in a DST Caused by Earthquakes.

Fractile	Earthquake Return-Year Frequency		
	10^{-2}	10^{-3}	10^{-4}
5th	10^{-4}	2×10^{-2}	0.25
50th	10^{-3}	10^{-1}	0.5
95th	10^{-2}	0.5	1.0

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10.0 NOMENCLATURE

- A rupture opening area ($A \geq A_{cr}$)
- A_{cr} critical rupture opening area for liquid entrainment
- C numerical coefficient in Eq. (2-7)
- C_D rupture opening discharge coefficient or droplet drag coefficient
- $\bar{d}$ stable, mean-waste drop diameter within rupture opening
- d drop diameter in lognormal distribution, Eq. (5-8)
- d_b bubble diameter
- E_0 empirical liquid (waste) entrainment coefficient, Eq. (4-19)
- f_e respirable fraction for entrained liquid (supernatant) waste
- f_{rel} gas release frequency (events per year)
- g gravitational constant
- G gas generation rate in nonconvective layer ($\text{mole day}^{-1} \text{ m}^{-3}$)

H	headspace height
H_{cr}	height of convective layer
H_{nc}	height of nonconvective layer
k	empirical solid-waste entrainment constant (Eq. 4-1)
$\dot{m}_e$	mass rate of liquid entrained (kg s^{-1}) by headspace gas
m_e	mass of liquid waste entrained by headspace gas
m_f	mass of liquid aerosol produced by bubble bursting
m_p	mass of suspended solid-waste particles
$\dot{m}_p''$	waste particle entrainment mass flux
P_{cr}	critical headspace pressure below which entrainment ceases
P_{max}	maximum headspace pressure following burn
P_{nc}	pressure in nonconvective layer
P_0	initial headspace pressure ($\approx 1.0 \text{ atm}$)
P_{∞}	outside atmosphere pressure
Q	gas release rate ($\text{m}^3 \text{ s}^{-1}$)
r	radial coordinate measured along surface of waste
r_{max}	radial location of peak headspace gas velocity u_{max}
r_{off}	inner radial boundary of liquid entrainment region
r_{on}	outer radial boundary of liquid entrainment region
R_d	radial location of detonation wave
R_i	ideal gas constant for headspace gas
R_{id}	universal gas constant

R_0	radius of rupture opening
s	distance traveled by waste drop along streamline in vicinity of rupture opening
S_t	turbulent burning velocity
S_u	laminar burning velocity
t	time
T	headspace gas temperature under normal conditions
t_d	headspace gas discharge time through rupture opening
T_{hs}	headspace gas temperature following burn
T_{nc}	temperature in nonconvective layer
t_p	time period between rollover events
u	local gas velocity in plume or local headspace gas velocity just above liquid-waste surface
u_b	bubble terminal rise velocity
u_{cr}	critical velocity for liquid waste entrainment by headspace gas (Eq. 4-7)
u_d	waste drop velocity in vicinity of rupture opening
u_g	upward gas migration velocity in nonconvective layer or headspace gas velocity in vicinity of rupture opening
u_{max}	peak headspace gas velocity above waste surface
U_0	headspace gas velocity within entrance plane of rupture opening
U_∞	characteristic velocity of headspace gas for solid particle or liquid drop entrainment
u'	r.m.s. velocity of isotropic turbulence
v_e	liquid entrainment velocity, Eq. (4-19)
$v_{e,\mu}$	entrainment velocity of viscous liquid

V_f	volume of liquid aerosol produced by bubble bursting
V_g	volume of gas released
V_{hs}	volume of tank headspace
Vol%	volume percent of lognormally distributed drops with diameters less than d
We	Weber number, Eq. (5-1)

Greek Letters

α	void (gas volume) fraction in nonconvective layer
α_0	initial void fraction in nonconvective layer
α_{nb}	neutral buoyancy void fraction above which nonconvective layer rollover is possible
γ	headspace gas ratio of specific heats
γ_b	effective burned gas ratio of specific heats
$\Gamma(\gamma)$	γ function given by Eq. (4-16)
ΔT	waste surface-to-dome temperature difference
ϵ	parameter defined by Eq. (2-3)
μ_f	liquid (supernatant) viscosity
μ_{nc}	apparent viscosity of nonconvective layer
ρ_b	density of burned gas
ρ_f	density of liquid waste
ρ_g	density of headspace gas
ρ_{nc}	intrinsic density of nonconvective layer (minus voids)
ρ_u	density of unburned gas
σ	surface tension of liquid waste

σ_g geometric standard deviation of lognormal distribution

τ_{rel} duration of buoyant displacement GRE

Subscripts

ℓb lower bound

res refers to respirable mass

ub upper bound

5 5th fractile

50 50th fractile

95 95th fractile

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APPENDIX B.6
RATIONALE REPORTS

P. A. Gauglitz

May 1998

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1.0 INTRODUCTION

The Gas Release Safety Analysis project, through the involvement of many technical contributors, has developed an analysis framework that provides a consistent calculational method for quantifying the effect of potential controls on the risk of flammable gas ignition in double shell tanks. The safety analyses for double shell tanks use all the modeling for single shell tanks documented for the previous analysis framework, and then adds the effects that are needed to address the flammable gas safety control issues that may be caused by the presence of a liquid layer in a double shell tank and the unique construction and configuration of the double shell tanks.

To obtain quantitative comparisons of different control strategies, uncertainty distributions are used for some key parameters in the analysis model. This report provides written documentation of the uncertainty distributions developed by P. A. Gauglitz, and a summary of the basis for the technical opinions expressed in the form of these uncertainty distributions. In each of the following sections, the *Elicitation Parameter Rationales* are given for a specific parameter, including all case conditioning. The technical documents referenced in this report are listed by the sequential numbers used for these documents in the Gas Release Event Safety Analysis Tool Library if these references are listed in the library. For documents not listed in this library, a standard reference format is used. For presentations given during Workshops I and II for Double Shell Tanks, the presentations are referenced by the unique numbers given in Bratzel et al. (1998a, 1998b). As a result, the numbering for the references in this report are not sequenced. The references cited are listed in both the section where they appear and in the final section of the report where all the cited references are listed. In some cases, passages from previous elicitations are included verbatim in the specific sections where the elicitation for the double shell tanks is very closely tied to the previous elicitation. In these cases, the copied material is taken verbatim, shown clearly as indented text, and contains references in their original format (these references are not included in the reference list at the end of this report).

2.0 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LAYER OF LIQUID (> 1 M) BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BUOYANT DISPLACEMENT-TYPE GRES

This parameter is the expected number of gas release events per year of three different efficiencies of release (i.e., sizes) for the DST being evaluated. This parameter has the dimensions of "events/year".

Conditioning Factors:

- Small efficiency release.
- Medium efficiency release.
- Large efficiency release.

Total of 3 uncertainty distributions, each displayed as y-axis labeled "subjective probability that the release frequency is less than the corresponding x value", ranging from 0 to 1, and x-axis labeled "frequency of spontaneous gas releases that are not buoyant displacement-type". The x-axis is to be logarithmic, with as many cycles as required to display the full range of the individual expert's uncertainty distribution, with increasing frequency towards the right.

Elicitation Parameter Rational

For tanks having non-BD release mechanisms, the release behavior becomes essentially that of the single shell tanks. Specifically, in the absence of conditions giving buoyant displacement GREs, the role of having a liquid layer is largely insignificant for the other mechanisms. My previous discussion of release mechanisms for SSTs (126), I described the significant release mechanisms: 1) rollovers (now buoyant displacements), 2) weak sludge behavior, 3) large bubbles, 4) rupture of a sealing layer (pressure seal), and 5) percolation. A copy of this discussion is included at the end of this section for completeness. For my SST elicitation, I argued that the Facility Group II tanks would have a higher release frequency than Facility Group III tanks, largely because of the higher void fraction in the Facility Group II tanks. I estimated the Facility Group II tanks at 25% gas fraction for 50th percentile compared to Facility Group III tanks at ~2% gas fraction for 50th percentile. For the DST under consideration for non-BD releases, this suggests that the release frequencies should be less than the FG II tanks but larger than the FG III tanks. However, this particular elicitation is for tanks that do not pass any test indicating the potential for BD-GREs. These tests within the model are not perfect, so it is possible that the tests will miss a tank with the potential for a BD-GRE. This is a significant uncertainty, and I believe this is best represented by broadening the distributions. With this final point considered, I estimate that the release frequency (50th percentile) will be equal to what I used for Facility Group II single shell tanks (unpumped), but this distributions are broader. The table below gives the various points.

The key issue for this opinion is the degree similarity of the waste behavior for DST waste and SST waste in the absence of buoyant displacements. My opinion is that gas releases from DST and SST wastes are similar based on a number of studies and observations that highlight the similarities and differences of SST and DST waste. This opinion is based on a broad range of experience but that can be represented by a few selected references (21, 23, 39, 41, 45, 54, 60, 62, 63, 71, 83). In addition, two specific studies (56, 67) have shown gas retention and release data for DST waste where the supernatant liquid has been removed to avoid the buoyant displacement mechanism. These studies (56, 67) are the most significant references forming the basis of this opinion.

For the DSTs being considered here, the absence of BD GRE condition typically, but not always, is concurrent with a lower gas void fraction. In some cases neutral buoyancy requires unattainably high void fractions. For example, 25% gas could be retained and still be below neutral buoyancy for some wastes.

Table 2.1 Frequency of Spontaneous Gas Releases in DSTs That Have a Thick Layer of Liquid (> 1 m) but Do Not Pass Any Test Indicating the Potential Exists for Buoyant Displacement-type GREs

Release Size	Frequency		Comments
Small	Lower Bound		
	5%	0.001	
	50%	0.1	Releases of this size will certainly occur. This is not a BD-GRE, but a big percolation release
	95%	5	smooth fit. The AF has built in check that will not allow too many releases
	Upper Bound	smooth fit	
Medium	Lower Bound		
	5%	0.00001	
	50%	0.001	variety of mechanisms plausible, including that tests missed medium BD-GRE. This is still a significant release and it is unlikely that plausible mechanisms (percolation, pressure seal, large bubble, weak sludge) would be this big.
	95%	0.1	
	Upper Bound	smooth fit	
Large	Lower Bound		
	5%	10E-7	
	50%	0.00001	very unlikely for tests to miss potential BD-GRE of this magnitude
	95%	0.001	plausible for tests to miss potential BD-GRE
	Upper Bound	smooth fit	

The following passage is my elicitation on the frequency of spontaneous gas releases for single shell tanks and is copied here for completeness (78, 126).

2/5. Frequency of spontaneous gas releases. The expected number of gas release events per year of three different efficiencies of release (i.e., sizes) for the tank being evaluated. Dimensions of events/year.

Conditioning Factors:

Facility Group II tanks, small release.

Facility Group II tanks, medium release.

Facility Group II tanks, large release.

Facility Group III tanks, small release.

Facility Group III tanks, medium release.

Facility Group III tanks, large release.

Total of 6 elicitation distributions, each displayed as y-axis labeled A subjective probability that the release frequency is less than the corresponding x value@, ranging from 0 to 1, and x-axis labeled A frequency of spontaneous gas release@. The x-axis is to be logarithmic, with as many cycles as required to display the full range of the individual expert=s uncertainty distribution, with increasing frequency towards the right.

Major References

Scope Presentation by Barton (Historical tank Data on Gas Release) showing small gas releases

Scope Presentation by Barton (Field Estimated Gas Generation Rates) showing data for SSTs

Stewart, C.W., M.E. Brewster, P.A. Gauglitz, L.A. Mahoney, P.A. Meyer, K.P. Recknagle, H.C. Reed. 1997. Gas Retention and Release Behavior in Hanford Single-Shell Tanks. PNNL-11391, Pacific Northwest National Laboratory, Richland, Washington.

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Scope presentation by Barton "Evidence of Gas Release during Waste Intrusive Activities"

LANL Safety Assessments for Salt Well Pumping and Rotary Mode Core Drilling

Caley, S.M., L.A. Mahoney, and P.A. Gauglitz. 1996. *Summary of Tank Information Relating Salt Well Pumping to Flammable Gas Safety Issues. PNNL-11335, Pacific Northwest National Laboratory, Richland, Washington.*

Peurrung, L.M., S.M. Caley, E.Y. Bian, and P.A. Gauglitz. 1996. *Gas Release During Salt Well Pumping: Model Predictions and Comparisons to Laboratory Experiments. PNNL-11310, Pacific Northwest National Laboratory, Richland, Washington.*

Major Points

The major gas release mechanisms can be loosely separated into the categories of small, medium, and large, although there is some overlap

Rollover - a large release mechanism, but extremely unlikely at most

Weak Sludge Behavior (Gaughlitz et al. 1996) - requires weak waste material with high gas fractions. Of the SSTs with high gas fraction, such as S-102, the cores show stronger material. Surface photographs of tanks show uneven surfaces; these can only exist if the waste has moderate strength. Analysis by M. Epstein of Fauske argued that "weak sludge behavior" diminishes as the size distribution of bubbles becomes broader. I agree with these arguments and expect the actual distribution of bubbles to be much broader than the laboratory studies with simulants. While this mechanism has been observed in the laboratory, it seems very to extremely unlikely in tanks, all things considered.

Large Bubbles - While large bubbles (1 m diameter) can be retained based on theory, bubbles of this size would be highly distorted. Thus, the volume of gas in any single bubble will be much smaller than a sphere of this diameter. Because gas is somewhat uniformly generated, it is unlikely that gas would collect in a few large bubbles. Lab studies show uniform bubble distribution for a variety of actual waste experiments (both fast (2 hr) and slow (1 month) experiments). Stewart et al., Allemann et al., argue that the release of large bubble should not cause subsequent release of all bubbles, thus the release of individual bubbles results in small releases.

Rupture of Sealing Layer (pressure seal) - this mechanism was first analyzed in Allemann et al. I originally thought it could release about 15% of the retained gas. Subsequent calculations from a mathematics seminar (Oxford workshop) attended and reported by Brewster argued for a limited vertical extent of the gas trapped beneath the pressure seal. Stewart further argues that the connected gas probably as a limited areal extent as well. Accordingly, this mechanism seems less important and smaller now. Tank S-102 had a sludge layer toward the bottom of the tank, with salt cake below; this is an ideal opportunity for a sealing layer. If releasable gas had collected beneath this pressure seal, the recent core sampling should have given the gas an opportunity to be released. I am not aware of any evidence that a large gas release occurred. (Barton noted that a small release possibly occurred in a recent core sampling event in S-102, but I do not have any information quantifying when the gas release occurred in comparison to rupturing the potential sealing layer.) A spontaneous release is less likely than an induce release (which was small if it indeed did happen), so this qualitatively supports that this is not a common mechanism of retention and release.

Percolation of Connected Bubbles - this is the most likely release mechanism, giving small releases.

2) Gas generation rates for SSTs less than about 5 SCF/day or 1800 SCF/year. If typical small release is 30 ft³, then this occurs about 50 times a year. A small release (up to 5 % of retained gas) includes releases much larger than 30 ft³

(500,000 gal of waste, 5% release, gives 800 ft³ for 25% void (facility Group II) or 60 ft³ for 2% void (facility group III)).

Points

Facility Group II, large releases (>25%)

Only rollovers and weak sludge behavior can realistically release this much gas. Experiments and theory reported in Stewart et al. show that rollovers just don't happen with waste configurations that occur in the current SSTs. To my knowledge, all the SSTs have less than about a foot of supernatant liquid. So, a rollover of this size just should not happen. What would make this statement wrong? If the waste configurations, because of some currently unpostulated and never observed mechanism, actually looks more like DST SY-101; this seems extremely unlikely. For the weak sludge behavior, evidence I have seen (core photos, core extrusions, surface photos, ...) shows SST waste being relatively strong for the tanks that retain gas large quantities of gas.

5% - 10E-6 beyond extremely unlikely.

50% - 10E-5 this small number simply reflects my opinion that it just won't happen. There are no data, observations, or theories that give frequencies for these events.

95% - 10E-4 this number qualitatively reflects my opinion that 1 in 20 tanks may have a configuration that is 10 times more likely to experience an event that shouldn't occur.

Effect of Salt Well Pumping

Draining reduces the opportunity for a rollover by removing supernatant liquid should it exist and draining some of the interstitial liquid. If SWP does not release the retained gas, my qualitative opinion is that the retained gas must be strongly retained. Thus, pumped tanks will have lower frequencies by about 10 fold.

5%: reduce to 10E-7

50%: reduce to 10E-6

95%: reduce to 10E-5.

While Sludge tanks may not drain at all and salt cake may have sufficient heterogeneities to allow some drainage but still retain gas, if SWP does not release the retained gas must be strongly retained.

Facility Group II, medium releases (5-25%)

Partial rollovers, localized "weak sludge behavior", and spontaneous rupture of pressure seals are the important potential mechanisms. I view this is roughly a 5 fold smaller event or, equivalently, 1/5 of the tank has the unique situation that can lead to one of these postulated mechanisms. Roughly, this smaller release seems more plausible, and a bit more than 5 times more plausible - say 10 fold. The new mechanism for the medium releases is the 'pressure seal'. In many ways, I would equate an extremely large percolation release with a ruptured pressure seal. A number of arguments in Stewart et al have shown that the vertical and areal extent any connected gas phase "bubble" is limited. If the volume of waste containing a connected bubbles is roughly a disk 1 m high and 4 m diameter, this waste volume is 12 m^3 (3300 gal). For a tank with 500,000 gal of waste, this is less than 1% of the waste volume. It seems very unlikely that a connected bubble would span more than 5% of the waste volume. Still, the waste configurations needed to have large regions of connected gas occur. The uncertainty lies with the limits on the areal and vertical extent and whether a particular sealing layer that happens to be holding a large volume of gas will rupture allowing a 5-25% gas release. Roughly speaking, I believe the frequency of a ruptured pressure seal is of order the local rollover and weak sludge behavior.

5% - 10E-4 first thought was 10 fold higher than large release, but this did not seem consistent when scaling from the small releases which have some experimental data to support frequencies. So, this estimate is set at 100 times larger than the large release and 100 time smaller than the small release.

50% - 10E-3 first thought was 10 fold higher than a large release, but this did not seem consistent when scaling from the small releases which have some experimental data to support frequencies. So, this estimate is set at 100 times larger than the large release and 100 time smaller than the small release.

95% - 10E-2 first thought was 10 fold higher than a large release, but this did not seem consistent when scaling from the small releases which have some experimental data to support frequencies. So, this estimate is set at 100 times larger than the large release and 100 time smaller than the small release. This number also qualitatively reflects my opinion that 1 in 20 tanks may have a configuration that is 10 times more likely to experience an event that shouldn't occur.

Effect of Salt Well Pumping

Draining reduces the opportunity for a rollover by removing supernatant liquid should it exist and draining some of the interstitial liquid. If SWP does not release the retained gas, my qualitative opinion is that the retained gas must be strongly retained. Thus, pumped tanks will have lower frequencies by about 10 fold. If the draining is effective, situation resulting in potential gas release from the rupture of a

"pressure seal" go away. However, pumping may not effectively release the gas giving situations where a pressure seal may rupture more readily. The pressure seal mechanism was postulated for a waste with porous media characteristics confined by a fine particle layer (Allemann et al.). If the salt well pumping process is effective at draining the waste, gas should be released either through the waste through the salt well screen. Accordingly, I believe that pumping a tank reduces the frequency of a gas release by the rupture of a pressure seal about 10 fold as well.

5%: reduce to $10E-5$

50%: reduce to $10E-4$

95%: reduce to $10E-3$.

Facility Group II, Small releases (<5%)

Percolation of connected bubbles is the most important release mechanism. The release of moderate size bubbles (1/10 the size of the large bubbles described above) may also be an important mechanism. The previously discussed release mechanisms may still occur on a very local level (specifically the release mechanisms of partial rollovers, localized "weak sludge behavior", and localized spontaneous rupture of pressure seals). For these smallest releases, there is actual data to estimate frequency. Of course, 5% releases are less frequent than 1% releases. Still, I view these small releases as roughly a 5 fold smaller events than the medium releases. Roughly, these small releases are more plausible, and a bit more than 5 times more plausible - say 10 fold.

The new mechanism for the small releases is the percolation of connected bubbles. In many ways, I would equate a percolation release as initiated by the rupture of a localized pressure seal. A number of arguments in Stewart et al have shown that the vertical and areal extent any connected gas phase "bubble" is limited. If the volume of waste containing a connected bubbles is roughly a disk 1 m high and 4 m diameter, this waste volume is 12 m^3 (3300 gal). For a tank with 500,000 gal of waste, this is less than 1% of the waste volume. It seems likely that a dendritic bubble could span 0.1% of the waste volume. This volume of waste would contain $(0.1\%/100) * (500,000 \text{ gal}) * (0.25 \text{ void fraction}) = 125 \text{ gal of gas or } 17 \text{ ft}^3 \text{ of gas}$. It seems unlikely that a connected bubble would span ten times this volume or 1% of the waste volume. If a 0.1% (17 ft^3) release seems likely (about 1/year), then the unlikely 1% (170 ft^3) release would occur a bit less than about 0.1 times/year.

U-103 Example. The Barton Scope presentation shows 3 small events per year averaging 30 ft^3 in volume. RGS data from the SCOPE presentation by Shekarritz and Mahoney shows 10 to 37% void in U-103, giving an average of about 15% void. The tank contains 468,000 gal of waste (Hodgson et al or Hanlon) or $62,500 \text{ ft}^3$ of waste and 9300 ft^3 of gas assuming 15% void. A release of 30 ft^3 represents only

0.3% of the retained gas. Assuming a 10-fold larger release is a bit less than 1/10 as frequent give a 3% release a bit less than 0.3 times per year.

In previous arguments I have stated a 5-fold smaller release is 10 times more likely. Similarly, in the LANL Safety Assessment for Salt Well Pumping (Appendix L, Section L.3), and also the Rotary Mode Core Drilling SA, a 5-fold increase in release volume was taken as 10-fold less likely. So, with the this adjustment, I would extrapolate the U-103 data to give a 3% release occurring 0.1 times per year. This frequency agrees with the 0.1/year arrived at above. The first paragraph of this Small release discussion argued for roughly a 10 fold increase in release frequency from the medium release estimates, giving roughly a 0.01/year frequency. Considering the value of the actual data for the number and size of release event, I will select the 0.1/year is the typical release frequency.

5% - 0.01

50% - 0.1 Given 10 tanks with high gas contents (equivalent to S-106, U-103, or S-102), it is equally probable to find one with a 3% release of its retained gas.

95% - 1

Effect of Salt Well Pumping

If the draining is effective, some situations resulting in percolation release of connected bubbles (salt cake) go away. However, pumping may not effectively release the gas giving situations where percolation may occur more readily. Specifically, draining the waste will allow bubbles that were clearly retained by capillary pressure to become just barely retained, thus more easily released. Qualitatively, these two scenarios oppose each other for the frequency of small releases. I resolve this by returning to my general opinion: If SWP does not release the retained gas, the retained gas must be strongly retained. Thus, pumped tanks will have lower frequencies by about 10 fold.

5%: reduce to 0.001

50%: reduce to 0.01

95%: reduce to 0.1

2.1 SECTION REFERENCES

Scope Library References

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23. IN TANK PHOTO COLLAGES of the 177 Waste Storage Tanks for the Hanford 200 Areas.
 39. PNL-10120, UC-510 Mechanisms of Gas Bubble Retention, September 1994.
 41. PNL-10198 The Effects of Heating and Dilution on the Rheological and Physical Properties of Tank 241-SY-101 Waste, Pacific National Laboratory, Richland, Washington.
 45. PNL-10740 Gas Bubble Retention and Its Effects on Waste Properties: Retention Mechanisms, Viscosity, and Tensile and Shear Strengths, August 1995.
 54. PNNL-11296 In Situ Rheology and Gas Volume in Hanford Double-Shell Waste Tanks, September 1996.
 56. PNNL-11298 Mechanisms of Gas Bubble Retention and Release: Results for Hanford Waste Tanks 241-S-102 and 241-SY-103 and Single-Shell Tank Simulants, September 1996.
 60. PNNL-11391 Gas Retention and Release Behavior in Hanford Single-Shell Waste Tanks, December 1996.
 62. PNNL-11450, Rev. 1 Composition and Quantities of Retained Gas Measured in Hanford Waste Tanks 241-AW-101, A-101, AN-105, AN-104, and AN-103, March 1997.
 63. PNNL-11536, Rev. 1 Gas Retention and Release Behavior in Hanford Double-Shell Waste Tanks, May 1997.
 67. PNNL-11642 Mechanisms of Gas Retention and Release: Experimental Results for Hanford Waste Tanks 241-AW-101 and 241-AN-103.
 71. LA-UR-96-989 History of Organic Carbon in Hanford HLW Tanks: HDW Model Rev. 3.
 78. Safety Controls Optimization by Performance Evaluation (SCOPE) Flammable Gas Expert Elicitation Results for Hanford Site Single-Shell Tanks - July 1997.
 83. TWS96.3 Analysis of Visual Waste Observations for Single Shell Tanks, May 3, 1996.
 126. HNF-SD-WM-ES-412, Rev. 0 Safety Controls Optimization By Performance Evaluation (SCOPE) Expert Elicitation Results for Hanford Site Single-Shell Tanks.
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3.0 PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

This parameter is dimensionless. The probability that a buoyant displacement-type GRE might produce a disturbance that could cause equipment to bang and produce friction sparks, sparks from electrical failures, or other ignition sources. These are ignition sources specifically caused by the gas release event itself. These sources are most commonly considered to arise from GRE-induced waste motion, but other sources may exist. The probability is evaluated as dependent on the size of the GRE.

Conditioning Factors:

- Small efficiency buoyant displacement GRE.
- Medium efficiency buoyant displacement GRE.
- Large efficiency buoyant displacement GRE.

Total of 3 uncertainty distributions, displayed as y-axis labeled "subjective probability that the probability of a buoyant displacement-type GRE-induced ignition source is less than the corresponding x value", ranging from 0 to 1, and x-axis labeled "Probability of a buoyant displacement-type GRE-induced ignition source." The x-axis is to be logarithmic, with as many cycles as required to display the full range of an expert's uncertainty distribution. The right-most value is 1E-0 (i.e., unity).

Elicitation Parameter Rational

The energy during a gas release depends on the specific mechanism and the size of the release. I believe the waste motion, or energy, during buoyant displacement gas release events will be the major source of sparks from mechanical movement of equipment in the tank. This statement follows from three facts/opinions: 1) the buoyant displacement GRE (BD-GRE) mechanism involves significant waste motion, and 2) essentially all DSTs have equipment entering the tanks through risers that is in contact with the waste (so waste movement causes equipment movement), and 3) this kind of equipment movement causes friction and sparks between the pipes and the risers. The first two points are well supported by large number of references.

For the waste motion during a large BD-GREs, the video shown by Stewart (Bratzel et al. 1998a, 2.7.1) gave clear visual evidence of the waste motion during an SY-101 buoyant displacement and the rapid temperature changes during BD-GREs discussed by Kirch (Bratzel et al. 1998a, 2.19.3) provides a further example of the rapid (minutes) waste motion. In addition, I have watched many hours of video showing SY-101 BD-GRE events, and the waste motion is significant, and in some cases the waste motion is quite capable of bending large pipes in SY-101. For equipment entering the tank and waste, a wide variety of documents show the specific equipment configuration. The presentations by Hodgson (Bratzel et al. 1998a, 2.4 and 2.5) summarized typical configurations.

Information discussing how sparks result from equipment motion and friction between the equipment and risers (for example) during a BD-GRE is much less clear. The significant unknowns are the force and velocity of the equipment motion and the ability of this motion to cause sparks. I agree with the widely held opinion that equipment banging and scraping during a large GRE is capable of causing sparks (for example, see following safety assessments (112, 114b)). While the ignition sources for many activities are reduced or eliminated with controls (such as those described by Smet [Bratzel et al. 1998a, 2.18] or in the JCO [16]), these controls do not really reduce sparks from equipment movement caused by BD-GREs.

I have consulted a number of general reference for understanding how sparks occur, both electrical and mechanical [16, 91, 112 (particularly section 4.3 and 4.4 on equipment installation, appendix T), 114b]. I also provided uncertainty distributions for the probability of GRE-induced ignition for SSTs. The release mechanisms in SSTs are different from the BD-GRE, but I still considered the buoyant displacement mechanism in the SST elicitation as a mechanism that could occur in an oddball SST waste configuration. In general, I believe the DSTs with the overlying liquid layer, rather than just a solid layer, will have greater waste motion for the same efficiency release. The specific values chosen for the BD-GRE uncertainty distributions for DSTs are larger than the ignition probability in SSTs for the same efficiency release. The exception is the distribution for the large releases are equivalent because the BD-GRE mechanism was assumed for the SSTs.

The categories of small, medium, and large efficiency releases have increasing level of waste motion and therefore and increasing level of spark probability. For the large BD-GREs, I estimate the spark probability is 0.5/event for the 50 percentile. For the medium GRE, which is up to 25% of the retained gas, the frequency is ten fold lower. For the small efficiency release, there will be some minor waste motion. Roughly, a small release corresponds to a 1 inch or smaller level drop. I have not seen any evidence that significant waste motion occurs for the small releases. As with small releases in SST, I estimate the ignition probability to be so small that it becomes equivalent to the independent ignition frequency. The specific points for these distributions are given in the table below with a brief explanation.

Table 3.1 Probability of an Ignition Source Being Induced by a Buoyant Displacement GRE

Release Size	Probability		Comments
Small	Lower Bound		
	5%	0.0001	10-fold smaller
	50%	0.001	twice the independent ignition frequency. Small releases represent very little waste motion.
	95%	0.01	10-fold larger
	Upper Bound	0.1	
Medium	Lower Bound		
	5%	0.005	10-fold smaller; 5-fold larger than SST
	50%	0.05	~ 1 in 20 releases cause equipment motion because waste motion occurs near equipment and motion causes spark. This is 5-fold larger the SST
	95%	0.5	10-fold larger, 5-fold larger than SST
	Upper Bound	1	
Large	Lower Bound		
	5%	0.05	10-fold smaller
	50%	0.5	Large GRE will cause sparks, but perhaps not every time
	95%	smooth fit	
	Upper Bound	1	

3.1 SECTION REFERENCES

Workshop Presentations for 1998

Bratzel, D.R., D.J. Hammervold, and A.B. Rau, "Flammable Gas Double Shell Tank Expert Elicitation Presentations - Part A", HNF-2193, February, 1998a.

2.4 Status of Double Shell Tank Waste - K. Hodgson (LMHC)

2.5 Future Double Shell Tank Operations - K. Hodgson (LMHC)

2.7.1 GRE History of Hanford DSTs - C. Stewart (PNNL)

- 2.18 Waste Tank Ignition Sources and Controls - D.B. Smet (LMHC)
 2.19.3 Supplemental Temperature Profiles around 101-SY BD-GRE's

Scope Library References

16. HNF-SD-WM-JCO-007, Rev. 1 Flammable Gas/Slurry Growth Unreviewed Safety Question: Justification for Continued Operation for the Tank Farms at the Hanford Site.
91. WHC-SD-WM-CN-041, Rev. 0 Tank Farm Deflagration Rates Due to Various Ignition Sources.
112. WHC-SD-WM-SAD-035, Rev. 0-A A Safety Assessment for Rotary Mode Core Sampling in Flammable Gas Single Shell Tanks, Hanford Site, Richland, Washington.
- 114b. WHC-SD-WM-SAD-036 A Safety Assessment for Salt-Well Pumping Operations in Tank 241-A-101: Hanford Site, Richland, Washington.

4.0 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

This parameter has the dimension of "time". Each expert is free to choose the units they believe are most appropriate (seconds, minutes, hours). The uncertainty distributions will all be converted to consistent units before aggregating results. This is the expected time for GREs of three different release efficiencies to release the retained gas. The duration is limited to that time over which the release rate is high enough for the gases to participate in a plume combustion event. Extended GREs may have long duration "tails" with release rates so low that molecular diffusion and natural convection inside the tank headspace are sufficient to prevent the gases released in the later stages from accumulating into a stratified layer or supporting a standing diffusion flame. The duration times are thus not to include these extended tails. Because the Analysis Framework assumes a constant release rate to compute well-mixed headspace concentrations as a function of time, this parameter in the Analysis Framework is the time from the start of a buoyant displacement GRE to the time of peak release gas concentration in the headspace. Members of the expert panel stated that a functional definition of this parameter when considering headspace concentration data for recorded release events is the time from the start of the BD GRE to the time when the released gas concentration in the headspace reaches approximately 95% of the peak value.

Conditioning Factors:

- Small efficiency gas releases.
- Medium efficiency gas releases.
- Large efficiency gas releases.

Total of 3 uncertainty distributions, each displayed as y-axis labeled “subjective probability that the duration of a buoyant displacement-type GRE is less than the corresponding x value”, ranging from 0 to 1, and x-axis labeled “Duration of GRE in units of X.”, where X is seconds, minutes, hours, or days. The x-axis is to be logarithmic, with as many cycles as required to display the full range of an expert’s uncertainty distribution.

Elicitation Parameter Rational

The historical behavior of the six DSTs exhibiting buoyant displacements provides the most useful and valid information for developing these uncertainty distributions. These data shown in the figure below have been summarized by C. W. Stewart and forwarded by the project team by Scot Slezak on 2/18/98 (I do not have a formal reference for these data). A number of documents provide details of these BD-GREs (63, Bratzel et al. 1998a, 2.7.1). For the size of the releases shown, these data apply to the medium and small efficiency releases. Note that the releases from SY-101 were not included in Stewart’s data set.

There was no clearly observed trend for release duration being correlated with size for the medium and small releases summarized by Stewart. According, I will use the same distributions for small and medium release efficiencies.

For large releases, the pertinent data are from SY-101. Here, I have used a summary of information from Blaine Barton that I have reproduced at the end of this section. Additional information on the BD-GRE duration is available (see for example [63, Bratzel et al. 1998a, 2.7.1]) and these reports give release rates from which release durations can be inferred. Video images of SY-101 BD-GREs (presented by Stewart [Bratzel et al. 1998a, 2.7.1]) also provide an indication of the release duration. In general, the specific release duration data in the Barton summary agrees with the less precise data from the other references and video images. My uncertainty distributions are given in the table below.

Table 4.1 Duration of a Buoyant Displacement-type GRE

Release Size	Time, minutes		Comments
Small	Lower Bound	10	reflects fastest SY-101 BD-GRE
	5%	50	smaller than Stewart summary, this reflects a broader distribution
	50%	200	from Stewart summary
	95%	1000	from Stewart summary, but slightly larger to reflect a broader distribution
	Upper Bound	smooth	
Medium	Lower Bound	10	reflects fastest SY-101 BD-GRE
	5%	50	smaller than Stewart summary, this reflects a broader distribution
	50%	200	from Stewart summary
	95%	1000	from Stewart summary, but slightly larger to reflect a broader distribution
	Upper Bound	smooth	
Large	Lower Bound	4	hard to believe anything faster, bubbles need a minimum time to rise
	5%	5	slightly shorter than the lower bound of 7 min in the data, because this gives a broader distribution
	50%	15	from Barton Summary
	95%	100	essentially the upper bound on the data
	Upper Bound	smooth	

Reproduced below is a message from Blaine Barton (originally sent to Scot Slezak) that shows BD-GRE data for larger efficiency releases in SY-101. Data were also shown for the other DSTs, but I have only included the SY-101 data here.

Time to Peak Data

There are a number of ways the time to peak data can be derived from the SHMS/GC data. As a result we have established the following groundrules for the data.

- 1. The start point is the first point of the steep slope of the curve. In many BD GRE's there is a period, typically 0-3 hours, of very slow rising hydrogen concentration before the major release. This period is not included. For SHMS, data points are only recorded when there is a change in concentration. Thus, we may have a period of an hour or more immediately before the release starts that would be included if we started with the last baseline point. The Whittaker cell in the SHMS has a response time of ~2 minutes to 90% of full scale. Using the first point on the steep slope results in at most a two minute uncertainty on the start time. For Gas Chromatograph (GC) data we sample at a fixed interval, typically 10 minutes. Thus we have an uncertainty of that ten minute period on the start time.*
- 2. In many of the releases there is a point of inflection where the Hydrogen shifts from rapidly increasing to nearly constant but slowly increasing followed by slow decreasing to exponential decrease. We are calling the "peak" the point of inflection rather than the absolute maximum which may occur a couple hours later.*
- 3. In some cases a spike of high concentration gas is seen while the tank average is increasing. This spike is of short duration but may exceed the highest value attributed to the well mixed tank condition. We ignore these points when looking for the "peak".*

The time to peak data is presented in a summary table for each tank. Backing up this summary we have included the SHMS/GC output for each event as separate pages of an EXCEL workbook. If you have questions feel free to call me at (509)-376-5118.

*Blaine Barton
3/4/98*

Nick Kirch extracted the following from the SY-101 gas release event evaluation reports. He picked the times off graphs so they might not be as precise as those reported above. This table only includes those releases which would be described as "large" using the AF criteria.

<i>Tank</i>	<i>Date</i>	<i>Time to Peak H₂, minutes</i>	<i>Release Efficiency %</i>	<i>Peak [H₂], ppm</i>
<i>SY-101</i>	<i>4/19/90</i>	<i>20</i>	<i>39.7</i>	<i>35,000</i>
	<i>10/24/90</i>	<i>7</i>	<i>35.2</i>	<i>47,000</i>
	<i>8/27/91</i>	<i>96</i>	<i>35.8</i>	<i>3800</i>
<i>SY-101</i>	<i>12/4/91</i>	<i>8</i>	<i>43.7</i>	<i>52,000</i>
	<i>9/3/92</i>	<i>7</i>	<i>67.0</i>	<i>51,200</i>
	<i>2/2/93</i>	<i>55</i>	<i>45.2</i>	<i>27,900</i>
	<i>2/26/93</i>	<i>17</i>	<i>45.7</i>	<i>34,000</i>

Average *30 minutes*
Median *17 minutes*

4.1 SECTION REFERENCES

Workshop Presentations for 1998

Bratzel, D.R., D.J. Hammervold, and A.B. Rau, "Flammable Gas Double Shell Tank Expert Elicitation Presentations - Part A", HNF-2193, February, 1998a.

