PNNL-11222

Probability of Ignition of Reactive Wastes by Rotary Sampling Drills

Patrick G. Heasler
Pacific Northwest National Laboratory

July 1996

Prepared for
Westinghouse Hanford Company and the
U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy

PNNL-11222

Battelle

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161

The document was printed on recycled paper.

PNNL-11222

Probability of Ignition of Reactive Wastes by Rotary Sampling Drills

P. G. Heasler

July 1996

Prepared for
Westinghouse Hanford Company and the
U. S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Summary

Sampling with a rotary drill could potentially cause a fire in some Hanford tanks. If the rotary drill experiences a failure while in fuel-rich, dry waste, the waste could be ignited by the hot drill bit. For the saltcake tanks subject to this hazard, this report presents a methodology for calculating the probabilities of fire due to core drill failure. The methodology utilizes sampling data from tank characterization studies to determine the amount of reactive waste in the tanks. The tanks are rated in order of their fire probabilities, and confidence limits are assigned to the estimates.

CONTENTS

Summary iii

1 **Introduction** 1

2 **Reactive Waste Calculations** 3

3 **Uncertainty Analysis** 7

4 **Fire Probabilities** 9

5 **Conclusions** 17

References 19

LIST OF FIGURES

Figure 1. Distribution of Calculated Reactive Waste Proportion, Tank BY-104 7

Figure 2. Proportion of Reactive Waste for Regions 1, 2, and 3 18

LIST OF TABLES

Table 1. Parameters for TOC and Moisture Distributions 5

Table 2. Probability Calculations for Reactive Region 1 10

Table 3. Probability Calculations for Reactive Region 2 12

Table 4. Probability Calculations for Reactive Region 3 14

1 Introduction

One of the safety concerns regarding the Hanford waste storage tanks is the possibility of a fire in reactive waste caused by rotary sampling drill failure. The object of this report is to estimate the probability of such an occurence during one drill deployment. In this report, reactive waste is defined as saltcake waste that is dry enough and that contains sufficient total organic carbon (TOC) to burn. The drill failures of concern are those, such as loss of coolant, that would cause ignition of the reactive waste. The probability of a fire occurring due to drill failure is equal to the probability of a drill failure during deployment times the probability of the drill bit being in reactive waste during failure. In other words,

$$\begin{aligned} Pr(\text{Fire}) &= Pr(\text{Drill Failure in Reactive Waste}) \\ &= Pr(\text{Drill Failure}) \cdot Pr(\text{Drill is in Reactive Waste}) \end{aligned}$$

This formula assumes that drill failure is no more likely to occur in reactive waste as compared to other waste.

The first term on the right in the equation, the probability that the rotary drill will fail during deployment, has been set to the nominal value of 10^{-4}, to illustrate the use of the above formula. This nominal value is similar to failure probabilities obtained by the Los Alamos National Laboratory (LANL) for this type of accident.

Estimation of the second term in this equation is the basic objective of this report. To evaluate the second term in the equation, the proportion of reactive waste in each tank is estimated. The proportion of reactive waste in each tank is considered to be equivalent to the chances of a drill failure occuring in reactive waste. This assumption would be true if the sampling location was randomly chosen with respect to the reactive waste. The assumption could also be justified if the reactive waste occured in layers and drill failure was random in time. The proportion of reactive waste in each tank can be calculated from the results of an earlier ANOVA study [3], which produced distributions of moisture content and TOC for each saltcake tank.

2 Reactive Waste Calculations

These calculations employ three definitions of reactive waste, so that the sensitivity of the desired value (proportion of reactive waste) can be determined. The definitions each equate reactive waste with a certain region in (H_2O, TOC) space, to fit the ANOVA data. The three regions are defined as follows:

Region 1: $H_20 < 20\%$ and $TOC\% > 4.5\% + 0.17H_2O\%$

Region 2: $H_20 < 40\%$ and $TOC\% > 3.0\% + 0.17H_2O\%$

Region 3: $H_20 < 20\%$ and $TOC\% > 3.0\% + 0.17H_2O\%$

The proportion of reactive waste in any tank is calculated by integrating the distribution of (H_2O, TOC) in the tank over the reactive region:

$$\text{Proportion Reactive Waste} = \int_{R_i} f(x,y)dxdy \tag{1}$$

where x and y are the concentrations of H_2O and TOC respectively, and R represents one of the reactive waste regions defined above. This report gives reactive waste estimates using each of the three reactive regions.

The ANOVA calculations in Reference [3] show that both moisture content and TOC are log-normally distributed (approximately). Thus, the form of the distribution function $f(x, y)$ is

$$f(x,y) = C_0exp\left(-\frac{1}{2}\begin{bmatrix} log(x) - \mu_1 \\ log(y) - \mu_2 \end{bmatrix}^T \begin{bmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{bmatrix}^{-1} \begin{bmatrix} log(x) - \mu_1 \\ log(y) - \mu_2 \end{bmatrix}\right) \tag{2}$$

where subscripts 1 and 2 refer to moisture content and TOC respectively, μ is the estimated mean of the log values for the tank, σ^2 is their estimated variability, ρ is the correlation factor between moisture content and TOC, and the constant C_0 in the formula is defined as:

$$C_0 = \frac{1}{2\pi\sqrt{1-\rho^2}\sigma_1\sigma_2} \tag{3}$$

It should also be noted that the log's in the above equation are base 10 logarithms.

