RAI Volume 2, Chapter 2.1.1.3, Second Set, Number 3:

> Provide the technical basis for the scoring methodology and individual point scores used to develop the ignition source frequencies.
>
> SAR Section 1.7.1.2.2, Event Sequences Initiated by Fire Events, and Attachment F Fire Analysis of BSC (2008b) discuss the methodology used to quantify ignition frequencies from different sources in different rooms of a facility. DOE assigned a score to a particular equipment type to estimate the ignition frequency. For each type of equipment, a score has been assigned by weighting the individual ignition frequency by "either the actual count of sources, a weighted point score of sources, or, for the case of no equipment involved, the total floor area of the facility" (BSC, 2008b, Section F5.3 Ignition Source Frequency). The method for assigning weights to each equipment category differs based on the piece of equipment, but has not been justified. For example, internal combustion engines are given a score of 100 whereas electrical motors are given a score of 1 only if it is over 5 hp. On the contrary, welding units are given a score of 1 per hour of use. No consideration for the duration through which the motor would be running has been given.

1. RESPONSE

1.1 INTRODUCTION

The quantification of fire initiating event frequency involves three steps. First, the overall frequency of fire ignition for the facility is determined. Second, the facility frequency is allocated to the individual room in the facility based on the number and types of ignition sources in the rooms. Third, propagation probabilities are applied to determine the overall frequency of a fire that reaches beyond its ignition area. This RAI response addresses the second step of the process.

The second step (facility room allocation) of the three-step process is broken down into five subparts:

2a) Identify the fire ignition sources present in the room, and assign them to the appropriate fire ignition source categories,

2b) Obtain the total category population for a facility by adding the equipment unit score for each room, organized by ignition source category,

2c) Obtain the fire frequency per unit of equipment within each of the ignition source categories by dividing the facility fire frequency per ignition source category by the category facility population obtained in step 2b,

2d) For each ignition source category within the room, multiply the equipment unit count for the category by the equipment unit fire frequency calculated for that category, 2e) Add all fire ignition source category fire frequencies within that room to obtain the room fire frequency.

The methodology for determining the fire frequency depends on the type of ignition source. Table 1 shows the equipment type and scoring methodology applied to that equipment. More detail on the counting methodology and justification for that methodology is provided in the response to RAI 2.2.1.1.3-2-001.

Table 1. Ignition Source Category Scoring

Ignition Source Category	Scoring Method
Torches, welders, burners	Operational time
Electrical	Count
HVAC	Count
Heat generating	Count
Office/kitchen	Count
Portable	Count
Mechanical	Count, residence fraction
Internal combustion engines	Count-percent, residence fraction
No equipment involved	Floor area

1.2 TORCHES, WELDERS, AND BURNERS FIRE FREQUENCIES

The fire frequencies for the ignition source category "Torches, welders, and burners" are based on the expected operational time within each room, which is consistent with NUREG/CR-6850, *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities* (EPRI and NRC 2005, Section 6.5.7.2), concerning maintenance activities. Welding operations are the only contributors to this category at the repository. Welding receptacles are provided in various areas of the facility for the purpose of occasional welding. The welding receptacles are provided for convenience and are not expected to see significant use. Use of each receptacle is estimated to be 5 hours per year and each is assigned a score of 5 points. The primary maintenance welding station and the waste package closure system weld end effectors are assigned scores of 400 points and 1,011 points, respectively, based on estimated utilization in *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008, Section F5.4.5).

Fire ignition frequencies are determined in the Excel spreadsheet, "CRCF Fire Frequency – No Suppression jwm.xls," included in Attachment H to the categorization analysis (BSC 2008). As an example, in the worksheet "Room Ignition Frequency", Room 1027 of the Canister Receipt and Closure Facility (CRCF) has a portable welding receptacle. Thus, the score for welders for Room 1027 is five points (step 2a). Performing this step for every CRCF room and adding the individual room scores results in a total of 1,446 welding points in the CRCF (step 2b). [Note that, in the categorization analysis (BSC 2008), Table F5.4-1 and Table F5.5-1 show example source population and ignition frequency spreadsheets. The final spreadsheets and values are contained in the Attachment H Excel file. The Attachment H values were used in the final fire hazards analysis.]

The overall CRCF facility fire frequency is 3.7 events over a 50-year period (BSC 2008, Table F5.2-1). The ignition frequency category fraction for welding is 0.219 (BSC 2008, Table F5.3-1). Thus, the fire frequency per equipment unit within the welding category is:

$$(3.7 \text{ events over a 50-year period} \times 0.219)/1{,}446 \text{ points} = 5.6 \times 10^{-4} \text{ /point (step 2c).}$$

To obtain the fire frequency for the welding category within each room, the results from steps 2a and 2c are multiplied together. For Room 1027:

$$5 \text{ points} \times 5.6 \times 10^{-4}\text{/point} = 2.8 \times 10^{-3} \text{ events over a 50-year period (step 2d).}$$

1.3 ELECTRICAL, HVAC, HEAT GENERATING, OFFICE, AND PORTABLE EQUIPMENT FIRE FREQUENCIES

For the majority of the source categories, fire frequencies are determined by the number of pieces of equipment (counts). Scores in each room are determined consistent with the counting guidance in NUREG/CR-6850 (EPRI and NRC 2005, Sections 6.3.2 and 6.5.6) (e.g., all motors over 5 hp are counted as one each, without regard to usage level). For example, CRCF Room 1008 has two units identified in the "HVAC" category; therefore, the room score for the HVAC category is two (step 2a). The remaining steps 2b through 2d are similar to the welding example.

1.4 MECHANICAL EQUIPMENT AND INTERNAL COMBUSTION ENGINES FIRE FREQUENCIES

When a single piece of mechanical equipment or an internal combustion engine is used in more than one room, a fractional time of residence in each room (called a residence fraction) is applied in order to apportion the equipment count among rooms. This approach is also consistent with the guidance of NUREG/CR-6850 (EPRI and NRC 2005, Section 6.5.7.2) concerning occupancy. The residence fraction for "mechanical" category has fractional counts, while the "internal combustion engines" category uses percentages (BSC 2008, Table F5.5-1).

The "mechanical" category equipment counts are based on fractions rather than percentages and, therefore, normalization is not used. As such, there are 68 pieces of mechanical equipment with several fractions of counts in Table F5.5-1 of the categorization analysis (BSC 2008).

The "internal combustion engines" category uses percentages of the operation time spent in different rooms and normalization is used to facilitate partitioning between rooms. For example, there are two transporters (e.g., the site transporter and the site prime mover) that utilize internal combustion engines in the CRCF, which provide the entire contribution to the internal combustion engines category. In order to facilitate the partitioning of the equipment units that share operational time between rooms, those equipment units are each assigned 100 normalized units of occupancy to avoid dealing with fractions when converting residence percentages.

Because there are two equipment units moving between two rooms, there are a total of 200 normalized units for this category.

The site transporter occupies Rooms 1027 and 1026 and its residence percentages in each room are shown in Table F5.4-1 of the categorization analysis (BSC 2008). For Room 1027, the site transporter has a residence percentage of 10%. For Room 1026, the site transporter has a residence percentage of 90%.

Therefore, for Room 1027, the fire frequency for the "internal combustion engines" category is:

$$10\% \text{ residence percentage} \times 100 \text{ normalized units} = 10 \text{ normalized units}$$

for the normalized units, as shown in Table F5.4-1 of the categorization analysis (BSC 2008) (step 2a).