2.7.1 GRE History of Hanford DSTs - C. Stewart (PNNL)

Scope Library References

63. PNNL-11536, Rev. 1 Gas Retention and Release Behavior in Hanford Double-Shell Waste Tanks, May 1997.

5.0 PROBABILITY OF A SEISMIC-INDUCED GRE

This parameter is dimensionless. This parameter is the probability that an earthquake would induce a gas release in each of three different release efficiencies. It is assumed that earthquakes of 1E-1/year and higher frequencies have a probability of 0 for inducing GREs of all sizes. It is also assumed that earthquakes of 1E-5/year and lower frequencies have a probability of 1 for inducing GREs of all sizes. Uncertainty distributions are for the 100-year, 1,000-year, and 10,000-year earthquakes.

NOTE: Because small, medium, and large efficiency releases can be induced by the same seismic event, the different size releases are mutually exclusive. That is, if a large release occurs, then by definition a medium or small release does not occur because any local medium or small release merely constitutes a part of the large release. The small and medium efficiency release probabilities are inherently conditional on the larger releases *not* occurring. The consequence of this is that the sum of the probabilities for the three events do *not* have to sum to be less than or, at most, equal to unity.

Probability of a seismic-induced GRE in a DST. This parameter defaults to only cases conditioned on a thick layer of liquid (i.e., > 1 meter) being present because the expert panel directed that the uncertainty distributions for unpumped Facility Group 2 SSTs are also to be used for DSTs when a thick liquid layer is not present.

- 1E-2/year return frequency earthquake, small efficiency gas release, thick liquid layer.
- 1E-2/year return frequency earthquake, medium efficiency gas release, thick liquid layer.
- 1E-2/year return frequency earthquake, large efficiency gas release, thick liquid layer.
- 1E-3/year return frequency earthquake, small efficiency gas release, thick liquid layer.
- 1E-3/year return frequency earthquake, medium efficiency gas release, thick liquid layer.
- 1E-3/year return frequency earthquake, large efficiency gas release, thick liquid layer.
- 1E-4/year return frequency earthquake, small efficiency gas release, thick liquid layer.
- 1E-4/year return frequency earthquake, medium efficiency gas release, thick liquid layer.
- 1E-4/year return frequency earthquake, large efficiency gas release, thick liquid layer.

Total of 9 uncertainty distributions, each displayed as y-axis labeled "subjective probability that the probability of an earthquake inducing a gas release in a DST containing a thick layer of liquid is less than the corresponding x value", ranging from 0 to 1, and x-axis labeled "Probability of a seismic-induced GRE in DSTs containing a thick layer of liquid." The x-axis is to be logarithmic, with as many cycles as required to display the full range of the individual expert's uncertainty distribution. The right-most value is 1E-0 (i.e., unity).

Elicitation Parameter Rational

In developing the uncertainty distributions for this parameter, I mostly consulted the report by Reid and Deibler (68), the summary by Stewart (Bratzel et al. 1998a, 2.7.3), the report by Stewart et al. (60), and the presentations at the 1997 SCOPE Conference by Reid and by Rohay (73, 74, 75, 76). A critical parameter is the strength of the DST waste and while a large number of references relate to this topic, a few references were heavily consulted (Bratzel et al. 1998a, 2.7.3, 54, 56, 60, 63, 67, and Gauglitz and Aikin, 1997).

Earthquake induced gas releases were evaluated for SSTs previously, and I will repeat some of my previous arguments because they apply to DST waste configuration. The specific unique situation with the DSTs is the thick liquid layer, that earthquakes cause large surface waves when this liquid layer is present, that these waves amplify the induced waste motion (in comparison to SSTs), and the result is large gas releases (and certainly larger than the releases estimated for SSTs).

Shearing waste reduces its strength and viscosity (shear thinning behavior is well documented (41, 54) for DST waste). The reduction in strength and viscosity persist for a period of time, and some reduction will persist for probably tens of days or more. These points suggest that it is possible for earthquake induce shearing and waste motion to release bubbles (by reducing the waste strength and viscosity) that would otherwise have been retained. The question is really how much earthquake energy is necessary to initiate the migration of gas bubbles, and will the bubbles actually be released or will the waste regain sufficient strength quickly enough to retain the bubbles after the earthquake ceases. While there is some information on the waste shearing caused by earthquakes, there is great uncertainty in how these results are connected to give gas release. Specifically, the waste strength is important but this property is quite variable and uncertain. There is even greater uncertainty in how long the reduced waste strength and viscosity will persist. Even more qualitatively, earthquakes are known to liquefy certain soils, particularly those that are loosely compacted sands and silts. Actual tank waste is somewhat like loosely compacted sands and silts, in my view. Accordingly, this also suggests gas can be released by seismic activity. Again, it is difficult to quantify the magnitude of the release.

The summary by Stewart (Bratzel et al. 1998a, 2.7.3) and the report by Reid and Deibler (68) gave estimates showing a significant gas release (>50%, or a large release for the purpose of this discussion) for calculations based on a quake essentially equivalent to a 1000-yr quake. This calculation was for a 300 Pa waste strength and a deep liquid layer. I believe these parameters are representative of a typical DST. Accordingly, my starting point is given a 1000-year quake, there is a 50% probability of a large release for the 50th percentile. The remainder of the points are essentially scaled from this single point. I should add that it is quite reasonable for a 1000-yr earthquake to release significant portion of the retained gas, and these results seem reasonable with earlier estimates and my understanding of the expected behavior of the waste.

To scale of the single point given above, I will assume a 100-yr quake has 1/10 the energy and a 10,000 quake has 10 times the energy of a 1000-yr quake, roughly speaking. So, the probability

of a large release is $0.5/10 = 0.05$ for a 100-yr quake. For the 10,000-yr quake, the probability of releases increases 10-fold. The probability of a medium release is certainly greater than for a large release, and I estimate that it is 10-fold more likely. Similarly, the probability of a small release is 100-fold large than for a large release.

These scalings are essentially the same as I used in the SST elicitation, and the DST results are roughly 50-fold higher probability when compared to my SST results. The tables below have the specific points for the uncertainty distributions.

Table 5.1 Probability of a Seismic-induced GRE for a 100-year Earthquake

Release Size Quake Size	Probability		Comments
Small GRE 100-yr Quake	Lower Bound		
	5%	.5	
	50%	0.8	smooth fit
	95%		
	Upper Bound	1	
Medium GRE 100-yr Quake	Lower Bound		
	5%	.05	
	50%	.5	given a 100-yr quake, it is expected that medium releases will occur
	95%	smooth fit	
	Upper Bound	1	
Large GRE 100-yr Quake	Lower Bound		
	5%	.005	
	50%	.05	given a 100-yr quake, 1 in 20 tanks will have a large release
	95%	.5	
	Upper Bound	smooth fit	

Table 5.2 Probability of a Seismic-induced GRE for a 1000-year Earthquake

Release Size Quake Size	Probability		Comments
	Lower Bound	smooth fit	
Small GRE 1000-yr Quake	5%	0.9	fewer than 1 in 20 tanks will not have a small release or a 1000-yr quake
	50%	1	smooth fit
	95%	1	smooth fit
	Upper Bound	1	
Medium GRE 1000-yr Quake	Lower Bound		
	5%	.5	10-fold larger than large release
	50%	0.8	smooth fit
	95%	1	smooth fit
	Upper Bound	1	
Large GRE 1000-yr Quake	Lower Bound		
	5%	0.05	given 20 tanks, at least one would have large release.
	50%	0.5	this is the starting point from Stewart and Reid and Deibler, and is the most defensible estimate
	95%	smooth	
	Upper Bound	1	

Table 5.3 Probability of a Seismic-induced GRE for a 10,000-year Earthquake

Release Size Quake Size	Probability		Comments
Small GRE 10,000-yr Quake	Lower Bound		
	5%	1	
	50%	1	
	95%	1	
	Upper Bound		
Medium GRE 10,000-yr Quake	Lower Bound		
	5%	1	
	50%	1	
	95%	1	
	Upper Bound		
Large GRE 10,000-yr Quake	Lower Bound		
	5%	.5	given 20 tanks, perhaps one would n
	50%	0.8 smooth fit	a large GRE was fully expected (0.5) for a 1000-yr quake, so this is certainly going to happen
	95%	1	1
	Upper Bound	1	

Probability of a seismic-induced GRE in SSTs. This is precisely the same parameter as quantified by panel members during the week of May 19-23, 1997, except that the additional conditioning factor of the SST's pumping status has been added. Only panel members who previously provided uncertainty distributions for this parameter without quantifying the impact of the tank pumping status are to provide uncertainty distributions for the following cases.

Conditioning Factors:

- 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG2.
- 1E-2/year return frequency earthquake, medium efficiency gas release, unpumped, FG2.
- 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG2.
- 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG2.
- 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG2.
- 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG2.
- 1E-2/year return frequency earthquake, small efficiency gas release, unpumped, FG3.
- 1E-2/year return frequency earthquake, medium efficiency gas release, unpumped, FG3.
- 1E-2/year return frequency earthquake, large efficiency gas release, unpumped, FG3.
- 1E-2/year return frequency earthquake, small efficiency gas release, pumped, FG3.
- 1E-2/year return frequency earthquake, medium efficiency gas release, pumped, FG3.
- 1E-2/year return frequency earthquake, large efficiency gas release, pumped, FG3.
- 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG2.
- 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG2.
- 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG2.
- 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG2.
- 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG2.

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- 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG2.
 - 1E-3/year return frequency earthquake, small efficiency gas release, unpumped, FG3.
 - 1E-3/year return frequency earthquake, medium efficiency gas release, unpumped, FG3.
 - 1E-3/year return frequency earthquake, large efficiency gas release, unpumped, FG3.
 - 1E-3/year return frequency earthquake, small efficiency gas release, pumped, FG3.
 - 1E-3/year return frequency earthquake, medium efficiency gas release, pumped, FG3.
 - 1E-3/year return frequency earthquake, large efficiency gas release, pumped, FG3.
 - 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG2.
 - 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG2.
 - 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG2.
 - 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG2.
 - 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG2.
 - 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG2.
 - 1E-4/year return frequency earthquake, small efficiency gas release, unpumped, FG3.
 - 1E-4/year return frequency earthquake, medium efficiency gas release, unpumped, FG3.
 - 1E-4/year return frequency earthquake, large efficiency gas release, unpumped, FG3.
 - 1E-4/year return frequency earthquake, small efficiency gas release, pumped, FG3.
 - 1E-4/year return frequency earthquake, medium efficiency gas release, pumped, FG3.
 - 1E-4/year return frequency earthquake, large efficiency gas release, pumped, FG3.

Total of 36 uncertainty distributions, each displayed as y-axis labeled "subjective probability that the probability of an earthquake inducing a gas release in an SST is less than the corresponding x value", ranging from 0 to 1, and x-axis labeled "Probability of a seismic-induced GRE in an SST."

The x-axis is to be logarithmic, with as many cycles as required to display the full range of the individual expert's uncertainty distribution. The right-most value is 1E-0 (i.e., unity).

Elicitation Parameter Rational

The effect of pumping status (pumped vs unpumped) on the ability of an earthquake to release gas is difficult to determine. Obviously the waste strength plays a role and undrained (or unpumped and wetter) and drained (pumped and sometime more dry) waste will have a different strengths. Usually, partially drained but still moist waste is stronger than completely wet waste due to capillary forces (45), suggesting that pumped tanks would have a lower probability of releasing gas. In contrast, if a pumped tank has any retained gas, it is likely this gas is held more weakly (because of a high degree of connected gas occupied pores). This effect suggests that pumped tanks would have a higher probability of a gas release. It is my opinion that these effects off-set, so there is no difference between pumped and unpumped behavior for the probability of earthquake-induce GREs. Accordingly, my elicited distributions (actual fitted distributions) previously published in HNF-SD-WM-ER-412, Rev 0 (126) for this parameter should be applied to both pumped and unpumped tanks. In addition, I believe these distributions apply to both Facility Group II and Facility Group III tanks.

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6.0 PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

This parameter is dimensionless. This is a special case of a common-cause ignition source. It is the probability that an earthquake will cause an ignition source *that would not be included* in either the parameter "Probability of an ignition source being induced by a buoyant displacement GRE" (see #2 above) or the parameter "Probability of a GRE-induced ignition source" for non-BD GREs (see Analysis Framework for SSTs). This parameter supplements the other two parameters because earthquakes can cause equipment motion, electrical failures, structural damage, or other potential ignition sources that are not caused by a GRE that is induced by the

same event. This parameter does not include the contribution to ignition source probability that results from the earthquake-induced GRE because that probability is already accounted for through the relation:

$$\begin{aligned} &\text{probability of seismic-induced GRE inducing an ignition source} = \\ &\quad (\text{probability of a seismic-induced GRE in a DST}) \\ &\quad \times (\text{probability of a GRE-induced ignition source}) \end{aligned}$$

and the two right-hand terms are quantified by uncertainty distributions from the panel. It is assumed that earthquakes of 1E-1/year and higher frequencies have a probability of 0 for causing ignition sources not already included in the probability of a GRE-induced ignition source. If a tank passes a criteria indicating that the tank is at risk for exhibiting buoyant displacement GRE behavior, then the uncertainty distribution for the probability of an ignition source being induced by a buoyant displacement GRE will be used. If a tank is not at risk for BD-type GREs, then the probability of a GRE-induced ignition source for non-BD GREs will be used. It is assumed that earthquakes of 1E-5/year and lower frequencies have a probability of 1 for causing ignition sources. Uncertainty distributions are for the 100-year, 1,000-year, and 10,000-year earthquakes.

Conditioning Factors:

- 1E-2/year return frequency earthquake.
- 1E-3/year return frequency earthquake.
- 1E-4/year return frequency earthquake.

Total of 3 elicitation distributions, each displayed as y-axis labeled "subjective probability that the probability of a seismic-induced ignition source in a DST is less than the corresponding x value", ranging from 0 to 1, and x-axis labeled "Probability of an earthquake-caused ignition source." The x-axis is to be logarithmic, with as many cycles as required to display the full range of the individual expert's uncertainty distribution. The right-most value is 1E-0 (i.e., unity).

Elicitation Parameter Rational

An earthquake will cause waste motion separate from the motion caused by a GRE. It is the energy of this waste motion which is important. Roughly speaking, I believe the waste sloshing and moving will be more effective at moving equipment than in releasing gas, but not all equipment motion will cause sparks. Roughly speaking, the summary by Stewart (Bratzel et al. 1998a, 2.7.3) and the report by Reid and Deibler (68) showed that a 1000-yr earthquake caused substantial motion of essentially all of the waste in the tank and also caused wave motion in the overlying liquid layer. I estimated that a 1000-yr earthquake would readily (50% probability for 50th percentile) cause a large gas release. Consistent with my elicitation for SSTs and my elicitation for the *Probability of an ignition source being induced by a buoyant displacement GRE* in Section 3.0, I estimate that the probability of an ignition source during a 1000-yr quake is about the same as the spark probability during a large GRE. For understanding sparks and ignition sources and typical tank configuration, I have consulted the same material I referenced

when developing uncertainty distributions for the *Probability of an ignition source being induced by a buoyant displacement GRE* (16, 91, 112 (particularly sections 4.3 and 4.4 and appendix T), 114b, Bratzel et al. 1998a 2.4, 2.5, and 2.18). The table below contains specific points for my uncertainty distributions.

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- 2.5 Future Double Shell Tank Operations - K. Hodgson (LMHC)
- 2.7.3 Seismic Response of DST Waste - C. Stewart (PNNL)
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Table 6.1 Probability of an Ignition Source in a DST Caused by an Earthquake

Quake Size	Fraction		Comments
100-yr Quake	Lower Bound		
	5%	.005	10-fold less
	50%	.05	10-fold less energy and waste motion than 1000-yr quake. Roughly 1 in 20 tanks will have sufficient waste and equipment motion to cause a spark.
	95%	.5	
	Upper Bound		
1000-yr Quake	Lower Bound		
	5%	.05	
	50%	.5	This is the primary point. A 1000-yr quake provides sufficient equipment motion to cause sparks, but perhaps not every time.
	95%	smooth fit	
	Upper Bound	1	
10,000-yr Quake	Lower Bound		
	5%	.5	Unusual not to get a spark for this event and waste sloshing
	50%	.8	Consistently get sparks with waste sloshing
	95%	smooth fit	
	Upper Bound	1	

7.0 DEFINITIONS

GRE (Gas Release Event): (A) a single coherent release of trapped gases from the waste that is sufficiently rapid and localized enough to potentially form a locally flammable region that is for a time at risk of burning as a plume, and/or (B) a release of trapped gases from the waste that is sufficiently rapid and large enough to form a flammable mixture in the headspace after becoming well-mixed with the headspace gases. A release of gas is not considered a GRE if it is (1) diffused

over a large enough area, (2) sufficiently slow in flowing out of the waste, and/or (3) small enough in size to not form a locally flammable mixture of sufficient size that if ignited could clearly be detected by field instruments such as pressure monitors. Rather, these minor releases are considered unimportant temporal variations on the steady state release rate of gases.

Small GRE: A gas release event that releases no more than 5% of the total inventory of retained gases.

Medium GRE: A gas release event that releases at least 5% of the total inventory of retained gases, but not more than 25% of the retained gases.

Large GRE: A gas release event that releases at least 25% of the total inventory of retained gases.

Locally Waste-Disturbing Operation: Any waste intrusive operation that mechanically disturbs only the waste that is close to the equipment. Examples of locally waste-disturbing operations are core drilling, auger sampling, and inserting thermocouple trees, liquid observation wells, pumps, etc., with or without water injections to sluice in the equipment.

Globally Waste-Disturbing Operation: Any waste intrusive operation that mechanically disturbs most or all of the waste in a tank. Examples of globally waste-disturbing operations are large water additions, past practice sluicing, and waste transfer operations. Saltwell pumping is a globally waste-disturbing operation that is comparatively very slow and is therefore treated separately by the Analysis Framework.

Facility Group: The Justification for Continued Operations document identified three separate categories of tanks called Facility Groups 1, 2, and 3. All 177 tank farm storage tanks were classified as belonging to one of these three categories. The function of the Facility Groups was to identify the level of flammable gas safety controls that were to be applied to the member tanks.

Facility Group 1 tanks are those facilities which are acknowledged with little or no controversy to be of the greatest concern with respect to the flammable gas hazard. The five tanks classified as Group 1 are all double shell tanks that have undergone observed, significant GREs and are conservatively postulated to have the potential for large spontaneous and large induced GREs.

Facility Group 2 tanks are those conservatively postulated to have the potential for a large induced GRE but only a small spontaneous GRE. SSTs in Facility Group 2 are those that fail the GRE evaluation methodology in (Hodgson 1996) and thus are estimated to retain gas amounts sufficient to cause the dome space concentration to exceed 25% of the LFL if 25% of the retained gas is released. A tank failed the Hodgson methodology if any one retained gas volume estimation method (surface level rise, barometric pressure vs. height evaluation, or unexplained sudden level drops) indicated that sufficient gas might be retained.

Facility Group 3 tanks are all of the remaining tanks not assigned to Facility Groups 1 or 2.

Dome Intrusive: (1) Any location within the tank between the top of the riser and the surface of the waste, (2) ventilation ducting up to the first mixing point with flow from another tank (or the entire duct system if the fan is inoperative), or (3) regions where activities in direct contact with the outside of the above boundaries that could result in an ignition source inside the boundary (e.g., welding, grinding). Saltwell pump pits are considered dome intrusive during operation of saltwell pumps.

Waste Intrusive: Any equipment or vapor space inside equipment that penetrates into waste or makes contact with the surface of the waste.

Ex-Tank Intrusive: All vapor spaces with a direct connection to the tank dome space but which do not meet the definition of either a dome intrusive region or a waste intrusive region. Examples of ex-tank intrusive regions are (1) pits (e.g., pump pits, transfer pits) that are not isolated from the dome by a vapor tight barrier, (2) the area outside of a tank opening, which is directly connected to the dome space, out to a distance of 18 opening diameters, 15 ft, or the boundary of temporary containment device, whichever is shorter, and (3) regions where activities in direct contact with the outside of the above boundaries could result in an ignition source inside the boundary (e.g., welding, grinding).

Tank Intrusive: Generic term for any activity or region that is dome intrusive, waste intrusive, or ex-tank intrusive.

8.0 REFERENCES

General

Gauglitz, P.A., and J.T. Aikin. 1997. *Waste Behavior During Horizontal Extrusion: Effect of Waste Strength for Bentonite and Kaolin/Ludox Simulants and Strength Estimates for Wastes from Hanford Waste Tanks 241-SY-103, AW-101, AN-103, and S-102.* PNNL-11706, Pacific Northwest National Laboratory, Richland, Washington.

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2.5 Future Double Shell Tank Operations - K. Hodgson (LMHC)

2.7.1 GRE History of Hanford DSTs - C. Stewart (PNNL)

- 2.7.2 Overview of DST Field Data - C. Stewart (PNNL)
- 2.7.3 Seismic Response of DST Waste - C. Stewart (PNNL)
- 2.18 Waste Tank Ignition Sources and Controls - D.B. Smet (LMHC)
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Bratzel, D.R., D.J. Hammervold, and A.B. Rau, "Flammable Gas Double Shell Tank Expert Elicitation Presentations - Part B", HNF-2193, February, 1998b.

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- 114b. WHC-SD-WM-SAD-036 A Safety Assessment for Salt-Well Pumping Operations in Tank 241-A-101: Hanford Site, Richland, Washington.
- 126. HNF-SD-WM-ES-412, Rev. 0 Safety Controls Optimization By Performance Evaluation (SCOPE) Expert Elicitation Results for Hanford Site Single-Shell Tanks.

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APPENDIX B.7
RATIONALE REPORTS

J. Havens

May 1998

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1.0 INTRODUCTION

This report describes the author's preparation for and execution of an elicitation for several parameters required for the Analysis Framework developed for the Stage II Gas Release Event Safety Analysis Project. This elicitation was conducted by Mr. Richard John in Richland, Washington, on March 13, 1998.

2.0 ELICITATION PARAMETER RATIONALES

2.1 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LAYER OF LIQUID (> 1 M) BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BUOYANT-DISPLACEMENT-TYPE GRES

This parameter is the expected number of gas release events per year for a DST. It is to be determined for three conditioning factors: small efficiency releases (that release no more than 5% of the retained gas), medium efficiency releases (that release at least 5%, but not more than 25% of the retained gas), and large efficiency releases (that release at least 25% of the retained gas).

General considerations

If a thick liquid layer is present, but rollover is not indicated, then there is very little chance of a large efficiency release. Small efficiency releases are most likely, followed by medium efficiency releases, and large efficiency releases are least likely. DST experience indicates about 5 (assumed to be) large efficiency BDE-GREs for 30 tanks in about 10 years (300 tank years), or frequency = $1/60$ per year per tank.

Large efficiency releases

I considered that large efficiency spontaneous non-BD releases were about 100 times less likely than BD releases. Accordingly, I set the median frequency-of-release for such events to be $1/6000$, or 0.000167 events per year per tank. I estimated the 5% fractile frequency to be about 2 (large efficiency) events per year $(1/6000)(2/5) = 1/15000$, or 0.0000667 events per year per tank, and I estimated the 95% fractile frequency to be about 10 (large efficiency) events per year $(1/6000)(10/5) = 1/3000$, or 0.000333 events per year per tank.

Medium efficiency releases

I considered that medium efficiency releases were about 10 times more likely than large efficiency releases, with the following results: 5% fractile frequency = 0.000667 events per year per tank,

50% fractile (median) frequency = 0.00167 events per year per tank, and 95% fractile frequency = 0.00333 events per year per tank.

Small efficiency releases

I considered that small efficiency release were about 100 times more likely than large efficiency releases (i.e., about the same as experienced for BD releases when thick liquid layers are present), with the following results: 5% fractile frequency = 0.00667 events per year per tank; 50% fractile (median) frequency = 0.0167 events per year per tank, and 95% fractile frequency = 0.0333 events per year per tank.

2.2 PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

This dimensionless parameter is the probability that a buoyant displacement-type-GRE will produce a disturbance resulting in the creation of an ignition source in a DST. It is to be determined for three conditioning factors: small efficiency releases (that release no more than 5% of the retained gas), medium efficiency releases (that release at least 5%, but not more than 25% of the retained gas), and large efficiency releases (that release at least 25% of the retained gas).

General considerations

The minimum ignition energy for hydrogen is comparatively low. Since the GRE event itself is the only cause (of an ignition source) being considered, and since the degree of disturbance of the tank contents is expected to increase with the efficiency of the GRE, the probability that a GRE will cause an ignition source is least for a small efficiency GRE, somewhat greater for a medium efficiency GRE, and greatest for a large efficiency GRE. I assumed that the probability that a GRE will cause an ignition source is proportional to the efficiency of the GRE. I considered that the uncertainty is primarily associated with the requirement for co-location of such a spark and a region in the tank which contains a flammable gas mixture. DST experience indicates no (observed) combustion events, but experience indicates that GREs resulted in mixed headspace concentrations less than about 1/3 lfl. I assumed that the probability that a spark and an lfl gas concentration being collocated is about 1 in 10, independent of the efficiency of the release. Finally, the probability that a GRE will cause an ignition source cannot be greater than 1.

Large efficiency releases

I assumed that for the large efficiency releases the median probability that a GRE would generate an ignition source with energy exceeding the minimum ignition energy (MIE) would be about 0.1, with 5% fractile and 95% fractile probabilities of 0.01 and 0.9, respectively.

Medium efficiency releases

Let the probability that a GRE of a given efficiency will cause an ignition source with an energy E_{eff} exceeding the MIE be denoted as P_{eff} , where eff is S (small efficiency release), M (medium efficiency release), or L (large efficiency release). It follows that P_M/P_L is proportional to E_M/E_L . I assumed that the energy of the GRE event is directly proportional to the volume of the gas released, hence P_M/P_L is proportional to V_{gM}/V_{gL} . I then assumed that the ratios of the gas volumes characteristic of small, medium, and large efficiency gas releases were given by 2.5/15/35 (taking the midpoint of the (defining) range for the small and medium efficiency releases and estimating a median value of the percent (of retained) gas that is released in a large efficiency release to be 35%). It follows that P_M/P_L is 15/35, and $P_M = 3/7 P_L$, giving 5% fractile, 50% fractile, and 95% fractile values of the probability that a GRE with medium efficiency will cause an ignition source with energy exceeding the MIE of 0.0043, 0.043, and 0.386, respectively.

Small efficiency releases

It follows that P_S/P_L is proportional to E_S/E_L and hence to V_{gS}/V_{gL} . P_S/P_L is then 2.5/35 and $P_S = 1/14 P_L$, giving 5% fractile, 50% fractile, and 95% fractile values of the probability that a GRE with small efficiency will cause an ignition source with energy exceeding the MIE of 0.00071, 0.0071, and 0.064, respectively.

2.3 TOTAL MASS OF TRANSPORTABLE WASTE MATERIAL (A,B,C) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (D,E) RELEASED FROM A DST BY A COMBUSTION EVENT THAT CAUSES A STRUCTURAL FAILURE OF A DST

This parameter has the dimension of "mass". The parameter is to be determined for five conditioning factors:

- a. A headspace burn of sufficient pressure to fail the HEPA filter (nominally 1 psi)
- b. A headspace burn of less than 20 psi that fails the HEPA filter
- c. A headspace burn of more than 20 psi that does not fail the DST dome (nominally 47 psi)
- d. A headspace DEFLAGRATION of sufficient pressure to fail the DST dome (nominally 47 psi)
- e. A headspace DETONATION sufficient to fail the DST dome (nominally 47 psi).

For the cases where the combustion event is insufficient to fail the DST dome, this parameter is the total amount of transportable waste material that is knocked loose from the dome and walls and suspended in the headspace from the waste surface due to combustion generated gas flows, falling debris impacting the waste surface, radiation-driven ablation of the waste surface, and any other mechanism which may cause waste to aerosolize. The mass is that which may remain suspended for a time comparable to or longer than the time required to depressurize the tank.

For the cases where the combustion event is sufficient to fail the DST dome, this parameter is the total amount of transportable waste material that is released from a tank and capable of being transported far enough to expose an on-site individual 100 meters from the point of release.

General considerations

I considered only the (waste removal) mechanism associated with (waste) material knocked loose from the dome and wall surfaces, and suspended in the headspace, due to (combustion generated) gas flows. The magnitudes of the combustion generated flows that occur were estimated from the amount of hydrogen gas which would be required to be burned to generate the specified pressure. I assumed, for purposes of characterizing the combustion generated flows, that ignition occurred at the waste level ($h = 0$) at the center ($r = 0$) of the headspace. The headspace was assumed to consist of two subsystems initially:

Zone 1 - a zone, centered at $r = 0$, $h = 0$, containing H_2 mixed with stoichiometric air

Zone 2 - the air in the headspace surrounding the flammable subsystem (Zone 1)

The volume of the unburned flammable gas (Zone 1) was computed from the prescribed pressure increase (assuming no venting). The volume (and mass) of the gas products resulting from complete combustion of the gas in Zone 1 was computed assuming adiabatic combustion of the gas mixture therein. The volume of the burned gas indicates its (radial and vertical) extent. The time required to reach (this extent) is set by the speed of the burning front, which was assumed to be the laminar flame speed. The velocity which could entrain particles from the surfaces in the headspace is taken to be a spatial average (over radius, r) with zero velocity at the center and at the outer wall and the laminar flame speed at the flame front. Using the estimated velocities which were assumed to be characteristic of the velocity scales which would effect entrainment from the surfaces in the headspace, data for entrainment flux as a function of free stream velocity provided by Gelbard and Brockmann (1) was used to estimate the entrainment flux. The entrainment flux was then multiplied by the area reflecting the extent of the burned gas (Zone 1) to estimate the transportable mass entrained into the headspace, and the result was taken to be the median value (for the prescribed overpressure). The 5% fractile and 95% fractile values of the transportable mass suspended were determined by estimating the 95% confidence belt (between $E/2.2$ and $E*2.2$, where E is the median value of the mass).

Headspace burn of insufficient pressure to fail the HEPA filter (nominally 1 psi)

For the prescribed overpressure of 1 psi, the predicted (median) value of the transportable mass suspended was 0.035 kg, and the 5% fractile and 95% fractile values of the transportable mass suspended were $0.035/2.2$ and $0.035*2.2$, respectively.

Headspace burn of less than 20 psi that fails the HEPA filter

For the prescribed overpressure of less than 20 psi, the (median) value of the transportable mass suspended was calculated for a pressure of 10 psi (middle of the pressure range for this "class") to be 0.144 kg. The values of the transportable mass suspended were also calculated for pressures of 2 psi and 20 psi. The mass value obtained for 2 psi was 0.049 kg and the mass value obtained for 20 psi was 0.217 kg. These values were adjusted to reflect the uncertainty in the entrainment data (95% confidence belt), giving $0.049/2.2$ for the 5% fractile value and $0.217*2.2$ for the 95% fractile value.

Headspace burn of more than 20 psi - does not fail the DST dome (nominally 47 psi)

For the prescribed overpressure of more than 20 psi, but less than 47 psi, the (median) value of the transportable mass suspended was calculated for a "midrange" pressure of 33.5 psi to be 0.277 kg. The values of the transportable mass suspended were also calculated for pressures of 22 psi and 47 psi. The mass value obtained for 22 psi was 0.228 kg and the mass value obtained for 47 psi was 0.317 kg. These values were adjusted to reflect the uncertainty in the entrainment data (95% confidence belt), giving $0.228/2.2$ for the 5% fractile value and $0.317*2.2$ for the 95% fractile value.

Headspace DEFLAGRATION sufficient to fail the DST dome (nominally 47 psi)

For the prescribed overpressure of more than 47 psi (assumed sufficient to fail the dome), calculations were made to estimate the transportable mass suspended for pressures of 50 psi, 68 psi, and 86 psi. The predictions of transportable mass suspended for pressures 50 psi, 68 psi, and 86 psi were 0.324 kg, 0.359 kg, and 0.386 kg, respectively. Applying the uncertainty assigned to the entrainment data (see above), the value for 50 psi was divided by 2.2, and the value for 86 psi was multiplied by 2.2. Since the desired parameter is the transportable mass released to the environment, the resulting values of transportable mass (suspended) were multiplied by a factor to account for the filtering of the material which would occur as the released material penetrated the overburden above the failed dome. The "filtering factor" was determined as follows. Using data for Penetration Factor vs Particle Diameter provided by Gelbard and Brockman (1), an upper limit on the confidence interval for the filtering factor (defined here to be the fraction released) was based on data for 2 cm gravel. For 2 cm gravel, the data suggested that about 60% of the mass would be completely trapped, and of the remaining 40%, about half would get through the overburden. On this basis, the upper limit of the confidence interval on the amount released was estimated to be 0.2. A lower limit on the confidence interval for the filtering factor was (similarly) based on data for 0.5 cm gravel, resulting in an estimate that about 2.4% of the mass would get

through the overburden. The median value of the filtering factor was estimated as $(0.2 \times 0.024)^{1/4}$. Accordingly, the 5% fractile, 50% fractile, and 95% fractile values for the mass released were estimated to be $0.024 \times 0.324/2.2$, 0.07×0.359 , and $0.2 \times 0.386 \times 2.2$, respectively.

Headspace DETONATION sufficient to fail the DST dome (nominally 47 psi)

For a headspace detonation which fails the dome, I assumed that the transportable and respirable fractions are the same. Based on information suggested to me by a fellow panel member I assumed that 1 kg of respirable/transportable material would be produced for each kg of TNT equivalence of the detonation, as reported in DOE Handbook 3010-94 (2). I associated the uncertainty with the amount of flammable gas mixture which could be present in the headspace. Assuming a headspace volume of 0.5 million gallons, and stoichiometric hydrogen/air concentration, the head space would contain about 23,000 moles of H_2 . Assuming 60 kcal liberated per mole of H_2 , the resulting energy release would be about 1.4×10^6 kcal or about 1200 kg TNT equivalent, with a resulting mass release of 1200 kg. I assumed that the assumed value of 1 kg released per kg TNT equivalent might be high by as much as a factor of 10, and I assumed for estimating the median value of the mass released that the value was 0.5 kg per kg TNT, for estimating the 5% fractile value that the value was 0.1 kg per kg TNT, and that for estimating the 95% fractile value that the value was 1.0 kg per kg TNT. Finally, all three fractiles were multiplied by 2/3 to account for the conservative assumption of stoichiometric gas composition. Accordingly, the 5% fractile, 50% fractile, and 95% fractile values for the mass released were estimated to be $1200 \times 0.1 \times 2/3$, $1200 \times 0.5 \times 2/3$, and $1200 \times 1.0 \times 2/3$, respectively.

2.4 TOTAL MASS OF RESPIRABLE WASTE MATERIAL (A,B,C) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (D,E) RELEASED FROM A DST BY A COMBUSTION EVENT THAT CAUSES A STRUCTURAL FAILURE OF A DST

This parameter has the dimension of "mass". The parameter is to be determined for five conditioning factors:

- a. A headspace burn of sufficient pressure to fail the HEPA filter (nominally 1 psi)
- b. A headspace burn of less than 20 psi that fails the HEPA filter
- c. A headspace burn of more than 20 psi that does not fail the DST dome (nominally 47 psi)
- d. A headspace DEFLAGRATION of sufficient pressure to fail the DST dome (nominally 47 psi)
- e. A headspace DETONATION sufficient to fail the DST dome (nominally 47 psi).

For the cases where the combustion event is insufficient to fail the DST dome, this parameter is the total amount of respirable waste material that is knocked loose from the dome and walls and suspended in the headspace from the waste surface due to combustion generated gas flows, falling debris impacting the waste surface, radiation-driven ablation of the waste surface, and any other mechanism which may cause waste to aerosolize. The mass is that which may remain suspended for a time comparable to or longer than the time required to depressurize the tank.

For the cases where the combustion event is sufficient to fail the DST dome, this parameter is the total amount of respirable waste material that is released from a tank and capable of being transported far enough to expose an on-site individual 100 meters from the point of release.

Headspace burn of insufficient pressure to fail the HEPA filter (nominally 1 psi)

The values obtained for the corresponding release of transportable material were multiplied by 0.8, based on a (workshop) proposal that 80% of suspended mass is respirable based on particle size analysis (Gelbard and Brockman (1)).

Headspace burn of less than 20 psi that fails the HEPA filter

The values obtained for the corresponding release of transportable material were multiplied by 0.8, based on a (workshop) proposal that 80% of suspended mass is respirable based on particle size analysis (Gelbard and Brockman (1)).

Headspace burn of more than 20 psi - does not fail the DST dome (nominally 47 psi)

The values obtained for the corresponding release of transportable material were multiplied by 0.8, based on a (workshop) proposal that 80% of suspended mass is respirable based on particle size analysis (Gelbard and Brockman (1)).

Headspace DEFLAGRATION sufficient to fail the DST dome (nominally 47 psi)

The values obtained for the corresponding release of transportable material were multiplied by 0.8, based on a (workshop) proposal that 80% of suspended mass is respirable based on particle size analysis (Gelbard and Brockman (1)).

Headspace DETONATION sufficient to fail the DST dome (nominally 47 psi)

The values obtained for the corresponding release of transportable material are used here also, since it was assumed that for the detonation event the transportable mass and respirable mass are the same.

2.5 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

This parameter is the expected time (duration) for GREs to release gas. The duration is understood to be limited to that time over which the release rate is high enough for the gases to participate in a plume combustion event. The parameter is to be determined for three conditioning factors : small efficiency release, medium efficiency release, and large efficiency release.

General considerations

The distributions I provided were suggested to me by analyses I made of hydrogen concentration data for 6 BD-GRE events provided during the workshop. I assumed that all 6 of these BD-GRE events were large efficiency releases, and I made estimates of duration by measuring the time for the hydrogen gas concentration to rise to about 95% of the maximum value attained. I made one measurement of the time duration for each of the six events, and obtained the times 173 minutes, 86 minutes, 10 minutes, 29 minutes, 115 minutes, and 29 minutes. The mean of these values is 73.7 minutes and the standard deviation is 57.4 minutes.