The proportion of reactive waste in a tank (and thus, the probability of drill failure in the reactive waste) can be calculated from Equations 1 and 2, given suitable estimates of the distribution parameters μ_1, μ_2, σ_1, σ_2, and ρ. These parameter estimates were obtained for each saltcake tank from References [3] and [2], and are listed in Table 1, along with the standard error (StdErr) and degrees of freedom (DOF) for each estimate. The other parameter needed to solve Equations 1 and 2 is the correlation factor ρ. This parameter was assumed equal to 0.39, based on [3].

It should be noted that the integral and distribution Equations 1 and 2 apply only to the saltcake phase of waste in the tank. When applied to the data from Reference [2], these equations yield the proportion of reactive waste in the saltcake. To produce the proportion of reactive waste to the entire waste content, one must multiply by a factor representing the proportion of saltcake in the tank. These factors have been estimated from [5].

Table 1 contains the parameters that define the TOC and moisture distributions for each saltcake tank. The estimates in this table are in units of log_{10} of weight percent. The standard error columns in the table represent the uncertainty associated with the estimate, and the "DOF" represent the amount of data used to estimate the sigma parameters. The DOF determines the uncertainty in the sigma's.

Table 1: Parameters for TOC and Moisture Distributions

	TOC Parameters				H_2O Parameters			
	— μ_2 —		— σ_2 —		— μ_1 —		— σ_1 —	
Tank	Est	StdErr	Est	DOF	Est	StdErr	Est	DOF
A101	-0.23	0.18	0.49	8	1.59	0.05	0.08	8
A102	-0.23	0.18	0.49	8	1.63	0.11	0.08	8
AX101	-0.23	0.18	0.49	8	1.63	0.11	0.08	8
AX102	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
AX103	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
B102	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
B104	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
B105	-0.29	0.20	0.49	8	1.63	0.11	0.08	8
BX105	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
BX110	-0.25	0.17	0.49	8	1.68	0.06	0.08	8
BX111	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
BY101	-0.19	0.16	0.49	8	1.23	0.14	0.08	8
BY102	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
BY103	-0.19	0.16	0.49	8	1.63	0.11	0.08	8
BY104	-0.19	0.16	0.49	8	1.21	0.04	0.08	8
BY105	-0.19	0.16	0.49	8	1.63	0.11	0.08	8
BY106	-0.19	0.16	0.49	8	1.63	0.11	0.08	8
BY107	-0.19	0.16	0.49	8	1.23	0.14	0.08	8
BY108	-0.19	0.16	0.49	8	1.23	0.14	0.08	8
BY109	-0.25	0.17	0.49	8	1.63	0.11	0.08	8
BY110	-0.19	0.16	0.49	8	1.23	0.14	0.08	8
BY111	-0.19	0.16	0.49	8	1.23	0.14	0.08	8
BY112	-0.19	0.16	0.49	8	1.23	0.14	0.08	8
S101	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S102	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S103	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S105	-0.37	0.14	0.49	8	0.93	0.16	0.08	8
S106	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S107	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S108	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S109	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S110	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
S111	-0.37	0.14	0.49	8	1.20	0.04	0.08	8
S112	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
SX101	-0.37	0.14	0.49	8	1.09	0.11	0.08	8
SX102	-0.37	0.14	0.49	8	1.12	0.06	0.08	8
SX103	-0.37	0.14	0.49	8	1.09	0.11	0.08	8
SX104	-0.37	0.14	0.49	8	1.07	0.06	0.08	8

Table 1: Parameters for TOC and Moisture Distributions

Tank	TOC Parameters				H_2O Parameters			
	— μ_2 —		— σ_2 —		— μ_1 —		— σ_1 —	
	Est	StdErr	Est	DOF	Est	StdErr	Est	DOF
SX105	-0.37	0.14	0.49	8	1.11	0.06	0.08	8
SX106	-0.37	0.14	0.49	8	1.09	0.11	0.08	8
TX102	-0.37	0.14	0.49	8	0.93	0.16	0.08	8
TX104	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
TX105	-0.37	0.14	0.49	8	0.93	0.16	0.08	8
TX106	-0.37	0.14	0.49	8	0.93	0.16	0.08	8
TX107	-0.37	0.14	0.49	8	1.33	0.12	0.08	8
TX108	-0.22	0.20	0.49	8	1.23	0.14	0.08	8
TX109	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX110	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX111	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX112	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX113	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX114	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX115	-0.19	0.17	0.49	8	1.23	0.14	0.08	8
TX116	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX117	-0.29	0.20	0.49	8	1.23	0.14	0.08	8
TX118	-0.22	0.20	0.49	8	1.23	0.14	0.08	8
TY102	-0.29	0.20	0.49	8	1.71	0.06	0.08	8
U102	-0.19	0.17	0.49	8	1.63	0.11	0.08	8
U103	-0.19	0.17	0.49	8	1.63	0.11	0.08	8
U105	-0.18	0.20	0.49	8	1.32	0.06	0.08	8
U106	-0.19	0.17	0.49	8	1.63	0.11	0.08	8
U107	-0.18	0.20	0.49	8	1.33	0.12	0.08	8
U108	-0.18	0.20	0.49	8	1.33	0.12	0.08	8
U109	-0.18	0.20	0.49	8	1.48	0.06	0.08	8
U111	-0.19	0.17	0.49	8	1.58	0.05	0.08	8

3 Uncertainty Analysis

No estimate is ever completely accurate. An advantage of ANOVA is that uncertainties (in the form of standard errors) are given for the estimates. Since some estimates contain substantial uncertainty, it is important to account for this in the reactive waste estimates. Simply plugging the ANOVA estimates into formulas 1 and 2 may produce a non-conservative result. To assess the uncertainty, a Monte Carlo simulation [1] was performed.