There are a total of two equipment units (one site prime mover and one site transporter in the CRCF rooms), equal to 200 normalized units (step 2b). The overall CRCF facility fire frequency is 3.7 events over a 50-year period (BSC 2008, Table F5.2-1). The ignition frequency category fraction for internal combustion engines is 0.021 (BSC 2008, Table F5.3-1). Thus, the fire frequency per normalized unit within the internal combustion engines category is:

$$(3.7 \text{ events over a 50-year period} \times 0.021)/200 \text{ normalized units} = 3.9 \times 10^{-4} \text{ /normalized unit}$$
(step 2c).

To obtain the fire frequency for the internal combustion engine category within each room, the results from steps 2a and 2c are multiplied together. For Room 1027:

$$10 \text{ normalized units} \times 3.9 \times 10^{-4}\text{/normalized unit} = 3.9 \times 10^{-3} \text{ events over a 50-year period}$$
(step 2d).

The constant of 100 normalized units per equipment unit cancels out when calculating the fire frequency.

1.5 NO EQUIPMENT INVOLVED FIRE FREQUENCY

Because there are no attributed ignition sources in the "no equipment involved" category, the fire frequency is determined by floor area. The fire frequency is calculated as the room floor area divided by the facility floor area (i.e., the total of all the room floor areas). For example, Room 1027 has a floor area of 342 m^2 and the CRCF floor area is 19,611 m^2. The overall CRCF facility fire frequency is 3.7 events over a 50-year period (BSC 2008, Table F5.2-1). The ignition frequency category fraction for "no equipment involved" is 0.134 (BSC 2008, Table F5.3-1). The "no equipment involved" category fire frequency for Room 1027 is:

$$(342 \text{ m}^2 \times 3.7 \times 0.134)/ 19{,}611 \text{ m}^2 = 8.6 \times 10^{-3} \text{ events over a 50-year period (step 2d).}$$

1.6 SUMMARY

The fire ignition source category fire frequencies within each room are summed to obtain the room fire frequency (step 2e). The sum of all room fire frequencies of the same ignition source category equals the facility fire frequency assigned to the ignition source category.

This response provides additional details on the technical basis of the scoring methodology. It shows that the normalization constant and other modification factors, also expressed as "scores" in the analysis, are cancelled out in the calculation of the fire frequency; therefore, the normalization constant and other modification factors do not bias the calculation.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080311.0031.

EPRI (Electric Power Research Institute) and NRC (Nuclear Regulatory Commission) 2005. *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities*. Volume 2. EPRI TR-1011989 and NUREG/CR-6850. Palo Alto, California: Electric Power Research Institute. ACC: MOL.20070323.0062.

RAI Volume 2, Chapter 2.1.1.3, Second Set, Number 6:

Verify that the derivation of the overall initiating event probabilities accounts for all large fire initiating event probabilities outlined in Attachment H ("CRCF Fire Frequency – No Suppression jwm.xls") of BSC (2008b). Although the reference is to the Canister Receipt and Closure Facility, the same equation was used for the other facilities of the repository.

The "Initiating Event Frequency" sheet of, "CRCF Fire Frequency – No Suppression jwm.xls" describes 19 large-fire initiating events for the CRCF. These events provide initiating event frequencies per waste form and for different locations within the CRCF. Review of the probabilities given in Column D of the "Crystal Ball Results" sheet of "CRCF Fire Frequency – No Suppression jwm.xls" indicates that the probabilities found in Cells K205 to K223 on the "Initiating Event Frequency" sheet are inconsistently applied. For example, Cell K215, "Large Fire Threatens HLW and DOE-SNF in WP" and Cell K222, "Large Fire Threatens DPC (VTC) in CTM" are omitted from the calculations on the "Crystal Ball Results" sheet. Similarly, "Large Fire Threatens TC/DOE SNF (Diesel Present)," "Large Fire Threatens TC/DOE SNF (No Diesel)," and "Large Fire Threatens DOE SNF-MCO in CTM (per canister)" are counted in two cumulative probabilities. No explanation has been provided.

1. RESPONSE

This RAI response provides an explanation of the connection between the large fire initiating event frequencies and the large fire basic events input to System Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE), and shows that the overall initiating event frequencies account for all large fires identified in Attachment H of each waste handling facility analysis, for example *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008). Tables 1 through 5 serve as roadmaps from the large fire initiating event frequencies, as presented in Attachment H, to the basic events input to SAPHIRE. An explanation for specific instances of large fire initiating event frequencies that do not appear to have been included in the SAPHIRE model or were included in the development of more than one basic event is also provided. Furthermore, this response discusses how the initiating event frequencies specifically identified in this RAI were utilized in the development of large fire basic event sequences.

The large fire initiating event frequencies calculated in "CRCF Fire Frequency – No Suppression jwm.xls" were specified, in some cases, in more detail than needed for use in the SAPHIRE models. Such combinations are shown at the bottom of the "Crystal Ball Results" sheet of "CRCF Fire Frequency – No Suppression jwm.xls." (The methodology for calculating these combinations is further discussed in the response to RAI 2.2.1.1.3-2-010). The bottom portion of this sheet is for combinations only, and thus, not all fire initiating event frequencies are listed there.

Other fire initiating event frequencies presented in the “Initiating Event Frequency” worksheet of “CRCF Fire Frequency – No Suppression jwm.xls” are directly input into the facility SAPHIRE model, and thus they are not listed among the combinations.

The combinations shown in the “Crystal Ball Results” tab were preliminary in nature and used to illustrate the method of combination; they do not represent all of the combinations used in the facility SAPHIRE model. A complete mapping of fire initiating event frequencies used in the SAPHIRE model, whether or not in combination, is provided in Tables 1 through 5. In Table 1, all large fire initiating event frequency names are provided (as listed in the “Fire Frequency – No Suppression” spreadsheets for each facility), and an index number is assigned to each, which is used in Tables 2 through 5. Tables 2 through 5 provide the combinatorial method for each initiating event frequency in each waste handling facility used in the SAPHIRE model using the index numbers in Table 1.

The RAI specifically notes two fire initiating event frequencies that were omitted from the combinations listed at the bottom of the “Crystal Ball Results” tab of “CRCF Fire Frequency – No Suppression jwm.xls.” They are:

- Large Fire Threatens HLW and DOE-SNF in WP – Table 1, Index C11
- Large Fire Threatens DPC (VTC) in CTM – Table 1, Index C18.

Fire initiating event frequency “Large Fire Threatens HLW and DOE-SNF in WP” was not included in the “Crystal Ball Results” tab because that portion of the spreadsheet addresses only frequencies that were combined. This frequency was input directly into SAPHIRE for the basic events 060-H&D-LARGE-FIRE and 060-H&M-LARGE-FIRE, as shown in Table 2. This direct input is shown in Table 6.3-10 of the *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008).

The other event specifically identified in the RAI as being omitted from the summations, “Large Fire Threatens DPC (VTC) in CTM” (Index number C18 of Table 1), was included in the combination with Table 1, Index numbers C16, C17, and C19; as a contribution to basic event 060-DPC-LARGE-FIRE, as shown in Table 2.

Basic event 060-DPC-LARGE-FIRE is one of the combination frequencies that reflects preliminary information in the “Crystal Ball Results” sheet of “CRCF Fire Frequency – No Suppression jwm.xls,” however, the large fire initiating events (listed in Table 1) are appropriately used in the correct combinations to determine the fire initiating events (shown in Tables 2 through 5).