Large efficiency releases

I assigned the average value of the measurements (rounded to 75 minutes) to the 50% fractile value of the duration time. I estimated the 5% fractile value to be 5 minutes (½ the minimum value observed), noting that there is a relatively small chance that the duration can be much less than 5 or 10 minutes because of the time scales for mixing in the DST's. I estimated the 95% fractile value to be 250 minutes by (roughly) extrapolating the six observed times to a representative "maximum" value.

Medium efficiency releases

I assumed that there is a characteristic "velocity" (of rollover) scale, defined as (characteristic depth of rollover cell)/(duration of release) or D/t , and I assumed that this characteristic "velocity" determination applies for all three of the different efficiency releases. I then assumed that the ratio of large to medium (efficiencies) of release is equal to the corresponding ratio of the depth of rollover cells. It follows that the duration for a medium efficiency release, t_M , is given by $t_M = (D_M/D_L)t_L$ or $((0.05*0.25)^{1/3}/(0.25))^{1/3} = 0.76$, and the values estimated for the large efficiency release were multiplied by 0.76 to obtain the corresponding values for the medium efficiency release.

Small efficiency releases

Following the method used above for medium efficiency releases, the small efficiency release duration time, t_s , is given by $t_s = (D_s/D_L)t_L$ or $(0.025/0.25)^{1/3} = 0.46$. Accordingly, the values estimated for the large efficiency release were multiplied by 0.46 to obtain the corresponding values for the small efficiency release.

3.0 REFERENCES

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**APPENDIX B.8
RATIONALE REPORTS**

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May 1998

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**1.0 1. FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS
WITH A THICK LAYER OF LIQUID BUT DO NOT SATISFY
THE BD GRE CRITERIA**

The observations in the double-shell tanks indicate that no DST other than the six on the watch list has registered a large change in level, pressure, or hydrogen concentration such as those associated with the buoyancy driven (BD) GRE mechanism (Ref. 1). However, the level measurements are incapable of measuring very small releases ($\sim 100 \text{ ft}^3$) and gas measurements inside the tanks are taken only in the 6 DS tanks that have exhibited BD releases. From gas monitors on SY, AW and AV stacks it can be concluded that no large, or medium or even small releases have taken place from DS tanks other than those on the watch list (Ref. 2&3). Furthermore, even intrusive industrial activities do not seem to produce observed releases. Only one event in 17 tank-years of observations has occurred during void fraction measurement instrument insertion in AW101. Another event is reported to have occurred in AY102 due to waste transfer (Ref. 3).

I will assume that the controlling gas release mechanisms in these tanks can be similar to the SSTs of Facility Group II tanks that are unpumped (Ref. 4). However, the larger layer of supernate would allow the accumulation of larger masses of gas at a higher pressure. Hence, the frequency of medium releases will be higher (I will assume a factor of 1.5) but the frequency of small releases will be lower (I will assume by a factor of 3).

Starting from the reported frequencies of GREs in the SSTs as reported to SCOPE in Ref. 1, I will modify them to account for the above considerations including lack of actual observations of GREs in these tanks. The mean values can be estimated as follows:

	Annual Frequency		
	Large	Medium	Small
Observed SST GREs	0.0	0.027	0.37
GRE modified for DST mechanisms	0.0	0.04	0.12
Reduced GRE for lack of observations upon intrusion	0.0	0.01	0.03

Note that since 20 double-shell tanks had no observed medium releases in 15 years, the frequency of releases would be smaller than 1 in 300 tank years or less than 0.0033.

The distribution of the releases will be as follows, based on modifications applied to the SST distributions with the same logic applied above:

For large releases:

Frequency, x	E-6	E-5	E-4	E-3	E-2
Prob. less than x	0.2	0.5	0.9	0.99	1.0

For medium and small releases:

Frequency, x	0.001	0.003	0.01	0.03	0.1	0.3
Prob., y Medium	0.1	0.2	0.5	0.9	0.99	1.0
Prob., y Small	0.0	0.1	0.2	0.5	0.9	0.99

References

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4. Gauglitz, P.A., Rassat, S.D. et al., "Mechanisms of Gas Bubble Retention and Release: Results for Hanford Waste Tanks, 241-S-102 and 241-SY-103 and Single Shell Tank Simulants," PNNL-11298, September 1996, Pacific Northwest Laboratory, Richland, Washington.

2.0 3.A. TOTAL MASS OF TRANSPORTABLE WASTE MATERIAL SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF DST

(Note: References for Sections 3.A and 3.B will be listed together after 3B)

1. The following background information is relevant to the estimation of the mass suspended before the burn:

- 1.1 Atmospheric concentrations of airborne materials usually range between 10 and 100 microgram/m³.
- 1.2 Partition factors can be used to determine the mass suspended after an event. Based on Kimura and Lindsey (presented in Ref. 1 based on Ref. 3) the partition factors (density ratio of suspended aerosols to particle bed) are 10⁻¹¹ to 10⁻¹⁰ in a stagnant space but is about 10⁻⁹ with mixing. Hence, for a gas burst, the concentration of the suspended materials might be 10⁻⁹ x 1300 kg/m³ = 1.3 mg/m³.
- 1.3 The Delphi group (Ref. 4) estimated the release due to drilling may be 0.385 g and reasoned that aerosol concentrations from sampling during drilling were in a confined space and not representative of the entire headspace.
- 1.4 The Los Alamos group estimated that the entire headspace might be at the concentration found during drilling and came up with a total suspended mass of 350 g in the 1300 m³ headspace as a result of the gas release (based on statements in Ref. 4).

My estimate of the mass suspended before the a burn is based mostly on the partition factor information in the presence of mixing which gives: 1.5 mg/m³ x 1300 = 2.0 g.

2. Due to the burn, additional amounts will be suspended, due to entrainment and splash from falling debris. The following information provides some background material on this amount.
 - 2.1 LANL estimates (based on Ref. 4) the nominal amount suspended to be 10 kg and the maximum amount possible without dome collapse to be 100 kg.
 - 2.2 The Delphi group (Ref. 4) considered two sources: splash of solid debris on top of a surface and sheared liquid by entrainment. TI-753 report estimated 0.35 kg of waste attached to surfaces. The Delphi group estimates about 8 grams will be suspended due to 50 mph wind associated with the maximum pressure before dome collapse.

Considering the splash mechanism, I will consider the amount attached to surfaces to be 1 kg and only 30% of it could be mobilized. Ballinger, et al., (Ref. 5) provide information on the dependence of the airborne fraction on viscosity and height. Ballinger and Hodgson give graphs reproduced from Ref. 6 in Ref. 1 for the percent of airborne materials after a spill. The range is from 2×10^{-4} to 4×10^{-3} . Application of these figures to the 0.3 kg which could be mobilized gives a range of 0.06 g to 1.2 g due to splash.

As for entrainment, the major factor would be the wind speed and duration as a result of the burn. Data provided on a page from an article by J. Fitzgerald distributed to the SCOPE panel on February 11, 1989, shows entrainment rate to be proportional to the velocity to the power 3.4 (Ref. 10).

Combining the Delphi group value with Fitzgerald's observations one gets:

Overpressure (psi)	Representative Wind Speed (m/s)	Mass Entrained (g)
0.50	2.27	0.0023
10.0	10.2	0.22
30.0	17.0	2.46
60.0	25.0	8.00
60 (detonation)	50.0	25.0

The Dry Powders data collected by Gelbard and Brockman and given in both Ref. 1 and Ref. 2 show a wide range of entrainment rates. A brief version can be given as:

<u>Velocity</u> (m/s)	<u>Entrainment Rate</u> (kg/m ² .s)	<u>Mass Suspended from the tank surface (500 m²) in one second</u> (kg)
40	10 ⁻⁵ to 10 ⁻¹	5 x 10 ⁻³ to 50
10	10 ⁻⁶ to 10 ⁻²	5 x 10 ⁻⁴ to 5
2	10 ⁻⁶ to 10 ⁻⁴	5 x 10 ⁻⁴ to 0.05

However, it should be noted that wet powders will likely be less mobile than dry ones. Note also that above 10 g/m³ coalescence might be very fast (Fitzgerald data shows that a steady wind leads to a loading of 30 - 300 µg/m³ of sea water aerosols). This translates into a maximum loading of between 39 mg to 390 mg in the entire 1300 m³ headspace.

Based on the above estimates the total suspended masses in the headspace can be as follow:

normally	2.0 g	(max. 350 g)
splash effects	0.06 g to 1.2 g	(max 100 g)
hydrogen burn effect	1 psi: 0.0023 to 0.5 g	(max 50 g)
	<20 psi: 1.0 to 50 g	(max 5000 g)
	<47 psi: 8.0 to 500 g	(max 50,000 g)

Thus, the probability distribution for suspended mass before dome collapse is as follows:

Mass x (g) prob. less than:	0.1	1.0	3.0	10	100	1000	10,000	100,000
p $\approx$ 1 psi	0.0	0.1	0.5	0.75	0.99	1.0	1.0	1.0
p $\approx$ 20 psi	0.0	0.0	0.05	0.4	0.9	0.99	1.0	1.0
p $\approx$ 47 psi	0.0	0.0	0.0	0.05	0.5	0.90	0.99	1.0

3.0 3.B. MASS OF TRANSPORTABLE MATERIALS RELEASED IN CASE OF DOME COLLAPSE FOR DSTS

3B.1 In case of dome collapse, only a fraction of the mobilized mass would be able to penetrate the dirt pile:

- SAND 83-0840 mentions 10^{-3} as the effective filter efficiency (Ref. 7).
- Ref. 8 mentions that the cloud dust at 20 - 75 m from an explosion had about 2.5 - 7 kg out of 400 to 500 kg removed from the crater, i.e., transportable mass 0.5 - 2%.

3B.2 Delphi group, in considering this case determined that 200 g will be mobilized (Ref. 4).

3B.3 McFarlane et al., (Ref. 9) mentions several sources of released materials in similar events:

- 0.15 kg from HEPAs
- 80% of seared crust material (actually a range from 60 to 100%)
- 5% of time, wind >20 mph adds entrainment after the fact
- This leads to an estimated release of 10.8 kg, plus more due to subsequent wind effects.

Hence, starting with my estimates for the released materials from the SST tanks, but taking into consideration:

- 1 - wet materials less aerosolized by entrainment
- 2 - wet materials may splash upon impact of dirt

My estimate for the released material is:

$$500 \text{ m}^2 \times (4 \text{ m of dirt} \times 1.8 \times 10^3 \text{ kg/m}^2) \times 10^{-3} \text{ mobile} \times 10^{-3} \text{ filter} \approx 4 \text{ kg.}$$

If the mobile fraction is taken to be 0.02, the released material will be 80 kg. That can be a rough estimate for the maximum value. Overall, the distribution is as follows:

Mass mobilized and transportable

Mass (x) in grams	10	100	400	1000	4000	10,000	100,000
Probability less than x:							
SST	0.001	0.05		0.5		0.9	1.0
Deflagration (DST)	0.0	0.05	0.2	0.5	0.8	0.95	1.0
Detonation (DST)	0.0	0.02	0.1	0.2	0.5	0.90	1.0

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4.0 4. THE RESPIRABLE MASS FRACTION

The respirable mass is a fraction of the suspended mass in 3A or the transportable mass in 3B. Hence, my comments are hinged on the discussion 3A and 3B taking into consideration the following.

- 4.1 Herting et al., found 70% to 100% (average 80%) of aerosols have $d < 10 \mu\text{m}$ in SY101 dome space (Herting, D. L., et al., "Laboratory Characterization of Samples in December 1991 - Window E - from Hanford Waste Tank 241-SY-101," WHC-SD-WM-DTR-026, 1993).
- 4.2 There will be a collection efficiency for small particles by larger particles which will reduce the mass fraction available for respiration at 100 m distance from a tank, leaving a larger fraction of smaller particles in the reduced mass.
- 4.3 There is a large effect for a gravel pile which captures aerosol materials. The larger the diameter (within 1-6 μm) the less is the penetration factor out of the pile. Lana et al., (SAND83-0840, 1984) shows $5 \times 10^{-3} \pm 4 \times 10^{-3}$ respirable release fractions from gravel.

Based on the above information, I estimate the respirable waste material suspended to be 50% of the total suspended material for case 3A, where there is no dome collapse.

However, for cases with dome collapse, only 20% of the transportable material will be in the respirable range due to the strong effects of the dirt pile from the soil.

5.0 5. DURATION OF BUOYANT DISPLACEMENT GAS RELEASE

Summaries of gas releases from double-shell tanks are provided in Ref. 1 and Ref. 2. The data include the level drops, the volumes of gas released and period between release events, but not the duration of the releases. The expected behavior based on the analytical model for buoyancy driven gas release are given in Tables 1 and 2 which were provided by C. Stewart to the panel (Ref. 2).

Table 1. GRE Volume (Std. m³).

	AN-103	AN-104	AN-105	AW-101	SY-101	SY-103
From level drop (PNNL-11536 rev 1)						
First event date	06/01/89	02/27/86	05/20/85	11/17/86	03/25/89	12/08/89
Last event date	02/10/96	05/04/96	04/05/97	12/22/94	06/26/93	07/14/96
Number rec.	19	30	21	17	15	28
Average $\pm$ std dev.	14 $\pm$ 4	23 $\pm$ 16	26 $\pm$ 11	14 $\pm$ 10	131 $\pm$ 47	13 $\pm$ 6
From level drop (since 1993)						
First event date	02/10/93	04/27/93	01/23/93	04/10/94	12/04/91 (E)	07/01/93
Last event date	02/10/96	05/04/96	04/05/97	12/29/95	06/26/93 (I)	11/27/97
Number rec. from 1993	7	12	6	9	5	18
Average $\pm$ std dev.	15 $\pm$ 4	16 $\pm$ 5	21 $\pm$ 8	9 $\pm$ 4	151 $\pm$ 54	14 $\pm$ 9
From SHIMS						
First event date	08/22/95	11/06/94	08/21/95	10/01/94	12/04/91 (E)	01/22/95
Last event date	08/22/95	05/01/97	09/25/97	06/05/96	06/26/93 (I)	11/27/97
Hydrogen fraction in waste	0.62 $\pm$ 0.07	0.47 $\pm$ 0.04	0.62 $\pm$ 0.04	0.32 $\pm$ 0.02	0.31 $\pm$ 0.03	0.58 $\pm$ 0.06
Number of events rec.	1	7	4	16	4	9
Peak [H ₂] * headspace volume	5	8 $\pm$ 5	13 $\pm$ 12	11 $\pm$ 5	142 $\pm$ 44	9 $\pm$ 6
Integrate [H ₂] model	4	10 $\pm$ 6	18 $\pm$ 17	19 $\pm$ 7		12 $\pm$ 9
Best Estimate GRE History	-	10 $\pm$ 6	18 $\pm$ 17	19 $\pm$ 7	142 $\pm$ 44	12 $\pm$ 9

Table 2. Distributions.

	Release (m ³)	Time to Peak (min)	Relative Rel	Distribution of Relative Rel.	LOGNORMAL	-0.1 0.4
AN105	35	108	1.31	2.29	100.00%	98.99%
	18	110	0.69	2.16	96.50%	98.50%
Average	27	109		1.76	93.10%	95.14%
				1.39	89.60%	86.00%
				1.35	86.20%	84.07%
AN104	20	104	1.76	1.31	82.70%	82.16%
	11	135	0.98	1.28	79.30%	80.72%
	11	218	0.97	1.26	75.80%	79.47%
	8	86	0.68	1.24	72.40%	78.26%
	7	166	0.62	1.21	68.90%	76.76%
Average	11	142		1.05	65.50%	64.10%
				1.03	62.00%	62.73%
AN103	5	120		0.98	58.60%	58.36%
				0.97	55.10%	56.42%
AW101	30	240	1.39	0.94	51.70%	54.16%
	29	315	1.35	0.90	48.20%	49.30%
	27	540	1.26	0.88	44.80%	47.09%
	26	497	1.21	0.82	41.30%	40.43%
	22	480	1.05	0.81	37.90%	38.94%
	22	337	1.03	0.80	34.40%	38.27%
	19	840	0.88	0.69	31.00%	25.11%
	17	240	0.80	0.68	27.50%	23.27%
	13	517	0.62	0.66	24.10%	21.72%
	9	660	0.41	0.62	20.60%	17.36%
Average	21	467		0.62	17.20%	17.00%
				0.52	13.70%	8.61%
SY103	27	1128	2.29	0.51	10.30%	7.53%
	25	97	2.16	0.49	6.80%	6.52%
	11	96	0.94	0.41	3.40%	2.36%
	11	179	0.90	0.37	.00%	1.37%
	9	86	0.81			
	6	197	0.52			
	6	180	0.51			
	6	519	0.49			
	4	418	0.37			
Average	12	322				
SY101	182		1.28			
	176		1.24			
	94		0.66			
	117		0.82			
Average	142					

The volumes of the releases in DSTs based on the SHMS data are provided in Table 1 which is compiled from Refs. 1 to 3. The released volumes determined from SHMS date differ from those estimated based on level drop data, both those since 1989 and those since 1993. The release volumes have been used at PNNL (Ref. 4) to compare the releases to predictions of analytical models, which can be used to provide an estimate of the confidence in the predicted gas release volume (Table 2). However, Table 2 also provides data on time to reach peak value of H_2 concentration as measured by the SHMS data.

Values of convective layer and nonconvective layer depths are included in Table 3, which was provided to the panel at the January workshop by C. Stewart. A summary of all the data above is:

Tank	Release Volume (m^3)		Release Time (min) Table 2	Layer Depth (m) from Table 3	
	(Table 4.1.1, Ref. 2)	(Table 2)		Nonconvective	Convective
AN101	14	21	467	2.83	6.93
SY103	13	12	322	3.37	3.34
AN103	14	5	120	3.79	4.13
AN104	23	11	142	4.15	5.24
AN105	26	27	109	4.52	5.59
SY101	131	142	?	5.84*	4.70

*Pre-mixer pump activity. For post-mixer activity a value of 2.00 is given in Table 3.12 of Ref. 2.

It is evident from the combined data that the duration of BD-GRE is inversely dependent on the nonconvective layer depth, H_{NC} . For simplicity, I will assume a relation of the form

$$\tau^* = A/H_{NC}^2; \text{ where } \tau^* \text{ is in minutes and } H_{NC} \text{ in meters.}$$

A reasonable fit for the mean time of releases is obtained with the constant A taken as A = 3000. The calculated and observed values for the release times can be seen to be within $\pm 50\%$:

	τ^* (min)	
	Calculated	Observed
AN101	382	467
SY103	264	322
AN103	207	102
AN104	174	142
AN105	148	109
SY101	89 pre-mixer	--
	750 post mixer	

Table 3. Steady-State Void Predictions for DSTs.

Tank	G (mol/day/m ²)	NCL Height (m)	CL Height (m)	NCL Density ¹ (kg/m ³)	CL Density (kg/m ³)	Mean Temp. (K)	Mean Pres. (atm)	NB Void	Max Void ² (N=0)	Max Void ² (N=N ₀)	Ave Void ² (N=0)	Ave Void ² (N=N ₀)	Max/Cht (N=0)	Max/Cht (N=N ₀)	Tank
SY101	3.23E-5	5.84	4.7	1700	1500	323	2.1	0.118	0.647	1.029	0.440	0.686	3.64126	6.55195	SY101
SY103	3.66E-6	3.37	3.34	1545	1470	308	1.7	0.049	0.236	0.192	0.161	0.128	3.22145	2.97131	SY103
AN105	2.38E-6	4.52	5.59	1578	1421	313	2.1	0.099	0.233	0.277	0.158	0.185	1.55113	2.08162	AN105
AN104	4.71E-6	4.15	5.24	1590	1396	317	2.0	0.122	0.281	0.296	0.191	0.197	1.52149	1.82107	AN104
AW101	6.40E-6	2.83	6.93	1595	1430	314	2.2	0.103	0.234	0.148	0.159	0.098	1.49164	1.07101	AW101
AN103	3.44E-6	3.79	4.13	1730	1459	314	1.9	0.157	0.237	0.209	0.161	0.139	0.99199	1.00100	AN103
AN107	1.59E-5	2.280	7.440	1540	1357	308	2.1	0.119	0.277	0.134	0.188	0.089	1.53181	0.84141	AN107
CI06	2.06E-5	1.800	0.500	1550	1170	355	1.2	0.245	0.330	0.116	0.225	0.078	0.89123	0.35158	CI06
AP105	3.54E-6	0.820	0.709	1380	1230	320	1.1	0.109	0.110	0.015	0.075	0.010	0.67102	0.10112	AP105
AW102	5.04E-6	0.285	0.507	1500	1400	320	1.1	0.067	0.060	0.002	0.041	0.001	0.59194	0.02110	AW102
AW105	2.07E-6	2.717	0.776	1420	1080	320	1.2	0.239	0.197	0.128	0.134	0.085	0.54156	0.39194	AW105
AZ102	1.10E-5	0.870	7.370	1490	1100	355	1.8	0.262	0.143	0.020	0.098	0.013	0.36128	0.05163	AZ102
AN102	8.66E-6	0.817	9.169	1800	1390	320	2.3	0.228	0.107	0.012	0.073	0.008	0.31113	0.03192	AN102
SY102	1.28E-6	2.158	1.366	1560	1030	320	1.2	0.340	0.139	0.062	0.094	0.041	0.27109	0.13169	SY102
AW106	1.22E-6	2.093	2.888	1800	1230	320	1.5	0.317	0.121	0.047	0.082	0.031	0.25125	0.11114	AW106
AZ101	1.30E-5	0.320	7.860	1490	1187	345	1.9	0.204	0.076	0.003	0.052	0.002	0.24168	0.01101	AZ101
AY101	4.39E-6	0.765	7.948	1500	1100	320	1.9	0.267	0.093	0.011	0.063	0.007	0.22199	0.02199	AY101
AW104	4.23E-7	2.680	7.650	1460	1038	304	1.9	0.289	0.097	0.060	0.066	0.040	0.22121	0.15167	AW104
AW103	1.47E-6	1.390	3.350	1489	1011	303	1.4	0.321	0.104	0.027	0.071	0.018	0.21145	0.06122	AW103
AY102	6.72E-6	0.500	7.400	1400	990	310	1.7	0.293	0.084	0.006	0.057	0.004	0.18192	0.01146	AY102
AN106	8.70E-7	0.155	3.699	1800	1400	320	1.5	0.222	0.019	0.000	0.013	0.000	0.05162	0.00108	AN106
AN101	5.93E-7	0.254	9.717	1800	1256	320	2.2	0.302	0.020	0.000	0.014	0.000	0.04147	0.00012	AN101
AP104	1.61E-7	0.025	10.357	1100	1030	320	2.0	0.064	0.003	0.000	0.002	0.000	0.03158	0.00101	AP104
AP101	1.44E-6	0.003	6.798	1800	1330	320	1.9	0.261	0.001	0.000	0.001	0.000	0.00134	0.00010	AP101
AP102	1.30E-6	0.003	10.139	1800	1200	320	2.2	0.333	0.001	0.000	0.001	0.000	0.00124	0.00010	AP102
AP103	5.70E-6		0.249	1800	1000	320	1.0	0.444							AP103
AP106	7.23E-7		3.376	1800	996	320	1.3	0.447							AP106
AP107	6.09E-6		0.254	1800	1400	320	1.0	0.222							AP107
AP108	8.77E-7		2.350	1800	1190	320	1.3	0.339							AP108

¹1800 is the default.²if steady state can be obtained.

It should be noted that the observed release times in the same tank themselves have considerable variability. For example, the following two events have been observed in tank AN104:

Oct. 95 release (Fig. 4.5.5 Ref. 1) ~85% release in 180 minutes
 May 96 release (Fig. 4.5.7 Ref. 1) ~90% release in 100 minutes

The efficiency (or volume) of the release itself does not seem to correlate with the release times as can be seen in pp. 5.8 to 5.10 in Ref. 2:

- SY101 and AN101 releases are high efficiency but they have different release times.
- SY103, AN103, AN104 and AN105 have smaller fractional releases (10-30%) which make their releases medium efficiency. They also have varied release times.

The distribution of the release times can be determined from the history of SY103 releases given in Table 2:

- 0 events have times below $0.2 \tau^*$ (out of 9 events)
- 3 events have times about $0.3 \tau^*$
- 3 events have times about $0.6 \tau^*$
- 2 events have times about $1.5 \tau^*$
- 1 event has time about $3.7 \tau^*$

Thus, I will choose a range of release times that emphasizes the possibility of $0.5 \tau^*$ to $2.0 \tau^*$, hence, in summary, the probability distribution of the GRE time can be given as follows:

Time (minutes)	$0.25\tau^*$	$0.5\tau^*$	τ^*	$2\tau^*$	$4\tau^*$
Probability	0.01	0.1	0.5	0.9	0.99

where $\tau^* = 3000/H_{NC}^2$; H_{NC} in meters.

References

1. Stewart, C.W. et al., "In Situ Rheology and Gas Volume in Hanford Double-Shell Waste Tanks," PNNL-11296, September 1996.
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3. Wilkins, N.E., Bauer, R.E. and Ogden, D.M., "Results of Vapor Space Monitoring of Flammable Gas Watch List Tanks," HNF-SD-WM-TI-797, 1996.
4. Stewart, C.W., "Data On Applications of the Buoyant Displacement Model to DSTs," provided as e-mail to the Panel.

6.0 61. PROBABILITY OF A SEISMIC INDUCED GAS RELEASE EVENT IN A DOUBLE-SHELL TANK

The seismicity of the Hanford site was discussed in Ref. 1. The analysis of gas mobilization in the DST tanks has been carried out at PNNL for a 1000-year design basis earthquake based on elastic behavior and spectral analysis. The spectrum for acceleration lies in the range of 0.3 to 30 Hz with a peak acceleration of 0.5 g (Ref. 2 and Ref. 3). These early efforts are given in Ref. 4 and 5. Elastic-plastic structural simulations of the possible strains in solid layers with overlying layers of liquid were obtained using the code ANSYS under several conservative assumptions. The important assumptions are:

1. The materials in the tank were taken to be homogenous, thus neglecting any energy dissipation at interfaces between liquid, gas and solid components. Gas presence in any medium usually reduces the pressure wave propagation speed and amplitude.
2. The presence of the annular gap around the first tank wall was neglected. The gap should also be able to reduce pressure wave reflected at the outer surface. The perfect solid waste coupling to the soil assumed in the analysis is conservative.
3. Perfectly plastic behavior is assumed to occur in the waste once the strain reaches 5%. The energy dissipation in the extra strain is thus neglected.
4. Motion of particle clouds in fluids is associated with higher drag forces than motion of a single particle. Hence, the suitability of the viscosity used in the analysis which relied on measurements by a single ball for the behavior of the sludge over the entire range of strain is uncertain.
5. Mobilization of 50% of the gas is assumed when the strain reaches 100%. This is based on the observed rollover events in SY101 and the buoyancy model of Ref. 5. This assumption does not account for the fact that once gas is mobilized, it will dampen the effects of pressure waves within the waste itself.

The results of the analysis show that for a liquid layer above a solid layer almost 100% of the waste volume reaches the strain energy density limit if the shear strength is taken to be 300 PA. However, no region reaches the strain energy density limit if the shear strength is taken as 6000 Pa.

In an earlier assessment of (Ref. 7), Brewster and Whitney had estimated that for a 1000-year earthquake, 50% of the gas might be released while for a 100-year earthquake only 10% of the gas would be released.

The new analysis by ANSYS shows that a much greater release potential exists in a DST with an overlying water region. It also shows that the deeper is the solid layer, the larger is the potential for reaching the 100% strain limit.

Based on the above, I would assume a linear probability line over a logarithmic scale for the frequency of the earthquake as shown in the graph (Figure 1).

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1. Rohay, Alan, "Seismic Data for the Hanford Site," presented to Expert Panel Workshop, April 28-May 2, 1997.
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3. Reid, H.C. and Deibler, J.E., "Seismic Event Induced Waste Response and Gas Mobilization Predictions for Typical Hanford Waste Tank Configurations," PNNL-11680, September 1997.
4. Steward, C.W. et al., "Gas Retention and Release Behavior in Hanford Single-Shell Tanks," PNNL-11391, 1996.
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6. Stewart, C., "Seismic Response of DST Tanks," presented to Expert Panel, January 1998.
7. Brewster, M.E. and Whitney, P.D., "Estimates of the Frequency of Potentially Hazardous Gas Releases from Hanford Waste Tanks," included as appendix in Tom Powers and G.R. Sawtelle, "Tank Farm Deflagration Rates Due to Various Ignition Sources," WHC-SD-WM-CN-041, August 1996.

Figure 1. Uncertainty distributions for the frequency of earthquake-induced GREs.

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APPENDIX B.9
RATIONALE REPORTS

N. W. Kirch

May 1998

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1.0 INTRODUCTION

This elicitation took place on March 10, 1998 with Thomas Eppel of Decisions Insights, Inc.

I have just a few comments to make on the expert elicitation process. As an engineer who has spent several years evaluating tank data, I obviously found more comfort with the parameters associated with waste behavior. Other parameters that are more outside of my area of expertise required me to rely on the analyses from others, tempered with my own judgements. In forming an opinion about the elicitation process as a whole, I considered whether it would be better to have only elicitations from experts in their field of expertise. Although this may tighten the distributions, there are some problems that are encountered. I think the disadvantages to this are:

1. The number of experts required is greatly increased
2. The experts do not gain an understanding of the complete process, which may cause them to not properly condition their information
3. The experts may share a common bias that inaccurately reflects the broader opinion regarding that parameter's variability.

The approach used here, with experts from several different technical backgrounds eliciting on topics that may be outside their expertise, seems to be an appropriate compromise for providing the range of uncertainty with these parameters.

2.0 ELICITATION PARAMETER RATIONALES

2.1 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LIQUID LAYER (BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BD GRE)

I start my rationale with the premise that all nuclear waste generates hydrogen (and other gases) at some rate and therefore, all nuclear waste has some amount of gas retained in the waste matrix. In most tanks, the steady-state release of gas is equivalent (over long periods of time) to the gas generation rate. Most tanks do not exhibit any evidence of increasing retained gas inventory (slurry growth, level increases) nor do they have the indicators that a potential exists for BD GREs. Few mechanisms exists (other than BD) for gas releases large enough to meet the definition of GRE for this process (a single coherent release of trapped gases from the waste that is sufficiently rapid and localized enough to potentially form a locally flammable region that is for a time at risk of burning as a plume, and/or a release of trapped gases from the waste that is sufficiently rapid and large enough to form a flammable mixture in the headspace after becoming

well-mixed with the headspace gases). There are mechanisms for steady-state release from these tanks and that indicates there is some (in my estimate, very low) probability that a spontaneous gas release could occur that would meet the definition of a small, medium or large efficiency GRE.

This parameter is the frequency (per year) of spontaneous gas releases in DSTs that have a thick layer of liquid (>1m) but do not pass any test indicating the potential exists for BD GREs.

A review of Reference 98 was used to determine the estimated flammable gas inventory of the tanks that do not indicate BD GRE characteristics. The inventories at 0.25 quantile (75th percentile on a cumulative probability) are provided in Table 2-1 below. Additionally, the hydrogen generation rates from Reference 14 are also provided in this table.

Table 2-1. Retained Gas Inventory and Hydrogen Generation Rate for
Tanks that do not Possess Buoyant Displacement
Gas Release Event Characteristics.

Tank	Retained Gas Inventory, ft ³	Hydrogen Generation Rate, ft ³ /day
241-AP-101	NR	2.7
241-AP-102	NR	35.9
241-AP-103	-	0.4
241-AP-104	NR	0.5
241-AP-105	4625	1.5
241-AP-106	-	0.7
241-AP-107	NR	0.4
241-AP-108	-	0.6
241-AW-102	-	1.1
241-AW-103	-	1.9
241-AW-104	3922	1.2
241-AW-105	NR	2.0
241-AW-106	NR	1.6
241-AN-101	NR	1.6
241-AN-102	NR	23.6
241-AN-106	NR	0.9
241-AN-107	NR	42.0
241-AY-101	2986	10.4
241-AY-102	NR	26.4
241-AZ-101	NR	28.9
241-AZ-102	NR	24.6
241-SY-102	NR	1.2

NR- No retained gas inventory was indicated by barometric pressure-surface level correlation. (Blanks mean tank was empty or had significant transfer activity)

The evaluation of retained gas inventory indicates that most tanks in this category have no measurable indication of a retained gas inventory, with three tanks indicating an inventory of 3000-5000 ft³. The minimum detectable inventory using barometric pressure-surface level correlation is approximately 1000 ft³ if an Enraf level gauge is used. The minimum detectable inventory is approximately 1500 ft³ the FIC and 3000 ft³ with a manual tape. Therefore, the approximate size of spontaneous, non-BD GREs for the three categories of efficiencies is:

- Small efficiency release - <50 to 250 ft³
- Medium efficiency release - 50 to 750 ft³
- Large efficiency release - >750 ft³

Reviewing the estimated hydrogen generation rate and taking into account that hydrogen makes up from 30% to 70% of the retained gas (from Table 5.1.1 in Reference 63), a maximum bound on frequency can be estimated, assuming no other (i.e., steady-state release) mechanisms to release gas. Using this approach, small efficiency releases can occur as frequently as several times per month in high gas generation rate (30 ft³/day) tanks and 2-3 times per year in low generation rate (<2 ft³/day) tanks. However, the gas release volume in a small efficiency release from a tank with a high generation rate is comparable to the estimated daily steady-state release volume, and it is unlikely that it could be distinguished from the steady-state release. The comparison between generation rates and size of small efficiency release GREs indicates that these releases are not likely to contribute significantly to the overall risk.

Table 2-2. Small Efficiency Release Per Tank.

Upper bound	10 per year
95 th	3 per year
50 th	1 per year
5 th	10 ⁻¹ per year
Lower bound	10 ⁻² per year

For medium release efficiency events, the gas volume release is a factor of 10 to several hundred times the daily gas generation volume. These events, being larger, are by nature, more infrequent and require a mechanism. Eliminating BD GREs and intrusive activities, leaves limited mechanisms (e.g. Solubility driven, percolation) which do not have the capability to release large quantities of gas. Also, releases of medium efficiency would result in a detectable level drop, using 1 inch of level is equivalent to 400 ft³ of gas. In approximately 300 tank-years of double-shell tank operations, these types of releases have not been observed in tanks that do not meet the BD GRE criteria.

Table 2-3. Medium Efficiency Release Per Tank.

Upper bound	Did not specify
95 th	10 ⁻¹ per year
50 th	10 ⁻² per year
5 th	10 ⁻³ per year
Lower bound	Did not specify

For large efficiency releases in tanks that do not exhibit BD GRE characteristics, the size of event makes it very unlikely that a mechanism exists for this size of release. I used a range of release sizes from 750 ft³ up to 2000 ft³ to evaluate the frequency of large efficiency events from other mechanisms. Because this is equivalent to a range from 30 to 1000 times the daily generation volume, and represents a 2-inch to 5-inch level drop, these releases are far outside the range of observed tank behavior. Mechanisms other than BD GREs, for spontaneous large efficiency releases are 3 orders of magnitude less likely than medium efficiency releases.

Table 2-4. Large Efficiency Release Per Tank.

Upper bound	Did not specify
95 th	10 ⁻⁴ per year
50 th	10 ⁻⁵ per year
5 th	10 ⁻⁶ per year
Lower bound	Did not specify

2.2 PROBABILITY OF IGNITION SOURCE BEING INTRODUCED BY BD GRE

This parameter is specific to ignition sources caused by a BD GRE and the probability is given per BD GRE of specified release efficiency.

There must be significant waste movement that leads to intrusive equipment damage for a BD GRE to cause an ignition source. The probability that a given BD GRE will cause an ignition is small and includes the uncertainty related to whether motion occurs and whether the motion is strong enough to damage equipment and generate a spark.

Reference 6 was reviewed which indicated that the industrial experience is that the most commonly cited ignition source for hydrogen accidents is high temperature spontaneous ignition (14.67%), followed by electrical spark (12.96%). However, "unknown/other" accounted for 37.41% of ignition sources. Mechanical sparks were not cited on the table. The only conclusion I can draw from this is that BD GREs are unique from industrial accident experiences and often the ignition sources are not determined.

A review of potential ignition sources in tanks was performed (Reference 104) and indicated no active electrical equipment that was subject to BD GRE caused failures. The fire hazard analysis for the tank farms (Reference 106) states that low energy ignition sources such as static electricity or metal-to-metal contact are capable of igniting flammable gas mixtures. Therefore, it is assumed that these types of sources are credible to be caused by BD GREs.

Reference 27, pg. 4-11 states "The contributions of sparks from static electricity and metal-to-metal contact are negligible in comparison with the other ignition sources." Sparks from Food Instrument Corporation surface level gauges (FIC) were judged to have a probability distribution of:

$$95^{\text{th}} = 4.38 (10^{-3})/\text{yr}$$

$$50^{\text{th}} = 4.38 (10^{-4})/\text{yr}$$

$$5^{\text{th}} = 4.38 (10^{-5})/\text{yr}$$

For a small efficiency release, there is little waste movement and therefore, the ignition source probability is judged to be significantly less than the FIC failure rate. I would put this in the category of extremely unlikely (using the guidance of DOE 1994). The distribution that I selected is:

Table 2-5. Probability of an Ignition Source Being Introduced by a Small Efficiency Release.

Upper bound	Did not specify
95 th	10 ⁻⁴
50 th	10 ⁻⁵
5 th	10 ⁻⁶
Lower bound	Did not specify

The probability of a medium efficiency BD GRE introducing a spark source is increased because the size of the release is more likely to result in equipment motion or damage. I estimate this probability to be approximately the same as the probability for a FIC failure to result in an ignition source.

Table 2-6. Probability of an Ignition Source Being Introduced by a Medium Efficiency Release.