The Monte Carlo method uses standard Bayesian posterior distributions to describe parameter uncertainty. The log means μ were assumed to be normally distributed about their estimated means, and the sigma terms σ were assumed to have an inverse chi-square distribution defined by their estimates. These distribution parameters were simulated 1000 times, based on their calculated variabilities, and the proportion of reactive waste was calculated for each simulation. For each tank, the results were formed into an empirical distribution as illustrated in Figure 3 for Tank BY-104.

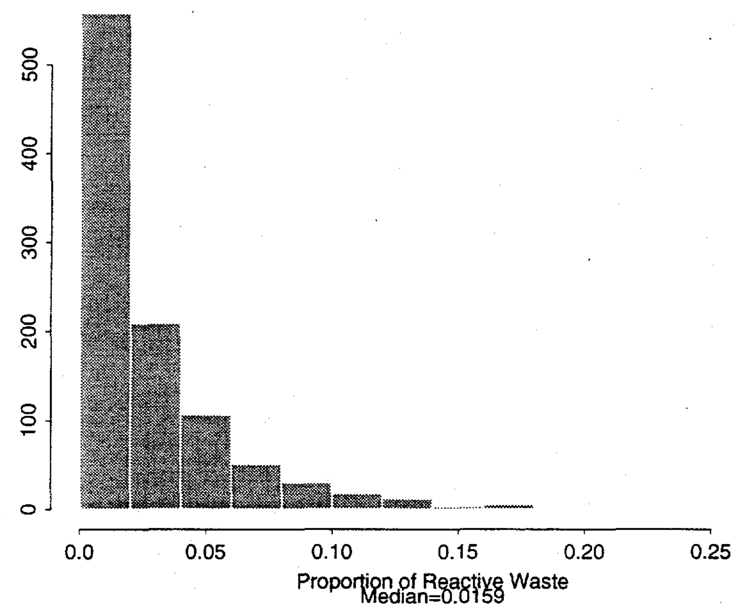


Figure 1: Distribution of Calculated Reactive Waste Proportion, Tank BY-104

This distribution describes the uncertainty associated with the reactive waste calculation for this particular tank. From the figure, the proportion of reactive waste is most probably less than 2 percent. On the other hand, there is a small chance that the proportion might be as high as 15 percent or above. The uncertainty presented in this plot is typical of the reactive waste estimates.

From the Monte Carlo simulations, uncertainties associated with the final results can be calculated. In the next section, the final calculated probabilities are reported both as median values (best estimates) and at the upper 95% confidence level.

4 Fire Probabilities

The following tables present, for each saltcake tank, the calculated estimates of

- the probability of drill failure in reactive waste, and
- the probability of fire due to drill failure.

For all probabilities, both the median values and the upper 95% confidence level values are tabulated. Tables 2 through 4 show the results for reactive regions 1, 2, and 3, respectively. In each table, the tanks are listed in ascending order of the fire probability. As noted earlier, the fire probabilities in the last two columns are calculated by multiplying the values in the two middle columns by the probability of drill failure, taken as 10^{-4} (one chance in 10,000). Table 2 also contains the waste volume of the tank, while Table 3 contains the number of TOC observations (samples) made on each tank.

For Region 1, the "best" tank (BX-110) has a zero probability of fire, while the "worst" tank (BY-104) has a probability of about 10^{-6} (one chance in a million), indicating that most tanks are safe. For Region 2, the best and worst probabilities are about 3×10^{-9} and 6×10^{-6}, respectively. As one might expect, this definition yields much higher proportions of reactive waste (and higher probabilities of fire), due principally to the higher moisture content threshold. For Region 3, the results in Table 4 show a range of fire probabilities from zero to 3×10^{-6}.