The RAI notes the following examples of large fire initiating event frequencies that were counted in two separate combinations (cumulative probabilities) and used as input to the Canister Receipt and Closure Facility (CRCF) SAPHIRE model without explanation:

- Large Fire Threatens TC/DOE SNF (Diesel Present) – Table 1, Index C12
- Large Fire Threatens TC/DOE SNF (No Diesel) – Table 1, Index C13

- Large Fire Threatens DOE SNF in CTM (per canister) – Table 1, Index C14 (DOE SNF also represented as MCO).

As can be seen in Table 2, in addition to the examples noted in the RAI, the large fire initiating event frequencies listed below are also used in two separate combinations for input into the CRCF SAPHIRE model:

- Large Fire Threatens DOE SNF in Staging Area – Table 1, Index C15
- Large Fire Threatens HLW and DOE SNF in WP – Table 1, Index C11.

Although the forms of DOE spent nuclear fuel (SNF) are not accounted for in the fire ignition frequency analysis, it was noted that multicanister overpacks (MCOs) specifically contain DOE SNF from the Hanford site. Because of this relationship, basic events considered DOE SNF twice: as DOE SNF and as MCOs. Thus, the sum of the first four large fire frequencies (Table 1, Index numbers C12 through C15) represents the large fire initiating events separately affecting DOE SNF or MCO waste forms (060-MCO-LARGE-FIRE and 060-DSNF-LARGE-FIRE, as shown in Table 2). The last frequency listed above (Index C11) is represented twice in SAPHIRE as “H&M” (high level waste (HLW) and MCO) and “H&D” (HLW and DOE SNF). This is necessary because either HLW and MCO or DOE SNF and HLW may be contained in the same container. The resultant initiating event frequencies were weighted using the expected quantities of each waste form (DOE SNF versus MCOs) within the facility SAPHIRE model.

As can be seen in Table 4, the large fire initiating event frequencies listed below are also used in two separate summations for input into the Receipt Facility (RF) SAPHIRE model:

- Large Fire Threatens TC/TAD or TC/DPC (TTC & VTC) (Diesel) – Table 1, Index R1
- Large Fire Threatens TAD or DPC (TTC & VTC) in CTM – Table 1, Index R3
- Large Fire Threatens TAD or DPC (TTC & VTC) in AO (Diesel) – Table 1, Index R4.

For the RF, the parameters used to calculate the fire initiating event frequencies were exactly the same for the transportation, aging, and disposal (TAD) canister and dual-purpose canister (DPC) waste forms. Thus, rather than display identical calculations twice, these events were named appropriately (using an “or”) to indicate that the frequency is the same for each waste form. Thus, it is appropriate and necessary to use these large fire events for both the TAD canister and DPC waste forms.

In conclusion, the large fire initiating event frequencies identified in Attachment H of the waste handling facility analyses are correctly mapped to the large fire basic events input used in the SAPHIRE models. The overall initiating event frequencies account for all large fires identified in Attachment H of the waste handling facility analyses, and certain large fire initiating event frequencies are used in the development of more than one basic event.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080311.0031.

Table 1 – Large Fire Initiating Event Frequency Names

Facility	Waste Form/Location	Index
CRCF	Large Fire Threatens TC/TAD (Diesel Present)	C1
CRCF	Large Fire Threatens TC/TAD (No Diesel)	C2
CRCF	Large Fire Threatens TAD in AO (Diesel Present)	C3
CRCF	Large Fire Threatens TAD in CTM	C4
CRCF	Large Fire Threatens TAD in WP in WPTT	C5
CRCF	Large Fire Threatens TAD in WP in TEV	C6
CRCF	Large Fire Threatens TC/HLW (Diesel Present)	C7
CRCF	Large Fire Threatens TC/HLW (No Diesel)	C8
CRCF	Large Fire Threatens HLW in CTM (per individual canister)	C9
CRCF	Large Fire Threatens HLW in WP	C10
CRCF	Large Fire Threatens HLW and DOE SNF in WP	C11
CRCF	Large Fire Threatens TC/DOE SNF (Diesel Present)	C12
CRCF	Large Fire Threatens TC/DOE SNF (No Diesel)	C13
CRCF	Large Fire Threatens DOE SNF in CTM (per canister)	C14
CRCF	Large Fire Threatens DOE SNF in Staging Area[1]	C15
CRCF	Large Fire Threatens TC/DPC (VTC) (Diesel)	C16
CRCF	Large Fire Threatens TC/DPC (VTC) (No Diesel)	C17
CRCF	Large Fire Threatens DPC (VTC) in CTM	C18
CRCF	Large Fire Threatens DPC (VTC) in AO (Diesel)	C19
IHF	Large Fire Threatens TC/NSNF (Diesel)	I1
IHF	Large Fire Threatens TC/NSNF (No Diesel)	I2
IHF	Large Fire Threatens NSNF in CTM	I3
IHF	Large Fire Threatens NSNF in WP	I4
IHF	Large Fire Threatens TC/HLW (Diesel)	I5
IHF	Large Fire Threatens TC/HLW (No Diesel)	I6
IHF	Large Fire Threatens HLW in CTM	I7
IHF	Large Fire Threatens HLW in WP	I8
RF	Large Fire Threatens TC/TAD or TC/DPC (TTC & VTC) (Diesel)	R1
RF	Large Fire Threatens TC/TAD (No Diesel)	R2
RF	Large Fire Threatens TAD or DPC (TTC & VTC) in CTM	R3
RF	Large Fire Threatens TAD or DPC (TTC & VTC) in AO (Diesel)	R4
RF	Large Fire Threatens TC/DPC (TTC) (No Diesel)	R5
RF	Large Fire Threatens TC/DPC (VTC) (No Diesel)	R6
RF	Large Fire Threatens TC/DPC (HTC) (Diesel)	R7
RF	Large Fire Threatens TC/DPC (HTC) (No Diesel)	R8
WHF	Large Fire Threatens TC/SNF or TC/DPC (all) (Diesel Present)	W1
WHF	Large Fire Threatens TC/SNF (No Diesel)	W2

Table 1 – Large Fire Initiating Event Frequency Names (Continued)

Facility	Waste Form/Location	Index
WHF	Large Fire Threatens TC/DPC (TTC) (No Diesel)	W3
WHF	Large Fire Threatens TC/DPC (No Diesel)	W4
WHF	Large Fire Threatens DPC (all) in CTM	W5
WHF	Large Fire Threatens STC/DPC (all)	W6
WHF	Large Fire Threatens STC/DPC (all) (Dry Cavity, Wet Annulus)	W7
WHF	Large Fire Threatens STC/DPC (all) (Wet Cavity, Wet Annulus)	W8
WHF	Large Fire Threatens TC/SNF (Wet Cavity)	W9
WHF	Large Fire Threatens STC/TAD (Wet Cavity, Wet Annulus)	W10
WHF	Large Fire Threatens STC/TAD (Dry Cavity, Wet Annulus)	W11
WHF	Large Fire Threatens STC/TAD (Dry Cavity, Dry Annulus)	W12
WHF	Large Fire Threatens TAD in CTM	W13
WHF	Large Fire Threatens TAD in AO	W14

NOTE: [1]Since no time restriction exists for staging, the frequency was divided by the number of DOE Standardized canisters handled in the CRCF (3,300 canisters).