Upper bound	Did not specify
95 th	$5(10^{-3})$
50 th	$5(10^{-4})$
5 th	$5(10^{-5})$
Lower bound	Did not specify

The probability of a large efficiency BD GRE introducing a spark source is higher than the medium efficiency release because the experience and observations of 241-SY-101. It is known that large efficiency releases often result in equipment motion and damage. However, the probability is not unity, since 241-SY-101 has exceeded the lower flammability limit on at least 4 occasions and there is no evidence that a flammable gas burn has occurred. Additionally, because the relative motion in a large efficiency release can vary from very little to very significant, the probability that a given release will introduce an ignition source has a larger degree of uncertainty. The median falls into the unlikely category, however the tail includes anticipated events. I adjusted my median value to distinguish the difference between the medium and large events. Therefore, my estimate is as follows:

Table 2-7. Probability of an Ignition Source Being Introduced by a Large Efficiency Release.

Upper bound	Did not specify
95 th	10^{-1}
50 th	$5(10^{-3})$
5 th	10^{-4}
Lower bound	Did not specify

2.3 DURATION OF BD GRE

Given the definition of GRE ("being sufficiently rapid") this allows extremely slow (long duration) GREs to be truncated from the distribution. The truncation occurs at the duration time that transitions from GRE to "temporal variations in steady-state release."

The general tank farm experience is that the duration of a BD GRE is inversely proportional to the fraction of retained gas released in the GRE. Certainly the largest BD GREs in 241-SY-101 occurred very quickly, but for small and medium efficiency releases other tanks must be evaluated.

The following tables compare the time from the start of gas release events (defined as the deviation from hydrogen monitoring baseline) to the peak hydrogen concentration (data provided by WE Barton). Also, included in the tables is the fraction of retained gas released in the GRE from Reference 63. The tables have been grouped into small and medium efficiency releases.

Table 2-8. Time to Peak Hydrogen Concentration for Small Efficiency Releases.

Tank	Date	Time to Peak H ₂ , minutes	Release Efficiency %	Peak [H ₂], ppm
241-AN-103	8/22/95	12	3.0	1600
241-AN-104	10/8/95	31	5.0	2000
241-SY-103	12/3/95	137	3.3	640
241-SY-103	6/6/96	147	3.8	900

Table 2-9. Time to Peak Hydrogen Concentration for Medium Efficiency Releases.

Tank	Date	Time to Peak H ₂ , minutes	Release Efficiency %	Peak [H ₂], ppm
241-AN-104	2/16/95	111	5.6	2000
241-AN-104	10/2/95	96	8.1	2850
241-AN-104	5/3/96	85	5.8	5900
241-AN-105	8/21/95	4	15.6	16,000
241-AN-105	5/30/96	73	7.5	14,500
241-SY-103	1/22/95	100	6.6	960
241-SY-103	3/2/95	88	9.3	2200
241-SY-103	5/2/95	56	8.8	1330
241-SY-103	8/23/95	255	6.0	1140
241-SY-103	9/6/95	51	11.3	1830
241-SY-103	7/14/96	512	5.3	1770

The lower bound for duration of BD GREs is instantaneous (i.e., duration equal zero). There appears to be little difference in distribution between the small and medium efficiency release duration, therefore I have treated these two conditioning factors identically. The duration of BD GREs appears to be log-normally distributed.

Table 2-10. Small Efficiency BD GRE Duration.

Upper bound	3,600 minutes (2.5 days)
95 th	720 minutes (12 hours)
50 th	90 minutes
5 th	1 minute
Lower bound	0.02 minute (1 second)

Table 2-11. Medium Efficiency BD GRE Duration.

Upper bound	3,600 minutes (2.5 days)
95 th	720 minutes (12 hours)
50 th	90 minutes
5 th	1 minute
Lower bound	0.02 minute (1 second)

The upper bound was chosen because after five days, the release rate is nearly equivalent to the steady-state gas release rate.

In general, the large efficiency gas release events that have occurred in 241-SY-101, have occurred in short periods of time. The shortest observed has been the December 1991 (Reference 107) which occurred in ~ 2 minutes (per video observation). During this event, the tank dome space was above atmospheric pressure for 2.8 minutes and the peak hydrogen concentration occurred 8 minutes into the event.

Although Reference 63 shows that historically other tanks have exhibited large efficiency GREs, the only tank data available to evaluate durations is from 241-SY-101. Because of the large volume of gas released in a large efficiency GRE, the release cannot be instantaneous. Additionally, the vigorous rollover of the waste in a large efficiency release, leads to a short duration for the release. Table 2-12 provides information for the duration of large efficiency releases that have occurred in 241-SY-101. The time to peak hydrogen concentration and peak hydrogen concentrations are taken from the 241-SY-101 gas release event evaluation reports.

Table 2-12. Time to Peak Hydrogen Concentration for Large Efficiency Releases.

Tank	Date	Time to Peak H ₂ , minutes	Release Efficiency %	Peak [H ₂], ppm
241-SY-101	4/19/90	20	39.7	35,000
241- SY-101	10/24/90	7	35.2	47,000
241- SY-101	8/27/91	96	35.8	3800
241- SY-101	12/4/91	8	43.7	52,000
241- SY-101	9/3/92	7	67.0	51,200
241- SY-101	2/2/93	55	45.2	27,900
241- SY-101	6/26/93	17	45.7	34,000

Using the data from 241-SY-101, the duration distribution for large release efficiency BD GREs is:

Table 2-13. Large Efficiency BD GRE Duration.

Upper bound	1440 minutes (1 day)
95 th	120 minutes (2 hours)
50 th	15 minutes
5 th	2 minutes
Lower bound	1 minute

2.4 PROBABILITY OF SEISMIC-INDUCED GRE

The probability of a seismic-induced GRE is given on a per earthquake basis. The presentation by C.W. (Chuck) Stewart provided at the February 1998 Panel Workshop and the technical report, which provides the basis for that presentation (Reid and Deibler 1997, reference 68), were reviewed to evaluate the probability of a seismic-induced GRE.

The figure 20 in Reference 142 was used to establish a relationship between earthquake annual frequency and peak acceleration. This relationship is given in Table 2-14.

Table 2-14. Peak Acceleration for Earthquakes.

Earthquake Frequency	Peak Acceleration, g
10^{-2} /year	0.03
10^{-3} /year	0.18
10^{-4} /year	0.39

The Reid and Deibler 1997 report evaluated the effect of the 10^{-3} /year (0.18g) earthquake. The report evaluated the volume of waste mobilized during this earthquake by determining the fraction of solids volume that exceeded a strain energy density criterion. The DST case (liquid over solids) concluded that > 80% of the solids volume was mobilized if the solid shear strength was 300 Pa, where as for stronger solids (6000 Pa), no solids were mobilized. The yield strength data in reference 63 indicate that 300 Pa is the appropriate value to use. The results of this analysis are that a large efficiency release is very likely from a 10^{-3} /year earthquake and this release is just as likely from the stronger 10^{-4} /year earthquake.

A certain amount of judgement is required to extrapolate the Reid and Deibler 1997 results to the 10^{-2} /year return frequency earthquake. During 1997, Edward Siciliano, Fluor Daniel Northwest, reviewed seismic data for the state of Washington to determine if there was a correlation between the small, frequent earthquakes (magnitude 3-4) and GREs. The results were presented at a Flammable Gas Weekly Program meeting, but have not been published. It was reported that site accelerometers, which have been set at 0.02 g, have never recorded any event. For the small, frequent quakes that had registered below 0.02 g, there was no correlation between the seismic event and a GRE. The maps from C.W. Stewart's presentation lead me to estimate that the 10^{-2} /year earthquake is approximately magnitude 5 or intensity VI on the Modified Mercalli Scale. The description provided by the US Geologic Service states, "Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster Damage slight." The conclusion that I reach from this information is that small efficiency releases are likely from the 10^{-2} /year event, but medium and large releases are unlikely. I estimated that the large releases are an order of magnitude more unlikely than the medium releases.

Table 2-15. Probability of a Small Efficiency GRE Caused by 10^{-2} /year Earthquake.

Upper Bound	Did not specify
95 th	0.5
50 th	10^{-1}
5 th	10^{-2}
Lower Bound	Did not specify

Table 2-16. Probability of a Medium Efficiency GRE
Caused by 10^{-2} /year Earthquake.

Upper Bound	Did not specify
95 th	10^{-1}
50 th	10^{-2}
5 th	10^{-3}
Lower Bound	Did not specify

Table 2-17. Probability of a Large Efficiency GRE
Caused by 10^{-2} /year Earthquake.

Upper Bound	Did not specify
95 th	10^{-2}
50 th	10^{-3}
5 th	10^{-4}
Lower Bound	Did not specify

Table 2-18. Probability of a Small Efficiency GRE
Caused by 10^{-3} /year Earthquake.

Upper Bound	Did not specify
95 th	0.8
50 th	0.5
5 th	10^{-1}
Lower Bound	Did not specify

Table 2-19. Probability of a Medium Efficiency GRE
Caused by 10^{-3} /year Earthquake.

Upper Bound	Did not specify
95 th	0.5
50 th	10^{-1}
5 th	10^{-2}
Lower Bound	Did not specify

Table 2-20. Probability of a Large Efficiency GRE
Caused by 10^{-3} /year Earthquake.

Upper Bound	Did not specify
95 th	0.5
50 th	10^{-1}
5 th	10^{-2}
Lower Bound	Did not specify

Table 2-21. Probability of a Small Efficiency GRE
Caused by 10^{-4} /year Earthquake.

Upper Bound	Did not specify
95 th	0.8
50 th	0.5
5 th	10^{-1}
Lower Bound	Did not specify

Table 2-22. Probability of a Medium Efficiency GRE
Caused by 10^{-4} /year Earthquake.

Upper Bound	Did not specify
95 th	0.8
50 th	0.5
5 th	10^{-1}
Lower Bound	Did not specify

Table 2-23. Probability of a Large Efficiency GRE
Caused by 10^{-4} /year Earthquake.

Upper Bound	Did not specify
95 th	0.5
50 th	10^{-1}
5 th	10^{-2}
Lower Bound	Did not specify

2.5 PROBABILITY OF IGNITION SOURCE IN A DST CAUSED BY EARTHQUAKE

This parameter is the probability of a 10^{-2} /year, 10^{-3} /year and 10^{-4} /year return frequency earthquake creating an ignition source independent of whether a BD GRE occurs in the tank.

The relationship between earthquake annual frequency and peak acceleration from section 2.4, Probability of Seismic-Induced GRE, was also used in this section. These accelerations are below the controlling failure mode for DSTs discussed in Reference 20, shear failure at the wall without dome collapse, which occurs at 0.8g. At this level of earthquake, the primary liner would hold, therefore there is anticipated to be a very low probability that a seismic-induced ignition source would occur within the primary tank, other than those ignition sources that would result from a BD GRE.

Reference 4 was reviewed, which indicated that the viscosity effects of seismic events on waste tanks can typically be discounted. This report looked at two earthquake motions (0.24 g and 0.81 g) for fluid viscosities ranging from 60 to 10,000 cP. The report concluded that for viscosity effects to become noticeable in the response of the tank, the waste viscosity must be greater than 10,000 cP. A letter report on waste viscosity versus temperature reported that tank waste maximum viscosities were below 100 cP (Reynolds 1988).

It was noted that the 10^{-5} /year earthquake has an ignition source probability of 1. The peak acceleration from this earthquake exceeds the 0.8 g threshold for tank damage; therefore it is reasonable to have a step-change in the ignition source probability.

The conclusions that I reach from these reports are:

- The 10^{-2} /year, 10^{-3} /year and 10^{-4} /year earthquakes will result in little or no damage to the DSTs
- These earthquakes will create waste movement that is not capable of damaging in-tank equipment
- It is extremely unlikely that these earthquakes cause an ignition source, without the additional waste motion that results from a seismic-induced GRE.

The probabilities that I estimate for an ignition source caused by an earthquake are the same for the 10^{-2} /year and 10^{-3} /year return frequency earthquakes. Because the peak acceleration associated with the 10^{-4} /year earthquake starts to approach the damage threshold, I increased the ignition source probability by one order of magnitude.

Table 2-24. Probability of Ignition Source in DST
Caused by 10^{-2} /year Earthquake.

Upper Bound	Did not specify
95 th	10^{-5}
50 th	10^{-6}
5 th	10^{-7}
Lower Bound	Did not specify

Table 2-25. Probability of Ignition Source in DST
Caused by 10^{-3} /year Earthquake.

Upper Bound	Did not specify
95 th	10^{-5}
50 th	10^{-6}
5 th	10^{-7}
Lower Bound	Did not specify

Table 2-26. Probability of Ignition Source in DST
Caused by 10^{-4} /year Earthquake.

Upper Bound	Did not specify
95 th	10^{-4}
50 th	10^{-5}
5 th	10^{-6}
Lower Bound	Did not specify

3.0 REFERENCES

3.1 REFERENCES FROM GAS RELEASE EVENT SAFETY ANALYSIS PROJECT LIBRARY

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63. PNNL-11536, Rev. 1, *Gas Retention and Release Behavior in Hanford Double-Shell Waste Tanks*, May 1997
68. PNNL-11668, *Seismic Event-Induced Waste Response and Gas Mobilization Predictions for Typical Hanford Waste Tank Configurations*
98. WHC-SD-WM-ER-526, Rev. 1A, *Evaluation of Hanford Tanks for Trapped Gas*, March 1996 and January 1997.
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3.2 OTHER REFERENCES

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**APPENDIX B.10
RATIONALE REPORTS**

G. Paulson

May 1998

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1.0 INTRODUCTION

The detailed elicitations on the double shell tank (DST) parameters that are, by reference, a part of this report were obtained by Thomas Eppel of Decision Insights during a session held on March 12, 1998 in Richland, Washington. I understand they will be provided separately directly to the Sandia team, so they are not included with this report. I did, however, have copies of them available when I prepared this report. In addition, in preparing for the elicitation of March 12, 1998, as well as this report I reviewed the report I prepared last year (Paulson, 1997) to review my reasoning regarding certain features related to the single shell tanks (SSTs) and more general phenomena. I did not, however, review the reports or the elicitations of other members of the Panel, since that seemed inconsistent with the core features of this process.

In addition to the specific references from the library assembled for the Panel's use that are cited in the body of the report, and including pertinent references cited in certain sections of Paulson, 1997, I also based my analysis on concepts found in Morgan and Henrion, 1994, Cooke, 1991, and Piattelli-Palmarini, 1994.

These introductory observations should be seen as an integral part of this report. First, I wish to explicitly endorse the Analytical Framework as developed by Slezak and others. The Analytical Framework as finally agreed to by the Panel appears to me to capture both the key physical and chemical parameters governing buoyant displacement gas releases. Second, I wish to commend the entire project team for the quality and responsiveness of its work during the entire process, not only during the workshops and the week of the elicitations, but between these times and after hours, as well. The responsiveness of all team members, including the presenters and technical experts in Richland, was outstanding, and the logistic arrangements made it easy for the Panel members to focus on the task at hand with no distractions. Third, I wish to strongly support all efforts to substitute data for elicited parameters as time progresses, particularly if the Analytical Framework and the associated Analytical Tool is in fact used not only to resolve the unresolved safety question and evaluate the potential effectiveness of potential technical controls and other types of control strategies, but for other purposes as well (for example, to evaluate transfers of waste between tanks). For example, I understand that there are now extensive measurements on void fractions in single shell tanks, data which were not available during the first phase of this process. Any such data available now or in the future should be promptly substituted for elicited parameters as soon as possible. Fourth, again assuming that the Framework and the Tool find future uses, it seems desirable that future data gathering activities on the entire tank complex should be significantly influenced by the phenomena and the explicit or implicit needs for data that are found in the Framework. Finally, I encourage the Project Team to periodically inform the Panel members of future developments related to the Panel's work. This could take the form of informal memos or by simply sending the Panel copies of the summaries of key subsequent documents. All Panel members invested substantial intellectual capital in the process, and I for one would like to learn from time to time what the return on that investment is.

For convenience, I have used **bold type** to identify parameter/conditioning factor combinations in the same manner as in the Final Parameter List, 1998.

2.0 ELICITATION PARAMETER RATIONALES

2.1 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LAYER OF LIQUID (> 1 METER) BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL EXISTS FOR BUOYANT DISPLACEMENT-TYPE GAS RELEASE EVENTS (GRES)

The key published references that provide the background for my reasoning are Meyer et al., 1997, Wilkens et al., 1997, and Antoniuk, 1993. Just as important were several workshop presentations, notably Stewart, 1998a and Barton, 1998. The two workshop presentations provide insights as to the number of GRES, without regard to size, in tanks which "pass the test", and thus provide information that can be used to judge an upper bound for tanks that do not pass the test. For example, Figure 5 in Barton, 1998 provides GRE frequencies for six tanks with a supernate layer, ranging from a low of about 0.25 GRES per year (AN-103) to a high of about 4.75 GRES per year (AW-101), without distinguishing size/efficiency. The average across this group is about 2.3 GRES per year. Calculations using the number of GRES detected by different techniques over different periods of time in Stewart's table titled GRE history summary show a somewhat different range, from a low of about 2 per year to a high of over 9 (for AW-101, from SHMs data). In round terms, I assumed a typical frequency of 1 event per year average for tanks that fail the tests, and to truncate my distribution for tanks that do not pass the tests, I assumed a frequency for large and medium of GRES of 0.01 of that frequency, or 0.01 per year.

My other fundamental conclusion is that if there had been significant GRES (large or medium efficiency releases, in terms of the conditioning factors) in any DSTs other than those six that have been relatively intensively monitored since 1985, there is a very high probability (95%) that they would have been detected by one or another means. This means about 264 tank-years of experience (22 DSTs times 12 years) without a large or medium GRE. I assign a 95% probability to this frequency, which is 0.0038 per year. The other points on the curve are scaled as shown in the table, just below. For small efficiency GRES, which would be more probable, though harder to detect, I adjusted the distribution upward by a factor of 10, with a 0.1 event per year assigned a P of 1.0.

For comparison, for large efficiency GRES, the frequency at a given probability is about 10 times greater for DSTs than I developed for Group II SSTs last year using different information, which is the direction of the trend I would suspect in DSTs, compared to SSTs.

1 b, 1 c: Medium and Large Efficiency GREs

x	f(x)
0.01	1.0
0.0038	0.95
0.00038	0.50
0.000038	0.05

1 a: Small Efficiency GREs

x	f(x)
0.1	1.0
0.038	0.95
0.0038	0.50
0.00038	0.05

2.2 PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

I am impressed with the violent motions that have been videotaped during GREs, especially in SY-101. Coupled with the fact that DSTs typically have a significant amount of intrusive equipment, there is a high potential for sparking, which could of course be extremely serious if it occurred when there were appropriately elevated flammable gas levels. This is not a situation that can be fixed; that is, it is not likely that the intrusive equipment can be removed, or its range of motion restricted, or that existing equipment can be totally replaced with spark-proof equivalents during the remaining life of the DSTs. Thus it seems prudent to assume quite significant probabilities for ignition sources being induced by large efficiency GREs, and lower but still significant probabilities for medium and small GREs to create an ignition source. However, I do not believe simple scaling by a factor of 10 is appropriate, since I wish to preserve the possibility of induced ignition sources even for the smaller size GREs.

However, I have been unable to find any specific quantitative justification for these distributions in the technical materials I have reviewed. It is of course extremely likely that there has never been an ignition source occurring in a tank while lower flammability limits were exceeded; such an event would in all likelihood have been noted at the time, even without sophisticated monitoring equipment. At the same time, it would be a matter of pure luck for an ignition source to have been detected during a GRE that did not lead to gas levels exceeding the lower flammability limit. All distributions are to be truncated at 1,1.

2 c: Large GRE

x	f(x)
1	1
0.1	0.95
0.01	0.5
0.001	0.05

2 b: Medium GRE

x	f(x)
1	1
0.1	0.99
0.01	0.90
0.001	0.5
0.0001	0.10

2 a: Small GRE

x	f(x)
1	1
0.1	1
0.01	0.98
0.001	0.89
0.0001	0.50
0.00001	0.10

**2.3 TOTAL MASS OF TRANSPORTABLE WASTE MATERIAL
(A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT
THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR
(B) RELEASED FROM A DST BY A COMBUSTION EVENT THAT
CAUSES STRUCTURAL FAILURE OF A DST**

Just as in last year's elicitation, this proved to be a particularly difficult group of parameters. After reviewing my judgments from last year (Paulson, 1997, pp 11ff and the references cited there) in light of the newly presented information (Julyk, 1998; Gelbard & Brockmann, 1998), I concluded that for the worst case in this group, 3(e), a detonation sufficient to fail the DST dome, the probability/mass distribution I developed for the worst case last year was appropriate, and to be conservative, I assumed that the this mass was transportable and would be released in a detonation (by definition, a highly energetic event). I reduced the mass by a factor of 5 for each

specified probability for 3(d), a deflagration that would fail the dome, to take into account the lower energy conditions.

For 3(c), a high pressure burn that does not fail the dome, I assumed the same distribution as for 3(d). Even though the dome is not failed in scenario 3(c), this scenario is based on a high energy event that would be associated with significant transportable materials suspended in the headspace. For the lower energy burns, I further reduced the transportable mass by a factor of 5 at each step.

The elicitor captured my distributions accurately, but because there are relatively few of them, I include them here. All mass units are in kilograms; the distributions are not truncated.

2.3.1 (A) For the Cases Where the Combustion Event is Insufficient to Fail the DST Dome:

3 a: burn insufficient to fail filter

x (kgm)	f(x)
3.6	0.95
1.8	0.90
.4	0.50
.08	.020
.008	0.05

3 b: burn < 20 psi, fails filter

x (kgm)	f(x)
18	0.95
9	0.90
2	0.50
0.4	0.20
0.04	0.05

3 c: burn > 20psi, fails filter, not dome

x (kgm)	f(x)
88.4	0.95
44	0.90
10	0.50
2.0	0.20
0.2	0.05

2.3.2 (B) For the Cases Where the Combustion Event Is Sufficient to Fail the DST Dome:

3 d: headspace *deflagration* that fails dome

x (kgm)	f(x)
88.4	0.95
44	0.90
10	0.50
2	0.20
0.2	0.05

3 e: headspace *detonation* that fails dome

x (kgm)	f(x)
442	0.95
221	0.90
50	.050
10	.020
1	0.05

2.4 TOTAL MASS OF RESPIRABLE WASTE MATERIAL (A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (B) RELEASED FROM A DST BY A COMBUSTION EVENT THAT CAUSES STRUCTURAL FAILURE OF A DST

This parameter and its sub-set of conditioning factors is identical to the prior one, except that it deals not with (total) *transportable* material in the air, but that fraction of the total which is *respirable*. I assumed that the respirable mass would be 50% of my estimates for the total transportable mass for each scenario; there is no specific quantitative basis for this assumption. However, the basic circumstances postulated to occur—fires or explosions—have the potential to produce significant quantities of small particles; the turbulence of conditions inside the dome, whether or not the dome later fails, would also have this tendency. If in the final analysis this parameter and the prior one turn out to be the truly dominating features, it might be possible to develop controlled experiments, using real or simulated waste, that could somewhat narrow the range of uncertainty for both transportable and respirable mass. However, such experiments could also raise more questions than they answer, and at this stage of understanding, I do not recommend that this specific route be seriously pursued, in spite of the more general point I made in my introductory comments.

2.4.1 (A) For the Cases Where the Combustion Event is Insufficient to Fail the DST Dome:

4 a: burn insufficient to fail filter

x (kgm)	f(x)
1.8	0.95
0.9	0.90
0.2	0.50
0.04	0.020
0.004	0.05

4 b: burn < 20 psi, fails filter

x (kgm)	f(x)
9	0.95
4.5	0.90
1	0.50
0.2	0.20
0.02	0.05

4c: burn > 20psi, fails filter, not dome

x (kgm)	f(x)
44.2	0.95
22	0.90
5	0.50
1	0.20
0.1	0.05

2.4.2 (B) For the Cases Where the Combustion Event is Sufficient to Fail the DST Dome:

4 d: headspace *deflagration*
that fails dome

x (kgm)	f(x)
44.2	0.95
22	0.90
5	0.50
1	0.20
0.1	0.05

4 e: headspace *detonation*
that fails dome

x (kgm)	f(x)
221	0.95
110	0.90
25	0.050
5	0.020
0.5	0.05

2.5 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

This is a parameter where actual data could increasingly substitute for elicited parameters, and I recommend that this be given a high priority, especially in view of the increasing body of information from the SHMs instruments. To develop my distributions, I chose to use only the recent SHMs data, as originally provided by Barton to Cheng (Cheng, 1998)¹. This is recent, highly reliable data regarding GRE events in the five tanks that are generally thought to be the ones currently demonstrating buoyant displacement GRE behavior (the “usual suspects”). To the best of my knowledge, the data set has not yet been analyzed in a way that the events chronicled could be associated with, for example, retained gas fractions or void volumes, and thus with even a partial picture related to the conditioning factors for this parameter of small, medium and large efficiency releases, and I did not have the time to attempt this in detail during the week of the elicitation.

Instead, I grouped the events into three categories based on the peak hydrogen concentrations measured in each event, and assumed there was a rough correlation between these three groups with small, medium and large GREs. By this analysis, there were two releases that were clearly larger than all the others, and roughly an equal number of releases that I attributed to medium efficiency and small efficiency releases (the cutoff point between small and medium was a peak concentration of 3,000 ppm hydrogen). Each of these events is associated with a time to the peak concentration, which I took as a surrogate for the duration of the GRE. (For this very small data set, it did not seem significant to incorporate the 95% to peak criterion agreed to by the Panel.)

¹I believe that this data is in the project library, and also may have been submitted to the full Panel previously by e-Mail, though my computer system has been unable to routinely retrieve data files attached to e-Mail messages during this project—a failure at my end, not a failure of the Project Team. In any event, I obtained the data set only during the week of my elicitation, and therefore had only a brief time to work with it before being elicited on this parameter.

Finally, from this small overall data set, grouped as stated, I constructed the approximate distributions provided below. The unit for the duration is minutes. Based on the data set, I was able to select a duration level associated with a probability of 0 for each efficiency group.

5 a: small efficiency GRE		5 b: medium efficiency GRE		5 c: large efficiency GRE	
x (minutes)	f(x)	x (minutes)	f(x)	x (minutes)	f(x)
10,000	1	10,000	1	1,000	1
3,000	0.95	3,000	0.95	500	0.95
1,000	0.5	1,000	0.88	100	0.5
100	0.05	500	0.5	50	0.05
1	0	10	0.05	10	0
		1	0		

2.6 PROBABILITY OF A SEISMIC-INDUCED GRE

In developing my elicitations for this large group of parameters, I relied significantly on my analysis of last year (Paulson, 1997) and the references cited there for seismic issues, as well as Stewart, et al., 1996 and Ried and Diebler, 1997, augmented by Stewart's Workshop presentation on this subject (Stewart, 1998b).

2.6.1 (A) Probability of a Seismic-Induced GRE in a DST:

The 61 a-I elicitations are all for DSTs, with a thick liquid layer. My basic conclusion is that for earthquakes with a return frequency of both 1 in 1,000 years (1E-3/year) and 1 in 10,000 (1E-4/year), there is a 100% probability that GREs will be induced. Thus my elicitations for the six elicitations **61 d-I** are identical, step functions with a single point, where $f(x) = 1$ when $x = 1$.

For earthquakes with a return frequency of 1 in 100 years (1E-2/year), I believe it is certain that such an earthquake will induce small GREs in DSTs with thick liquid layers. This my elicitation for **61 a**, is a step function, with the single point of $x = 1$ and $f(x) = 1$.

For medium and large GREs induced by 1E-2/year earthquakes, I believe there is some likelihood, albeit low, that neither a medium or a large GRE will be induced. To capture this, I have constructed the two distributions below.

61 b: 1E-2/year frequency, medium release **61 c:** 1E-2/year frequency, large release

x	f(x)	x	f(x)
1.0	1.0	1.0	1.0
0.99	0.90	0.98	0.90
0.95	0.50	0.90	0.50
0.90	0	0.80	0.00

2.6.2 (B) Probability of a Seismic-Induced GRE in SSTs:

In developing my distributions, I continue to believe that 1 in 10,000 year earthquakes will have a 100% probability of causing GRE events in unpumped tanks. Thus for **64 a-c** and **64 g-I**, I have identical, step function distributions, where $f(x) = 1$ when $x = 1$.

For pumped FG2 tanks, covered by the distributions **64 d-f**, I do not use a step function. In particular, for **64 d**, the small efficiency release in a pumped FG2 tank, I foresee a higher likelihood of release in the more serious earthquake than for 63d (see below). Thus I revised the distribution for 63 d in the proper direction, though not by a single factor, as follows:

64 d: *Small Releases in a Pumped FG2 Tank*

x	f(x)
1	1
0.5	0.50
0.1	0.05
0.01	0.0

For **64 e**, I adjust 64 d downward by a factor of 10, and for **64 f**, by another factor of 10, to reflect the lower probability of medium or large releases, compared to small releases.

For **64 j-l**, pumped FG3 tanks, I have concluded there is no probability of a flammable gas release even under the extreme stress of a 1E-4/year earthquake.

My anchoring distribution for many distributions in this large set of elicitations (62 a-l, 63 a-l and 64 a-l) is **63 d**, a 1 in a 1000 year earthquake's predicted consequences for a small efficiency gas release in a pumped FG2 tank. This distribution is basically identical to that for the equivalent distribution last year, where I did not distinguish between pumped and unpumped tanks, but where in reviewing my reasoning, the focus was the result in a pumped tank. In essence, I foresee some probability that an earthquake of this severity could cause a small gas release event, even in a pumped tank, a conservative position.

63d: Small Releases in a Pumped FG2 Tank

x	f(x)
1	1
0.1	1
0.05	0.5
0.01	.05
0.005	0.01

For medium releases (**63 e**), which are less likely, I move the distribution an order of magnitude to the left, and for large releases (**63 f**), another order of magnitude.

However, for **64 a-c**, unpumped FG2 tanks, I believe there is a 100% probability for a 1E-3 earthquake to cause GREs, which is a conservative but in my opinion appropriate judgment.

For **63 g**, unpumped FG3 tank, small release, I change the distribution for **63 d** by one order of magnitude, for **63 h** by an additional order of magnitude, and for **63 i**, by yet another. For the balance of this group, **63 j-l**, which are pumped FG3 tanks, I set the probability at 0 for all size releases.

Finally, that leaves the 62 series, all for one in a hundred year earthquakes. For this set, I began with the distribution for **63 d**, as described above, and constructed a distribution by analogy (less probable) for **62 d**, as follows:

62 d: Small efficiency, pumped, FG2

x	f(x)
1	1
0.1	1
0.05	0.5
0.01	0.05
0.005	0.01

For **62 e**, this was scaled by a factor of 10, and for **62 f**, an additional factor of 10.

For the 62 a-c group, unpumped tanks in the FG2 group, I adjusted the probability for **62 a**, for small releases, from that just shown for **62 d**, as follows:

62 a: Small efficiency, unpumped, FG2

x	f(x)
1	1
0.50	0.95
0.10	0.5
0.01	0.05

For **62 b**, the distribution should be scaled by a factor of 5, and for **62 c**, an additional factor of 5. I have no specific quantitative justification for this. However, the work cited earlier led me to conclude there is a significant chance for GREs to be caused by 1E-2 frequency earthquakes in DSTs due to the presence of a liquid layer. Therefore the possible presence of a liquid layer in unpumped SSTs causing the same result needs to be retained, specifically for FG2 tanks.

The series 62 g-I cover unpumped FG3 tanks. For all three, there is still a logical upper bound of 1,1. For the rest of the distribution of 62g, I scaled each x value for 62e down by a factor of 10 for each specified f(x); for 62h, an additional factor of 5; and for 62i, another factor of 5. This leaves only the **62 j-I** elicitations. For these, I set the probability at 0 for a release of any size.

Note that I particularly carefully reviewed the graphs provided to me by Mr. Eppel while preparing this report, and I am confident that he accurately translated my specific numerical elicitations and the adjusting factors into the curves and descriptions he has by now provided to you.

2.7 PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

I have found no reason to change my opinions since the report I prepared last year (Paulson, 1997). In that report, I concluded that in my opinion, a 1E-3/year return frequency earthquake and a 1 E-4/ year return frequency earthquake have a 100% probability of causing an ignition source; this covers **7 b** and **7 c**. For **7 a**, a 1E-2 return frequency earthquake, here is the distribution:

7 a: 100 year return frequency earthquake

x	f(x)
1	1
0.1	0.95
0.01	0.50
0.001	0.05

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**APPENDIX B.11
RATIONALE REPORTS**

A. K. Postma

May 1998

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1.0 INTRODUCTION

This report summarizes the opinions of the writer on a specific set of technical questions related to the flammable gas safety issue at the Hanford site. The author served as a member of an expert panel convened by Sandia National Laboratories as part of the Stage II Gas Release Event Safety Analysis Project. Findings documented herein represent subjective judgments of the author that were deduced from available information. The findings presented herein were arrived at independently; i.e., the author had no knowledge of specific judgments of other members of the expert panel at the time when elicitation parameters were quantified.

Information which characterizes the flammable gas issue in Hanford Site waste tanks was presented to the panel at two meetings of the Stage II Project. The meetings were held in Richland, Washington during the weeks of January 19-23, 1998 and February 9-13, 1998.

This report deals with double shell tanks (DSTs) only. Phase I of this project dealt with single shell tanks (SSTs). The author was part of the Stage I project, and his elicitations are documented in Postma (1997).

2.0 AUTHOR'S COMMENT ON OVERESTIMATE OF FLAMMABLE GAS RISK

Author believes that the risk posed by flammable gases in Hanford Site waste tanks has been significantly overstated in prior safety analyses and that the current analysis framework (Slezak et al., 1998) will continue this overstatement of risk. Several specific examples of methodology where I believe unwarranted conservatisms are used to evaluate risk are the following.

1. Dilution of Vented Gases

The concentrations of toxins at ground level receptors is currently predicted by models which neglect both the momentum and buoyancy of gases predicted to be vented as a result of hypothetical hydrogen burns. In reality, both momentum and buoyancy would cause released toxins to be diluted to a far greater extent (orders of magnitude) than the current atmospheric model predicts. This over-prediction of toxin concentrations directly affects comparisons with risk guidelines and may cause unwarranted expenditure of resources to control a risk that is erroneously projected to exceed site guidelines.

2. Neglect of Natural Convective Mixing in Dome

The current methodology for analyzing so-called "plume" releases neglects mixing by natural convection. As a result, many "stratified" burns are predicted. In reality, releases are spread out

over hours or more, a time period which is long enough to assure mixing of released hydrogen by natural convection which is present in every tank that contains significant volumes of waste. Therefore, I conclude that "plume" or "stratified" burns beyond deminimus burns, are impossible. It follows that risk predicted for "plume" and "stratified" burns is fictitious, and if such risk served as a basis for the expenditure of resources (to control predicted risk), it would represent a waste of time and money.

3. Conservatisms in Elicited Data

Based on my perception of information presented and discussed at expert meetings, I conclude that significant conservatisms will be captured in the elicitation process. I sensed a strong feeling among experts that, above all, the hazard posed by flammable gases should not be understated. While this "do not understate hazard" philosophy is expected on the part of safety analysts, I believe the net result is an overstatement of risk. While I can not quantify the factors of conservatism that are embedded in elicited parameters, I believe it to be significant. If a future expert elicitation project is undertaken, I recommend that it be stressed early and often that the 50 percentile subjective estimate be a true "best-estimate" as opposed to a "mean that reflects conservatism to assure that the hazard will not be understated". While Dr. von Winterfeldt made this point several times, my judgment is that this point can not be over-stressed.

4. Overall Conservatisms

The three conservatisms mentioned above do not capture the full extent of conservatisms built into the analysis framework and elicited parameters. It might be worthwhile for a SNL/Hanford team to systematically identify and quantify all significant conservatisms in the framework to establish the degree to which risk from hydrogen burns is overstated. I do not see how decision makers (DOE personnel) can make realistic management decisions in the absence of realistic risk projections.

3.0 TECHNICAL APPROACH

The probability distributions presented herein represent the authors subjective judgment of complex technical issues. Hard scientific evidence on which to make judgments was typically unavailable, so judgments had to be made on the basis of the authors perception of the technical issue in combination with his knowledge of related scientific information. Thus there can be no assurance as to the accuracy of the predictions made herein. Also, the time available for analyzing each elicitation parameter was quite limited, and it is possible that better (more accurate) estimates could be made on the basis of a more in-depth study.

4.0 PROBABILITY DISTRIBUTIONS FOR ELICITED PARAMETERS

This section presents the findings of this work. Each elicited parameter is described, key assumptions are briefly summarized, a basis for quantification of the elicited parameter is stated, and then the probability distribution is tabulated.

4.1 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS THAT HAVE A THICK LAYER OF LIQUID (>1M) BUT DO NOT PASS ANY TEST INDICATING THE POTENTIAL FOR BUOYANT DISPLACEMENT-TYPE GRES

4.1.1 Parameter Definition

This parameter, called Parameter 1, is the expected number of gas release events per year of GREs of three different efficiency (i.e., sizes) for the DST being evaluated. This parameter has the units of "events/year tank". This frequency will be used to evaluate risk posed by DSTs that are projected to not undergo buoyant displacement GREs, for DSTs that have liquid layers 1m or more in thickness.

4.1.2 Conditioning Factors

Conditioning factors are release size: small releases are those which release 0% - 5% of retained gas, medium releases are those which release 5% - 25% of retained gas, and large releases are those which release >25% of retained gas (Slezak et al. 1998).

4.1.3 Key Assumptions

- The liquid layer identified in the title of this parameter is assumed to be the same as supernatant liquid.
- A supernatant liquid 1-m thick would occupy a volume of

$$1m * \frac{3.28 \text{ ft}}{m} * \frac{4418 \text{ ft}^2}{\text{tank}} * \frac{7.48 \text{ gal}}{\text{ft}^3} * \frac{1 \text{ kgal}}{1000 \text{ gal}} = \frac{108.4 \text{ kgal}}{\text{tank}}$$

Therefore the 1-m thickness is equivalent to a "supernate" volume of 108.4 kg/tank.

- It is assumed that DSTs that are not on the flammable gas watch list have not been observed to experience a medium or larger GRE.
- It is assumed that observed behavior for DSTs that have thick liquid layers but do not experience periodic GREs is applicable for projecting a "best estimate" frequency. Stated another way, the lack of observed GREs tells us something about the frequency of GREs in such tanks.