Table 2: Probability Calculations for Reactive Region 1

Tank	Vol M^3	Fail Prob	React. Waste Median	React. Waste Upper-95%	Prob Fire Median	Prob Fire Upper-95%
BX110	785	1e-04	0.00e+00	6.10e-08	0.00e+00	6.10e-12
TY102	243	1e-04	0.00e+00	4.41e-07	0.00e+00	4.41e-11
BX105	193	1e-04	4.33e-11	5.60e-06	4.33e-15	5.60e-10
B104	1410	1e-04	7.20e-11	1.74e-05	7.20e-15	1.74e-09
BX111	800	1e-04	1.59e-10	3.82e-05	1.59e-14	3.82e-09
B102	121	1e-04	1.67e-10	2.82e-05	1.67e-14	2.82e-09
A102	155	1e-04	2.52e-10	8.18e-05	2.52e-14	8.18e-09
B105	1160	1e-04	2.82e-10	5.01e-05	2.82e-14	5.01e-09
AX102	148	1e-04	3.63e-10	5.29e-05	3.63e-14	5.29e-09
U103	1770	1e-04	4.54e-10	7.20e-05	4.54e-14	7.20e-09
AX101	2830	1e-04	5.61e-10	6.54e-05	5.61e-14	6.54e-09
BY103	1520	1e-04	5.62e-10	1.16e-04	5.62e-14	1.16e-08
BY109	1600	1e-04	6.44e-10	3.75e-05	6.44e-14	3.75e-09
BY102	1290	1e-04	6.49e-10	9.88e-05	6.49e-14	9.88e-09
BY106	2430	1e-04	6.68e-10	1.15e-04	6.68e-14	1.15e-08
AX103	424	1e-04	8.05e-10	1.84e-04	8.05e-14	1.84e-08
U102	1420	1e-04	1.03e-09	1.19e-04	1.03e-13	1.19e-08
U106	857	1e-04	2.33e-09	2.46e-04	2.33e-13	2.46e-08
BY105	1910	1e-04	2.46e-09	1.74e-04	2.46e-13	1.74e-08
A101	3610	1e-04	3.73e-09	2.68e-05	3.73e-13	2.68e-09
U111	1250	1e-04	2.61e-08	4.90e-05	2.61e-12	4.90e-09
U109	1750	1e-04	7.22e-06	1.67e-03	7.22e-10	1.67e-07
S107	1430	1e-04	9.49e-05	6.07e-03	9.49e-09	6.07e-07
S101	1620	1e-04	1.57e-04	1.13e-02	1.57e-08	1.13e-06
S110	1480	1e-04	3.57e-04	2.18e-02	3.57e-08	2.18e-06
TX104	246	1e-04	4.19e-04	3.18e-02	4.19e-08	3.18e-06
S108	2290	1e-04	4.32e-04	3.80e-02	4.32e-08	3.80e-06
S112	1980	1e-04	4.45e-04	3.14e-02	4.45e-08	3.14e-06
S102	2080	1e-04	4.70e-04	3.34e-02	4.70e-08	3.34e-06
S103	940	1e-04	5.23e-04	2.75e-02	5.23e-08	2.75e-06
S106	1820	1e-04	5.28e-04	3.24e-02	5.28e-08	3.24e-06
S109	2150	1e-04	6.03e-04	2.90e-02	6.03e-08	2.90e-06
TX107	136	1e-04	6.89e-04	3.63e-02	6.89e-08	3.63e-06
U108	1770	1e-04	1.66e-03	5.53e-02	1.66e-07	5.53e-06
U107	1540	1e-04	2.04e-03	6.97e-02	2.04e-07	6.97e-06
U105	1580	1e-04	2.15e-03	4.42e-02	2.15e-07	4.42e-06
BY108	864	1e-04	2.92e-03	3.34e-02	2.92e-07	3.34e-06
TX109	1460	1e-04	4.26e-03	8.68e-02	4.26e-07	8.68e-06
TX112	2460	1e-04	4.80e-03	8.46e-02	4.80e-07	8.46e-06

Table 2: Probability Calculations for Reactive Region 1

Tank	Vol M^3	Fail Prob	React. Waste Median	React. Waste Upper-95%	Prob Fire Median	Prob Fire Upper-95%
S111	2260	1e-04	4.91e-03	4.77e-02	4.91e-07	4.77e-06
TX110	1750	1e-04	5.02e-03	8.48e-02	5.02e-07	8.48e-06
TX113	2300	1e-04	5.08e-03	8.89e-02	5.08e-07	8.89e-06
TX117	2370	1e-04	5.16e-03	8.07e-02	5.16e-07	8.07e-06
TX116	2390	1e-04	5.26e-03	8.29e-02	5.26e-07	8.29e-06
TX114	2030	1e-04	6.05e-03	8.10e-02	6.05e-07	8.10e-06
TX111	1400	1e-04	6.10e-03	8.87e-02	6.10e-07	8.87e-06
BY110	1510	1e-04	7.16e-03	8.21e-02	7.16e-07	8.21e-06
SX102	2060	1e-04	0.00721	0.0610	7.21e-07	6.10e-06
SX101	1730	1e-04	0.00735	0.0652	7.35e-07	6.52e-06
BY107	1010	1e-04	0.00747	0.0900	7.47e-07	9.00e-06
SX103	2470	1e-04	0.00778	0.0729	7.78e-07	7.29e-06
SX106	2040	1e-04	0.00780	0.0710	7.80e-07	7.10e-06
BY101	1470	1e-04	0.00823	0.0817	8.23e-07	8.17e-06
TX108	508	1e-04	0.00825	0.0978	8.25e-07	9.78e-06
BY112	1100	1e-04	0.00828	0.1050	8.28e-07	1.05e-05
SX104	2330	1e-04	0.00846	0.0642	8.46e-07	6.42e-06
TX118	1320	1e-04	0.00865	0.0990	8.65e-07	9.90e-06
SX105	2590	1e-04	0.00905	0.0763	9.05e-07	7.63e-06
TX115	2430	1e-04	0.00917	0.1040	9.17e-07	1.04e-05
BY111	1740	1e-04	0.01030	0.1070	1.03e-06	1.07e-05
TX106	1720	1e-04	0.01210	0.0916	1.21e-06	9.16e-06
TX105	2310	1e-04	0.01280	0.0936	1.28e-06	9.36e-06
S105	1730	1e-04	0.01290	0.0867	1.29e-06	8.67e-06
TX102	822	1e-04	0.01300	0.0930	1.30e-06	9.30e-06
BY104	1540	1e-04	0.01590	0.0937	1.59e-06	9.37e-06