Table 2 – Canister Receipt and Closure Facility (CRCF) Fire Initiating Events

Event Name	Contributing Fire Events	Mean	Error Factor
060-TAD-LARGE-FIRE	=SUM(C1:C6)	8.8×10^{-5}	2.1
060-HLW-LARGE-FIRE	=SUM(C7:C10)	2.9×10^{-5}	2.2
060-H&D- LARGE-FIRE	=C11	6.1×10^{-5}	2.2
060-H&M-LARGE-FIRE	=C11	6.1×10^{-5}	2.2
060-MCO-LARGE-FIRE	=SUM(C12:C15)	1.96×10^{-4}	2.1
060-DSNF-LARGE-FIRE	=SUM(C12:C15)	1.96×10^{-4}	2.1
060-DPC-LARGE-FIRE	=SUM(C16:C19)	2.7×10^{-5}	2.0

Table 3 – Initial Handling Facility (IHF) Fire Initiating Events

Event Name	Contributing Fire Events	Mean	Error Factor
51A-HLW-LG-FIRE	=SUM(I1:I4)	1.1×10^{-4}	2.2
51A-NVL-LARGE-FIRE	=SUM(I5:I8)	6.9×10^{-5}	2.2

Table 4 – Receipt Facility (RF) Fire Initiating Events

Event Name	Contributing Fire Events	Mean	Error Factor
ESD12-DPC-IN-LG-FIRE	=R1+SUM(R3:R8)	4.8×10^{-5}	2.2
ESD12-TAD-IN-LG-FIRE	=SUM(R1:R4)	1.9×10^{-5}	2.2

Table 5 – Wet Handling Facility (WHF) Fire Initiating Events

Event Name	Contributing Fire Events	Mean	Error Factor
050-FIRE-LARGE-CSNF	=W1+W2+W9	1.1×10^{-5}	2.3
050-FIRE-DPC-LARGE	=SUM(W3:W8)	1.0×10^{-4}	2.3
050-FIRE-TAD-LARGE	=SUM(W10:W14)	6.7×10^{-5}	2.3

RAI Volume 2, Chapter 2.1.1.3, Second Set, Number 7:

(a) Justify using data for Chemical, Plastic, or Petroleum Production Facilities or Industrial Chemical, Hazardous Chemical, and Plastic Facilities to estimate frequencies of fire related initiating events at the repository (BSC, 2008j). DOE has assumed that the intra-site operations at the repository are similar to Chemical, Plastic, or Petroleum Production Facilities, or, to Industrial Chemical, Hazardous Chemical, and Plastic Facilities, without any justification. Since none of these facilities handle any nuclear materials, justification is necessary to establish the appropriateness of these databases for estimating the ignition frequency of the intra-site operations.

(b) Explain the applicability of the two databases and resulting uncertainties used to estimate the frequency of initiating events at the intra-site facilities. Neither database deals with facilities handling nuclear materials. DOE used the National Fire Protection Association (NFPA) database for Chemical, Plastic, or Petroleum Products. As responses to NFPA query seeking information for this database are voluntary, NFPA adjusts the database to account for the uncertainty. The other database used is the Census Bureau database for 1997, also for Petroleum and Coal Products manufacturing, Chemical Manufacturing, and Plastic Product Manufacturing, but these two databases do not deal with exactly the same population. Consequently, as the census database is used as the denominator to estimate the ignition frequency, it is expected that it will result in a low estimate of facilities manufacturing chemical, plastic, and petroleum products. Although in Section F5.2.4 Uncertainty, BSC (2008b) has acknowledged the quality of these databases and arbitrarily added a large uncertainty associated with estimation (error factor = 15), the appropriateness of the estimated mean ignition frequency is not established. The categorization based on the frequency of occurrence is conducted at the mean level.

(c) Provide the calculations used to estimate the fire-related initiating event frequencies, provided in BSC (2008j). In BSC (2008j) (Attachment F) DOE has calculated the annual frequency of potentially significant outside fire using census data of 1997 (codes 324, 325, and 3261) of chemical, plastic, or petroleum production facilities in the country; however, the full calculation is not provided.

1. RESPONSE

This response justifies the type of data and the two databases used to estimate fire initiating event frequencies in *Intra-Site Operations and BOP Reliability and Event Sequence Development* Analysis (BSC 2008). The intra-site operations for the waste handling facilities are similar enough to chemical, plastic, and petroleum facilities that there is not significant variability in overall fire ignition frequencies. Census data from these facilities has been conservatively adjusted and used in the calculation of fire-initiating events for intra-site operations at the repository.

1.1 JUSTIFICATION FOR USING DATA FOR CHEMICAL, PLASTIC, OR PETROLEUM OR OTHER PRODUCTION FACILITIES TO ESTIMATE FREQUENCIES OF FIRE-RELATED INITIATING EVENTS

The fire data used in the preclosure fire hazards analysis were obtained from *Fires in or at Industrial Chemical, Hazardous Chemical and Plastic Manufacturing Facilities, 1988–1997 Unallocated Annual Averages and Narratives* (Ahrens 2000), *1997 Economic Census: Summary Statistics for the United States NAICS Basis* (U.S. Census Bureau 2000), and "Re: NFPA Correspondence" (Amico 2007), as stated in Section F4.3 of *Intra-Site Operations and BOP Reliability and Event Sequence Development Analysis* (BSC 2008). These data are used to develop estimates for the annual frequency of outside fires (fires external to the waste handling buildings) within the geologic repository operations area.

The data used in the preclosure fire hazards analysis apply to, and are used only for, ignition frequency, not for the characteristics of the fire that results from the ignition. The analysis is conservatively conducted without reliance on fire suppression. Just as all industrial facilities have the same general types of ignition sources with essentially the same ignition characteristics inside the facility, regardless of the function of the facility (see the response to RAI 2.2.1.1.3-2-002), the same type of ignition sources with essentially the same ignition characteristics potentially exist outside of industrial facilities. For outside fires (fires within the geologic repository operations area and external to the waste handling facilities), the types of ignition sources do not significantly vary from industrial facilities as delineated in the following:

- An industrial facility either has or does not have surrounding wooded areas, grassy areas, or shrubbery that can potentially ignite.

- Industrial facilities require delivery of materials. Conveyances used to accomplish this function could potentially include the use of rail, heavy trucks, and light trucks.

- Industrial facilities may use on-site transportation to move materials around the site. This task is potentially accomplished through use of combinations of both internal combustion engine-powered and electric-powered vehicles.

- Industrial facilities have on-site electric power distribution.

- Industrial facilities potentially have support equipment located outside the buildings proper, including equipment required for heating, ventilation, and air conditioning, water supply, etc.

Because the fire hazards analysis used these data for ignition frequency only, the type of material being handled by the facility is not a significant factor. However, the type of material being handled is an important factor in the type and severity of the fire, which is treated within the event sequence analysis but is not part of the ignition frequency analysis.

The similarity of ignition frequencies across categories and subcategories of industrial chemical, hazardous chemical, and plastics manufacturing facilities has been demonstrated in *Chemical Agent Disposal Facility Fire Hazard Assessment Methodology* (SAIC 2002, pp. 3-1 and 3-2), which shows that outside fire frequency is insensitive to the facility subcategory considered.

According to National Fire Protection Agency (NFPA) data (Amico 2007), there are approximately 287 outside fires involving property of value annually at chemical, plastics and petroleum facilities in the United States. Given that there are 29,303 chemical, plastics, and petroleum facilities in the United States (U.S. Census Bureau 2000), the frequency of potentially significant fires in these facilities is:

$$F = \frac{287\ fires/yr}{\left(29303\ \ facilities \times\ 8760\, hrs/yr\right)} = 1 \times 10^{-6}\ \ fires/facility\text{ - }hr$$

As with structure fires, the analysis was refined further, using subcategories within the classification systems to determine whether a particular subcategory of chemical, plastics, or petroleum facilities would be more representative of a chemical agent disposal facility. According to NFPA data, each year there are approximately 62 outside fires involving property of value in the subcategory "Industrial Chemical, Hazardous Chemical, and Plastics facilities." According to the *1997 Economic Census*, the total number of facilities in the corresponding subcategories is 5,870. Therefore, the frequency of potentially significant fires in these facilities is:

$$F = \frac{62\ fires/yr}{\left(5870\ facilities \times 8760\ hrs/yr\right)} \cong 1 \times 10^{-6}\ \ fires/facility\text{ - }hr$$

The two estimates of the outside fire frequency are virtually the same. Therefore, the use of a total mean outside fire frequency of 1×10^{-6} fires per facility per hour for a chemical disposal facility is deemed to be appropriate.