4.1.4 Basis for Quantification

Author quantifies expected frequencies on the basis of perceived tank experience. Data in HNF-SD-WM-CN-117, Rev. 0 indicates that 17 DSTs have supernate volumes greater than 108.4 kgal and are not on the flammable gas watch list. If it is assumed that one undetected GRE (medium efficiency) has occurred during 20 years of storage history, a frequency estimate of $1/20(17) = 3\text{E-}3/\text{yr}$ can be calculated. This frequency is taken as a best-estimate and is thus assigned a probability of 0.5, for medium releases. The 0.99 probability frequency is assigned a value of $1.2\text{E-}3/\text{yr}$ on the assumption that there is only a 1% probability that four medium GREs in the 17 tanks would have gone undetected during the 20 years of storage history. Frequency at the 1% probability level is assigned a value of 10% of the best estimate ($0.1 * 3\text{E-}3 = 3\text{E-}4$) to accommodate a fairly wide uncertainty band in frequency at the low end.

For small releases, the best estimate frequency is estimated as ten times higher than the best estimate frequency for medium releases ($10 * 3\text{E-}3 = 3\text{E-}2/\text{yr}$). This frequency implies that $3\text{E-}2 * 17 = 0.5/\text{yr}$ small releases occur yearly in the 17 DSTs considered. The 0.99 probability frequency is assigned a value of $1.2\text{E-}1$ on the assumption that $0.12 * 17 = 2$ events per year are quite unlikely (0.99 probability level) to have gone un-noticed. Frequency at the 0.01 probability level is assigned a value of 10% of the best estimate ($0.1 * 3\text{E-}2 = 3\text{E-}3$) to accommodate a fairly wide uncertainty band in frequency at the low end.

For large releases, it is assumed that the chances of not having detected a large release among the 340 tank years of operation are low (99% probability). Therefore a frequency of $3\text{E-}3$, (one event per 340 tank years) is assigned at the 0.99 probability level. Frequencies at 0.5 and 0.01 probabilities are estimated on the assumption that the probability distribution for large releases has the same shape as for medium and small releases: @ 0.5 probability, $f = 3\text{E-}3/4 = 0.75\text{E-}3/\text{yr}$ and @ 0.01 probability, $f = 0.75\text{E-}3 * 0.1 = 0.75\text{E-}4$.

4.1.5 Probability Distribution for Parameter 1

The probability distribution for GREs in non-burping tanks that have large liquid layers is summarized in Table 4.1.

Table 4.1. Probability Distribution for Frequency of GREs in
Non-Burping DSTs with Liquid Layer Depth >1m.

Subjective Probability that Frequency is Less than Stated	Frequency, Events/Tank Year		
	Small GREs	Medium GREs	Large GREs
1%	3E-3	3E-4	0.75E-4
50%	3E-2	3E-3	0.75E-3
99%	1.2E-1	1.2E-2	3E-3

4.2 PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

4.2.1 Parameter Definition

This parameter, called Parameter 2, is the probability that a buoyant displacement GRE will cause an ignition source that is effective in igniting combustible gases that may be present in the tank headspace during and after the GRE.

4.2.2 Conditioning Factors

Conditioning factors are release size: small releases are those which release 0% - 5% of retained gas, medium releases are those which release 5% - 25% of retained gas, and large releases are those which release >25% of retained gas.

4.2.3 Key Assumptions

- Electrostatic changes are not credible ignition sources inside the tank because the radiation field in the headspace produces a continuous supply of ions. The ions in headspace air provide a means for neutralizing static charges that might otherwise be present.
- Credible ignition sources are frictional sparks caused by waste motion and electrical sparks attributable to electrical equipment in the headspace.

- Ignition can be effective only if the ignitor is located within the flammable gas mixture. For small releases, flammable concentrations would exist only during a release and in close proximity to the surface of the waste. Sparks that occurred at other locations in the tank or at other times during the overall GRE duration would not cause ignition and therefore would not be ignition sources within the meaning intended herein.
- Ignition probability would be expected to increase with GRE size. A large GRE would be expected to cause more violent surface motion and also cause more of the headspace to reach flammable conditions in comparison with small releases. In the limit, the entire headspace can become flammable so an ignitor located anywhere in the headspace could be an effective ignition source.
- The apparent lack of ignition in any of the many observed buoyant displacement GREs provides information on an upper estimate of ignition probability.

4.2.4 Basis for Quantification

Author quantifies probability for ignition on the basis of available "no ignition" experience and subjective judgments of how ignition probability would vary with GRE size.

For the six tanks that experience buoyant displacement GREs, an average frequency of approximately 3.7 events/yr can be computed from data presented in Meyer et al. (1997). For an assumed history of 20 yr, one can estimate that $6 \text{ tanks} \times 3.7 \text{ event/yr tank} \times 20 \text{ yr} = 444$ events have occurred with no ignitions. This number is rounded downward to 400 events to account for a judgment that 20 yr is probably too long a time period for all of the tanks. Most of the GREs are assumed to be of medium size, though it is recognized that some are "small" and many of those that occurred in 101-SY are "large".

A best-estimate for ignition probability is made by dividing observed event frequency by 10: best estimate probability = $0.1/400 = 2.5\text{E-}4$. A rounded value $2\text{E-}4$ is assumed to apply to medium releases. The distribution of probabilities was quantified by assuming that the bulk of the uncertainty would be captured within a band that is higher and lower than the best-estimate by factors of 10. A log-normal distribution is thought to be adequate to describe the tails of the distribution.

For small releases, ignition probability was estimated as one-tenth that of medium releases. This factor accounts for both less energetic waste surface movements and smaller spatial volumes that reach flammable concentrations as compared to medium releases. A probability distribution was selected to reflect a subjective judgment that the bulk of the uncertainty would be captured within a band that is higher and lower than the best-estimate by factors of ten.

For larger releases a higher ignition probability is needed to reflect stronger waste motions and enlarged volumes of combustible gas clouds as compared to medium releases. Even "large"

category releases are unlikely to cause the whole headspace to come up to the flammability limit. Based on headspace volumes listed by Meyer et al. 1997 and gas inventories in the non-convective layer, hydrogen concentrations in the headspace can be estimated for postulated release sizes. For example, well-mixed hydrogen concentrations of 0.7% to 2.04% are calculated for a postulated release of 25% of retained gas. At 50% release, the well-mixed hydrogen concentrations are double the values listed above, ranging from 1.3% to 4.1%. Only one tank (AN-105) is calculated to exceed the LFL for a 50% release of stored gas.

The increased ignition probability for large GREs was quantified by multiplying the medium release probabilities by four. This factor is approximately the ratio of mean percent releases for large to medium releases $[(25 + 100)/(5 + 25) = 4.2]$. This factor is judged to reasonably account for both the stronger waste surface motions and larger flammable clouds that are expected for the large release category as compared to the medium category.

4.2.5 Probability Distribution for Parameter 2

The probability distribution for ignition induced by buoyant displacement GREs is summarized in Table 4.2.

Table 4.2. Probability Distribution for Ignition Caused by Buoyant Displacement GREs.

Subjective Probability that Probability of Ignition is Less than Stated	Probability of Ignition Per GRE		
	Small GREs	Medium GREs	Large GREs
1%	2E-6	2E-5	8E-5
5%	6E-6	6E-5	2.4E-4
50%	2E-5	2E-4	8E-4
95%	6E-5	6E-4	2.4E-3
99%	2E-4	2E-3	8E-3

**4.3 TOTAL MASS OF TRANSPORTABLE WASTE MATERIAL
(A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT
THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST,
OR (B) RELEASED FROM A DST BY A COMBUSTION EVENT
THAT CAUSES STRUCTURAL FAILURE OF A DST**

4.3.1 Parameter Definition

This is a two part parameter that quantifies aerosol mass, expressed in kilograms. For hydrogen burn events that do not cause failure of the dome, the parameter is defined as the mass of aerosol suspended in the dome headspace that could be carried 100 m downwind from the release point. For hydrogen burn events that do cause gross failure of the dome, the parameter is the mass of aerosol that is both released from the tank and is transportable by wind to a point 100m from the release point.

4.3.2 Conditioning Factors

Two sets of conditioning factors apply. The first set applies to burns that do not cause gross failure of the tank dome:

- A burn of insufficient pressure to fail the HEPA filter (nominally 1 psi)
- A burn of 20 psi or less that fails the HEPA filter
- A burn of more than 20 psi that does not fail the dome (nominally 47 psi).

The second set of conditioning factors apply to dome failure cases:

- A deflagration that fails the tank dome (nominally 47 psi)
- A detonation that fails the tank dome (nominally 47 psi).

4.3.3 Key Assumptions

- Waste is presumed to be present as a consolidated solid or a viscous liquid prior to a burn event.
- Burns are ignited in gas in the headspace and propagate in the headspace only. No burning within the waste is considered.
- Mechanisms for generating waste aerosol include ablation of waste by heating caused by the burn, pickup of waste by gas currents sweeping across the surface, and dislodging of surface (wall) deposits due to mechanical stress on the dome caused by burn pressurization.

- HEPA failure pressure is taken as 1 psi, i.e., HEPA failure is assumed to occur when a burn generates a gauge pressure of 1 psig.
- Dome failure is assumed to occur for burns that generate internal tank pressure of ~47 psig.

4.3.4 Basis for Quantification for Burns That Do Not Fail Dome

Bases for estimating aerosolization of waste for the several categories of hydrogen burns are described as follows.

Burns That Do Not Fail HEPA Filter

Burns that generate pressures between 0 and 1 psi involve the combustion of small localized gas volumes and could not be global burns. An energy balance calculation predicts that the combustion of 1.7 m³ of hydrogen in a dome volume of 1000 m³ would raise pressure by 1 psi, and raise the average gas temperature (after mixing) by ~22°K.

The small size of the burned gas volume would appear to preclude significant heating of the waste surface or a significant portion of the tank dome. Therefore, it is concluded that thermal means for generating a waste aerosol would be minimal. Likewise, a small localized burn that increased pressure by 1 psi or less would not generate air currents or dome strain that would cause significant waste aerosolization.

Author concludes that the small burns (<1 psi ΔP) should be considered deminimus burns for which no consequences are computed. Therefore the estimates of waste mass aerosolized are assigned a value of zero kilograms for this burn category.

Burns That Generate Pressures of 1 to 20 psi

Burns in this category burn enough hydrogen to yield pressures of 1 to 20 psig. Energy balance calculations (constant volume burn) indicate that complete combustion of ~3.6% hydrogen in air would generate a pressure of 20 psig. Since 3.5% is below the flammability limit, it is obvious that burns in this category would involve localized burns in richer mixtures or inefficient burns in mixtures marginally above the flammability limit. In any case the waste surface would undergo a temperature transient and a pressure pulse. Air currents at the waste surface are judged to be of relatively low velocity so relatively little waste would be aerosolized by wind pickup.

Fox et al. (1993) have analyzed hydrogen burns of this type in tank SY-103 and have quantified masses of aerosol suspended as a function of the volume of hydrogen combusted. Both the methodology used by Fox et al. (1993) and predicted results appear to apply to DSTs in general, so the results of Fox et al. (1993) are scaled to the present burn category on the basis of peak pressure (adiabatic, constant volume burn).

The median pressure for this burn category is $(1 + 20)/2 = 10.5$ psi, and for this peak pressure an airborne mass of 80 g is predicted. This value is taken as the best estimate for this burn category. Uncertainty in this parameter is judged to be roughly plus and minus a factor of ten. This uncertainty is quantified by estimating 1 percentile and 99 percentile probability masses by dividing and multiplying the 50 percentile value by a factor of ten. Intermediate and tail values are quantifiable by fitting a log-normal distribution to the points specified above.

Burns That Generate Pressures of 20-47 psi

This category of burns generate relatively high pressures but do not cause structural failure of the dome. The upper limit, 47 psig, corresponds to a burn in an air-hydrogen mixture that contains approximately 10% H_2 (Ratzel 1985). This concentration is higher than could be reached if 100% of hydrogen stored in the non-convective layer was released to the tank headspace, for any of the six DSTs on the flammable gas watch list. Based on data listed in Meyer et al. (1997), and Shekarriz et al. (1997), the maximum headspace hydrogen is estimated at 8.2%. The point is that the 47 psi explosion postulated here is an extremely unlikely, if not impossible, case with respect to the Hanford tank farms.

Total aerosolized mass for this burn category is quantified by scaling the predictions of Fox et al. 1993 to higher pressures. Methodology is similar to that described in the foregoing section (burns in 1-20 psi range). Results are as follows. The best estimate (50% probability) applies to the median pressure $[(20 + 47)/2 = 33.5$ psig], for which an aerosolized mass of 300 g is predicted. Uncertainty in this estimate is judged to be roughly plus or minus a factor of ten. This uncertainty is quantified by estimating 1 percentile and 99 percentile probability masses by dividing and multiplying the 50 percentile value by a factor of ten. Intermediate and tail values are quantifiable by fitting a log-normal distribution to the points specified above.

4.3.5 Probability Distribution for Parameters 3a, 3b, and 3c

The probability distributions for total waste masses aerosolized that is transportable to 100 m downwind for burns that do not fail the tank dome are summarized in Table 4.3.1.

Table 4.3.1 Probability Distribution for Total Transportable Aerosol Made Airborne In a Tank by Burns That Do Not Cause Dome Failure

Subjective Probability that Airborne Waste Mass is Less than Stated	Transportable Aerosol Mass, kg		
	Pressure 0-1 psi	Pressure Range 1 psi - 20 psi	Pressure Range 20 psi - 47 psi
1%	0	0.008	0.03
5%	0	0.025	0.1
50%	0	0.08	0.3
95%	0	0.25	1.0
99%	0	0.80	3.0

4.3.6 Basis for Quantification for Burns that Cause Gross Failure of Tank Dome

This case is based on burns in air that contain an average hydrogen concentration exceeding 10% by volume. As discussed in Section 4.3.3, there does not appear to be enough waste-stored-hydrogen to reach such high hydrogen concentrations in the headspace. Therefore, the best judgment offered by this author is that the gross dome failure case is too improbable to be considered in risk evaluation, and should be eliminated from this study.

Nevertheless, dome failure burns are analyzed to quantify the elicited parameters. The analyzed scenario is as follows: (1) The mother of all GREs releases enough hydrogen into the headspace to generate an adiabatic isochoric burn pressure of 80 psig. (2) The Hydrogen is ignited and burns in less than 1 second, generating a pressure sufficient to blow out a major hole in the top of the tank. (3) Hot gases rapidly vent (seconds or less) pressure down to 1 atm, causing ~75% of gases to escape. (4) Overburden and fractured concrete fall back into the tank through the ceiling rupture. (5) Cooling of remaining hot gas causes gas shrinkage, so no venting occurs during the time when debris is falling into the tank. (6) Falling debris atomizes waste and generates an aerosol in the tank. (7) Headspace aerosol is carried from the tank over time by natural convection, with depletion by sedimentation, plateout and possibly by filtration by overburden.

Aerosol released during the high pressure venting phase is quantified by venting 75% of aerosol predicted to become airborne by a burn at 80 psig. Based on the methodology discussed in Section 4.3.4, this amounts to $0.75 * 644 \text{ g} = 483 \text{ g}$. Aerosol released during the second period, i.e., carried out by natural convection through the breach, is quantified on the basis of an airborne concentration of 100 g/m^3 , a vented gas fraction of 10%, and a depletion factor of 10 to account for sedimentation and deposition on surfaces. Total released mass is: $1000 \text{ m}^3 * 0.1 \text{ kg/m}^3$

* $0.1 \times 0.1 = 1$ kg. The concentration given above (100 g/m^3) is judged to be a maximum for transportable aerosols; higher concentrations would rapidly coagulate into particles too large to remain an aerosol. The volume, 1000 m^3 , is cited as typical of headspace volumes. The convected volume, 10% of the total, is a guess of the impact of natural convection during the first few minutes after the explosion. It should be remembered that gas cooling would continue for several minutes and the shrinkage of headspace air would cause air inflow that would impede outflow. The depletion factor of 10 is a judgment based on how rapidly sedimentation would deplete airborne particles.

The best estimate of total aerosol release is the sum of the two sources, $0.48 + 1 = 1.48$ kg. This value is rounded to 1.5 kg for use as the 50 percentile mass. Uncertainty is captured by assigning the mass at 1 percentile a value of $1.5/10 = 0.15$ kg. The 99 percentile mass is likewise assigned a value of $1.5 \times 10 = 15$ kg. Intermediate and tail values should be quantified by a log-normal distribution that fits the points cited above.

The methodology used herein is believed to be applicable whether the burn is a violent deflagration or a detonation. Therefore, the same masses are estimated for detonations and deflagrations.

A final comment is offered regarding the plausibility of the headspace detonation case. This author believes the detonation case to be an extreme case of an extreme case, and of such low probability as to fall into the incredible category. It should not be used to assess the risk posed by waste tanks at Hanford.

4.3.7 Probability Distribution for Parameter 3d and 3e

The probability distributions for transportable waste masses released from a DST that is ruptured by a hydrogen explosion are summarized in Table 4.3.2.

Table 4.3.2. Probability Distribution for Transportable Aerosol Mass Released From a Ruptured DST.

Subjective Probability that Released Transportable Mass is Less than Stated	Transportable Aerosol Mass Released, kg	
	Deflagration	Detonation
1%	0.15	0.15
5%	0.5	0.5
50%	1.5	1.5
95%	5	5
99%	15	15

4.4 TOTAL RESPIRABLE WASTE MATERIAL (A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (B) RELEASED FROM A COMBUSTION EVENT THAT CAUSES STRUCTURAL FAILURE OF A DST

4.4.1 Parameter Definition

This is a two part parameter that quantifies aerosol mass expressed in kilograms. For hydrogen burn events that do not cause failure of the dome, the parameter is defined as the mass of respirable particles suspended in the dome. For hydrogen burn events that do cause gross dome failure, this parameter is the mass of respirable aerosol that is released from the tank into the environs.

4.4.2 Conditioning Factors

Two sets of conditioning factors apply. The first set applies to burns that do not cause gross failure of the tank dome:

- A burn of insufficient pressure to fail the HEPA filter (nominally 1 psi)
- A burn of 20 psig or less that fails the HEPA filters
- A burn of more than 20 psi that does not fail the dome (nominally 47 psig).

The second set of conditioning factors apply to dome failure cases:

- A deflagration that fails the tank dome (nominally 47 psig)
- A detonation that fails the tank dome (nominally 47 psig).

4.4.3 Key Assumptions

- Respirable particles are defined as those that have an aerodynamic diameter of 10 μm or less.
- The particle size distribution of in-situ waste particles is such that most (>50%) of the mass is associated with particles smaller than 10 μm .

4.4.4 Basis for Quantification

Respirable mass is quantified herein by multiplying total aerosol mass by the fraction that is respirable, i.e., the small size portion of the distribution. Respirable fraction is a number between 0 and 1, the mean between these values being 0.5. Considering the fact that our analysis approach for estimating total mass was focussed on relatively fine aerosols, a respirable fraction of 0.5 is deemed to be a reasonable guess. Therefore, respirable aerosol mass is calculated by multiplying total mass by 0.5.

4.4.5 Probability Distribution for Respirable Aerosol Mass

The probability distributions for respirable aerosol mass for the five categories of hydrogen burns are summarized in Table 4.4.

Table 4.4. Probability Distribution for Respirable Mass Airborne/Released as a Result of Hydrogen Burn Events.

Subjective Probability that Respirable Mass is Less than Stated	Respirable Mass Airborne In Headspace, kg			Respirable Mass Released, kg	
	Burn Pressure 0<1 psig	Burn Pressure 1-20 psig	Burn Pressure 20-47 psig	Dome Failure, Deflagration	Dome Failure, Detonation
1%	0	0.004	0.015	0.075	0.075
5%	0	0.013	0.05	0.25	0.25
50%	0	0.04	0.15	0.75	0.75
95%	0	0.13	0.5	2.5	2.5
99%	0	0.4	1.5	7.5	7.5

4.5 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

4.5.1 Parameter Definition

This parameter, called Parameter 5, is the duration of a buoyant displacement-type GRE expressed in minutes. Duration is limited to that time over which the release rate is high enough for the gases to participate in a plume combustion event. For purposes of this report, duration is defined as the time from the beginning of a release to the time at which headspace gases reach a peak concentration.

4.5.2 Conditioning Factors

Conditioning factors are release size: small releases are those which release 0% - 5% of retained gas, medium releases are those which release 5% - 25% of retained gas, and large releases are those which release >25% of retained gas.

4.5.3 Key Assumptions

- Observed release characteristics (rate, fractional release, time to peak) represent a sample from the population of possible buoyant displacement releases.

4.5.4 Bases for Quantification

Available data was reviewed to provide a basis for estimating GRE duration. Gas inventories stored in waste were taken from Meyer et al. (1997). Release volumes and time to peak for tanks AN-103, AN-104, AN-105, AW-101, and SY-103 were taken from Stewart (1998). Released volumes and times to peak for tank SY-101, prior to mixer pump mitigation were obtained from Barker et al. (1991), Erhart (1991), and from Fox et al. (1992).

Data on five GREs were found for tank 101-SY prior to mitigation. Volumes of gas released were in the range of 150 m³ to 312 m³, qualifying them as large releases. Time to peak varied from 15 m to 96 m. The released volume/peak time data pairs used herein for large releases are listed in Table 4.5.1.

Table 4.5.1. Time to Peak for Large Releases.

Released Volume, m ³	Time to Peak, min
198	96
312	24
238	15
150	49
331	20

The average of times listed in Table 4.5.1 is 40.8 min. A rounded value, 40 min is chosen as the best estimate, the value assigned to the 50% probability duration. The 5 percentile release time is chosen as the smallest observed, 15 min. The duration at 1 percentile is chosen as 5 minutes, on the grounds that physical factors would likely prevent a release in much less than 5 minutes. A minimum release duration of 2 minutes is prescribed for large releases. A duration of 100 minutes is selected for the 95 percentile probability. This value is marginally larger than the longest duration listed in Table 4.5.1. At 99% probability a duration of 200 minutes is estimated by doubling the 95 percentile duration.

Data on 18 medium releases were provided by Stewart (1998). The medium category data are displayed in Table 4.5.2.

Table 4.5.2 Time to Peak for Medium Releases

Released Volume, m ³	Time to Peak, min
35	108
18	110
20	104
30	240
29	315
27	540
26	497
22	480
22	337
19	840
17	240
13	517
9	660
27	1128
25	97
11	96
11	179
9	86

The average time to peak for these 18 medium releases is 365 min. A rounded value of 360 min is proposed as a best estimate, or 50 percentile duration. The duration at 5 percentile is assigned a value of 100 min because it is below most of the observations. Duration at 1 percentile is estimated as half the 5 percentile duration or 50 min. At the 95 percentile level, a duration of 800 min is selected on the basis that it is smaller than all but two of the observed data. The 99 percentile duration is estimated as double the 95 percentile, $2(800) = 1600$ min, and brackets the observation by an appreciable margin.

Data on nine releases we categorize as small releases is taken from Stewart (1998). The small category data are displayed in Table 4.5.3.

Table 4.5.3. Time to Peak for Small Releases.

Released Volume, m ³	Time to Peak, min
11	135
11	218
8	86
7	166
5	120
6	197
6	180
6	519
4	418

The average time to peak for the small releases listed in Table 4.5.3 is 227 min. A rounded value of the average, 200 min is taken as a best estimate and is assigned the position as 50 percentile duration. Durations at 5% and 95% are assigned values of 100 min and 400 min on the basis of the range of observed durations. Durations at 1% and 99% probability are estimated by extending 5% and 95% durations by a factor of two: 1% duration = $100 \text{ min}/2 = 50 \text{ min}$ and 99% duration = $2 * 400 = 800 \text{ min}$. The 1% and 99% durations bound the observations by a reasonable factor.

4.5.5 Probability Distribution for Parameter 5

The probability distribution for the duration of buoyant displacement-type GREs is summarized in Table 4.5.4.

Table 4.5.4. Probability Distribution for Duration of Buoyant Displacement GREs.

Subjective Probability that Duration is Less than Stated	Duration of GRE, Defined as Time to Peak Hydrogen Concentration in Headspace, minutes		
	Small GREs	Medium GREs	Large GREs
Lower Bound			2
1%	50	50	5
5%	100	100	15
50%	200	360	40
95%	400	800	100
99%	800	1600	200

4.5.6 Comments on Use of GRE Duration in AF

Based on the parameter definition given in Slezak (1998), the release duration will be used in the analysis framework to compute a time at risk for a plume combustion event. In other words, a stratified layer at the top of the dome will be presumed to exist during the duration and for an extended time during which the stratified layer is dissipated by molecular diffusion.

This use of the release duration will result in unrealistic projections of burn risk because natural convection mixing will prevent the formation of stratified layers of flammable gas. In reality, gas is evolved in a series of burps at various surface locations over a period of hours for small and medium releases. Such releases could not result in more than localized burns that fall into the deminimus category. Only the largest releases, which cause the entire headspace to become flammable have any serious potential for burns beyond the deminimus level.

4.6 PROBABILITY OF A SEISMIC-INDUCED GRE

4.6.1 Parameter Definition

This parameter is the probability that an earthquake would cause a prompt gas release in a DST that contains a deep (> 1m) liquid layer.

4.6.2 Conditioning Factor

Six conditioning factors apply to this parameter to capture the effect of earthquake magnitude and GRE size. Earthquake magnitudes to be considered are defined in terms of return periods:

- 100-year return period
- 1000-year return period
- 10,000-year return period.

GRE sizes to be considered are:

- Small GRE (0-5% gas release)
- Medium GRE (5%-25% gas release)
- Large GRE (>25% gas release)

4.6.3 Key Assumptions

The following assumptions played key roles in quantifying this parameter.

- A thick liquid layer is assumed to increase waste mobilization in an earthquake as compared to tanks with no liquid layer. This assumption is based on PNNL studies such as the one by Reid and Deibler (1997).
- A small release is more likely to occur than a larger release, given a particular seismic event.
- The probability of a gas release of any size increases as the magnitude of the seismic event increases.
- Yielding (large strain) of waste in the non-convective layer is a necessary condition for gas release, but is probably not a sufficient condition for significant gas release. Gas release requires that bubbles detach from solid waste particles and rise through the non-convective layer.

4.6.4 Basis for Quantification

Since there are no real data on gas releases from major earthquakes, gas release predictions are based on subjective judgments of theoretical studies (Reid and Deibler 1997) and a physical picture which requires bubble separation from solid waste particle in order for a release to occur.

Earthquakes are not considered as a trigger for buoyant displacement GREs because the frequencies (and therefore risk) of buoyant displacement GREs of various size are quantified elsewhere.

The anchoring point for quantification is based on a subjective estimate for a medium release in a 1000 yr quake. A best estimate is that the probability of a medium release is about 0.2. A fairly wide uncertainty band is quantified by setting the 99 percentile probability equal to 0.8, and the 1 percentile probability to 0.05. Intermediate values are estimated by interpolation. Limiting values are clearly 0 and 1 on probability. For small GREs the probabilities are increased and for large GREs the probabilities are lowered as compared to medium releases. Projected probabilities for the 1000 yr seismic event are summarized in Table 4.6.1.

Table 4.6.1. Probability of GREs in 1000 Year Seismic Event.

Subjective Probability that Probability is Less than Stated	Probability of Release, Dimensionless		
	Small GREs	Medium GREs	Large GREs
1%	0.1	0.05	0.02
5%	0.2	0.1	0.05
50%	0.5	0.2	0.1
95%	0.8	0.5	0.2
99%	0.9	0.8	0.5

Projections for a 100 year earthquake were based on an anchor point (medium GRE, 50 percentile subjective probability) quantified by dividing the 1000 yr projected probability by two. This relatively small difference between the two seismic events accounts for the thought that the probability of a given release decreases as the event magnitude decreases but that even the 100 yr quake is projected to mobilize a significant portion of the non-convective layer. Projected probabilities for small GREs are based on the notion that a 100 yr quake is quite likely to cause a small release. Conversely, it is believed that the 100 year quake is unlikely to cause a large GRE. Projected probabilities for a 100 yr seismic event are summarized in Table 4.6.2.

Table 4.6.2. Probability of GREs In 100 Year Seismic Event.

Subjective Probability that Probability is Less than Stated	Probability of Release, Dimensionless		
	Small GREs	Medium GREs	Large GREs
1%	0.05	0.02	0.01
5%	0.1	0.05	0.03
50%	0.2	0.1	0.05
95%	0.5	0.2	0.1
99%	0.8	0.4	0.2

Projections for a 10,000 yr earthquake were based on an anchor point (medium GRE, 50 percentile subjective probability) of 0.5 probability. Uncertainty was quantified by assigning a probability of 0.9 at the 99 percentile subjective probability level, and a value of 0.1 at the 1 percentile subjective probability level. Thus a 10,000 yr quake is thought to have a relatively high probability of causing a medium release.

Small GREs are considered to be even more likely than medium GREs, so probabilities are adjusted nearer to unity for the small GRE category. The best estimate probability is 0.7, a number that is probably indistinguishable from unity from a risk evaluation standpoint.

The probability of large GREs is thought to be lower than medium category GREs, so numbers are adjusted slightly downward. Again probabilities are not too far from unity, so calculated risk would be reduced only a modest degree as compared to unity probability for the 10,000 year earthquake.

Projected probabilities of GREs caused by a 10,000 yr earthquake are summarized in Table 4.6.3.

Table 4.6.3. Probability of GREs in 10,000 Year Seismic Event.

Subjective Probability that Ignition is Less than Stated	Probability of Release, Dimensionless		
	Small GREs	Medium GREs	Large GREs
1%	0.2	0.1	0.05
5%	0.4	0.2	0.1
50%	0.8	0.5	0.3
95%	0.9	0.7	0.6
99%	1.0	0.9	0.8

4.7 PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

4.7.1 Parameter Definition

This parameter is the probability that an earthquake will itself cause an ignition source that is effective in igniting any hydrogen that is released from waste as a result of the assumed earthquake. This parameter has the dimensions of probability per tank per earthquake.

4.7.2 Conditioning Factors

Conditioning factors are earthquake magnitude:

- 100 year earthquake
- 1000 year earthquake
- 10,000 year earthquake.

4.7.3 Key Assumptions

The following assumptions were used to evaluate ignition probability.

- Electrostatic charges are not credible ignition sources inside the tank because the radiation field in the headspace produces a continuous supply of ions. The ions in headspace air provide a means for neutralizing static charges that might otherwise be present.
- Credible ignition sources are frictional sparks caused by the scraping of solids (typified by steel equipment items) caused by quake motions and electrical sparks attributable to electrical circuit failures caused by earthquake motion.
- Ignition can be effective only if the igniter is located within the flammable gas mixture. For small releases, flammable concentration would exist only during a release and in close proximity to the surface of the waste. Sparks that occurred at other locations in the tank or at other times (e.g. prior to gas release) would not cause ignition and therefore would not be ignition sources within the meaning intended herein.
- Ignition probability would be expected to increase with GRE size. A large GRE would be expected to cause more of the headspace to reach flammable conditions as compared to small releases. In the limit, the entire headspace can become flammable so an igniter located anywhere in the headspace could be an effective ignition source. The impact of GRE size will have to be reflected in the uncertainty distribution because GRE size is not a conditioning factor.

4.7.4 Basis for Quantification

Ignition probability for a 100 yr quake and a medium GRE is quantified by considering three factors:

- Probability of an ignition source anywhere in the headspace
- Probability that the igniter is located with a specific gas volume
- Probability that the spark occurs during the release time, when a gas volume is flammable.

First, the mean release for the medium category amounts to $(5 + 25)/2 = 15\%$ of retained gas. Based on gas compositions and retained volumes in DSTs (Meyer et al., 1997, Shekarriz et al., (1997), the mixed headspace concentrations would be well below flammable following the release. Therefore, flammable regions would exist only near the waste surface at the gas exit point. Based on an assumed gas discharge area of 1 m^2 , a waste surface area of 400 m^2 , and an assumed

probability of 0.1 that an ignitor will be present in any 1 m² of projected surface, the ignition probability is $0.1/400 = 2.5\text{E-}4$. A rounded number of $2\text{E-}4$ is therefore assigned as the best estimate (0.5 subjective probability) for 100 yr quakes. Large releases, which are less likely to occur than medium releases, would have a significantly higher ignition probability. The median large release $(25\% + 100\%)/2 = 62.5\%$ is calculated to cause flammable conditions ($\sim 5\% \text{H}_2$) in one DST (AN-105). A judgment is made that the probability of ignition is increased by a factor of 100 for the limited set of cases defined by the upper 1% of cases. Therefore, a probability of ignition of $2\text{E-}4 * 100 = 2\text{E-}2$ is assigned at the 99 percentile subjective probability for the 100 yr earthquake. Ignition probability is lower for smaller GREs, and this effect is quantified by assigning a probability of $0.1 * 2\text{E-}4 = 2\text{E-}5$ at the 1 percentile subjective probability level. Ignition probabilities at the 5% and 95% may be quantified by logarithmic interpolation.

A 1000 year quake is postulated to cause more damage to tank structures and thereby increase the chances for an ignition source. Also, larger GREs would be more likely than for the 100 yr quake. A best estimate for the probability of ignition in a 1000 yr quake is made by assuming an effective gas release area of 4 m² and a probability of 0.2 for an ignition source to be located in the flammable gas region. These assumptions yield a probability of $0.2 * 4/400 = 2\text{E-}3$. This value is assigned to the 50 percentile level of subjective probability. In similarity with the analysis for 100 yr quakes, the probability at the 99 percentile level is estimated by multiplying the 50 percentile value by 100: $100(2\text{E-}3) = 2\text{E-}1$. Likewise the 1 percentile level ignition probability is estimated by dividing the best estimate by ten: $0.1 * 2\text{E-}3 = 2\text{E-}4$. Intermediate values on the subjective probability scale can be quantified by logarithmic interpolation.

The 10,000 year earthquake would result in the maximum damage to tank structures and would be most likely to cause a large GRE. Therefore the probability of ignition would be higher as compared to the 1000 yr quake. A best estimate for ignition is based on an effective release area of 40 m² (10% of tank area) and a probability of 0.5 that an ignition source would be located in the flammable gas region. These assumptions yield a probability estimate of $0.5 * 40/400 = 0.05$. At the upper end, the ignition probability is thought to approach unity. An ignition probability of 0.5 is assigned at the 95 percentile level, and a probability of 0.8 is assigned at the 99 percentile level. The uncertainty band needs to account for the possibility of smaller GREs that have a lower likelihood of being ignited. This is captured by assigning an ignition probability down one order of magnitude from the mean at the 5 percentile level of subjective probability: $0.1 * 0.05 = 5\text{E-}3$. An additional order of magnitude reduction in probability is judged to be a reasonable guess for the 1 percentile level of subjective probability.

4.7.5 Probability Distribution for Parameter 7

The probability distribution for the probability of ignition induced by earthquakes is summarized in Table 4.7.

Table 4.7. Probability of an Ignition Source Attributable to Seismic Events.

Subjective Probability that Ignition is Less than Stated	Ignition Probability, Per Tank Per Event		
	100 yr Earthquake	1000 yr Earthquake	10,000 yr Earthquake
1%	2E-5	2E-4	5E-4
5%	6E-5	6E-4	5E-3
50%	2E-4	2E-3	5E-2
95%	2E-3	2E-2	5E-1
99%	2E-2	2E-1	8E-1

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APPENDIX B.12
RATIONALE REPORTS

C. W. Stewart

May 1998

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1.0 INTRODUCTION

Charles W. Stewart, Pacific Northwest National Laboratory, was elicited by Detlof Winterfeld on March 10, 1998, on the following parameters:

1. Frequency of spontaneous gas releases in DSTs that have a thick layer of liquid (>1 m) but do not pass any test indicating the potential exists for buoyant displacement-type GREs: conditioned on small, medium and large efficiency releases (Section 2.1)
2. Probability of an ignition source being induced by a buoyant displacement GRE: conditioned on small, medium and large efficiency of BD GRE (Section 2.2)
3. Duration of a buoyant displacement-type GRE: conditioned on small, medium and large BD GRE (Section 2.3)
6. Probability of a seismic-induced GRE: conditioned on thick liquid layer, small, medium and large efficiency BD GRE and 100-, 1000-, and 10,000-year quake. Note that probabilities for SSTs conditioned on pumped/unpumped status were given in the Phase I elicitation (Section 2.4)
7. Probability of an ignition source in a DST caused by an earthquake: conditioned on 100-, 1000-, and 10,000-year earthquake (Section 2.5).

Elicitation rationale for each parameter is discussed in a separate section below. New distributions are given for all but Parameter 7, which is considered the same as for SSTs.

2.0 ELICITATION PARAMETER RATIONALE

The rationale for the elicited distributions for each of the assigned parameters is given in a separate section below. The actual distribution anchor points are given in a summary at the end of each section.

2.1 FREQUENCY OF SPONTANEOUS GAS RELEASES IN DSTS NOT SUBJECT TO BUOYANT DISPLACEMENT

The Phase II expert panel concluded that, if a DST has buoyant displacement GREs it is not subject to other spontaneous gas releases. However, the panel allowed for the possibility of other spontaneous releases if the criteria for buoyant displacement GREs was not met. Frequency distributions are to be provided for small, medium and large spontaneous GREs.

I believe that spontaneous GREs do not occur in those DSTs not subject to buoyant displacements. Non-burping DSTs uniformly have a deep liquid layer with a relatively thin, weak, fine grained solids layer with no lithostatic load. Gas retained in this material will be in the form of individual bubbles (Gauglitz et al. 1996, Stewart et al. 1996). Gas release will be steady by bubble migration as described in Perry Meyer's presentation (Bratzel et al. 1998, Part B, 2.2) and the void fractions are predicted to be small (per the table of void predictions on all the DSTs provided to the Phase II panel February 11 and included in Bratzel et al. 1998, Part B, 2.2). Episodic release by percolation of hydrodendritic bubbles does not occur since the void fraction will remain too low to produce hydrodendritic bubbles. Percolation of lithodendritic bubbles does not occur since the lithostatic load is negligible and the particle size is small, preventing formation of lithodendritic bubbles.