Table 3: Probability Calculations for Reactive Region 2

Tank	N Obs	Pr(fail)	Median R Waste	Upper 95 R Waste	Median Pr(fire)	Upper 95 Pr(fire)
BX110	0	1.00e-04	3.02e-05	1.14e-03	3.02e-09	1.14e-07
BX105	0	1.00e-04	1.80e-04	4.35e-03	1.80e-08	4.35e-07
TY102	1	1.00e-04	2.11e-04	1.22e-02	2.11e-08	1.22e-06
B104	0	1.00e-04	6.35e-04	1.50e-02	6.35e-08	1.50e-06
B102	0	1.00e-04	9.97e-04	2.44e-02	9.97e-08	2.44e-06
A102	0	1.00e-04	1.73e-03	4.22e-02	1.73e-07	4.22e-06
AX102	0	1.00e-04	2.01e-03	5.30e-02	2.01e-07	5.30e-06
BX111	0	1.00e-04	2.07e-03	3.95e-02	2.07e-07	3.95e-06
B105	0	1.00e-04	2.11e-03	6.34e-02	2.11e-07	6.34e-06
BY109	0	1.00e-04	2.29e-03	6.54e-02	2.29e-07	6.54e-06
BY102	0	1.00e-04	3.49e-03	7.47e-02	3.49e-07	7.47e-06
AX101	0	1.00e-04	3.51e-03	8.87e-02	3.51e-07	8.87e-06
AX103	0	1.00e-04	3.72e-03	7.62e-02	3.72e-07	7.62e-06
BY105	0	1.00e-04	3.89e-03	8.10e-02	3.89e-07	8.10e-06
U103	1	1.00e-04	3.98e-03	8.77e-02	3.98e-07	8.77e-06
U106	0	1.00e-04	4.21e-03	6.70e-02	4.21e-07	6.70e-06
BY106	0	1.00e-04	4.35e-03	8.29e-02	4.35e-07	8.29e-06
U102	0	1.00e-04	4.38e-03	8.32e-02	4.38e-07	8.32e-06
S107	0	1.00e-04	4.41e-03	2.39e-02	4.41e-07	2.39e-06
BY103	0	1.00e-04	5.18e-03	8.73e-02	5.18e-07	8.73e-06
A101	2	1.00e-04	9.04e-03	8.62e-02	9.04e-07	8.62e-06
S101	0	1.00e-04	9.76e-03	5.11e-02	9.76e-07	5.11e-06
S110	0	1.00e-04	1.40e-02	8.23e-02	1.40e-06	8.23e-06
U111	2	1.00e-04	1.53e-02	8.75e-02	1.53e-06	8.75e-06
BY108	0	1.00e-04	1.79e-02	6.41e-02	1.79e-06	6.41e-06
S103	0	1.00e-04	1.91e-02	1.03e-01	1.91e-06	1.03e-05
S111	3	1.00e-04	1.93e-02	9.14e-02	1.93e-06	9.14e-06
SX102	2	1.00e-04	2.00e-02	1.02e-01	2.00e-06	1.02e-05
TX107	0	1.00e-04	2.00e-02	1.11e-01	2.00e-06	1.11e-05
SX101	0	1.00e-04	2.05e-02	1.06e-01	2.05e-06	1.06e-05
S106	0	1.00e-04	2.17e-02	1.09e-01	2.17e-06	1.09e-05
SX104	0	1.00e-04	2.19e-02	1.13e-01	2.19e-06	1.13e-05
SX103	1	1.00e-04	2.23e-02	1.06e-01	2.23e-06	1.06e-05
SX106	0	1.00e-04	2.25e-02	1.12e-01	2.25e-06	1.12e-05
TX104	0	1.00e-04	2.27e-02	1.23e-01	2.27e-06	1.23e-05
S109	1	1.00e-04	2.33e-02	1.26e-01	2.33e-06	1.26e-05
S108	0	1.00e-04	2.33e-02	1.22e-01	2.33e-06	1.22e-05
SX105	0	1.00e-04	2.40e-02	1.15e-01	2.40e-06	1.15e-05
S102	0	1.00e-04	2.42e-02	1.28e-01	2.42e-06	1.28e-05