Similar calculations were performed for the occurrence of an outside chemical spill followed by a fire. Using the full population of chemical, plastics, and petroleum facilities, there are approximately 81 fires that accompany outside spills in such facilities annually. Therefore, the frequency of such fires in these facilities is:

$$F = \frac{81\ fires/yr}{\left(29303\ facilities \times 8760\ hrs/yr\right)} \cong 3 \times 10^{-7}\ \ fires/facility\text{ - }hr$$

Refining this estimate further, each year there are approximately 18 fires that accompany outside spills in the subcategory "Industrial Chemical, Hazardous Chemical, and Plastics facilities." Therefore, the frequency of such fires in these facilities is:

$$F = \frac{18\ fires/yr}{\left(5870\ facilities \times 8760\ hrs/yr\right)} \cong 4 \times 10^{-7}\ \ fires/facility\text{ - }hr$$

Thus, the variation in total outside fire frequency is approximately a factor of three across all subcategories. This variation is treated adequately in the consideration of parameter uncertainty in the uncertainty analysis.

In summary, the foregoing analysis shows that differences across process facilities do not cause a significant variation in ignition frequencies. The nature of operations and ignition sources outside of the waste handling buildings at the repository is similar to those at chemical, plastic, and petroleum product facilities. Therefore, the type of industrial facility is not a significant variable in overall fire ignition frequencies, and the outside fire ignition frequencies for industrial chemical, hazardous chemical, and plastic facilities are appropriate for the estimation of the ignition frequency of outside fires at the repository.

1.2 RESPONSE ON APPLICABILITY OF THE TWO DATABASES AND RESULTING UNCERTAINTIES USED

The applicability of the databases to facilities handling nuclear materials is addressed in the response to part (a) of this RAI.

As noted in the RAI, the combination of the two databases involves an element of uncertainty, such as the potential for a mismatch between the facility categorizations used in the two databases. Therefore, in determining the denominator to be used in the fire frequency calculation, economic census categories that matched, as closely as possible, the NFPA categories were selected.

As is noted in Section F5.2.4 of *Intra-Site Operations and BOP Reliability and Event Sequence Development Analysis* (BSC 2008), there is a possibility that the census data underestimates the number of facilities, thereby causing the fire ignition frequency to be overestimated. This conservative bias in the analysis was treated in an approximate way by assigning the calculated frequency to the mean of the lognormal distribution rather than to the median of the distribution. Given an error factor of 15, the mean value is greater than the corresponding median by a factor of 3.9. Thus, the probability distribution used in the analysis simulates a high probability (nearly 80%) that the calculated frequency conservatively overestimates the actual frequency. As the RAI notes, because the mean value is used as the basis for categorization, this conservative estimate is included in the event sequence frequency and categorization.

1.3 CALCULATIONS USED TO ESTIMATE THE FIRE-RELATED INITIATING EVENT FREQUENCIES

The description of how outside fire-related initiating event distributions have been determined is found in Sections F4 and F5 of *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis* (BSC 2008). There are three initiating outside fire events identified for intrasite operations:

1) A fire event during onsite transport (site transporter, cask tractor/cask transfer trailer, or site prime mover) occurring in the transporter (vehicle) area.

2) A fire event in the buffer (receiving) area.

3) A fire event on the aging pad (storage) area.

The number of fire events in each area *j* (*j* equals 1-Transporter, 2-Buffer, 3-Aging, and 4-Other) over the preclosure period, n_j, is calculated such that,

$$n_j = \left(\frac{N_j}{\sum N_j} \right) \cdot S \cdot T \cdot F$$

The outside area occurrence counts, N_j, are based on values in the event sequence development analysis (BSC 2008, Table F4.3-2; Ahrens 2000, Section 5). The count value for N_1 equals 16 (i.e., the number of fires in the vehicles area). The count value for N_2 equals 57 (i.e., the number of fires in the receiving area). The count value for N_3 equals 125 (i.e., the number of fires in the storage area). The count value for N_4 equals 425, which is the number of fires in all the other areas (trash/rubbish—84, equipment—121, open—84, and other—136). The sum of the outside area occurrence counts, $\sum N_j$, equals 623. The intrasite facility count, *S*, is six, the number of waste handling buildings: one each of the Initial Handling Facility, the Receipt Facility, and the Wet Handling Facility, and three Canister Receipt and Closure Facilities. The length of the preclosure period, *T*, is fifty years. The outside fire annual frequency per facility, *F*, is considered lognormal with a mean of 1×10^{-2} and an error factor of 15 (BSC 2008). This is calculated from data from the *1997 Economic Census: Summary Statistics for the United States NAICS Basis* (U.S. Census Bureau 2000), and “Re: NFPA Correspondence” (Amico 2007); the NFPA data provide an average of 62 outside fires in the “Industrial Chemical, Hazardous Chemical, and Plastics facilities” category, and the North American Industry Classification System data provide a total number of 5,870 such facilities. Rounded, the number of outside fires divided by the number of facilities produces 1×10^{-2}. In this calculation the occurrence counts, the facility count, and the preclosure period length are all considered constants.

The occurrence fraction is treated as a constant by using mean values, but the overall large variability from the outside fire annual frequency per facility (with an error factor of 15) provides adequate treatment of uncertainties.

The mean number of fire events over the preclosure period is calculated as:

$$E(n_j) = \left(\frac{N_j}{\sum N_j} \right) \cdot S \cdot T \cdot E(F)$$

where $\mathrm{E}(x)$ denotes the expected value of *x*.

$$E(n_1) = \left(\frac{16}{623}\right) \cdot [6\ facility] \cdot [50\ yr] \cdot \left[0.01 \frac{1}{yr \cdot facility}\right] = 7.7 \times 10^{-2}$$

$$E(n_2) = \left(\frac{57}{623}\right) \cdot [6\ facility] \cdot [50\ yr] \cdot \left[0.01 \frac{1}{yr \cdot facility}\right] = 2.7 \times 10^{-1}$$

$$E(n_3) = \left(\frac{125}{623}\right) \cdot [6\ facility] \cdot [50\ yr] \cdot \left[0.01 \frac{1}{yr \cdot facility}\right] = 6.0 \times 10^{-1}$$

Therefore, the distribution for the number of fire events over the preclosure period in each area is lognormal with the calculated mean and an error factor of 15 (since the multiplication by a constant will not alter the error factor value).

The total number of operations of transport vehicles over the preclosure period is estimated as 80,000 operations (BSC 2008, Section 5.2.1). The mean fire event count over the preclosure period per transport operation is, therefore, E(n_1) divided by 80,000 operations (equals 9.6×10^{-7}).

Results for the three intrasite areas outside fire events (BSC 2008, Table F5.3-1) are as follows:

1) The number of fire events per operation occurring in the Transporter area over the preclosure period is lognormal with a mean of 1×10^{-6} and an error factor of 15. (Table F5.3-1 erroneously shows the mean value as 9×10^{-7}).