There is one observation of a small hydrogen transient in the AN tank farm exhaust stack with no concurrent headspace excursion in any of the three known AN burpers (SHMS Monthly Report for November 1997). This could be taken to indicate a non-buoyant displacement release. However, the report also states that AN-101 was receiving overflow from catch tank A417 during that time. Also, since the Meyer/Stewart/Lessor criteria (Bratzel et al. 1998, Part B, 2.2) predict AN-107 to be a possible burper, the AN farm exhaust excursion can also be attributed to a buoyant displacement in that tank.

Based on the above discussion, I assign a zero probability to spontaneous GREs from DSTs that don't meet the buoyant displacement criteria.

Frequency of spontaneous gas releases in DSTs not subject to buoyant displacement:

Small GREs:	ZERO	no mechanism nor observation
Medium GREs:	ZERO	
Large GREs:	ZERO	

2.2 PROBABILITY OF AN IGNITION SOURCE BEING INDUCED BY A BUOYANT DISPLACEMENT GRE

The probability of a spark caused by a buoyant displacement in a DST is the product of the probability of waste motion and the probability of a spark caused by that waste motion. I consider the highest probability of sparking to be caused by suspended hardware banging against the sides of risers. I do not consider sparks due to static charges in floating crust motion credible because the crust is moist and the salt solution is quite conductive.

In my Phase I elicitation (Slezak & Bratzel 1997), I bounded the waste-motion-induced ignition probability by considering the number of large GREs that have NOT been ignited. Given the 33 large GREs in DSTs I counted from level data, the bounding (99th percentile) probability would be 0.03. From there I estimated a median value of 0.001 (a value associated with "unlikely" events in risk parlance). Since the Phase I elicitation, the level data has been

determined unreliable for GREs in AW101 (Kubic 1997) and AN104 (Kubic and Pillay 1997a), and one of the earlier large level drops in AN105 (Kubic and Pillay 1997b) was attributed to instrument problems. Eliminating the affected GRE indications reduces the number to 27 and increasing the bounding probability to 0.037. However, this is a small change within the overall uncertainty of the process and I will use the original values as the probability of ignition given significant waste motion.

Only the three largest GREs in SY101 out of the eleven that occurred when headspace flammability measurements were made actually caused the headspace to become flammable (Wilkins et al. 1997). Since no burns occurred during these three events, the limited data can be used to set an upper limit on the distribution at 1/3 or ~.3

Large GREs can be expected to cause waste motion in DSTs with a probability of 1. Therefore, consistent with my Phase I elicitation and the above discussion, I estimate the 99th percentile ignition probability as 0.03 with a median of 0.001. I place the 90th percentile at 0.01 and the 10th percentile at 0.0001 without any technical basis. The distribution should be truncated at 0.3.

Medium GREs have not been observed on video, but some tanks show evidence of disturbed crust surface indicating that some may cause waste motion (Meyer et al. 1997). However, even if a medium GRE induced significant waste motion, their release time is quite long (>1 hour) compared to a large release (~ minutes) so that waste motion would cease by the time the headspace could become flammable (see Section 2.3 below). Therefore I set the probability of ignition for medium GREs to zero. Note that, in my Phase I elicitation, the ignition probability for medium releases was not set to zero for SSTs. I believe this remains appropriate since the waste is much more heterogeneous and the solids column is deeper. These wastes would be more likely to move in the later stages of a gas release than DST waste.

I don't believe a small GRE to be capable of producing significant waste motion. Even if it did, the timing argument for medium GREs would still apply to make the ignition probability zero.

Probability of an ignition source being induced by a buoyant displacement GRE:

Small GREs:	ZERO	waste motion not credible
Medium GREs:	ZERO	waste motion occurs before flammability
Large GREs:		
Lower limit:	ZERO	physical limit
10%ile:	0.0001	no basis
Median:	0.001	"unlikely" in risk parlance
90%ile:	0.01	no basis
99%ile:	0.03	no ignitions in ~30 large events
Upper limit:	0.3	no ignitions in 3 flammable events

2.3 DURATION OF A BUOYANT DISPLACEMENT-TYPE GRE

The distributions for gas release duration I gave in Phase I were based on small releases from SSTs derived from hydrogen monitoring data. These showed release times on the order of days. The times for medium and large releases were assigned the same distribution but with units of hours for medium releases and minutes for large releases. This assignment was made because of indications that medium GREs in SSTs took hours and the video of large releases from SY101 were completed in several minutes.

Since the Phase I elicitation, the distribution of release duration for medium releases from DSTs has become much better defined. I derived release times from the headspace hydrogen concentration transients for all the medium GREs in DSTs for which I had headspace hydrogen data (SHMS GRE Data from Chuck Stewart). The release duration was computed as the time between initial departure from the baseline concentration and the occurrence of the peak concentration, ignoring spikes.

The resulting release durations are quite consistent with the assumptions made during Phase I. The duration for DSTs is apparently about twice that assumed for SSTs. The median duration for medium GREs in DSTs is 3.6 hours while the median predicted for medium GREs in SSTs is about 2.2 hours. The bounding (99th percentile) duration is ~20 hours for DSTs and 10 hours for SSTs. The two distributions are shown in Figure 1.

Blaine Barton, developed release times for several large gas releases in SY-101. The data are given in Table 1. The release efficiencies are calculated in Meyer et al. (1997). I attribute the long times recorded for 8/27/91 and 2/2/93 as the result of a delayed release of separate gobs and therefore exclude them in trying to establish a distribution. The video of the 9/3/92 and 6/26/93 events shows a sequential upwelling of separate gobs of waste from different parts of the tank. But the gobs must release their gas in relatively close sequence to act as a large release. If the

gob releases are spread out such that ventilation significantly clears one before the next one occurs, the effect is essentially a series of medium releases. The low hydrogen concentration of the 8/27/91 event may be such a case. The resulting distribution (recognizing that five data points challenges that concept) is shown in Figure 2.

Based on this distribution I set the median duration at 8 minutes and the 90th percentile at 20 minutes. The 99th percentile is set at 55 minutes since that duration really does not represent a large release. I set a lower bound of 30 seconds as a representative time for the dynamics of a single gob but a 10th percentile of 2 minutes which is the duration of the largest part of the release.

Table 1. SY-101 Gas Release Duration Compiled by Blaine Barton.

Date	Time to Peak [H ₂] (minutes)	Release Efficiency %	Peak [H ₂] (ppm)
4/19/90	20	39.7	35,000
10/24/90	7	35.2	47,000
8/27/91	96*	35.8	3800
12/4/91	8	43.7	52,000
9/3/92	7	67.0	51,200
2/2/93	55*	45.2	27,900
6/26/93	17	45.7	34,000

* Data points excluded from distribution.

Figure 1. Cumulative Distribution of Medium GRE Duration in DSTs and SSTs.

Figure 2. Cumulative Distribution for Large GREs in SY101.

For small releases in DSTs, I assign the distribution for medium releases directly. There are two small releases (AN104 10/8/95 and AN105 9/26/97) with durations similar to those recorded for medium releases. No small releases of several days duration are observed in the SST SHMS data.

Duration of a buoyant displacement-type GRE

Small and Medium GREs in DSTs:

1%ile	1 hour (less than shortest observed and Fig. 1)
10%ile	1.5 hours (from Fig. 1)
median	3.6 hours (from Fig. 1)
90%ile	10 hours (from Fig. 1)
99%ile	20 hours (greater than longest observed and Fig. 1)

Large GREs in DSTs:

Lower	0.5 min. (minimum for dynamics of fluid motion)
10%ile	2 min. (major portion of release from video)
median	8 min. (from Fig. 2)
90%ile	20 min. (from Fig. 2)
99%ile	55 min. (duration less than the rejected data point)

2.4 PROBABILITY OF A SEISMIC-INDUCED GRE (DST ONLY)

There is no solid basis for estimating seismic-induced GRE probability. Ried and Diebler (1997) performed extensive transient simulations using the ANSYS structural analysis code assuming an elastic/perfectly plastic material with displacement boundary conditions on the tank walls computed from the Hanford 1000-year design basis earthquake. This analysis showed that the presence of a deep liquid layer greatly amplified the stresses in the solid layer resulting in mobilizing almost the entire waste volume. Based on energy deposition arguments, the gas release from this kind of disturbance is estimated to be similar to the large buoyant displacement GREs in SY101 or 25-50% of the retained gas.

It is difficult to extrapolate up to a 10,000-year earthquake or down to a 100-year event because no calculations were performed for either. However, it could be said that, since the 1000-year quake already mobilizes most of the waste, a 10,000-year event could do little more and would also result in a "large" GRE. The smaller DBA might mobilize less waste, though the peak acceleration is on the same order as in the 1000-year DBA (Stewart et al. 1996). Therefore I consider the 100-year event most likely to produce a medium GRE.

The seismic-induced gas release from DSTs that exhibit buoyant displacements might be considered more energetic than in those that don't. In the burping tanks, a greater volume of

buoyant waste might release potential energy to the waste if the overburden were disturbed. However, I don't believe the difference is sufficiently well defined to warrant conditioning on buoyant displacement criteria.

Consistent with my elicitation on seismic-induced gas releases in Phase I (Slezak and Bratzel, 1997), I do not provide a distribution for each conditioning parameter but state the probability of a release as zero or one according to Table 2.

Table 2. Seismic GRE Matrix - DSTs.

	100-year	1,000-year	10,000-year
Small GRE	n/a	n/a	n/a
Medium GRE	DSTs	n/a	n/a
Large GRE	not credible	DSTs	DSTs

In constructing the table I envisioned a distribution of GRE size for each size of earthquake. The idea is sketched in terms of the probability densities in Figure 3. I believe the uncertainty is too high to ascribe a small probability to small and large releases in a 100-year earthquake, for example. Instead I assign a probability of 1.0 to the medium GRE with zero probability for the rest. Similarly, large GREs have a probability of 1.0 for 1000-year or greater earthquakes.

Figure 3. Probability Density of Seismic-Induced Release Efficiency.

Probability of a seismic-induced GRE

100-year event:	Small GRE, $P=0$ (only medium GREs) Medium GRE, $P=1$ (comparing 100-year & 1000 year magnitude) Large GRE, $P=0$ (only medium GREs)
1,000-year event:	Small GRE, $P=0$ (only large GREs) Medium GRE, $P=0$ (only large GREs) Large GRE, $P=1$ (per transient simulation results)
10,000-year event:	Same as 1,000-year earthquake (GREs can't get any larger than large).

2.5 PROBABILITY OF AN IGNITION SOURCE IN A DST CAUSED BY AN EARTHQUAKE

Ignition sources induced by an earthquake do not depend so much on the waste, but on the characteristics of the tank and suspended equipment. In a DST, suspended equipment is less likely to be immobilized by a deep layer of stiff solids as would more likely be the case in an SST. Also, seismic simulations by Reid and Deibler (1997) indicate large surface waves in tanks with a deep liquid layer. Therefore, tank and waste motion in DSTs would be more likely to cause the equipment to 'bang' in the risers and the ignition probability should be somewhat higher than in SSTs.

However, the seismic-induced ignition probabilities I gave in Phase I are already about an order of magnitude higher than expected for a large buoyant displacement GRE and I don't feel comfortable increasing the probability further. Therefore, I set the probability of ignition caused by an earthquake to be the same as for SSTs.

Probability of an ignition source in a DST caused by an earthquake:

100-year Earthquake:

5%ile	10^{-5}		
65%ile	0.0003		same as SSTs in Phase I
95%ile	0.003		

1,000-year Earthquake

5%ile	0.001	
65%ile	0.03	same as SSTs in Phase I
95%ile	0.3	

10,000-year Earthquake: P=1 (same as SSTs in Phase I)

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APPENDIX B.13
RATIONALE REPORTS

J. K. Thomas

May 1998

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1.0 INTRODUCTION

This report provides documentation for the elicitation parameter distributions provided by J. K. Thomas on 3/13/98 to support Analysis Framework for the Stage II Gas Release Event Safety Analysis Project. The parameter distribution values provided in this report were developed based on a combination of existing analyses, simplified scoping calculations, and engineering judgment. The specific parameters for which distributions are provided are:

- Buoyant displacement GRE ignition source probability
- Probability of a seismic-induced GRE in a DST
- Probability of a seismic-induced DST ignition source
- Total respirable mass
- Total transportable mass.

As part of the introduction to this report, I would like to record my support for the approach used in the Gas Release Event Safety Analysis Project. The technical issues associated with the potential for the formation and subsequent ignition of flammable gas within the Hanford waste tanks and the associated radiological source terms and consequences are complex. It is difficult, if not impossible, to develop a comprehensive technical position which will be acceptable to all of the Hanford Site stakeholders. The approach adopted in this project (i.e., the elicitation of a wide base of expert opinion coupled with the formation of cumulative distributions based on this elicitation) provides a mechanism to ensure that all relevant technical viewpoints are accurately reflected by the resulting accident analysis. This provides a risk-based safety assessment which neither neglects the potential for serious consequences nor is too conservative.

Both the Sandia project team and the staff members of the various Hanford Site organizations who supported this task are to be commended for their efforts.

2.0 BUOYANT DISPLACEMENT GRE IGNITION SOURCE PROBABILITY

2.1 INTRODUCTION

This parameter is the probability that a buoyant displacement-type gas release event (BD GRE) would result in an ignition source. This parameter is only intended to cover ignition sources which are specifically induced by the buoyant displacement (i.e., by the waste motion associated with the buoyant displacement); ignition sources not caused by the buoyant displacement which could ignite released flammable gas are included elsewhere within the analysis framework. This parameter is conditioned upon the GRE size [small (0-5%), medium (5-25%) or large (>25%), where the GRE size bin is based upon the per cent of retained gas which is released during the event].

2.2 BACKGROUND

2.2.1 Phenomenological Considerations

A buoyant displacement gas release event could potentially directly cause an ignition source as a result of the induced waste motion. Equipment which extends down through crust or into liquid will undergo some measure of displacement as a result of waste motion. Vigorous waste motion capable of causing limited equipment damage has been observed in some of the SY-101 release events [the Stage I panel was shown a video of severe liquid surface motion during an SY-101 BD GRE and photographs of bent tubes within the SY-101 vapor space (presumably caused by waste motion)]. There are four main physical mechanisms through which such an ignition source may be created:

- Induce equipment motion which damages equipment sufficiently to create an electrical spark
- Induce equipment motion which damages equipment sufficiently to allow flammable gas to exit tank and contact ignition sources external to the tank
- Induce equipment motion which results in an impact and frictional spark
- Static discharge from object(s) on the waste surface.

Equipment motion and damage which would be sufficient to create an electrical spark (mechanism #1), while possible, is judged to be a remote possibility. Based on this judgement, it is not considered to make a significant contribution to the ignition source probability.

The analysis framework already explicitly considers the expulsion of flammable gas due to head space pressurization during a GRE and therefore the 2nd mechanism listed above is directly accounted for by the framework. The probability of ignition would only be increased if the BD GRE disabled the tank ventilation system so as to increase the time at risk; this is judged to be incredible.

Frictional sparks due to equipment motion (mechanism #3) is judged to be a credible ignition source. Clearly, large GREs are capable of causing equipment motion so that contact could be made with other pieces of equipment, the sides of the riser in which the equipment is installed, the tank sidewall and/or sections of crust on top of the waste. However, it is expected that the equipment motion would be relatively slow so as to minimize the potential for frictional sparks. For a large GRE, a best-estimate ignition probability on the order of a few per cent is judged to be applicable.

Static discharge from object(s) on the waste surface (mechanism #4) is also judged to be a credible ignition source. However, such a mechanism would require rapid surface motion.

Such motion would be expected to result in a high water vapor concentration near the liquid surface. This would significantly reduce the ignition source probability. As a best-estimate, the ignition probability for a large GRE is judged to be on the order of a few per cent.

Although the mechanisms described above are not very likely to result in ignitions due to a BD GRE, it is judged that they are certainly credible. In considering these mechanisms and the associated ignition probabilities, it is prudent to bear in mind that the identification of potential ignition source mechanisms and the assignment of ignition probabilities probability values is far from an exact science. The ignition source in actual industrial explosion events can not be identified in roughly 1/4 to 1/2 of all such events. These unidentified sources are normally attributed to "static discharge" or some other similar "catch-all, ignition source of last resort" description. Hence, vanishingly small ignition source probability values should probably be viewed with some skepticism.

Based on the discussion given above, it is judged that the ignition probability for a large GRE would be approximately 5% with roughly double this at the 95% confidence level. The values for smaller GREs should be reduced significantly from this value due to the decreased potential for rapid motion of equipment or objects on the waste surface. The spread between the upper and lower confidence levels should be fairly wide (one to two orders of magnitude) since there is substantial uncertainty concerning the phenomena involved.

2.2.2 Field Data

There have been a large number of gas release events observed in the Hanford Waste Tank Farm without any indication of flammable gas ignition; it is assumed here that no explosions (i.e., ignitions) have occurred. Since no ignitions have occurred, an ignition probability cannot be calculated directly in an intuitive fashion. However, the mean ignition probability estimate can be made using a Bayesian update technique. The mean ignition probability can be calculated using the expression given below (NRC 1983):

$$P_i = 0.5 / (N+1) \quad (1)$$

where: P_i = Probability of ignition, and
 N = Number of events (all without ignition).

Similar expressions have been given in the literature with slightly different numerator values (i.e., 1/3 vs. the 0.5 value given above). However, the exact numerator value makes little difference to this discussion and the expression given above is judged to be sufficient. The presentation given by Chuck Stewart (Stewart 1998a) presented GRE data based on hydrogen concentration measurements. Based on these data, it appears that there have been 3 GREs which resulted in the tank vapor space hydrogen concentration exceeding the LFL (all in SY-101) and 21 GREs which gave hydrogen concentrations greater than 1/10 of the LFL (roughly half of which were in SY-101). The releases which gave hydrogen concentrations greater than the

LFL are consistent with large GREs, whereas those giving concentrations greater than 1/10 the LFL are consistent with medium GREs. The data from SY-101 spans the period from 4/90 through 6/93 (after which the mixing pump was installed) while that for the other tanks covers 10/94 through 1997 (depending upon the particular tank). It is assumed here that BD GREs have been occurring over a much longer time period than these observation periods. For the large GREs it is assumed that the total number of occurrences is 5 times the number which were measured via hydrogen concentration measurements in SY-101 over the time period noted above. Since medium releases would not attract as much attention and the hydrogen concentration measurements for other tanks were initiated later in time, a multiplier of 10 is used for these data. This scaling gives 15 large and 210 medium releases without an ignition. The ignition probabilities calculated using these values with eqn.(1) are 3% for a large GRE and 0.2% for a medium GRE. This ignition probability value for a large GRE is in relatively good agreement with the value developed based on judgement in Section 2.2.1 (i.e., 3% vs. 5%) so that these two values tend to support one another.

2.3 PARAMETER DISTRIBUTIONS

The parameter distribution values were assigned starting with the best-estimate values developed based on hydrogen concentration measurements discussed above in Section 2.2.2 (0.2 and 3%, respectively, for medium and large GREs). For the small GRE, ignition would be very difficult since the ignition source would have to be at the surface very near the release location or in the release plume. To account for this, the best-estimate medium ignition source probability was reduced by a factor of 5 (0.04%).

The 95% confidence level value for the large GRE was taken to be 10%. This value is judged to be near the maximum possible based on the phenomenological arguments presented in Section 2.2.1 and is double the best-estimate value. The 5% confidence level for the large GRE was taken to be 0.5%. This value is judged to be near the minimum possible based on the phenomenological arguments presented in Section 2.2.1 and is roughly equal to the best-estimate value for a medium GRE. The 95% confidence level value for the medium GRE was taken to be an order of magnitude lower than the corresponding value for a large GRE (1%) based on the reduced energetics associated with the two event classes; this is a factor of 5 larger than the best-estimate value, which is consistent with the uncertainty associated with the derivation of the best-estimate value. The 5% confidence level value for the medium GRE was taken to be equal to the best-estimate value for a small GRE (0.04%). The 95% and 5% for the confidence levels were simply taken to be rounded order of magnitude changes from the best-estimate value, which reflects the uncertainty associated with this parameter. The 95% value for the small GRE (0.1%) is as high as can reasonably be expected for a small release. The 5% value for the small GRE (0.001%) is essentially zero with respect to practical applications of the result.

These values are summarized in Table 1.

2.4 REFERENCES

NRC (1983) PRA Procedures Guide, NUREG/CR-2300, U.S. Nuclear Regulatory Commission, Jan. 1983 [cited in C.H. Blanton and S.A. Eide (1993) Savannah River Site Generic Data Base Development, WSRC-TR-93-262, Savannah River Site, Aiken, SC, June 1993].

Stewart, C.W. (1998a) "GRE History of Hanford DSTs," presentation at Expert Panel Elicitation Workshop #1, Jan. 19-23, 1998, Richland, WA.

Table 1. Ignition Probability due to BD GRE.

CDF (%)	Ignition Probability (per GRE)		
	Small GRE	Medium GRE	Large GRE
5	1×10^{-5}	4×10^{-4}	0.005
50	4×10^{-4}	0.002	0.03
95	1×10^{-3}	0.01	0.10

3.0 PROBABILITY OF A SEISMIC-INDUCED GRE IN A DST

3.1 INTRODUCTION

This parameter is the probability that an earthquake would induce a gas release in each of the three different GRE size ranges of interest [small (0-5%), medium (5-25%) or large (>25%), where the GRE size bin is based upon the per cent of retained gas which is released during the event]. The application of these values is limited to DSTs with a thick (> 1 meter) liquid layer present. This parameter is conditioned upon the seismic return period [100, 1,000, and 10,000 year periods].

Note that the analysis framework assumes a probability of unity for inducing a GRE due to a seismic events with return periods of 10,000 years or longer, and a probability of zero for return periods of 10 years or shorter. It should also be noted that the probability of inducing a release of a given size is conditional on a larger release not occurring, so that the sum of the probabilities for the three GRE sizes for a given seismic return period is not constrained to be less than unity.

3.2 BACKGROUND

3.2.1 ANSYS Analysis

The analysis developed by Reid and Deibler (1997) was judged to be the most relevant piece of information with respect to this parameter. This analysis examined the potential for a 1000-year seismic event to induce a GRE in a typical DST (liquid over solid) representative of the case of interest. The model utilized equal depths of liquid and solid with total depths of 300 and 400 in. and solid yield strengths of 300 and 6000 Pa. The yield strengths of the nonconvective layer in DSTs are in the range of 100 to 200 Pa with an uncertainty of approximately 100 Pa (Meyer et al. 1997), so that the 300 Pa cases are applicable. It is recognized that the yield strength is actually a function of location within a tank and strain rate, but reasonable variations should not take the resulting yield strength value very far above 300 Pa. Using a strain energy density limit (SEDL) criteria (mobilization at equivalent of 100% strain), Reid and Deibler report that 98 and 80% of the gas within the nonconvective layer would be mobilized at total waste depths of 300 in. and 400 in. Their analysis showed that the presence of a crust would increase the mobilization fraction to 100%. In this analysis, mobilization is meant to convey that waste has been disturbed sufficiently for the gas to be "mobilized" and hence available for release; gas mobilization is not necessarily equivalent to gas release (see Section 3.2.2).

These results, although obtained using a more sophisticated approach, are in general agreement with those reported by Stewart et al. (1996). It is also noted that Stewart, during his presentation on this topic (Stewart 1998b), indicated that these results would be relatively insensitive to the SEDL mobilization criteria value employed; he estimated that there would be virtually no change if the criteria were increased by 50% and only a slight decrease in the mobilization fraction of the criteria were doubled.

Since the mobilization fraction is near 100% for a 1000-year seismic event, it is reasonable to assume that all of the waste would be fully mobilized for a 10,000-year seismic event. These results cannot be directly applied to the 100-year seismic event. However, it is judged that a similar analysis would indicate significant mobilization fractions. Section 3.2.3 discusses the impact of seismic intensity.

There are several points which should be made with respect to the analysis performed by Reid and Deibler (1997). First, no allowance was made for the potential of waste mobilization due to hydrostatic loading, even though the calculated hydrostatic pressure variations were very large (on the order of ± 10 psi). From a physical viewpoint, there is reason to believe that significant hydrostatic pressure variations would be effective at mobilizing trapped gas since cyclic pressure variations will induce cyclic gas bubble volume variations. Reid and Deibler specifically note the existence of experimental data from the development of a sonic probe which indicates that pressure variations on the order of 1 to 10 times the waste yield strength may cause mobilization. Even assuming a relatively large yield strength (1000 Pa) and considering the high end of this range (factor of 10), this would indicate that pressure swings of 10,000 Pa (1.5 psi) would be

effective with respect to gas mobilization. The calculated hydrostatic pressure variations are an order of magnitude larger than this criterion would indicate are required for gas mobilization.

Second, it does not appear that the analysis of Reid and Deibler (1997) directly accounts for any loss of strength in the waste due to the accumulation of strain. That is, there is data which indicates that waste strength decreases dramatically once the waste has been disturbed and that it takes an extended period for strength recovery. For example, the ball rheometer tests show that the waste viscosity decreases noticeably after the first pass of the ball through the waste. Similarly, during a panel caucus, Phil Gauglitz reported he had observed (during laboratory tests) that waste simulants may be initially "stiff" and "resist deformation", but that once they were disturbed they appeared to be "much weaker". This type of data and information is consistent with the expected behavior of a slurry of solid particles for which the material strength is dependent upon particle interaction; disturbing the waste causes particle relocation and some time is required for the particles to resettle such that the undisturbed waste strength is recovered. These observations are also meaningful in that they indicate that the waste, once disturbed, may take a considerable period of time to regain a significant fraction of its initial yield strength.

These two factors indicate that the waste mobilization fractions reported by Reid and Deibler (1997) may be smaller than those which would actually be expected during a 1000-year seismic event. That is, the mobilization fractions may well be even closer to 100% than indicated by their results. This would also imply that the mobilization fractions for a 100-year seismic event could also be large.

3.2.2 Release Fraction

The results discussed above relate to the fraction of the gas in the waste which is mobilized and hence available for release. As noted above, gas mobilization is not necessarily equivalent to gas release. Several data sets are available which can be used to qualitatively relate release fraction to the degree of waste agitation.

A significant quantity of data is available on the release fraction associated with buoyant displacement GREs (BD GRE). The values given in Meyer et al. (1997) indicate the release fractions associated with relatively large BD GREs (i.e., those in SY-101) can approach 70% with average release fractions on the order of 35%. The release fractions for smaller BD GREs (i.e., those in other DSTs) are typically on the order of 10%, although some BD GREs exhibited release fractions several times higher. The discussion of Reid and Deibler's (1997) analysis for the 1,000-year seismic event indicated very large surface displacements indicative of severe liquid agitation. Hence, a severe seismic event would be expected to result in a higher level of agitation than a large BD GRE, so that the corresponding release fraction could approach 100% from the mobilized region. Conversely, a minor seismic event would be expected to result in less severe agitation than a large BD GRE, so that the corresponding release fraction would be on the order of 10%.

The lab-scale simulant tests discussed in Stewart et al. (1996) indicate release fractions of approximately 10% for the yield stress range of interest (hundreds of Pa). However, since these were lab-scale simulant tests and hence are subject to scaling and waste property issues, more weight is placed on the actual BD GRE data noted above.

Another relevant consideration with regards to release fraction is the loss of strength upon agitation noted in Section 3.2.1. This implies that the solid layer in a given waste tank may have sufficient material strength to resist a buoyant displacement GRE prior to a seismic event, but that it could be sufficiently weakened by the seismically-induced motion that a BD GRE occurs. In this situation, it is judged that the gas release fraction could be quite high.

3.2.3 Seismic Intensity

The analysis discussed in Section 3.2.1 only specifically addressed a 1,000-year seismic event. Some scaling is required to apply these results in an approximate fashion to the 100 and 10,000-year events. The presentation given by Rohay (1997) provided a table of peak spectral accelerations for the return periods of interest. These values indicate that the peak accelerations for the 1,000-year event are 4 to 5 times those for the 100-year event, and those for the 10,000-year event are 3 times those for the 1,000-year event.

A similar comparison can be made by comparing the calculated amount of energy input to the waste by the 100 and 1,000-year seismic events as reported by Stewart et al. (1996). This comparison indicates that the 1,000-year event imparts roughly 3 times the amount of energy to the waste as the 100-year event, which is in rough agreement with the comparison made above based upon the peak spectral accelerations reported by Rohay (1997).

Rohay (1997) also provided peak and spatial accelerations at various confidence levels for the seismic events of interest. To a first approximation, the 95% and 5% confidence level acceleration values for adjacent return frequencies are roughly equal. That is, the 95% confidence level acceleration for the 100-year event is roughly equal to the 5% confidence level acceleration for the 1,000-year event. This would imply, given no other large uncertainty factors, that the seismically-induced GRE probabilities should also overlap at the 95% and 5% confidence levels for adjacent return frequencies.

3.3 PARAMETER DISTRIBUTIONS

3.3.1 1,000-Year Seismic Event

The parameter distribution values were assigned starting with the 1000-year seismic event since this was the case specifically analyzed by Reid and Deibler (1997). The best-estimate value for a large GRE (>25% of retained gas released) is based on two factors. This first is that 100% gas

mobilization is expected based on the analysis provided by Reid and Deibler, consideration of the gas mobilization mechanisms not explicitly accounted for in their analysis, and the reported lack of any real sensitivity to the SEDL criterion. The second is that this event is judged to lead to larger releases from mobilized regions than a large BD GRE (e.g., larger than those associated with SY-101, which approached 70%). Accordingly, the best-estimate value for the large GRE was taken to be 0.90. The 95% confidence level should approach 100%. However, there is sufficient evidence of low release fractions associated with both BD GREs and lab-scale tests so that the 95% confidence level value was taken to be 0.95. Based on the reasoning outlined above, it is difficult to believe that the probability of a large GRE due to a 1,000-year seismic event can be very small; a value of 25% was assigned for the 5% confidence level (equivalent to 1 in 4 tanks undergoing a large GRE due to the 1,000-year seismic event).

The best-estimate value for the medium GRE (5-25% of retained gas released) with the 1000-year seismic event should approach unity given near 100% mobilization and that even the lower end of the BD GRE and lab-scale test data indicate release fractions near 10% (double the lower end of the medium GRE range). Accordingly, a best-estimate value of 0.95 was assigned; some margin below unity was preserved since not all aspects of the phenomena have been clearly defined at this time. The 95% confidence level was assigned a value of unity. The 5% confidence level was assigned a value of 0.50 (double the corresponding confidence level for the large GRE) since it is very difficult to conceive of a lower value being applicable to this case (equivalent to 1 in 2 tanks undergoing a medium GRE due to the 1,000-year seismic event).

A unity value was assigned to all confidence levels for the small GRE (<5% of retained gas released) since all of the available data and information indicates that this would be the case. That is, it is judged to be incredible that a 1000-year seismic event would not induce a small GRE in all DSTs.

3.3.2 10,000-Year Seismic Event

Based on the data and information discussed above in developing the parameter distributions for the 1,000-year seismic event and the fact that the 10,000-year event would be roughly 3 times more severe, the best-estimate value for a large GRE was taken to be unity for this case. At the 5% confidence level, a value of 0.75 was assigned. The non-unity value at the low confidence level is intended to convey a judgement that it is possible that 1) some combination of waste tank level, configuration, and rheology may be resistance to large gas releases, and 2) there is some evidence that even severe agitation will not lead to large gas release fractions. The 5% confidence level for a medium release was increased to 0.95 since it is almost certain that all DSTs would undergo at least a medium GRE with the 10,000-year seismic event.

Note that this places the 5% confidence level values for the 10,000-year event inside the 95% confidence level values for the 1,000-year event. Setting the values equal would only reflect the uncertainty in the peak and spatial accelerations for these events. The increased spread between these values reflects an increase in the uncertainty due to the mobilization and release phenomena.

3.3.3 100-Year Seismic Event

The 100-year seismic event would impart roughly 1/3 the energy into the waste as the 1,000-year event. Hence, it becomes reasonable to assume that neither the mobilization or release fractions would approach 100% on a best-estimate basis. Although not a rigorously correct approach, it is assumed here that the mobilization fraction would scale with the seismic energy, so that a mobilization fraction of 1/3 was assigned. The best-estimate gas release fraction from the mobilized region is taken to be 20 to 75% based on the data for large BD GREs so that the expected release fraction would be on the order of 7 to 25%.

The values developed above fall into the range of a medium GRE (5-25% of retained gas released). Accordingly, the best-estimate value assigned to the medium GRE for the 100-year seismic event was taken to be 0.75, indicating a relatively high level of confidence that this event would induce a medium GRE in most DSTs. The 95% confidence level was set to 0.95 (near unity); this value was not taken to be unity since there is some uncertainty in the actual impact of a 100-year seismic event in terms of the waste response and some evidence of very low release fractions in moderate BD GREs. Based on the reasoning outlined above, it is difficult to believe that the probability of a medium GRE due to a 100-year seismic event can be very small; a value of 0.25 was assigned at the 5% confidence level (equivalent to 1 in 4 tanks undergoing a medium GRE due to the 100-year seismic event).

On a best-estimate basis, it is judged that the probability of a large GRE for this event would not be very small since the upper-end of the best-estimate release fraction estimates developed above border on those for a large GRE. Accordingly, the best-estimate value was set equal to the medium release 5% confidence level value (0.25). However, it is judged unlikely that a large fraction of the DSTs would undergo a large GRE for this event; the 95% value was therefore taken to be only twice the best-estimate value (0.50). The 5% confidence level value was taken to be 0.1; based on the uncertainties associated with the mobilization and release phenomena, this is judged to be near the lowest value which can be supported.

A small GRE is judged to be very likely even for the 100-year event. It is expected that almost all of the tanks would undergo at least a minor GRE with this event. The best-estimate and 95% confidence level values were therefore taken to be 0.95 and 1.0. The 5% confidence level was taken to be 0.50; that is, it is judged to be very unlikely that less than half the DSTs would not undergo at exhibit a GRE due to this event.

Note that this places the 5% confidence level values for the 1,000-year event inside the 95% confidence level values for the 100-year event. As discussed in the preceding section, this is judged to be both an acceptable and desirable outcome.

3.3.4 Summary

The distributions developed in the preceding three sections are summarized in Table 2a, 2b, and 2c, respectively, for seismic events with 10,000, 1,000, and 100-year return frequencies.

It should be noted that in the cases where unity values have been assigned, these values could be decreased slightly in order to permit a reasonable distribution to be fit through the other confidence level values provided. That is, such modifications would not change the risk characteristics that these values are intended to convey and hence would have no meaningful impact on any calculations performed using the analysis framework with the resulting distributions.

3.4 REFERENCES

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- Stewart, C.W. et al. (1996) Gas Retention and Release Behavior in Hanford Single-Shell Waste Tanks, PNNL-11391, Pacific Northwest National Lab., Richland, WA, Dec. 1996.
- Stewart, C.W. (1998b) "Seismic Response of DST Waste," presentation at Expert Panel Elicitation Workshop #1, Jan. 19-23, 1998, Richland, WA.

Table 2a. Probability of Seismic-Induced GRE
(10,000 year return period).

CDF (%)	Probability of Inducing GRE		
	Small GRE	Medium GRE	Large GRE
5	1.0	0.95	0.75
50	1.0	1.0	1.0
95	1.0	1.0	1.0

Table 2b. Probability of Seismic-Induced GRE
(1,000 year return period).

CDF (%)	Probability of Inducing GRE		
	Small GRE	Medium GRE	Large GRE
5	1.0	0.50	0.25
50	1.0	0.95	0.90
95	1.0	1.0	0.95

Table 2c. Probability of Seismic-Induced GRE
(100 year return period).

CDF (%)	Probability of Inducing GRE		
	Small GRE	Medium GRE	Large GRE
5	0.5	0.25	0.10
50	0.9	0.75	0.25
95	1.0	0.95	0.50

4.0 PROBABILITY OF A SEISMIC-INDUCED DST IGNITION SOURCE

4.1 INTRODUCTION

This parameter is the probability that an earthquake would cause an ignition source that would not be included in either the “probability of an ignition source being induced by a buoyant displacement GRE (for BD GREs)” or the “probability of a GRE-induced ignition source (for non-BD GREs)” parameters. Hence, this parameter does not include the probability of ignition due to a GRE resulting from a seismic event. That is, this parameter is only intended to capture the increase in the probability of ignition due to the seismic event itself. This parameter is conditioned upon the seismic return period [100, 1,000, and 10,000 year periods]. However, it should be clearly recognized that the surface motion induced by a seismic event may be more severe than that induced by a GRE; hence, the mechanisms which may produce an ignition source during a GRE (see Section 2) may be “more prevalent” for a seismic event. That is, these same mechanisms must be considered here with respect to the potential for an increase in the ignition source probability relative to that ascribed to the GRE itself.

Note that the analysis framework assumes an ignition source probability of unity for seismic events with return periods of 10,000 years or longer, and a probability of zero for return periods of 10 years or shorter.

4.2 BACKGROUND

4.2.1 Relative Damage Levels

Based on the presentation and discussion provided by Rohay (1997), a seismic event with a return period of 100 years would have a peak acceleration of approximately 0.05 g and would result in damage to many systems, damage to weak structures, and potential loss of electrical power near the epicenter. A 1,000-year event would have a peak acceleration of approximately 0.2 g and would result in damage to all structures. A 1,000-year event would have a peak acceleration of approximately 0.5 g and would result in large-scale damage. It is recognized that this characterization of damage levels is very qualitative and approximate; nevertheless, this was deemed sufficient to assign approximate probabilities to the main ignition source mechanisms discussed below.

4.2.2 Phenomenological Considerations

The mechanisms by which a seismic event could induce an ignition source are essentially the same as those for a buoyant displacement gas release event (BD GRE, see Section 2). However, a seismic event can impart motion to the tank structure and internal tank components directly, as opposed to only via fluid motion as is the case for BD GRE. In addition, as noted above, a seismic event may cause more severe fluid motion than a BD GRE and hence increase the potential for an ignition source resulting from fluid motion.