Table 3: Probability Calculations for Reactive Region 2

Tank	N Obs	Pr(fail)	Median R Waste	Upper 95 R Waste	Median Pr(fire)	Upper 95 Pr(fire)
S112	0	1.00e-04	2.43e-02	1.18e-01	2.43e-06	1.18e-05
U109	0	1.00e-04	3.27e-02	1.47e-01	3.27e-06	1.47e-05
TX102	1	1.00e-04	3.39e-02	1.46e-01	3.39e-06	1.46e-05
TX111	0	1.00e-04	3.41e-02	1.70e-01	3.41e-06	1.70e-05
TX117	0	1.00e-04	3.57e-02	1.77e-01	3.57e-06	1.77e-05
TX112	0	1.00e-04	3.63e-02	1.81e-01	3.63e-06	1.81e-05
TX106	0	1.00e-04	3.63e-02	1.51e-01	3.63e-06	1.51e-05
TX109	0	1.00e-04	3.65e-02	1.85e-01	3.65e-06	1.85e-05
TX114	0	1.00e-04	3.71e-02	1.68e-01	3.71e-06	1.68e-05
TX113	0	1.00e-04	3.73e-02	1.72e-01	3.73e-06	1.72e-05
S105	0	1.00e-04	3.75e-02	1.53e-01	3.75e-06	1.53e-05
TX105	0	1.00e-04	3.78e-02	1.56e-01	3.78e-06	1.56e-05
TX116	0	1.00e-04	3.91e-02	1.77e-01	3.91e-06	1.77e-05
BY101	0	1.00e-04	4.02e-02	1.37e-01	4.02e-06	1.37e-05
TX110	0	1.00e-04	4.07e-02	1.74e-01	4.07e-06	1.74e-05
BY110	0	1.00e-04	4.08e-02	1.57e-01	4.08e-06	1.57e-05
BY107	0	1.00e-04	4.36e-02	1.49e-01	4.36e-06	1.49e-05
U107	0	1.00e-04	4.90e-02	1.90e-01	4.90e-06	1.90e-05
U108	0	1.00e-04	4.95e-02	1.92e-01	4.95e-06	1.92e-05
U105	1	1.00e-04	4.98e-02	1.76e-01	4.98e-06	1.76e-05
TX118	1	1.00e-04	5.14e-02	1.98e-01	5.14e-06	1.98e-05
BY104	4	1.00e-04	5.47e-02	1.91e-01	5.47e-06	1.91e-05
TX108	0	1.00e-04	5.50e-02	1.99e-01	5.50e-06	1.99e-05
BY112	0	1.00e-04	5.62e-02	2.03e-01	5.62e-06	2.03e-05
TX115	0	1.00e-04	5.64e-02	2.07e-01	5.64e-06	2.07e-05
BY111	0	1.00e-04	5.66e-02	1.95e-01	5.66e-06	1.95e-05

Table 4: Probability Calculations for Reactive Region 3

Tank	N Obs	Pr(fail)	Median R Waste	Upper 95 R Waste	Median Pr(fire)	Upper 95 Pr(fire)
BX110	0	1.00e-04	0.00e+00	2.90e-07	0.00e+00	2.90e-11
TY102	1	1.00e-04	0	1.13e-06	0.00e+00	1.13e-10
BX105	0	1.00e-04	1.49e-10	1.78e-05	1.49e-14	1.78e-09
B102	0	1.00e-04	2.90e-10	7.00e-05	2.90e-14	7.00e-09
B104	0	1.00e-04	3.27e-10	4.04e-05	3.27e-14	4.04e-09
A102	0	1.00e-04	7.59e-10	1.20e-04	7.59e-14	1.20e-08
BY109	0	1.00e-04	1.15e-09	1.09e-04	1.15e-13	1.09e-08
AX101	0	1.00e-04	1.44e-09	2.89e-04	1.44e-13	2.89e-08
U102	0	1.00e-04	1.48e-09	2.12e-04	1.48e-13	2.12e-08
BX111	0	1.00e-04	1.54e-09	7.88e-05	1.54e-13	7.88e-09
BY106	0	1.00e-04	1.84e-09	1.49e-04	1.84e-13	1.49e-08
BY102	0	1.00e-04	1.95e-09	2.00e-04	1.95e-13	2.00e-08
U106	0	1.00e-04	2.16e-09	1.90e-04	2.16e-13	1.90e-08
AX102	0	1.00e-04	2.35e-09	1.09e-04	2.35e-13	1.09e-08
U103	1	1.00e-04	2.39e-09	2.27e-04	2.39e-13	2.27e-08
B105	0	1.00e-04	2.54e-09	1.58e-04	2.54e-13	1.58e-08
AX103	0	1.00e-04	2.80e-09	1.35e-04	2.80e-13	1.35e-08
BY105	0	1.00e-04	2.91e-09	3.77e-04	2.91e-13	3.77e-08
BY103	0	1.00e-04	2.93e-09	3.03e-04	2.93e-13	3.03e-08
A101	2	1.00e-04	2.64e-08	6.87e-05	2.64e-12	6.87e-09
U111	2	1.00e-04	1.40e-07	1.43e-04	1.40e-11	1.43e-08
U109	0	1.00e-04	2.57e-05	2.97e-03	2.57e-09	2.97e-07
S107	0	1.00e-04	2.63e-04	1.10e-02	2.63e-08	1.10e-06
S101	0	1.00e-04	6.76e-04	1.83e-02	6.76e-08	1.83e-06
S110	0	1.00e-04	7.87e-04	3.05e-02	7.87e-08	3.05e-06
S108	0	1.00e-04	1.14e-03	4.67e-02	1.14e-07	4.67e-06
S106	0	1.00e-04	1.24e-03	4.21e-02	1.24e-07	4.21e-06
S112	0	1.00e-04	1.29e-03	5.44e-02	1.29e-07	5.44e-06
TX104	0	1.00e-04	1.30e-03	4.81e-02	1.30e-07	4.81e-06
S103	0	1.00e-04	1.33e-03	4.50e-02	1.33e-07	4.50e-06
S109	1	1.00e-04	1.50e-03	4.92e-02	1.50e-07	4.92e-06
S102	0	1.00e-04	1.58e-03	4.66e-02	1.58e-07	4.66e-06
TX107	0	1.00e-04	1.65e-03	5.53e-02	1.65e-07	5.53e-06
U107	0	1.00e-04	4.11e-03	8.39e-02	4.11e-07	8.39e-06
U108	0	1.00e-04	4.22e-03	8.82e-02	4.22e-07	8.82e-06
U105	1	1.00e-04	5.87e-03	6.70e-02	5.87e-07	6.70e-06
BY108	0	1.00e-04	7.35e-03	4.86e-02	7.35e-07	4.86e-06
TX113	0	1.00e-04	1.03e-02	1.26e-01	1.03e-06	1.26e-05
TX117	0	1.00e-04	1.09e-02	1.28e-01	1.09e-06	1.28e-05