2) The number of fire events in the Buffer area over the preclosure period is lognormal with a mean of 3×10^{-1} and an error factor of 15.

3) The number of fire events on the aging pad area over the preclosure period is lognormal with a mean of 6×10^{-1} and an error factor of 15.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

Ahrens, M. 2000. *Fires in or at Industrial Chemical, Hazardous Chemical and Plastic Manufacturing Facilities, 1988-1997 Unallocated Annual Averages and Narratives*. Quincy, Massachusetts: National Fire Protection Association. TIC: 259997.

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BSC (Bechtel SAIC Company) 2008. *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0032.

SAIC (Science Applications International Corporation) 2002. *Chemical Agent Disposal Facility Fire Hazard Assessment Methodology*. SAIC-01/2650. Abingdon, Maryland: Science Applications International Corporation. ACC: MOL.20080115.0138.

U.S. Census Bureau 2000. "Manufacturing United States." *1997 Economic Census: Summary Statistics for the United States*. Washington, D.C.: U.S. Census Bureau. Accessed March 7, 2008. ACC: MOL.20080310.0082. URL: http://www.census.gov/epcd/ec97/ustotals.htm.

RAI Volume 2, Chapter 2.1.1.3, Second Set, Number 10:

(a) Explain how the statistical distribution was determined for a basic event, shown in Table 6.3-10 of BSC (2008b), which was input to the SAPHIRE model.

(b) Explain the rationale behind the selected statistical distribution of ignition frequency, ignition source category, and extent of flame damage in the fire analysis.

It is not clear how the statistical distribution of a basic event with associated parameter values was determined. For example, cells E4 and E5 of Table 6.3-9 of BSC (2008b) indicate values of 1.2E−07 and 1.3E−07 for "On CTT in cask Unloading Room" and "Cask Unloading Room (diesel present)," respectively. Table 6.3-10 of BSC (2008b) indicates for basic event 060-TADAO-CUR-DIESEL that the frequency has been calculated to be 2.5E-07 by summing cells E4 and E5 of Table 6.3-9. Excel spreadsheet, "CRCF Fire Frequency – No Suppression jwm.xls," included in Attachment H to BSC (2008j), and Table 6.5-4 of BSC (2008b) show that 1.2E−07 and 1.3E−07 are the mean values of lognormal distributions and were used to develop the distribution for the basic event 060-TADAO-CUR-DIESEL. It is not clear how DOE determined the resulting distribution for this basic event would also be lognormal with a mean of 2.5E-07 and, as determined from the SAPHIRE model "CRCF Event Trees 2008-02-27 Locked.zip" included in Attachment H to BSC (2008b), an error factor of 2.3. Generally, addition of two lognormally distributed parameters would not result in a lognormally distributed parameter with mean equal to summation of two individual mean values. In addition, the Excel spreadsheet, "CRCF Fire Frequency – No Suppression jwm.xls" indicates an error factor of 2.2 for the same basic event, not 2.3 as in the SAPHIRE model. Moreover, no justification has been provided why the ignition source category and extent of flame damage would be normally distributed.

1. RESPONSE

1.1 DETERMINATION OF BASIC EVENT STATISTICAL DISTRIBUTIONS

The fire-related initiating event frequency statistical distribution for the basic event 060-TADAO-CUR-DIESEL in Table 6.3-10 of *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008) is determined from its two contributing initiating event statistical distributions, "On CTT in Cask Unloading Room" and "Cask Unloading Room (diesel Present)." The basic event 060-TADAO-CUR-DIESEL mean frequency has been calculated to be 2.5×10^{-7} by summing the mean values of 1.2×10^{-7} and 1.3×10^{-7} for "On CTT in Cask Unloading Room" and "Cask Unloading Room (diesel Present)," respectively (BSC 2008, Table 6.3-9).

As shown in Table 1, each fire initiating event frequency is a product of a lognormal distribution with multiplication and addition of one or more normal distributions and constants. Monte Carlo simulations are performed to determine the mean, standard deviation, variance, minimum, and maximum values of each of the fire initiating event frequencies using the Microsoft Excel add-on package Crystal Ball. For example, the initiating event frequency distributions for the two initiating events, "On CTT in Cask Unloading Room" and "Cask Unloading Room (diesel Present)" are determined from Monte Carlo simulations. Results of the simulations for the two initiating events are tabulated in Appendix F.VI of the event sequence analysis (BSC 2008, p. F-171 and F-150, respectively). As explained in the response to RAI 2.2.1.1.3-2-011, lognormal distributions were determined to accurately characterize the resultant distributions.

1.1.1 Basic Event Frequency Lognormal Distribution Basis

As indicated in Table 1, each initiating event frequency distribution is determined from the product and sum of distributions (e.g., *L, A, H*, and *J*) modified by the multiplication and addition of constants (c_i and *n*). Table 1 represents the formula and inputs for each ignition source category and is based on the "Initiating Event Frequency" worksheet of "CRCF Fire Frequency – No Suppression jwm.xls" (BSC 2008, Attachment H). Capitalized letters represent distributions, and subscripted lower-case letters represent constants.

Table 1. Parameters and Formulas for Derivation of Equations

	Column							Ignition Source
Ignition Source	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Frequency Formula**
Electrical	$L{\cdot}A$	c_1	c_2	H	c_3	J	n	$L{\cdot}A(c_1+Hc_2+Jc_3)n$
HVAC	$L{\cdot}B$	c_4	c_5	H	c_6	J	n	$L{\cdot}B(c_4+Hc_5+Jc_6)n$
Mechanical equipment	$L{\cdot}D$	c_7	c_8	H	c_9	J	n	$L{\cdot}D(c_7+Hc_8+Jc_9)n$
Heat generation equipment	$L{\cdot}E$	c_{10}	c_{11}	H	c_{12}	J	n	$L{\cdot}E(c_{10}+Hc_{11}+Jc_{12})n$
Torches, welders, burners	$L{\cdot}F$	c_{13}	c_{14}	H	c_{15}	J	n	$L{\cdot}F(c_{13}+Hc_{14}+Jc_{15})n$
Internal combustion engines	$L{\cdot}G$	c_{16}	c_{17}	H	c_{18}	J	n	$L{\cdot}G(c_{16}+Hc_{17}+Jc_{18})n$
Office/kitchen equipment	$L{\cdot}K$	c_{19}	c_{20}	H	c_{21}	J	n	$L{\cdot}K(c_{19}+Hc_{20}+Jc_{21})n$
Portable equipment	$L{\cdot}M$	c_{22}	c_{23}	H	c_{24}	J	n	$L{\cdot}M(c_{22}+Hc_{23}+Jc_{24})n$
No equipment involved	$L{\cdot}P$	c_{25}	c_{26}	H	c_{27}	J	n	$L{\cdot}P(c_{25}+Hc_{26}+Jc_{27})n$
Total								Sum

Note: Column contents are: 1 = ignition frequency per unit (*L*, which is lognormally distributed) times the category allocation (*A* through *P*, which is normally distributed); 2 = number at target; 3 = number near target; 4 = propagation probability to target (*H*, which is normal); 5 = number away from target; 6 = propagation probability to target (*J*, which is normal); 7 = target exposure time (fraction)

As an example, Equation 1 represents the formula used to calculate an individual electrical ignition source frequency. The residence time, *n*, in Equation 1, is a constant common to all ignition frequencies as shown in Table 1.

$$\text{individual electrical ignition source frequency} = L \cdot \{A(c_1 + Hc_2 + Jc_3)\} \cdot n \qquad \text{(Eq. 1)}$$