As discussed in Section 2, there are four main physical mechanisms by which such an ignition source may be created:

- Induce equipment motion which damages equipment sufficiently to create an electrical spark
- Induce equipment motion which damages equipment sufficiently to allow flammable gas to exit tank and contact ignition sources external to the tank
- Induce equipment motion which results in an impact and frictional spark
- Static discharge from object(s) on the waste surface.

Equipment motion and damage sufficient to create an electrical spark (mechanism #1) would be expected in the most severe seismic event (return period of 10,000 years) but is judged to be very unlikely for the least severe seismic event (return period of 100 years). A loss of power due to the seismic event could decrease the potential for this ignition source, but power would be restored if possible at some point to allow monitoring and facilitate recovery actions, at which time the damaged equipment could act as an ignition source. In a similar evaluation for a waste tank at the Savannah River Site, an equipment damage probability of 0.3 per piece of equipment was developed for a $a = 0.02g$ seismic (Cramer and Ford 1994). This is judged to be very conservative (high) for the least severe event, and probably not large enough for the most severe event. If this value were adopted along with assumptions that there are 10 such pieces of equipment in a DST and that a damaged piece of equipment would pose a 5% ignition source probability, then the total ignition source probability due to this source would be approximately $10\% [(0.3) \cdot (10) \cdot (5\%) = 15\%]$. The expected value for the 10,000-year seismic event would be higher.

The analysis framework already explicitly considers the expulsion of flammable gas due to head space pressurization during a GRE and therefore the 2nd mechanism listed above is directly accounted for by the framework. The probability of ignition would only be increased if the seismic event disabled the tank ventilation system. However, a loss of ventilation would be almost certain for 10,000-year seismic event, would be a distinct possibility for the 1,000-year event (~ 50% chance), and would be possible for even the 100-year event (~ 10% chance). If ventilation is lost and flammable gas exits the tank, then it is possible that the gas could be ignited by equipment or static discharge external to the tank and subsequently flashback into the tank vapor space. External ignition would not necessarily flashback through the leak path, but this would be the expected behavior. It is possible that a leak may not lead to ignition since a flammable mixture may not form in the immediate vicinity of an ignition source. However, an evaluation of hydrogen accidents performed by Zalosh and Short (1978) showed that most hydrogen leaks and releases led to fires and explosions; that is, the leaked combustible gas was ignited in the majority of cases. The releases evaluated by Zalosh and Short are much more severe than those expected for the case of interest, but it does suggest that the release of combustible gas could lead to external ignition and subsequent ignition of the gas within the vapor space. Furthermore, the density of ex-tank ignition sources could be increased by the seismic event relative to those present in the cases examined by Zalosh and Short. It is judged that a best-estimate ignition probability on the order of 10 to 25% is reasonable for a severe seismic event (10,000 year return period).

Frictional sparks due to equipment motion (mechanism #3) is judged to be a credible ignition source. Seismic events would be capable of causing equipment motion so that contact could be made with other pieces of equipment, the sides of the riser in which the equipment is installed, the tank sidewall and/or sections of crust on top of the waste. However, it is expected that the equipment motion during a seismic event would be relatively slow so as to minimize the potential for frictional sparks. For a severe seismic event (10,000 year return period), a best-estimate ignition probability via this mechanism on the order of a 10% is judged to be applicable.

Static discharge from object(s) on the waste surface (mechanism #4) is also judged to be a credible ignition source. However, such a mechanism would require rapid surface motion. Such motion would be expected to result in a high water vapor concentration near the liquid surface. This would significantly reduce the ignition source probability. As a best-estimate, the ignition probability for even the most severe seismic event (10,000 year return period) is judged to be no more than a few per cent.

It is noted that an argument could be made that the ignition probability depends to some extent on the length of time required to form a flammable mixture following the seismic event (e.g., since a flammable mixture would have to be present in order for combustion to occur), although the elicitation question was not explicitly posed to take this into account. Furthermore, if the release is relatively fast (as in a GRE), then the maximum gas concentration would be achieved fairly quickly. In addition, aftershocks would tend to limit the amount of credit which could be taken for timing considerations. Hence, this factor was not directly considered in formulating the CDF values for this parameter.

4.3 PARAMETER DISTRIBUTIONS

The best-estimate value for the 10,000-year seismic event was taken to be 0.5. This value is based on significant probabilities that equipment is damaged sufficiently to produce electrical sparks, that combustible gas would be ignited external to the tank and flash back into the tank vapor space, or that frictional sparks would be created. At the 95% confidence level, the probability is judged to be very high and a value of 0.9 was assigned. The 5% confidence level was taken to be 0.1; the spread between the low and high confidence levels is very large and reflects the degree of uncertainty associated with this parameter for the most severe seismic event.

The best-estimate value for the 1,000-year seismic event was taken to be an order of magnitude lower than the corresponding value for the 10,000-year event (0.05). This value is in line with that expected from the mechanisms described in Section 4.2. It is also roughly equal to the best-estimate value for a large GRE. The 95% confidence level was taken to be a factor of 5 higher (0.25); this probability is sufficiently large to encompass the upper end of the range expected based on the mechanisms described in Section 4.2. The 5% confidence level value was taken to 0.01 since this is judged to be the lowest reasonable value for a moderate energy seismic event.

The probability distribution values for a seismic event with a 100 year return period are more difficult to set. It is judged that this seismic event would not result in a damage level sufficient for the first two mechanisms outlined in Section 4.2 to be active. It is judged reasonable to assume that the ignition probabilities for this case should be an order of magnitude or more below those

for the 1,000-year event and should be roughly comparable to those for a medium BD GRE. Accordingly, the 5%, 50%, and 95% confidence level values were taken to be 1E-4, 1E-3, and 1E-2, respectively.

These values are summarized in Table 3.

4.4 REFERENCES

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Table 3. Probability of Seismic-Induced Ignition Source.

CDF (%)	Ignition Source Probability for Given Return Period		
	100 year	1,000 year	10,000 year
5	1×10^{-4}	0.01	0.10
50	4×10^{-3}	0.05	0.50
95	1×10^{-2}	0.25	0.90

5.0 TOTAL RESPIRABLE MASS

5.1 INTRODUCTION

This parameter is the total mass of respirable waste material (a) suspended in the tank headspace by a combustion event that does not cause structural failure of a DST, or (b) released from a DST by combustion event that causes structural failure of a DST. Respirable material is defined as material with an aerodynamic diameter of 10 microns or less. Material released from a HEPA filter is explicitly addressed by the analysis framework and is not included here.

The amount of material aerosolized is dependent upon the energy released, which is characterized by the resulting tank pressure. The specific tank pressure conditioning factors employed with this parameter are:

- Headspace burn of insufficient pressure to fail HEPA ($P < 1$ psi)
- Headspace burn which fails HEPA but is less than 20 psi ($1 < P < 20$ psi)
- Headspace burn which does not fail DST dome but is greater than 20 psi ($20 < P < 47$ psi)
- Headspace deflagration which fails DST dome ($P > 47$ psi)
- Headspace detonation which fails DST dome ($P > 47$ psi)

For combustion events which do not cause structural failure of the DST dome (conditioning parameters 1 through 3), the desired quantity is the respirable mass which may remain suspended for a period of time comparable to or longer than that required to depressurize the tank. It is not the respirable mass released from the tank; the mass released is based on the mass suspended, the gas volume which must be vented to depressurize the tank, and the tank by-pass fraction. For combustion events which cause structural failure of the DST dome (conditioning parameters 4 and 5), the desired quantity is the respirable mass which is released from the tank; any significant filtering effects should be accounted for directly (i.e., no tank by-pass fraction will be applied by the analysis framework).

As noted above, this parameter is intended to represent only the amount of respirable mass suspended within or released from the tank (aerodynamic diameter of 10 microns or less). The next report section (Section 6) addresses the amount of transportable mass suspended or released. Transportable is defined for the purposes of this evaluation as that material capable of remaining suspended long enough to be carried by atmospheric weather to expose an on-site individual 100 meters from the point of release. However, since the basic source term generation mechanisms are the same, the discussion given here will be applicable to the next section as well.

It should be recognized that, for most of the source term mechanisms, the actual source term is strongly dependent upon the specific tank configuration and explosion scenario of interest (liquid level, vapor space volume, ignition location, riser and/or tank breach configuration, etc.). As such, it was judged that the presentation and development of detailed analytical expressions for the individual source term generation mechanisms was not warranted since the results obtained by such an approach are dependent upon the specific assumed input parameters. Instead, a range of potential source term values was developed for each mechanism based primarily upon existing work and the parameter confidence levels were utilized to reflect the associated uncertainty. The general approach utilized with this parameter was therefore to: 1) develop source term ranges for each generation mechanism, 2) identify the active and dominant mechanisms for each conditioning

factor case, and 3) construct the corresponding distribution based on the source term range and associated uncertainty for the dominant mechanism(s).

5.2 BACKGROUND

This first portion of this section discusses the available particle size distribution data. Some of this data is indirectly relevant to the quantification of the respirable mass created by an explosion. Next, a discussion is provided on the potential for filtration in cases which cause structural failure of the DST dome (conditioning parameters 4 and 5). The remainder of the section discusses the individual source term generation mechanisms. The mechanisms considered are: (1) loss of material suspended in the tank vapor space prior to the deflagration (pre-existing aerosol), (2) entrainment of liquid or solids from the waste surface, (3) combustion of solids, (4) boiling of liquid (radiative flashing), (5) impact of tank structural elements on the waste surface, and (6) detonative aerosolization.

5.2.1 Respirable Fraction

Gelbard and Brockmann (1998) provide data on the particle size distribution for waste taken from SY-101 in terms of the percent of mass with diameters less than 10 microns (i.e., respirable). This is assumed to be sufficiently representative of other DSTs so as to be typical. Data are provided for a range of heights in the waste, from near the bottom of the tank up towards the liquid surface. All but the lowest position given respirable fractions greater than 70% with several near 100%. It was noted during the presentation that the measurement technique employed to generate these data has a lower detection limit near 1 micron and an upper detection limit of a few hundred microns. Furthermore, it was suggested that this technique would only pick up amorphous oxides and would not detect larger salt crystals. However, it is expected that the most of the radionuclides of interest with respect to radiological inhalation and ingestion hazards (i.e., the actinides) would be present as oxides or hydroxides. The salt compounds would not be expected to represent a significant portion of the radiological inhalation/ingestion risk (this would not necessarily be the case for exposure risks). Hence, the data presented by Gelbard and Brockmann (1998) has some direct relevance with respect to the particle size distribution prior to the explosion. It is recognized that 1) particle agglomeration within the waste, and 2) the stress applied to the waste as a result of the explosion will both impact the actual source term particle size distribution. These particle size distribution data were not used directly, but they do suggest that the respirable fraction of the source mass could be significant.

5.2.2 Filtration

As noted in Section 5.1, for combustion events which cause structural failure of the DST dome (conditioning parameters 4 and 5), any significant filtering effects should be accounted for directly since the analysis framework does not apply a tank by-pass fraction. The presentation by Gelbard

and Brockmann (1998) provided an extended discussion of possible filtering effects including filtering through the tank overburden (for releases through dome cracks) and filtering due to material falling back into the tank through the dome failure location. However, venting prior to dome failure will occur primarily through the risers since these will represent the path of least hydraulic resistance. Similarly, based on the expected tank failure mechanism (see Section 5.2.8), very little of the waste tank vapor space would be swept by material falling back through a dome failure location. Hence, neither of these effects are judged to have significant filtration potential. No credit was explicitly taken for either effect.

5.2.3 Pre-Existing Aerosol

The data given in the presentation by Gelbard and Brockmann (1997) provides vapor space respirable aerosol loadings of 1 mg/m^3 with liquid agitation, $1 \text{ } \mu\text{g/m}^3$ to 1 mg/m^3 during a waste transfer, and 10 ng/m^3 to $100 \text{ } \mu\text{g/m}^3$ for stagnant waste. For a 500 kgal tank vapor space volume (e.g., half the volume of a million gallon tank), this would correspond to respirable masses of 2E-3 kg with liquid agitation, 2E-6 to 2E-3 kg during a waste transfer, and 2E-8 to 2E-4 kg for stagnant waste.

A safety assessment performed for Hanford (LANL 1996) reports pre-existing respirable aerosol masses of 0.35 kg for rotary core drilling to 0.64 kg for a large GRE representative of SY-101 (prior to mixer pump installation). A recent Hanford waste tank safety evaluation also reports a tank vapor space respirable aerosol mass of 0.35 kg due to pre-existing aerosol following a GRE (Van Vleet 1996). These masses are much larger than those given above, as would be expected given the desire to provide bounding results in a safety assessment. Furthermore, safety assessments tend to assign very high values to this type of mechanism since it generally will not dominate the results. Hence, the safety assessment values given above can be viewed as the extreme high end of a distribution for severe waste disturbances.

5.2.4 Entrainment

For the entrainment of solids, the evaluations performed to date examined potential for entrainment due to the high gas velocities associated with the motion of the flame front across the surface. The model employed assumes that the entrained mass is proportional to the gas velocity squared, and that the velocity threshold required to initiate entrainment is 0.24 m/s (LANL 1992), which is consistent with the information compiled by Mishima and Pinkston (1994). An entrained mass of 5.45 kg is cited for a flame front velocity of 45 m/s with a respirable fraction of 0.52 (LANL 1996). Lower entrained masses would be calculated for reduced flame front speeds.

For the entrainment of liquids, the evaluations performed to date examined potential for entrainment due to the high gas velocities associated with the motion of the gas across the surface during blowdown. The model employed assumes that the entrained mass is proportional to the gas velocity, and that, for water and air, the velocity threshold required to initiate entrainment is

approximately 15 m/s (Paddleford and Thomas 1995). For a waste tank with a flat roof top (representative of Savannah River Site waste tanks, Hanford tanks have domed roofs), blowdown from 25 psia with a 3' freeboard and a 3' diameter vent was reported to yield an entrained mass of 350 kg (Paddleford and Thomas 1995). Past analyses have assumed that all entrained material is respirable, although this is conservative and a respirable fraction in the range of 0.5 represents a more realistic estimate. The maximum freeboard (minimum vapor space height) for entrainment is approximately 5 times the vent radius in the pressure range of primary interest (Paddleford and Thomas 1995).

5.2.5 Solids Combustion

Combustion of solids on the waste surface or tank walls can occur if the solid contains organic material and oxidant (e.g., sodium nitrate/nitrite). Initial heating of the solid to the required ignition temperature could occur due to radiative energy deposition from the product gas region. However, if the solid combustion does not release sufficient energy to raise the temperature of the adjoining solid region to the combustion temperature, then combustion will not be self-sustaining and the solid will "char" rather than burn. Ignition of solids as a result of a deflagration was evaluated for the waste tank employed in the In-Tank Precipitation process at the Savannah River Site by Thomas (1993a) and for one of the Hanford waste tanks by LANL (1992). In both cases, it was concluded that the solid would not support sustained combustion. Thomas (1993a) reports a combustion depth of 0.4 mm, corresponding to equivalent respirable waste mass of approximately 4 kg from a 10 cm band of solids at the liquid interface (Thomas 1993b). LANL (1992) reports a combustion depth of about 1 mm, corresponding to a 311 kg respirable mass released from the surface of waste. These respirable masses are approximately equal (within 20%) when expressed on a per unit surface area basis. This source term would only be significant for energetic explosions, as weak mixtures or those occupying only a portion of the volume of the vapor space would not yield sufficient radiative energy deposition to significantly impact solid deposits.

5.2.6 Radiative Flashing

Radiative flashing refers to the boiling of liquid off the surface due to radiative energy deposition from the product gas region. This source term would only be significant for energetic explosions, as weak mixtures or those occupying only a portion of the volume of the vapor space would not yield sufficient radiative energy deposition to lead to boiling (although this has often been ignored in bounding evaluations for the sake of simplicity). For a stoichiometric mixture with a very large vapor space (~1.4 million gallon), Thomas (1993b) reports an aerosol mass of 400 kg due to this mechanism with a respirable fraction of 0.1.

5.2.7 Surface Spalling

The spalling and subsequent entrainment of solid deposits on tank interior surfaces is not expected to make a significant contribution from the source term. As a rough bounding estimate, it was assumed that the tank liner undergoes significant deformation around the entire tank over a 10' wide band such that all surface deposits in this area were spalled off. Assuming a surface deposit $\frac{1}{2}$ mm deep and a density of 1 g/cm^3 , this would represent a total source mass of approximately 100 kg. Such spalling would not be expected to be effective at creating respirable material. Taking a respirable fraction of 10% would yield a respirable source term of 10 kg. This is judged to represent a very conservative estimate near the upper-bound for this mechanism.

5.2.8 Structural Element Impact

A safety assessment performed by LANL (1996) evaluated the potential source term resulting from dome collapse on either salt cake or liquid using a variety of approaches. Estimates were developed for collapse onto salt cake based on maximum aerosol density loading [1 kg/m^3 aerosol density with an respirable fraction of 0.07 ($\sim 130 \text{ kg}$ for 500 kgal vapor space volume)] and brittle fracture due to impact (96 kg respirable aerosol mass for nearly complete coherent collapse); both estimates yield comparable respirable aerosol masses. An equivalent spill approach with coherent collapse was employed to estimate the source for dome collapse onto a liquid surface ($\sim 130 \text{ kg}$ aerosol mass with an RF of 0.8) for collapse onto liquid; for an incoherent collapse, the calculated source term was reduced to 47 kg. The approaches utilized in the LANL safety assessment were intended to be conservative so as to provide bounding results. It should be noted that although these estimates were developed using very different approaches, they all give bounding estimates in the 50 to 100 kg range. It is judged that a best-estimate value would be roughly an order of magnitude lower.

Based on the presentation of tank failure modes (Julyk 1998), a "can opener" type failure restricted to the central region of the dome would be anticipated, any gross failure of the dome would be very unlikely. Essentially the same conclusion was reached by a group of structural experts which evaluated tank failure due to a vapor phase explosion (Han 1996). Given this failure mode, only a limited amount of structural material would be expected to fall back into the tank and impact the waste surface. As noted above, source term estimates for this mode provided in safety analyses are on the order of a hundred kilograms. Best-estimate and upper-bound values of a few kilograms and a few 10's of kilograms are judged to be applicable given the limited nature of the failure and conservative nature of the safety analysis estimates.

5.2.9 Detonative Aerosolization

Detonative aerosolization refers to the direct generation of aerosol as a result of a detonation. The model recommended by Mishima and Pinkston (1994) is based on tests with solid explosives detonated within or adjacent to the material to be aerosolized. The model can be approximated

by setting the respirable aerosol mass generated equal to the TNT equivalent mass. Hence, for a 500 kgal vapor space with a stoichiometric hydrogen-air mixture, the respirable aerosol mass calculated in this fashion would be 1200 kg. This model is judged to be extremely conservative with respect to both the total source term mass and respirable fraction, and a best-estimate respirable source term value would be approximately an order of magnitude lower (~ 120 kg for case described above). However, on a best-estimate basis, the mixture will not be a stoichiometric hydrogen-air and hence the expected source term would be reduced; as a rough estimate for mixtures capable of detonating and yielding pressures above 47 psi, the average energy release was assumed to be 2/3's that for a stoichiometric mixture. In addition, it is expected that a detonation would actually involve only a portion of the tank vapor space; as a rough estimate it was assumed that only half the vapor space participated in the detonation. Making these adjustments gives a best-estimate respirable aerosol mass of approximately 40 kg.

5.3 PARAMETER DISTRIBUTIONS

The parameter distributions developed below for each of the conditioning cases are summarized in Table 4 (given at end of section).

5.3.1 Headspace Burn of Insufficient Pressure to Fail HEPA ($P < 1$ psi)

A deflagration yielding a pressure less than 1 psig would correspond to a very weak mixture occupying only a small portion of the tank. It is virtually impossible that any source term generation mechanism would be active, so that the resulting source term would be due almost exclusively to that present in the tank vapor space prior to the event. The corresponding source terms were discussed in Section 5.2.3.

For the best-estimate value, it is expected that the flammable gas release occurred due to a minor waste disturbance or small BD GRE. The best-estimate value was therefore taken to be 0.1 grams, which is in the range expected for waste transfers. The 5% confidence level was taken to be on the upper end of the range of stagnant waste values ($1E-4$ grams); no lower confidence level value was assigned since this source term is extremely small. The source term for agitated waste (2 grams) was adopted at the 95% confidence level. The 99% confidence level value was taken to be 10 grams to reflect the potential for a much higher level of agitation than reflected at the 95th percentile.

5.3.2 Headspace Burn Which Fails HEPA But is Less Than 20 psi ($1 < P < 20$ psi)

A deflagration in this pressure range potentially has the capacity to activate other source term generation mechanisms (i.e., in addition to that present in the tank vapor space prior to the event). Hence, the potential source terms resulting from entrainment, solids combustion, radiative flashing

and surface deposit release must be considered. However, these mechanisms would not be expected to make significant contributions at the lower end of this range.

Assuming a hydrogen concentration on the order of 10%, a 10 psig pressure corresponds to a vapor cloud occupying approximately 40% of the tank vapor space. The burning velocity at this concentration would be on the order of 50 cm/s (laminar burning velocity near 10 to 20 cm/s) and flame speeds in the range of a few m/s would be expected. The potential for entrainment due to passage of the flame front depends on the location of the flammable gas volume; some entrainment could occur if the volume were in contact with the waste surface. Based on the safety analysis type source term estimates of a few kilograms, would expect a value on the order of a few grams with the high end approaching 100 grams.

The potential for entrainment during vessel blowdown is difficult to predict since it is a function of the specific riser configuration and vapor space volume. However, it is possible that this mechanism could make a significant contribution at the upper end of the pressure range. Based on the safety analysis type source term estimates of a few hundred kilograms, would expect a value on the order of a 10 grams with the high end approaching 1 kilogram.

It is not expected that radiative flashing, solids combustion, or surface deposits would make significant contributions for this case. Based on these considerations, the best-estimate value was taken to be 10 grams (representative of relatively weak entrainment). At the high end of the range (99th percentile), a source term of 1 kg was assigned based on the high end of the potential entrainment range; the 95% confidence level value was taken to be an order of magnitude lower. The lower end of the distribution was set based on the source terms corresponding to the vapor space inventory prior to the event.

5.3.3 Headspace Burn Which Does Not Fail DST Dome But Is Greater Than 20 psi ($20 < P < 47$ psi)

The same entrainment mechanisms discussed above would be active for this case, but the energy released and flame front velocity would be higher. The solids entrainment mass increases as the square or cube of the gas velocity so that doubling the flame front velocity would increase the corresponding entrainment rate by a factor of 4 to 8. The expected source term would therefore be on the order of a tens of grams with the high end approaching several kilograms. Entrainment during blowdown would be more likely than in the prior case due to the increased pressure. The expected source term for this mechanism for this case would be on the order of a kilogram with the far end of the distribution approaching 10 kilograms.

Boiling due to radiative heat deposition could make a significant contribution, particularly at the upper end of the pressure range, with the corresponding source terms ranging from below 1 kilogram up to 10 kg at the high end of the distribution. Solids combustion would also have the potential to contribute up to a few kg for this case. While extensive deformation would not be expected, a minor contribution from spalling waste from interior tank surfaces. The contribution

from material suspended in the tank vapor space prior to the deflagration would be negligible in comparison to the values associated with the other mechanisms.

The best-estimate source term value for this case was taken to be 2 kilograms (best-estimate values of approximately 1 kg for several different independent mechanisms). The upper end of the distribution (99th percentile) was taken to be 20 kg, which represents the combined effects for several mechanisms at the high end of their distributions. The 95th percentile value was taken to be half this (10 kg). Most of the mechanisms examined would be expected to generate some source term for this case so that source terms much less than 1 kg would be very surprising. Accordingly, the 5 and 1% confidence level values were taken to be 0.5 and 0.01 kg, respectively.

5.3.4 Headspace Deflagration Which Fails DST Dome ($P > 47$ psi)

It is anticipated that source term generation via structural element impact would be the dominate source term generation mechanism for this case. The other mechanisms would, of course, still be active and potentially entrainment during blowdown through the failure location could be represent a large fraction of the total source term.

The best-estimate source term value for this case was taken to be 10 kg, which represents a reasonable estimate for structural element impact with an allowance for contributions from the other modes. The upper end of the distribution (99th percentile) was taken to be 100 kg, which represents the combined effects for several mechanisms at the high end of their distributions. However, source term values approaching this value are judged to be very unlikely and the 95th percentile value was only taken to be double the best-estimate (20 kg). Source terms on the order of a few kilograms are judged to be near the absolute minimum possible for a deflagration capable of failing the tank; the 5 and 1% confidence level values were therefore taken to be 2 and 1 kg, respectively.

5.3.5 Headspace Detonation Which Fails DST Dome ($P > 47$ psi)

Essentially all of the major source term generation mechanisms discussed above would be active and would generate roughly the same type of source term masses for this case. The structural impact source term is more uncertain for this case because the tank failure mechanism may not be the same with a detonation. The major difference between the two cases is the potential for direct shock wave aerosolization with a detonation.

Based on the discussion given in Section 5.2.9, the best-estimate contribution from the detonation was taken to be 40 kg, which gives a total best-estimate value of 50 kg. The upper-bound (99th percentile) detonation contribution was taken to be 300 kg (total of 400 kg); this is still a factor of 4 less than the safety analysis type value noted in Section 5.2.9, which reflects the judgement that such values have a very high degree of conservatism. The 95th percentile value was taken to be double the best-estimate, which is the same ratio as applied for the deflagration

case. The 5th percentile value for the detonation case was set equal to the 50th percentile value for the deflagration case, and the lower-bound value was taken to be half this. Note that the detonation source terms assigned above are 4 to 5 times those for the deflagration case.

The upper-bound value for this case is very large, nearly one-half of a metric ton (400 kg). While this value may appear unreasonably large and overly conservative, it should be noted that this corresponds to the complete aerosolization of a 0.8 mm deep layer across the waste surface.

5.4 REFERENCES

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Thomas, J.K. (1993a) Potential for a Solids Fire During an ITP Waste Tank Deflagration and the Impact on Gas Pressure, WSRC-RP-93-997, Savannah River Site, Aiken, SC, 7/93.

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Table 4. Respirable Source Term.

CDF (%)	Respirable Source Term Mass (kg)				
	Burn With P < 1 psi	Burn With 1 < P < 20 psi	Burn With 20 < P < 47 psi	Deflagration w/ P > 47 psi	Detonation w/ P > 47 psi
1	n/a	1×10^{-7}	0.01	1	5
5	1×10^{-7}	2×10^{-3}	0.5	2	10
50	1×10^{-4}	0.01	2	10	50
95	2×10^{-3}	0.1	10	20	100
99	1×10^{-2}	1.0	20	100	400

6.0 TOTAL TRANSPORTABLE MASS

6.1 INTRODUCTION

This parameter is the total mass of transportable waste material (a) suspended in the tank headspace by a combustion event that does not cause structural failure of a DST, or (b) released from a DST by combustion event that causes structural failure of a DST. Transportable is defined for the purposes of this evaluation as that material capable of remaining suspended long enough to be carried by atmospheric weather to expose an on-site individual 100 meters from the point of release. Material released from a HEPA filter is explicitly addressed by the analysis framework and is not included here.

As discussed in Section 5.0, the same mechanisms which generate the respirable source term will generate the transportable source term. The only difference is that the transportable source term includes larger particles (respirable particles were taken to be those with aerodynamic diameters of 10 microns or less).

It should be noted that in the several week period between the last panel meeting and the elicitation, most of the time devoted to this project was focused on the parameters discussed in Sections 2 through 5. Comparatively little effort was devoted to this parameter since it will not

drive the most relevant risk metrics provided by the analysis framework. Similarly, the presentations to the panel and the panel discussions devoted little attention to this parameter. A definitive definition of "transportable" in terms of particle size distributions was not developed. Hence, most of the parameter distribution values provided in this section are based on a combination of the respirable source term distribution (Section 5) along with a judgement as to the capacity of the relevant mechanisms to generate larger transportable particles.

6.2 PARAMETER DISTRIBUTIONS

The parameter distributions developed below for each of the conditioning cases are summarized in Table 5 (given at end of section).

6.2.1 Headspace Burn of Insufficient Pressure To Fail HEPA ($P < 1$ psi)

As discussed in Section 5.3.1, the source term for this case would be due almost exclusively to that present in the tank vapor space prior to the event. Since larger particles created by waste transfers or agitation would tend to settle out fairly rapidly, it is anticipated that most of the source term available for release would be respirable. Severe disturbance immediately prior to the combustion event is not anticipated due to the very low pressure associated with this case. Hence, most of the transportable source term would actually be in the respirable range. The 5th and 50th percentile values were therefore taken to be the same as for the corresponding respirable cases. The 95th and 99th percentile values were increased by an order of magnitude relative to the corresponding respirable cases to reflect the potential for some larger particles being suspended in the vapor space immediately before the combustion event.

6.2.2 Headspace Burn Which Fails HEPA But Is Less Than 20 psi ($1 < P < 20$ psi)

The lower end of the distribution was set based on the source terms corresponding to the vapor space inventory prior to the event, which is the same approach utilized to define the respirable source term for these percentiles. Some contribution from entrainment would be expected for this case, as discussed in Section 5.3.2. In this case, it is therefore expected that a significant portion of the source term could be above the respirable range size. The ratio of the transportable to respirable source was taken to be 5 (i.e., transportable source term order of magnitude greater than respirable source term) for the 50% confidence levels for this case. The higher confidence limit values for the respirable source term correspond partially to more efficient aerosolization so that these were only scaled up by a factor of 2.

6.2.3 Headspace Burn Which Does Not fail DST Dome But Is Greater Than 20 psi ($20 < P < 47$ psi)

Contributions from entrainment, solids combustion, radiative flashing and surface deposit release would be expected for this case, as discussed in Section 5.3.3. As with the preceding section, a significant portion of the source term could be above the respirable range size. It is expected that a higher fraction of the source term could be above the respirable range since the combustion event is much more energetic. The ratio of the transportable to respirable source was taken to be 10 (i.e., transportable source term order of magnitude greater than respirable source term) for the 1, 5 and 50% confidence levels for this case. The higher confidence limit values for the respirable source term were only scaled up by a factor of 5.

6.2.4 Headspace Deflagration Which Fails DST Dome ($P > 47$ psi)

Essentially the same type of scaling relative to the respirable source term employed for the case above was used here. However, the high end of the respirable source was dominated by structural element impact. Such an impact would occur near the end of the event with little driving force to move heavier particles out of the tank vapor space. Accordingly, the respirable source term was only increased by a factor of 2 for the 99th percentile value.

6.2.5 Headspace Detonation Which Fails DST Dome ($P > 47$ psi)

The respirable source terms were increased by a factor of 5 for all percentile levels for this case. This factor is partially based on judgement, but it is reasonably consistent with the expected distribution for the assumed detonation source term generation mechanism. The nominal detonation source term was taken to be the equivalent of 0.1 grams per gram of TNT equivalent (Section 5.2.9). Based on the data base utilized to form the detonation source term approximation [Mishima and Pinkston (1994), Steindler and Seefeldt (1980)], this would correspond to a median particle diameter of approximately 30 microns [equivalent to a mass ratio of 10 (figs. 1 and 2 in Steindler and Seefeldt)]. If it is assumed that "transportable" particles are defined as those with diameters less than 100 microns, then the transportable to respirable mass ratio for a lognormal particle distribution with geometric standard deviation of 3 and median particle diameter of 30 microns is 5.4 (equal to the scaling factor employed for this case).

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Table 5. Transportable Source Term.

CDF (%)	Transportable Source Term Mass (kg)				
	Burn With P < 1 psi	Burn With 1 < P < 20 psi	Burn With 20 < P < 47 psi	Deflagration w/ P > 47 psi	Detonation w/ P > 47 psi
1	n/a	1×10^{-7}	0.1	10	25
5	1×10^{-7}	2×10^{-2}	5	20	50
50	1×10^{-4}	0.05	20	50	250
95	2×10^{-2}	0.2	50	100	500
99	1×10^{-1}	2.0	100	200	2000

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**APPENDIX B.14
RATIONALE REPORTS**

M. Yost

May 1998

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**1.0 PARAMETER 1. FREQUENCY OF SPONTANEOUS GAS RELEASES
IN DOUBLE SHELL TANKS (DSTs) THAT HAVE A THICK LAYER OF
LIQUID (> 1 M) BUT DO NOT PASS ANY TEST INDICATING THE
POTENTIAL EXISTS FOR BUOYANT DISPLACEMENT-TYPE
GAS RELEASE EVENTS (GRES)**

This parameter is the expected number of gas release events per year of three different efficiencies of release (i.e., sizes) for the DST being evaluated. This parameter has the dimensions of "events/year".

Conditioning Factors:

- 1a: Small efficiency release.
- 1b: Medium efficiency release.
- 1c: Large efficiency release.

Since there was essentially no monitoring data to support an assessment of the potential for such a non-BD GRE event, this parameter was difficult to assess. The one possible indication of this type of event is the occurrence of "unexplained" hydrogen releases, as mentioned in the panel discussion and in the presentation by Barton. These have appeared as observations of relatively small hydrogen releases, recorded as peaks in the SHMS monitoring of DST tank common exhaust stacks. These events appear without any specific evidence of buoyant displacement (BD) releases occurring in the (6) DSTs currently monitored directly in the tank and known to have BD behavior or potential. A few examples were discussed during the sessions, such as an event in November 1997 on the AN farm (although it may be related instead to waste transfer operations). This problem is compounded by a paucity of SHMS data from the 22 individual DSTs which don't have a known BD history. There is considerable secondary data from waste-level monitoring in the tanks. This data does not support the notion of significant non-BD releases. For example, an examination of data in WHC-SD-WM-TI-755, which relies on level change data to estimate the dL/dP of all DSTs, indicates that only a few tanks may have enough retained gas to be candidates for a relatively large spontaneous release. Most of these DSTs with large dL/dP are known BD GRE tanks, but a few such as AN107 or possibly AW104 may be of concern.

Given that reliable direct hydrogen monitoring data has been available only about 3 to 4 years (since about 1994-95, see Stewart PNNL SA 29606) it is quite possible that relatively small hydrogen release episodes may have occurred unnoticed in DSTs. However, it appears extremely unlikely that medium or large GRE releases by some other mechanism than BD would have occurred unnoticed, and for that reason I believe that these probabilities are essentially zero. (Parms 1b,c).

To estimate the distribution for the small releases, parameter 1a, I proceeded as follows. I assumed that small release non-BD behavior could be modeled as a Poisson random process to define the number of events occurring in a continuous interval. The process appears to fit the underlying assumptions of such a particular model: (1) that the chance of more than 1 event in a small time interval is negligible; and (2) the chance of an event in a given small interval does not depend on the

prior history.¹ The latter assumption may be questionable for large releases, since depletion of the gas inventory clearly could occur and introduce a refractory period. But for small (or even medium) events, this depletion is not an issue.

The history for 22 DSTs over the recent period of 3 to 4 years of intensive monitoring suggests between 77 to 88 "tank-years" of observation; I choose 80 tank-years as a convenient nominal observation base. During this period one or two credible events have been noted, and assuming an equal number may have gone unnoticed leads to an estimate of about 4 small non-BD events over this observation period. This gives a frequency of 0.05 events per year per tank which take as the parameter for a Poisson process to create the distribution function given below. This was set to the median for the elicited distribution; the 5th and 95th percentiles were taken as the fractiles nearest to those corresponding probability points for the Poisson distribution.

Figure 1. Distribution Estimated for Parameter 1a: Frequency of Small Non-BD Releases.

Table 1. Percentile Points Specified for Parameter 1a.

Events per Year per Tank	Subjective Prob.
0.013	0.05
0.05	0.50
0.10	0.95

References:

1. I. Millar and J. Freund, Probability and Statistics for Engineers, 2nd Ed. p.80
2. WHC-SD-WM-TI-755
3. PNNL SA 29606

**2.0 PARAMETER 3: TOTAL MASS OF TRANSPORTABLE WASTE MATERIAL
(A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES
NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (B) RELEASED FROM
A DST BY A COMBUSTION EVENT THAT CAUSES STRUCTURAL
FAILURE OF A DST.**

To estimate these parameters I elected to develop model calculations based on the correlation presented by F. Gelbard and J. Brockmann in the Feb 11 workshop proceedings. The presentation, slide 6A presents a compendium of connective entrainment data for dry powders in the form of a plot. This plot shows entrainment fluxes verses free stream velocity from a variety of studies. The data most relevant to this analysis is that from Tamanini and Ural, or Singer et al. which pertain to entrainment from air blasts over a range of peak velocities. The particles were assumed to be transportable if less than about 60 μm in aerodynamic diameter. This size will be transported more than 100 meters if suspended in air in light winds at > 10 meters height (based on Hinds, p 407). Three values representative of low medium and high estimates for average entrainment flux were taken from the plots presented: $1 \times 10^{-3} \text{ kg m}^{-2} \text{ s}^{-1}$ (low), $1 \times 10^{-2} \text{ kg m}^{-2} \text{ s}^{-1}$ (medium) and $1.5 \times 10^{-1} \text{ kg m}^{-2} \text{ s}^{-1}$ (high). These values from the plots are for dry powders, and the situation in DSTs at Hanford certainly has liquid surfaces. However, I have elected not to reduced the dry powder values for the following reasons. First, substantial areas of the tank surface (dome walls for example) could be free from the liquid and may be covered with adhered powder that could be dislodged; further, some tanks may have a floating crust that could be relatively dry. Finally, it is conservative to assume a dry surface, since wetting the surface would likely only reduce entrainment.

Next I assumed an average speed for the air velocity due to the combustion. In the case of a low energy deflagration, a reasonable value for the average velocity is probably about 10 m/s (Hinds 1982, p 355) and in more energetic events could be 40 m/s or more. I elected to use three values of 10 m/s, 20 m/s and 30 m/s to represent low, medium and high estimates for the average air velocity.

These velocity values were paired with the appropriate entrainment flux values above from the correlation plots.