Table 4: Probability Calculations for Reactive Region 3

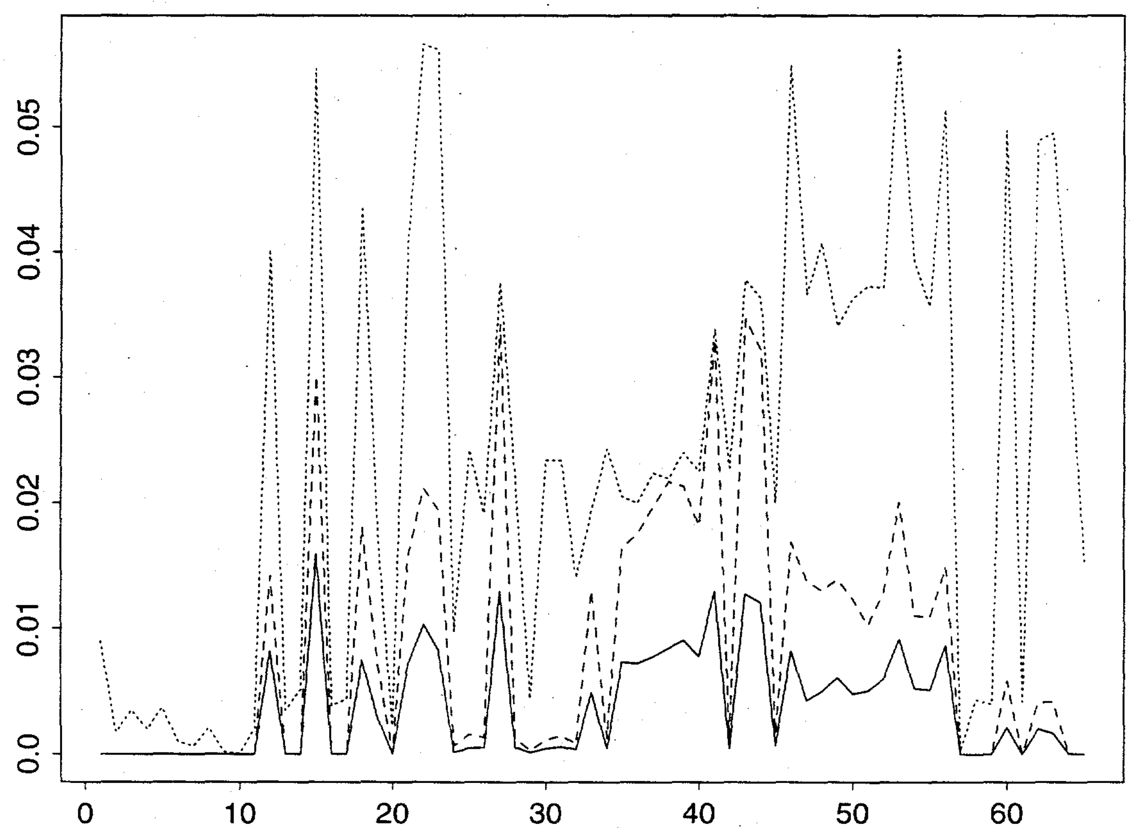
Tank	N Obs	Pr(fail)	Median R Waste	Upper 95 R Waste	Median Pr(fire)	Upper 95 Pr(fire)
TX116	0	1.00e-04	1.10e-02	1.30e-01	1.10e-06	1.30e-05
TX112	0	1.00e-04	1.23e-02	1.29e-01	1.23e-06	1.29e-05
TX114	0	1.00e-04	1.29e-02	1.38e-01	1.29e-06	1.38e-05
TX110	0	1.00e-04	1.30e-02	1.26e-01	1.30e-06	1.26e-05
S111	3	1.00e-04	1.31e-02	7.34e-02	1.31e-06	7.34e-06
TX109	0	1.00e-04	1.38e-02	1.16e-01	1.38e-06	1.16e-05
TX111	0	1.00e-04	1.39e-02	1.34e-01	1.39e-06	1.34e-05
BY101	0	1.00e-04	1.42e-02	1.17e-01	1.42e-06	1.17e-05
TX118	1	1.00e-04	1.49e-02	1.39e-01	1.49e-06	1.39e-05
BY110	0	1.00e-04	1.57e-02	1.15e-01	1.57e-06	1.15e-05
SX101	0	1.00e-04	1.64e-02	8.53e-02	1.64e-06	8.53e-06
TX108	0	1.00e-04	1.69e-02	1.49e-01	1.69e-06	1.49e-05
SX102	2	1.00e-04	1.75e-02	9.45e-02	1.75e-06	9.45e-06
BY107	0	1.00e-04	1.80e-02	1.19e-01	1.80e-06	1.19e-05
SX106	0	1.00e-04	1.81e-02	1.00e-01	1.81e-06	1.00e-05
BY112	0	1.00e-04	1.94e-02	1.49e-01	1.94e-06	1.49e-05
SX103	1	1.00e-04	1.96e-02	1.04e-01	1.96e-06	1.04e-05
TX115	0	1.00e-04	2.00e-02	1.59e-01	2.00e-06	1.59e-05
BY111	0	1.00e-04	2.11e-02	1.56e-01	2.11e-06	1.56e-05
SX105	0	1.00e-04	2.13e-02	1.09e-01	2.13e-06	1.09e-05
SX104	0	1.00e-04	2.17e-02	9.60e-02	2.17e-06	9.60e-06
BY104	4	1.00e-04	3.01e-02	1.30e-01	3.01e-06	1.30e-05
TX106	0	1.00e-04	3.22e-02	1.48e-01	3.22e-06	1.48e-05
TX102	1	1.00e-04	3.31e-02	1.58e-01	3.31e-06	1.58e-05
S105	0	1.00e-04	3.42e-02	1.43e-01	3.42e-06	1.43e-05
TX105	0	1.00e-04	3.47e-02	1.48e-01	3.47e-06	1.48e-05