In general, a total fire initiating event frequency, IE_X, for initiating event *X* is a sum of more than one ignition source category. This is shown in Equation 2 for the situation in which the initiating event frequency is the sum of frequencies of three categories. The differences between each ignition source are the constants and the category allocation frequency distributions (represented by *A, B, D*, etc.).

$$IE_X = \{L \cdot \{A(c_1 + Hc_2 + Jc_3)\} + L \cdot \{B(c_4 + Hc_5 + Jc_6)\} + L \cdot \{D(c_7 + Hc_8 + Jc_9)\}\} \cdot n_X$$

(Eq. 2)

Crystal Ball calculates the combination of all these distributions. Considering that the constants by which distributions *H* and *J* are manipulated in the ignition frequency formula $(c_k + Hc_{k+1} + Jc_{k+2})$ are the only factors which change within the parentheses in Equation 2, this portion of the equation is replaced with the symbol M_k. Equation 3 is the result of this replacement in Equation 2.

$$\begin{aligned} IE_X &= \{LAM_1 + LBM_2 + LDM_3\} \cdot n_X \\ &= L \cdot \{AM_1 + BM_2 + DM_3\} \cdot n_X \end{aligned} \qquad \text{(Eq. 3)}$$

Equation 4 represents the basic event frequency used in SAPHIRE, *BE*, calculated as the sum of two fire initiating event frequencies, IE_X, and IE_Y, with three ignition sources each. Equation 5 rearranges and combines the contributions by ignition source category.

$$\begin{aligned} BE &= IE_X + IE_Y \\ BE &= L \cdot \{AM_1 + BM_2 + DM_3\} \cdot n_X + L \cdot \{AM_1 + BM_2 + DM_3\} \cdot n_Y \end{aligned} \qquad \text{(Eq. 4)}$$

$$BE = L \cdot \{AM_1 + BM_2 + DM_3\} \cdot (n_X + n_Y) \qquad \text{(Eq. 5)}$$

The combined distributions in Equation 5 illustrate that the form of a single ignition frequency for one initiating event (Equation 3) is preserved when multiple initiating event frequencies are combined for a basic fire event. The distribution is a product of a lognormal distribution, *L*, with multiplication and addition of one or more normal distributions and constants. As discussed in the response to RAI 2.2.1.1.3-2-011, the initiating event frequencies determined by Crystal Ball simulations based on Equation 3 are approximated as lognormal.

In the general case, the sum of two different lognormals is not a lognormal. However, a lognormal distribution multiplied by a constant is lognormal; and by corollary, the sum of the same lognormal multiplied by two (or more) different constants is lognormal. In the limit, where the normal distributions' variances approach zero, the terms multiplying *L* in Equation 3 would be constants. The mean would be the same for both the sum of constants and the sum of normal variants. This is why the results are well approximated as lognormal with the correct mean. Only the probability density function in the neighborhood of zero would not resemble the lognormal, which is what is shown in the response to RAI 2.2.1.1.3-2-011.

Thus, for the case of initiating event frequencies of the form of Equation 3 used in the preclosure safety analysis, the basic event distributions that are derived from Equation 5, and by extrapolation to any number of contributing fire initiating events, can be approximated as lognormal.

1.1.2 060-TADAO-CUR-DIESEL Error Factor

This RAI also identifies an inconsistency between the error factor (EF) derived from the analysis (EF = 2.2) and that entered in the SAPHIRE model (EF = 2.3) for fire initiating event frequency, "Localized fire threatens TAD in Cask Unloading Room." The correct EF is 2.2. The SAPHIRE input value of 2.3 is conservative with respect to event sequence categorization.

1.2 RATIONALE FOR STATISTICAL DISTRIBUTIONS

The response to RAI 2.2.1.1.3-2-009 shows that the annual fire ignition frequency distribution may be represented as lognormal. The response to RAI 2.2.1.1.3-2-008 provides graphical comparisons for the normal approximation to the exact binomial distributions that indicate that the probability distributions for ignition source category (ignition source) and extent of flame damage (fire extent) are well represented by the normal approximation to the binomial. Thus, the statistical distribution of ignition frequency, ignition source category, and extent of flame damage are based on reasonable and appropriate comparisons between statistical distributions and relevant data for the fire analysis.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080311.0031.

RAI Volume 2, Chapter 2.1.1.3, Second Set, Number 12: Provide the input and formulas that were used in Crystal Ball to generate the results displayed in spreadsheets, "CRCF Fire Frequency – No Suppression jwm.xls" and "CRCF CB Report.xls" included in Attachment H of BSC (2008b). Although the reference is to the Canister Receipt and Closure Facilities, the same need applies to analyses of fire-related initiating event frequencies for other facilities.

1. RESPONSE

This response explains how the inputs and formulas used in Crystal Ball are contained within the "CRCF Fire Frequency – No Suppression jwm.xls" and "CRCF CB Report.xls" files in Attachment H of *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008a). This response includes an attached spreadsheet that provides an example of how Crystal Ball is used in the analyses of fire-related initiating event frequencies.

The worksheets within "CRCF Fire Frequency – No Suppression jwm.xls" contain embedded formulas used to calculate parameters such as initiating event frequencies, shown in the "Initiating Event Frequency" tab. Crystal Ball is a Microsoft Excel add-in that allows probability distributions to be combined in a worksheet. The spreadsheet "CRCF Fire Frequency – No Suppression jwm.xls" uses such Crystal Ball input. In using the Crystal Ball software, the user supplies probability distributions for uncertain model inputs (the locations of these in the worksheets are highlighted in green in the "Total Frequency," "Ignition Source Frequency," and "Propagation Probability" tabs of the "CRCF Fire Frequency – No Suppression jwm.xls" file). However, Crystal Ball does not embed its inputs into Microsoft Excel cells and does not show the input formulas. Only a single valued number is displayed in "CRCF Fire Frequency – No Suppression jwm.xls" in cells with Crystal Ball inputs.

For the uncertainty inputs highlighted in green in the "Total Frequency," "Ignition Source Frequency," and "Propagation Probability" tabs, the user identifies the probability distributions with the proper parameters from the set of possible distributions available within Crystal Ball. These distributions are not recorded within the spreadsheet. Instead, Crystal Ball provides a report that contains the input probability distributions and the input parameters. For "CRCF Fire Frequency – No Suppression jwm.xls," the input probability distribution report is contained in the file "CRCF CB Report.xls." For example, cell H2 from the "Ignition Source Frequency" tab in "CRCF Fire Frequency – No Suppression jwm.xls" results in the distribution shown in Figure 1, which also appears in the "CRCF CB Report.xls" spreadsheet.

The normal distribution in Figure 1 is used with a mean of 0.086 and a 97.5-percentile value of 0.126, which is the input for cell H2. The shape of the distribution is illustrated in the plot. Crystal Ball uses standard formulas for the two probability distributions used in the model, normal and lognormal. The attached file "CB Input Examples.xls" is a copy of "CRCF Fire Frequency – No Suppression jwm.xls" with excerpted distribution inputs from "CRCF CB Reports.xls." This example illustrates how the Crystal Ball inputs from "CRCF CB Reports.xls" are used within the "CRCF Fire Frequency – No Suppression.xls" spreadsheet. To determine the input distributions in "CRCF Fire Frequency – No Suppression jwm.xls," match the cell number (in green) to a cell number in "CRCF CB Reports.xls." The associated distribution in "CRCF CB Reports.xls" is the input for the corresponding cell number in "CRCF Fire Frequency – No Suppression jwm.xls".