Finally, I used a fraction of the tank diameter as a scaling factor to estimate the duration of an entrainment event and the extent of the tank surface area impacted. This calculation proceeded as follows using a representative tank diameter of 75 feet (11.43 meters radius). This diameter was taken from report PNNL 10-773 page 18. I assumed that the burn event affected a circular region between 0.1 and 1.0 of the tank diameter. The duration of an event, was computed as the time for the air traveling at a given velocity (selected from low to high above) to traverse this distance; the surface area affected by the event was taken as the area of a circle with the stated diameter. Using a circular area could understate the affected surface in the dome by a factor of more than 2 (i.e., the upper and lower surface of a cylinder plus the walls). However, considering that at least 1/2 of the surface cross section should be wetted in a typical DST would balance this out. Also, no attempt was made to account for no uniform velocity or variable entrainment over the surface. The values were assumed to represent typical time averages over the brief duration of the event. With the above parameters it was possible to compute estimates for the transportable mass suspended. To evaluate the transportable mass released into the atmosphere in a dome failure, I considered the possible filtering effect of falling tank wall material and the overburden. Gravel and overburden filtration is only credible given that the filtering layer remains intact, which seems inconsistent with conditions surrounding a dome failure and venting. Based on the presentation data of Gelbard, the collection efficiency of large chunks of falling debris (>10 cm diameter) would be negligible; smaller chunks about 1 to 2 cm diameter could have a collection efficiency up to 40% or as low as 10%. These values were used as high and low filtering efficiencies and applied to the case of a deflagration or detonation. For a deflagration I assumed a higher collection efficiency. In the case of a large detonation, I assumed a lower collection efficiency, reasoning that the energy would be sufficient to blow a portion of the overburden clear of the failure zone, so that filtering from falling debris would be reduced.

Table 2 below summarizes the associated conditions for the parameter calculations.

Table 2. Parameter Conditions for Transportable Mass Calculations.

Parameter Number	Velocity	Entrainment value	Diameter fraction	percentile	Calculated mass (kg)
3a	Low	Low	0.1	0.05	0.0009
< 1.0 psi			0.3	0.50	0.025
			0.6	0.95	0.2
3b	Med	Med	0.1	0.05	0.005
< 20 psi			0.4	0.50	0.3
HEPA fails			0.7	0.95	1.6

Table 2. Parameter Conditions for Transportable Mass Calculations.

Parameter Number	Velocity	Entrainment value	Diameter fraction	percentile	Calculated mass (kg)
3c	High	High	0.1	0.05	0.03
>20 psi			0.4	0.50	2.25
dome intact			0.7	0.95	12
3d*	High	High	0.2	0.05	0.17
deflagration			0.6	0.50	4.6
dome fails			1.0	0.95	21
3e**	High	High	0.2	0.05	0.25
detonation			0.6	0.50	6.8
dome fails			1.0	0.95	32

* overburden filter efficiency = 0.4

** overburden filter efficiency = 0.1

References:

WC Hinds, Aerosol Technology, Wiley Interscience, 1982

F. Gelbard and J. Brockmann, "Respirable Material Release", Presentation to flammable gas safety review expert's workshop #2, Feb 11, 1998

3.0 PARAMETER 4. TOTAL MASS OF RESPIRABLE WASTE MATERIAL (A) SUSPENDED IN THE HEADSPACE BY A COMBUSTION EVENT THAT DOES NOT CAUSE STRUCTURAL FAILURE OF A DST, OR (B) RELEASED FROM A DST BY A COMBUSTION EVENT THAT CAUSES STRUCTURAL FAILURE OF A DST

This elicitation parameter was evaluated using the previous methodology applied to parameters 3a-e for the amount of transportable mass. In addition to the parametric assumptions discussed in the previous section, additional values were applied to obtain the respirable fraction of the total mass suspended. The respirable fraction is generally taken as less than about 10 um aerodynamic diameter. In the presentation by Gelbard, analysis of the bulk waste material indicated that an upper limit for the respirable fraction was around 80%. This value was derived from an average over all layers and a more typical value for upper layers was about 70%. I assumed this 70% respirable

fraction was the limiting case for energetic burn releases (those >20 psi), where sufficient energy from the burn could suspend and break up waste material on surfaces. For less energetic releases, < 20 psi events, I assumed a respirable fraction of 20%, which is more typical of industrial dusts (Hinds p 221) and also soil -derived dusts (Army report EL-84-6). These two respirable fraction estimates were applied to the values calculated for parameter 3a-e, depending on the pressure involved in the event. Table 3 summarizes the results of the calculations.

Table 3. Parameter Conditions for Respirable Mass Calculations.

Parameter Number	Velocity	Entrainment value	Resp. fraction	Diameter fraction	percentile	Calculated mass (kg)
4a	Low	Low	0.2	0.1	0.05	0.0002
< 1.0 psi				0.3	0.50	0.005
				0.6	0.95	0.04
4b	Med	Med	0.2	0.1	0.05	0.001
< 20 psi				0.4	0.50	0.06
HEPA fails				0.7	0.95	0.32
4c	High	High	0.7	0.1	0.05	0.02
>20 psi				0.4	0.50	1.6
dome intact				0.7	0.95	8.5
4d*	High	High	0.7	0.2	0.05	0.1
deflagration				0.6	0.50	3.0
dome fails				1.0	0.95	15
4e**	High	High	0.7	0.2	0.05	0.2
detonation				0.6	0.50	5.0
dome fails				1.0	0.95	22

* overburden filter efficiency = 0.4

** overburden filter efficiency = 0.1

References:

WC Hinds, Aerosol Technology, Wiley Interscience, 1982

US Department of Army, "Results of Fort Carson Colorado terrain dust obscuration tests using explosives" Misc. Paper EL-84-6, Corps of Engineers, Sept. 1984

4.0 PARAMETER 5: DURATION OF BD TYPE GRE EVENT (0 TO 95% OF PEAK)

Conditioning Factors:

- 5a: Small efficiency gas releases.
- 5b: Medium efficiency gas releases.
- 5c: Large efficiency gas releases.

SHMS data was provided by Stewart in the form a spreadsheet with duration of release read directly off of data records for tanks AN105, AN104, AN103, AW101, SY103 and SY101. This data was the primary basis for my assessment of this parameter. As secondary data, I looked at data from the presentation by Stewart, modeling the time constant of a release from headspace concentrations. Although this was not directly relevant to our definition of a GRE event duration it provided a qualitative check on the magnitude of the parameters. The data provided in spreadsheet form gives the volume of gas released in various GRE events. The spreadsheet data was for both medium releases and smaller (fraction released < 0.25), as determined by looking up the best estimate retained gas volume in each tank in report PNNL 11536 page 3.10 and using these data to normalize the volume released to obtain the fractional release. Plotting this data for time to peak vs. the fraction of total gas released suggests that at least for medium to small sized releases, there appears to be very little correlation between the duration of the gas release events and the size of the event. The scatterplot below illustrates the lack of correlation between release fraction and the time to peak. The correlation factor is 0.09 which is not statistically significant. Attempts to stratify the data by individual tanks, to stratify by waste properties (crust/no crust), or to transform the data in various ways did not improve the relationship between fraction of release and time to peak. Therefore, there appears to be no meaningful basis for distinguishing between small and medium releases as conditioning factors for the duration of a release. From this I concluded that the estimates for the duration of small efficiency releases should be about the same as for medium efficiency releases, and used the same distribution for both.

Figure 2. Scatterplot of Time to Peak Compared to Release Fraction.

4.1 CASE 5a-b: SMALL AND MEDIUM EFFICIENCY RELEASE, LESS THAN 25% OF TOTAL INVENTORY

Data are available for small and medium efficiency releases, less than 25% of total gas inventory, so reasonably good estimates can be made for a distribution function. I elected to use a simple polynomial curve fit to obtain a smoothed line for the cumulative fraction of the data from Stewart. To obtain estimates for the elicitation, I fit a high order polynomial (degree 6) to draw a smooth curve through the data points and then graphically obtained the 5th, 50th and 95th percentiles from the plot by hand. This polynomial fit is illustrated in Figure 3 below and has an R^2 of about 0.99. A second order polynomial produced almost the same fit results with an R^2 of 0.97, but created the problem of giving unrealistic estimated y values > 1 for some x values in the upper range of the observed data. Table 4 gives the percentile points estimated from the curve.

Figure 3. High Order Smoothing Polynomial Fit to GRE Data for Small and Medium Events.

Table 4. Percentile Points Specified for Parameter 5a,b.

Duration in Minutes	Subjective Prob.
75	0.05
210	0.50
675	0.95

4.2 CASE 5c: LARGE EFFICIENCY RELEASE, GREATER THAN 25% OF TOTAL INVENTORY

Relatively little data is available on large releases, particularly since SY101 has had a mixing pump installed to prevent large releases. However, the time course could be indirectly estimated from information provided, from video observations and from temperature profile monitoring, and this seems to indicate a typical release time on the order of 10 to 20 minutes, rather than 200 minutes as in the previous case (5 a-b). Therefore I scaled the data for small-medium releases by a factor of 10 to adjust the median for the distribution to correspond to approximately 22 minutes; in doing this I've also assumed the relative variability will be roughly the same for large releases as in the small-medium data. The data for SY-103 in PNNL11296 p 4.17 suggests that some large releases may occur over a period approaching 3 hours. To include such possibility in the data I included some extreme data points at the upper percentile tails to extend the maximum up to 160 minutes. Finally, I fitted an exponential curve to the scaled fractional release data over the range of interest to obtain a smooth curve for estimating the fractiles. This curve is the dark line illustrated in Figure 4 below. From the smooth line plot I then estimated the fractiles by hand, these values are shown in Table 5.

Figure 4. Smoothing Polynomial Fit to Scaled GRE Data to Represent Large Releases Events.

Table 5. Percentile Points Specified for Parameter 5c.

Duration in Minutes	Subjective Prob.
3	0.05
24	0.50
120	0.95

5.0 PARAMETER 6 a-i PROBABILITY OF A SEISMIC-INDUCED GRE IN A DST WITH A THICK LIQUID LAYER

Naturally, for this parameter there is no actual data from an earthquake induced GRE upon which to extrapolate or base distributions. Some engineering reports are available that have analyzed potential earthquake impacts; principally PNNL 11391 (Stewart, Dec. 1996) and PNNL 11668 (Reid, Sept. 1997) which give results for single shell tanks and double shell tanks. The latter report only has information that deals with a 1000 year design basis event. These reports were the primary basis for the elicited distributions provided.

Two considerations made this parameter somewhat complex to assess. One factor was that the engineering reports only covered a 100 or 1000 year design basis earthquakes (see WHC report SD GN DA 30018 for definitions). We were asked to respond for a 10,000 year event which presumably would be more severe than any evaluated. I assumed this could be approached by scaling up the values from a 1000 year event. The second consideration involved the conditional definition for the size of GREs; since the events were mutually exclusive the small and medium sized releases were inherently conditional on a larger sized release not occurring. I interpreted this conditioning as illustrated in the following diagram.

The probability values I assigned for medium and small sized release events were based on the assumption that a larger event could have occurred but did not, because of this conditioning. In my estimation a large or medium sized release event seemed highly likely in many cases. So, if a larger release does not occur, this implies that the waste is not very responsive in terms of an earthquake induced GRE and so a smaller sized release is then less likely. Therefore in all cases I started by evaluating the subjective probability of a large release occurring given an earthquake event of the stated size, and then scaled back from there to estimate medium and small releases.

I started by evaluating the cases related to a 1000 year earthquake event. This situation has the most engineering evaluation data available from the above reports. The PNNL 11668 report indicates that the presence of a thick liquid layer acts as a harmonic oscillator that significantly enhances the mobilization and motion of waste in the tank. This report indicates that between 37 to 98 percent of the waste would be mobilized and capable of releasing a large fraction (i.e., >25%) of the retained gas in the waste. (This fraction varies somewhat depending on the criteria used to evaluate waste mobilization and on liquid layer thickness.) The average fraction of the waste mobilized for the cases with a liquid layer greater than 1 meter is about 0.7, which I used as the median value for the probability distribution in case 61c. Since the analysis indicated that there is a strong chance that virtually all the waste could be mobilized, I assigned the upper 95% tail would have 5% or less of the remaining release probability. For the lower 5% tail, I assumed that some small fraction of cases could fall below the lowest fraction reported and set this at 30%. These values appear in Table 7 under item 61-f, large release efficiency event. The estimates for a medium efficiency release assume that the median and 5th percentile probability was reduced by about 20% compared to that for a large release. I left the upper 95 percentile unchanged from the large release because I felt the chance of a significant release remains high even if a large release did not occur, so that in the tail the two distributions converge. The corresponding values appear in item 61-e of Table 7. The estimates for a small release were further reduced from those for a medium release by about 20% at the median value. The rationale for this probability assignment was that for a small release event to occur the waste must either behave like a homogeneous solid, or have a relatively high shear strength so that only a small fraction is mobilized. For homogeneous waste the smallest fraction mobilized was about 5% which was used as the lowest 5th percentile. The upper 95th tail was set to be similar to the median value for a large release so that the two distributions would overlap at the upper tail. These values appear in item 61-d of the tables below.

The 100 year design basis earthquake was evaluated based on the previous analysis found in report PNNL 11391. This report presents a qualitative result of earthquake impacts based on a spectral energy analysis. This report concludes that a 100 year event in a DST would most likely also release a large fraction (>25%) of the retained gas in a tank. A quote from page 4.47 of PNNL 11391 illustrates this finding: "Thus if the analogy holds, a 100 year earthquake might cause a rapid release of about 50% of the stored gas in a typical DST."

The values selected for the 95th percentile and median of a large release due to a 100 year event were taken from the median and 5th percentile of the 1000 year basis earthquake values. This reduction in the median value by about 60% is reasonably consistent with the expected reduction in the power spectral density of about 66% due to the lower accelerations in a 100 year event. (See appendix A1 in report PNNL 11668). The medium release probability for a 100 year event was scaled from the large release values. A 20% reduction was applied to the median value and the 95th percentile value as described above, and the 5th percentile was unchanged. The small release was assumed to be equally likely compared to the medium release event for this case. These values appear in Table 6, items 61-a, 61-b and 61-c.

The 10,000 year design basis earthquake was evaluated based on the comments found in report PNNL 11668. This report presents a qualitative discussion of the results for a large earthquake. The report concludes that a 10000 year event in a DST would most likely also release a large fraction (>25%) of the retained gas in a tank and could mobilize a greater fraction of the waste. A quote from page 9.2 of PNNL 11668 illustrates this finding: "A 10,000 year (earthquake) would almost certainly result in increased gas release from the homogeneous waste, but how much cannot be estimated. For the other waste configurations with a liquid layer, it is unlikely that a 10,000-year event would increase the gas release much beyond the result for the 1000 year (earthquake) since mobilization is already near 100%."

The values selected for the 95th percentile and median of a large release due to a 10,000 year event were scaled up from the median and 5th percentile of the values for a large release 1000 year basis earthquake. A 20% increase was applied to the median value and the 5th percentile value to account for greater mobilization in a 10,000 year event; the 95th percentile was also increased slightly. The medium release values were taken as the same as the values given for a large release in a 1000 year event. The small release values were taken as the same as for a small release in a 100 year event, since in the absence of a larger GRE response to such a large earthquake event, the waste probably would be fairly poorly mobilized and a small release seems rather unlikely. The assigned values appear in Table 8, items 61-g, 61-h and 61-i.

Table 6. 10^{-2} Earthquake Event - Small, Medium, and Large Release Efficiency.

P of Seismic Event	61a - Small Release	61b - Med. Release	61c - Large Release
0.05	0.02	0.05	0.05
0.50	0.1	0.1	0.3
0.95	0.5	0.5	0.7

61a: Probability of a GRE from a $1E-2$ /year earthquake, small efficiency gas release.

61b: Probability of a GRE from a $1E-2$ /year earthquake, medium efficiency gas release.

61c: Probability of a GRE from a $1E-2$ /year earthquake, large efficiency gas release.

Table 7. 10^{-3} Earthquake Event - Small, Medium, and Large Release Efficiency.

P of Seismic Event	61d - Small Release	61e - Med. Release	61f - Large Release
0.05	0.02	0.1	0.3
0.50	0.3	0.5	0.7
0.95	0.5	0.95	0.95

61d: Probability of a GRE from a $1E-3$ /year earthquake, small efficiency gas release.

61e: Probability of a GRE from a $1E-3$ /year earthquake, medium efficiency gas release.

61f: Probability of a GRE from a $1E-3$ /year earthquake, large efficiency gas release.

Table 8. 10^{-4} Earthquake Event, Probability of Earthquake Induced GRE.

P of Seismic Event	61g - Small Release	61h - Med. Release	61i - Large Release
0.05	0.02	0.3	0.5
0.50	0.10	0.7	0.9
0.95	0.5	0.95	0.98

61g: Probability of a GRE from a $1E-4$ /year earthquake, small efficiency gas release.

61h: Probability of a GRE from a $1E-4$ /year earthquake, medium efficiency gas release.

61-i: Probability of a GRE from a $1E-4$ /year earthquake, large efficiency gas release.

References:

PNNL report 11668: HC Reid and JE Deibler. Seismic event incurred waste response and gas mobilization predictions for typical Hanford waste tank configurations. Sept. 1997

PNNL report 11391: CW Stewart, ME Brewster, PA Gauglitz, LA Mahoney, PA Meyer, KP Recknagle and HC Reid. Gas retention and release behavior in Hanford single shell waste tanks. Dec. 1996

WHC report SD-GN-DA 30018: EO Weiner and AC Rohay. Design basis for earthquake time histories for 1992 SDC-4.1, revision 12. 1992

APPENDIX C
INDIVIDUAL UNCERTAINTY DISTRIBUTIONS, WITH AGGREGATIONS,
FOR EACH PARAMETER

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Figure C-1. Frequency of Spontaneous Non-Buoyant Displacement GREs in DSTs; Small Efficiency Gas Release Events.

Figure C-2. Frequency of Spontaneous Non-Buoyant Displacement GREs in DSTs, Medium Efficiency Gas Release Events.

Figure C-3. Frequency of Spontaneous Non-Buoyant Displacement GREs in DSTs; Large Efficiency Gas Release Events.

Figure C-7. Mass of Transportable Waste Material Suspended in a DST Headspace by a Burn: No HEPA Failure.

Figure C-8. Mass of Transportable Waste Material Suspended in a DST Headspace by a Burn:
HEPA Fails, Peak Pressure < 20 psig, No Dome Failure.

Figure C-9. Mass of Transportable Waste Material Suspended in a DST Headspace by a Burn:
HEPA Fails; Peak Pressure > 20 psig But No Dome Failure.

Figure C-10. Mass of Transportable Waste Released From DST by a Headspace Deflagration That Causes Dome Failure.

Figure C-11. Mass of Transportable Waste Released From a DST by a Headspace Detonation That Causes Dome Failure.

Figure C-12. Mass of Respirable Waste Material Suspended in a DST Headspace by a Headspace Burn: No HEPA Failure.

Figure C-13. Mass of Respirable Waste Material Suspended in a DST Headspace by a Headspace Burn:
HEPA Failure; Peak Pressure <20 psig; No Dome Failure.

Figure C-14. Mass of Respirable Waste Material Suspended in a DST Headspace by a Headspace Burn:
HEPA Failure; Peak Pressure > 20 psig But No Dome Failure.

Figure C-15. Mass of Respirable Waste Released From a DST by a Headspace Deflagration That Causes Dome Failure.

Figure C-16. Mass of Respirable Waste Released From a DST by a Headspace Detonation That Causes Dome Failure.

Figure C-17. Duration of a Small Efficiency Buoyant Displacement-type Gas Release Event.

Figure C-18. Duration of a Medium Efficiency Buoyant Displacement-type Gas Release Event.

Figure C-19. Duration of a Large Efficiency Buoyant Displacement-type Gas Release Event.

Figure C-20. Probability of an Ignition Source in a DST Caused by a 100-Year Return Frequency Earthquake.

Figure C-21. Probability of an Ignition Source in a DST Caused by a 1,000-Year Return Frequency Earthquake.

Figure C-22. Probability of an Ignition Source in a DST Caused by a 10,000-Year Return Frequency Earthquake.

Figure C-23. Probability of a 100-Year Earthquake-Induced Small Efficiency Gas Release Event in a DST.

Figure C-24. Probability of a 100-Year Earthquake-Induced Medium Efficiency Gas Release Event in a DST.

Figure C-26. Probability of a 1,000-Year Earthquake-Induced Small Efficiency Gas Release Event in a DST.

Figure C-27. Probability of a 1,000-Year Earthquake-Induced Medium Efficiency Gas Release Event in a DST.

Figure C-28. Probability of a 1,000-Year Earthquake-Induced Large Efficiency Gas Release Event in a DST.

Figure C-29. Probability of a 10,000-Year Earthquake-Induced Small Efficiency Gas Release Event in a DST.

Figure C-30. Probability of a 10,000-Year Earthquake-Induced Medium Efficiency Gas Release Event in a DST.

Figure C-31. Probability of a 10,000-Year Earthquake-Induced Large Efficiency Gas Release Event in a DST.

Figure C-32. Probability of a 100-Year Earthquake-Induced Small Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-33. Probability of a 100-Year Earthquake-Induced Medium Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-34. Probability of a 100-Year Earthquake-Induced Large Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-35. Probability of a 100-Year Earthquake-Induced Small Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-36. Probability of a 100-Year Earthquake-Induced Medium Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-37. Probability of a 100-Year Earthquake-Induced Large Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-38. Probability of a 100-Year Earthquake-Induced Small Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure 39. Probability of a 100-Year Earthquake-Induced Medium Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-40. Probability of a 100-Year Earthquake-Induced Large Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-41. Probability of a 100-Year Earthquake-Induced Small Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-42. Probability of a 100-Year Earthquake-Induced Medium Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-43. Probability of a 100-Year Earthquake-Induced Large Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-44. Probability of a 1,000-Year Earthquake-Induced Small Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-45. Probability of a 1,000-Year Earthquake-Induced Medium Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-46. Probability of a 1,000-Year Earthquake-Induced Large Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-47. Probability of a 1,000-Year Earthquake-Induced Small Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-48. Probability of a 1,000-Year Earthquake-Induced Medium Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-49. Probability of a 1,000-Year Earthquake-Induced Large Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-50. Probability of a 1,000-Year Earthquake-Induced Small Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-51. Probability of a 1,000-Year Earthquake-Induced Medium Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-52. Probability of a 1,000-Year Earthquake-Induced Large Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-53. Probability of a 1,000-Year Earthquake-Induced Small Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-54. Probability of a 1,000-Year Earthquake-Induced Medium Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-55. Probability of a 1,000-Year Earthquake-Induced Large Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-56. Probability of a 10,000-Year Earthquake-Induced Small Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-57. Probability of a 10,000-Year Earthquake-Induced Medium Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-58. Probability of a 10,000-Year Earthquake-Induced Large Efficiency GRE in an Unpumped Facility Group 2 SST.

Figure C-59. Probability of a 10,000-Year Earthquake-Induced Small Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-60. Probability of a 10,000-Year Earthquake-Induced Medium Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-61. Probability of a 10,000-Year Earthquake-Induced Large Efficiency GRE in a Pumped Facility Group 2 SST.

Figure C-62. Probability of a 10,000-Year Earthquake-Induced Small Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-63. Probability of a 10,000-Year Earthquake-Induced Medium Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-64. Probability of a 10,000-Year Earthquake-Induced Large Efficiency GRE in an Unpumped Facility Group 3 SST.

Figure C-65. Probability of a 10,000-Year Earthquake-Induced Small Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-66. Probability of a 10,000-Year Earthquake-Induced Medium Efficiency GRE in a Pumped Facility Group 3 SST.

Figure C-67. Probability of a 10,000-Year Earthquake-Induced Large Efficiency GRE in a Pumped Facility Group 3 SST.

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APPENDIX D
EXPERT PANEL WORKSHOP AGENDAS

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Agenda

Gas Release Event Safety Analysis

STAGE II EXPERTS' PANEL ELICITATION WORKSHOP #1 January 19 - 23, 1998

DoubleTree Hotel Richland • Hanford House
802 George Washington Way
Richland Washington

**Agenda reflects Workshop # 1 as it actually occurred*

Monday, January 19 - Moderator: Chris Olson / SNL
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2.1.0	8:00	Welcome - Craig Groendyke / DOE/RL, Tom Geer / DESH
2.1.1	8:15	"Introduction - Expert Panel Workshop #1 Double Shell Tanks"
- Chris Olson / SNL
2.1.2	8:45	"RL Tier 2 Review Comment Resolution and
Data Correlation Results" - Blaine Barton / LMHC
2.1.3	9:00	"Overview of Results for SSTs" - Scott Slezak / SNL
	9:30	BREAK
2.1.4	9:45	<i>Resolve!</i> (the Analysis Tool) Demonstration- Steve Humphreys / SNL
<i>VERSION 1.4 FOR SSTs</i>
2.1.5	10:30	"Status of DST Waste" - Kent Hodgson / LMHC
<i>GENERAL REVIEW AND HISTORY OF DST WASTE TYPES;
CURRENT TANK CONDITIONS AND OPERATIONS;
COMPARISON OF DSTs AND SSTs;
HARDWARE DIFFERENCES BETWEEN DSTs AND SSTs</i>

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-
- 2.1.6 11:15 **"Future DST Operations" - Kent Hodgson / LMHC**
*DISCUSSION OF POTENTIAL CONFIGURATIONS, ADDITIONS AND/OR
OPERATIONS IN FUTURE WASTE TRANSFERRED FROM SSTs OR
PRETREATED FOR VITRIFICATION PLANTS; REVIEW OF PRECLUDED
OPERATIONS AND WASTE MIXING*
- 12:00 **WORKING LUNCH**
- 2.1.7 1:00 **"Future DST Operations" - Kent Hodgson / LMHC**
*DISCUSSION OF POTENTIAL CONFIGURATIONS, ADDITIONS AND/OR
OPERATIONS IN FUTURE WASTE TRANSFERRED FROM SSTs OR
PRETREATED FOR VITRIFICATION PLANTS; REVIEW OF PRECLUDED
OPERATIONS AND WASTE MIXING*
- 2.1.7. 2:00 **"Introduction to Proposed Analysis Framework for DSTs"**
 - Scott Slezak / SNL
 **Only presented through viewgraph
 # 28*
- 3:00 **Panel Caucus on Analysis Framework**
- 4:30 **Discussion of Analysis Framework**
 Summary of Day's Topics / Q&A Session
 - Panelists & PHMC/SNL Teams
- 5:00 **Adjourn / Project Teams (SNL, PHMC) Caucus**

Tuesday, January 20 - Moderator: SNL

- 8:00 **"Tier II Review Comment Clarifications"**
 Lou Kovach / CRS
 **No viewgraphs or other visuals used in presentations*
- 2.1.8 8:15 **"GRE History of Hanford DSTs" - Chuck Stewart / PNNL**
*GRE RELEASE HISTORIES IN DSTs; REVIEW OF OBSERVATIONS
AND DATA ON BUOYANT DISPLACEMENT RELEASES*
- 2.1.9 **"DST Field Data"**
REVIEW OF CORE SAMPLE RHEOLOGY RESULTS, BALL RHEOMETER
-
-

FINDINGS, VFI MEASUREMENTS, RGS RESULTS, ETC

- 2.1.10 9:30 "Predictive Models for Buoyant GREs in Hanford Waste Tanks"
- Perry Meyer / PNNL
*SUMMARY OF ANALYTICAL MODELING AND EXPERIMENTAL TESTS
ON BUOYANT DISPLACEMENT GRES; REVIEW OF GAS RETENTION AND
RELEASE MECHANISMS*
- 10:30 BREAK
- 2.1.11 10:45 "Mixer Pump Operations" - Nick Kirch / LMHC
*REVIEW OF INFORMATION ON EFFICIENCY OF GAS RELEASE BY
101SY; VOLUME OF WASTE AFFECTED; LABORATORY AND COMPUTER
MODELING RESULTS*
- 2.1.7 11:30 "Introduction to Proposed Analysis Framework for DSTs" continued
from Monday - Scott Slezak / SNL
**Presented from viewgraph # 29 to
viewgraph # 37*
- 11:45 WORKING LUNCH
- 2.1.12 12:45 "Gas Generation Rates, Retained Gas Composition Data,
and Modeling" - Dan Reynolds / LMHC
*DATA RELEVANT TO THE TOTAL GAS GENERATION RATES FOR EACH
TANK AND THE H₂ GENERATION MODELING FOR DSTS AND SSTS.
DATA AND MODELING FOR THE RETAINED GAS COMPOSITION.
GIVEN A MODEL THAT NEEDS TOTAL GAS GENERATION RATE, AND THAT
THE HU MODEL ONLY GIVES H₂ GENERATION RATE, THIS PRESENTATION
ADDRESSES HOW WELL WE CAN RELATE THE TWO.*
- 2.1.13 1:45 "Introduction to Proposed Analysis Framework for DSTs" continued
from Morning - Scott Slezak / SNL
**Presented from viewgraph # 37 to
viewgraph # 54*
- 3:00 Panel Caucus on Analysis Framework
- 4:45 Discussion of Analysis Framework
Summary of Day's Topics / Q&A Session
- Panelists & PHMC/SNL Teams
-

5:15 Adjourn / Project Teams Caucus

Wednesday, January 21 - Moderator: SNL

8:00 Status / Action Items Update

8:15 Document Panel Consensus Positions and Open Issues

2.1.14 9:00 “Double-shelled Tank Intrusive Activity History”
 - Blaine Barton / LMHC
 *REVIEW OF HISTORY AND DESCRIPTION OF TANK INTRUSIVE
 ACTIVITIES; DATA INDICATION RELEASES DURING ACTIVITIES;
 DESCRIPTION OF ACTUAL AND POTENTIAL ACTIVITIES UNIQUE TO
 DSTS*

2.1.15 9:45 “Ammonia Release Data” - Blaine Barton / LMHC
 *REVIEW OF NH₃ OBSERVATIONS ASSOCIATED WITH BUOYANT
 DISPLACEMENT GRES; DISCUSSION OF NH₃ RELEASE MECHANISMS FOR
 WASTE TRANSFER IN OR OUT OF TANKS*

10:15 BREAK

2.1.16 10:30 “Proposed Analysis Framework for Ammonia Release During
 Buoyant Displacement GREs and Waste Intrusive Activities”
 - Wu-Ching Cheng / SNL

12:00 WORKING LUNCH

1:00 Panel Caucus on Analysis Framework

 Breakout Meeting: Project Teams (PHMC, SNL) Caucus
 with Observers and DOE/RL

3:30 Discussion of Analysis Framework
 Summary of Day’s Topics / Q&A Session
 - Panelists & PHMC/SNL Teams

5:00 Adjourn

7:00 Group Dinner [tbd]

Thursday, January 22 - Moderator: SNL

8:00 Status / Action Items Update

2.1.17 8:15 "GRE Control Strategies" - Mike Grigsby / G&P Consulting

9:00 "Waste Tank System Models"
 - William Kubic / LANL
*PHYSICAL PARAMETER CONSIDERATIONS IN GAS RELEASE
 MECHANISMS; REVIEW OF EXISTING MODELS*

10:30 BREAK

2.1.18 10:45 "Evaluation of Mitigation Strategies in Facility Group 1
 Double-shell Flammable Gas Tanks at Hanford Site"
 - Cetin Unal / LANL

2.1.19 11:45 "Modeling Controls Implementation in the Analysis Framework"
 - Scott Slezak / SNL

12:15 WORKING LUNCH

1:00 "Ammonia Sensitivity Analysis" - Wu Cheng / SNL

Time ? "Temperature Profile Data from 101SY Gas Release Events"
 - Nick Kirch / LMHC

2.1.20 1:15 "Waste Tank Ignition Sources and Controls"
 - Richard Schlosser / TWRS Equipment Engineering
*REVIEW OF POSSIBLE EX-TANK AND IN-TANK IGNITION
 SOURCES; IMPLICATIONS OF IC SET 1 VS. SET 2 VS. PAST PRACTICES*

2.1.21 2:15 "Proposed AF for Mixing and Ex-tank Ignition Controls"
 - Scott Slezak / SNL
*Slides #39, 42, 47, 53 from "Introduction to Proposed Analysis
 Framework for DSTs" presentation*

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-
3:00	Panel Caucus on Analysis Framework
4:30	Discussion of Analysis Framework
Summary of Day's Topics / Q&A Session
- Panelists & PHMC/SNL Teams
5:00	Adjourn / Project Teams Caucus

Friday, January 23 - Moderator: Chris Olson / SNL
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8:00	Status / Action Items Update
2.1.23 9:00	"Proposed AF on Seismic Response" - Scott Slezak / SNL
- <i>*Slide # 43 from "Introduction to Proposed Analysis Framework for DSTs" presentation was used for this Presentation</i>
10:15	Document Panel Consensus Positions and Open Issues
11:15	General Discussion of Panel Process / Feedback from Experts
Plans for Workshop #2 (February 9 - 13, 1998) / Assignments
11:30	Adjourn

Only expert panel members and the Panel Moderator shall be seated at the main table. Only the Panel Moderator and the panel members shall be allowed to speak or ask questions of guest speakers or to engage in panel discussions, except that the Panel Moderator may specifically recognize non-panel members for the purpose of efficiently covering necessary topics of discussion or for the purpose of efficiently conducting the meeting.

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- 11:15 Topic: Safety Analysis Approach and Results**
- 20 minutes: Presentation: Jon Young/ PHMC Team
 - 20 minutes: Questions & Answers
 - 10 minutes: Discussion on Implications for Analysis Framework
- 12:05 Working Lunch**
- 12:35 *Analysis tool (SST version): demonstration and discussion (Executive Boardroom)***
 - Steve Humphreys / SNL
- 1:05 Panel Caucus on Analysis Framework**
- Project Teams (PHMC Team, SNL) Caucus (Executive Boardroom)**
- Tuesday, February 10 Technical Moderator: Scott Slezak / SNL**
 Facilitator: Richard Harrington / PHMC Team
- 7:30 Status, Action Items**
Discussion of Analysis Framework and Previous Day's Topics
- 8:00 Topic: Combustion-related Phenomena**
- 20 minutes: Presentation: Scott Slezak / SNL
 - 20 minutes: Questions & Answers
 - 20 minutes: Discussion on Implications for Analysis Framework
- 9:00 Topic: Tank Headspace Mixing**
- 20 minutes: Presentation: Zen Antoniak / PNNL
 - 20 minutes: Questions & Answers
 - 10 minutes: Discussion on Implications for Analysis Framework
- 9:50 Break**
- 10:00 Topic: Ventilation for Flammable Gas**
- 20 minutes: Presentation: James Kriskovich / PHMC Team
 - 20 minutes: Questions & Answers
 - 10 minutes: Discussion on Implications for Analysis Framework
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10:50 **Topic: DST Dome Response to Overpressure**

- 20 minutes: Presentation: Julyk / PHMC Team
- 20 minutes: Questions & Answers
- 20 minutes: Discussion on Implications for Analysis Framework

11:50 **Working Lunch**

12:20 ***Analysis tool (SST version): demonstration and discussion (Executive Boardroom)***
 - Steve Humphreys / SNL

12:50 **Panel Caucus on Analysis Framework**

Project Teams (PHMC Team, SNL) Caucus (Executive Boardroom)

Wednesday, February 11 **Technical Moderator: Chris Olson / SNL**
 Facilitator: Richard Harrington / PHMC Team

7:30 **Status, Action Items**
 Discussion of Analysis Framework and Previous Day's Topics

8:00 **Topic: Respirable Material Release**

- 20 minutes: Presentation: Fred Gelbard / SNL
- 20 minutes: Questions & Answers
- 20 minutes: Discussion on Implications for Analysis Framework

9:00 **Topic: Proposed Analysis Framework for Ammonia Release During Buoyant Displacement**

GREs and Waste Intrusive Activities - Part II

- 20 minutes: Presentation: Wu-Ching Cheng / SNL
- 20 minutes: Questions & Answers
- 20 minutes: Discussion on Implications for Analysis Framework

10:00 **Break**

10:10 **Topic: Combustion Modeling for Plumes and Strata**

- 20 minutes: Presentation: Mike Epstein / Fauske & Assoc.
- 20 minutes: Questions & Answers
- 20 minutes: Discussion of Implications for Analysis Framework

11:00 **Topic: Verification & Validation Results**

- 20 minutes: Presentation: Fred Gelbard / SNL
- 20 minutes: Questions & Answers
- 20 minutes: Discussion on Implications for Analysis Framework

12:00 **Working Lunch**

12:30 *Analysis tool (SST version): demonstration and discussion (Executive Boardroom)*
 - Steve Humphreys / SNL

1:00 **Panel Caucus on Analysis Framework**

Project Teams (PHMC Team, SNL) Caucus (Executive Boardroom)

6:00 **Group Dinner**

Thursday, February 12 **Technical Moderator: Scott Slezak / SNL**
 Facilitator: Chris Olson / SNL

7:30 **Status, Action Items**
Discussion of Analysis Framework and Previous Day's Topics

8:00 **Topic: Seismic Response of DST Waste**

- 20 minutes: Presentation: Chuck Stewart / PNNL
- 15 minutes: Questions & Answers
- 15 minutes: Discussion on Implications for Analysis Framework

8:50

9:50 **Break**

- 10:00** **Topic: Finalization of Analysis Framework and Elicitation Structure**
- 30 minutes: Presentation: Scott Slezak / SNL
 - 30 minutes: Questions & Answers
 - 30 minutes: Discussion on Implications for Analysis Framework
- 11:30** **Topic: Elicitations - the Graduate-Level Course**
- 30 minutes: Presentation: D. von Winterfeldt / Decision Insights
 - 15 minutes: Questions & Answers
- 12:15** **Working Lunch**
- 12:45** ***Analysis tool (SST version): demonstration and discussion (Executive Boardroom)***
 - Steve Humphreys / SNL
- 12:55** **Panel Caucus on Analysis Framework**
- Project Teams (PHMC Team, SNL) Caucus (Executive Boardroom)**
- Friday, February 13** **Technical Moderator: Chris Olson / SNL**
 Facilitator: Scott Slezak / SNL
- 7:30** **Status, Action Items**
 Discussion of Analysis Framework
- 8:00** **Panel Caucus**
 Document Panel Consensus Positions and Open Issues
 Quality Assurance Issues
- 9:30** **Panel Report on Analysis Framework and Elicitation Structure**
- 10:15** **Assignments for Elicitations and Rationale Reports**
- 10:45** **Report of Panel on Open Issues**
- 11:00** **Adjourn**
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