5 Conclusions

Figure 5 compares the proportions of reactive waste calculated under the three definitions. Each ordinate represents a tank, while the three lines in this figure identify calculations performed using one definition of reactive waste. From this figure one can see that using Region 1 as the definition of reactive waste produces a proportion that is almost always less than one in a hundred. On the other hand, the most conservative definition of reactive waste (Region 2) produces proportions that are in the three out of a hundred range.

When reactive Region 1 is used to define reactive waste, the proportion of reactive waste in most tanks is therefore quite low. For about half the tanks the proportion is less than 1 in a thousand. The "high" tanks, which contain proportions of reactive waste in the range of 1% are not unreasonable. For example, about 1.5% of all compiled TOC measurements are above the 4.5% threshold.

The probabilities associated with reactive Region 1 are most relevant to tank safety. Reactive Region 1 is the criterion used in [3] to define reactive waste. Given this definition, the median fire probabilities are generally below the one-in-a-million threshold normally used to identify unacceptable risk. As one can see, only six tanks have a fire probability higher than one-in-a-million.



(Region 1=solid, Region 2=dotted, Region 3=dashed)

Figure 2: Proportion of Reactive Waste for Regions 1, 2, and 3.

References

[1] Box GEP, Tiao GC, "Bayesian Inference in Statistical Analysis," Addison-Wesley, 1973.

[2] Toth JJ, Heasler PG, Hill JG, Lerchen ME, Whitney PD, "Analysis of Organic Carbon and Moisture in Hanford Single-Shell Tank Waste," PNL-10360, May 1995.

[3] Webb AB, Stewart JL, Turner DA, "Preliminary Safety Criteria for Organic Watch List Tanks at the Hanford Site," WHC-SD-WM-SARR-033, Rev 0, Nov. 95.

[4] "A Safety Assessment for Rotary Mode Core Sampling Operations in Single-Shell Tanks that are on the Flammable Gas Watchlist," Nuclear Systema and Analysis Group, LANL, Draft.

[5] Hanlon, B.M., 1995, Waste Tank Summary Report for Month Ending June 30, 1995, WHC-EP-0182-87, WHC.

Distribution

No. of Copies		
OFFSITE		
	Los Alamos National Laboratory P.O. Box 1663 Los Alamos, NM 87545 Attn: W.L. Kubic/K575	
ONSITE		
3	**DOE Richland Operations Office**	
	J.M. Gray	S7-54
	M.F. Jarvis	K8-50
	G.W. Rosenwald	S7-54
8	**Westinghouse Hanford Company**	
	H. Babad	S7-14
	L. Jensen	R2-12
	N.W. Kirch	R2-11
	J.W. Lentsch	S7-14
	E.J. Lipke	A2-34
	J.E. Meacham	S7-14
	D.A. Reynolds	R2-11
	R.J. Van Vleet	A3-34

No. of Copies		
18	**Pacific Northwest Laboratory**	
	J.W. Brothers	K9-20
	P.M. Daling	K8-07
	R.T. Hallen	P8-38
	P.G. Heasler (3)	K5-12
	V.L. Hunter	K7-97
	F.M. Ryan	K5-12
	J.J. Toth	K7-94
	P.D. Whitney	K5-12
	M.D. Zentner	K8-37
	Information Release Office (7)	K1-06