As discussed in the response to RAI 2.2.1.1.3-2-008 and Appendix F.II of the reliability and event sequence categorization analysis documents (*Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008a), for example), the distribution inputs for ignition source and propagation probabilities are determined based on the normal approximation to the marginal binomial distribution. The total fire ignition frequency distribution is lognormal (see Total Frequency tab of "CRCF Fire Frequency – No Suppression jwm.xls") with parameters obtained using linear regression, as described in the response to RAI 2.2.1.1.3-2-009 and Appendix F.III of the reliability and event sequence categorization analysis documents.

The other waste handling facilities (Initial Handling Facility, Receipt Facility, and Wet Handling Facility) are analyzed using the same methodology with the spreadsheet worksheets similarly named; e.g., for the Wet Handling Facility the worksheet is titled "WHF Fire Frequency – No Suppression.xls" (BSC 2008b, Attachment H); for the Receipt Facility the worksheet is "RF Fire Frequency – No Suppression.xls" (BSC 2008c, Attachment H), etc. The attached file titled "CB Input Examples.xls" illustrates how the Crystal Ball inputs from "CRCF CB Reports.xls" are used within the "CRCF Fire Frequency – No Suppression.xls" spreadsheet.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008a. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080311.0031.

BSC 2008b. *Wet Handling Facility Reliability and Event Sequence Categorization Analysis*. 050-PSA-WH00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0033.

BSC 2008c. *Receipt Facility Reliability and Event Sequence Categorization Analysis.* 200-PSA-RF00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0030.

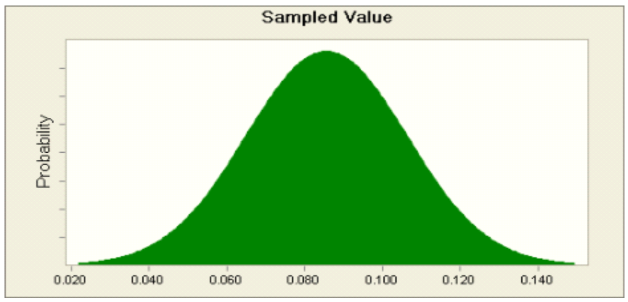
Figure 1. Sample Crystal Ball Report with Input Probability Distributions and Input Parameters

Worksheet: [CRCF Fire Frequency - No Suppression.xls] Ignition Source Frequency

Assumption: Sampled Value **Cell: H2**

Normal distribution with parameters:

Mean	0.086	(=I2)
97.5%	0.126	(=J2)



Source: CRCF CB Report.xls

RAI Volume 2, Chapter 2.1.1.3, Second Set, Number 18:

> Justify the error factor of 2 used for fire ignition frequency at Low Level Waste Facility in BSC (2008j), Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis." 000–PSA–MGR0–00900–000, Rev. 00A.
>
> The error factor for the estimated fire frequency of the Low Level Waste Facility is taken as 2 in BSC (2008j). Two sources are given for this value: 1) Appendix F.I in Attachment F of BSC (2008j) and 2) an email copied under the 'L Plumb LLWF Fire Feb 27' tab of spreadsheet 000-PSA-MGR0-00900-000a09-Mar-11-2008.xls from BSC (2008j). However, Table F.I-2 of Attachment F.I of BSC (2008j), which gives the error factor equal to 2, notes that mean and median values used to calculate error factor are not values estimated for the Low Level Waste Facility at Yucca Mountain repository. They are for fires in industrial buildings in Finland. On the contrary, analysis for event sequence ISO-ESD07-LLW, given under the ESD07 tab of the 000-PSA-MGR0-00900-000a09-Mar-11-2008.xls spreadsheet, assumed the error factor to be 10.

1. RESPONSE

As the DOE noted in the March 25, 2009 clarification call, an error factor of two is used for the fire ignition frequency in the Low-Level Waste Facility (LLWF), not an error factor of ten. Although the "ESD07" tab of the "000-PSA-MGR0-00900-000a09-Mar-11-2008.xls" spreadsheet in Attachment H of *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis* (BSC 2008) includes a note that an error factor of ten was used, it is noted in the "IEs" tab of the "000-PSA-MGR0-00900-000a09-Mar-11-2008.xls" spreadsheet in Attachment H of the categorization analysis (BSC 2008) that an error factor of two was the actual input value.

Attachment F of the categorization analysis (BSC 2008, p. F-21), states that warehouse data in *Utilisation of Statistics to Assess Fire Risks in Buildings* (Tillander 2004) was used as the basis for the LLWF fire ignition frequencies. An error factor of two was suitable for this fire ignition frequency as a similar value was found for the industrial data (BSC 2008, p. F-21). Demonstration of the applicability of the data in *Utilisation of Statistics to Assess Fire Risks in Buildings* (Tillander 2004), to the waste handling facilities at the repository has been provided in the responses to RAI 2.1.1.3-2-001 and RAI 2.1.1.3-2-002.

1.1 CONFIRMATION OF ERROR FACTOR

Five ignition frequency data points are used to determine prediction limits. These data points correspond to the five floor areas in the range, 2,500 to 32,000 m^2 of the warehouse data (Tillander 2004) that encompass the actual LLWF floor area of 5,514 m^2 (BSC 2008, p. F-21). The uncertainty in the logarithm of the annual fire ignition frequency per meter squared, $\log_{10}(f(A))$, is approximated using the prediction interval from the linear regression to these five points of $\log_{10}(f(A))$ given $\log_{10}(A)$.

In the analysis, the uncertainty of $\log_{10}(f(A))$ values (for a specific floor area, *A*) is considered to be normal (*N*) distributed with mean (μ) and variance (*V*). The mean and variance are functions of the area, with the mean equal to $\log_{10}(f_m(A))$ where $f_m(A)$ is given by Equation F-3 and the variance is given by the relations in Equations F.I-2, F.I-3, and F.I-4 of the categorization analysis (BSC 2008). To summarize mathematically,

$$\log_{10}(f(A)) \sim N\left(\mu = \log_{10}(f_m(A)), \quad V = \left(\frac{a \cdot \sigma(\log_{10}(A))}{z_2}\right)^2\right).$$

The *f*(*A*) values are lognormal (*LN*) distributed with median (*M*) and error factor (*EF*) given as:

$$f(A) \sim LN\left(M = f_m(A), EF = \text{antilog}_{10}\left(\frac{z_1}{z_2}(a \cdot \sigma(\log_{10}(A)))\right)\right)$$

$$\text{where} \quad z_1 = \Phi^{-1}(0.950) = 1.645, \quad z_2 = \Phi^{-1}(0.975) = 1.960$$

Here, the function $\Phi(x)$ is the area under the Standard Normal curve from $-\infty$ to x. The value of a equals 3.182, the Student's-*t* variant with three degrees of freedom (i.e., five data points minus the two regression parameters determined from the data) associated with the 0.975 quantile. The prediction error standard deviation, $\sigma(x_o)$, is given by the relations in Equations F.I-2, F.I-3, and F.I-4 of the categorization analysis (BSC 2008).

The error factor calculated, using the aforementioned five data points in the above formulation, is equal to 1.8. Therefore, the value of two used in the analysis is reasonable, but larger than 1.8. The error factor is used in Equation F-4 of the categorization analysis (BSC 2008, p. F-22) to estimate a mean value. The mean, therefore, used in the categorization analysis (BSC 2008) is slightly larger than the mean that would be obtained by using the value of 1.8 determined here. This more conservative result justifies the use of the value of two for the error factor.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008. *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0032.

Tillander, K. 2004. *Utilisation of Statistics to Assess Fire Risks in Buildings.* Ph.D. dissertation. Espoo, Finland: VTT Technical Research Centre of Finland. TIC: 259928.