RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 3:

Explain how containment is maintained on various cask transfers to and from the pool ledge.

a) Explain how the transportation cask would provide containment for a drop or tipover while transferring the cask to the pool following preparation. DOE identifies on page 91 of BSC, 2008bo that, "Transportation cask sampling and cooling are completed through transportation cask access ports, which are uncovered during the preparation steps."

b) Explain how DOE would determine that the STC would be capable of maintaining containment for a drop or tipover while lifting the STC from the pool. DOE describes on page 144 of BSC, 2008bo that, "A minimum number of fasteners are on the STC and are tightened to ensure proper containment."

For both WHF-ESD20-CSNF (Figure F-20 of BSC, 2008bo) and WHF-ESD24-TAD (Figure F-24 of BSC, 2008bo), DOE credits the cask for maintaining containment if an event such as a drop or tipover occurs. For the transportation cask, DOE identifies basic event, "CASK-DROP-OPERATIONAL" in Table A4.20-3 and Table A4.20-7 of BSC, 2008bq. For the shielded transfer cask, DOE identifies basic event, "CASK-DROP-OPERATIONAL" in Table A4.24-3 and Table A4.24-7 of BSC, 2008bq. Table 6.3-8 of BSC, 2008bq shows a value of 1×10^{-5} for this basic event and describes it as, "Failure of cask due to drop from operational height."

1. RESPONSE

Containment during transportation cask and shielded transfer cask (STC) transfers (while holding either uncanistered commercial spent nuclear fuel (SNF), opened dual-purpose canisters (DPCs), or unsealed transportation, aging, and disposal (TAD) canisters) is maintained by ensuring that the correct number of lid bolts are in place and secured on casks entering and exiting the Wet Handling Facility (WHF) pool. Procedural Safety Control (PSC)-6 requires that whenever an unsealed TAD canister or unsealed DPC is being moved in an STC, or uncanistered SNF is being moved in a transportation cask, the STC or transportation cask will have a lid held in place with the required minimum number of installed fasteners such that the stress on the fasteners as a result of a drop or tipover is less than the yield stress of the fastener material.

1.1 Transportation Cask Containment

The tasks performed to prepare a transportation cask for transfer into the pool ensure that the transportation cask provides containment in the event of a drop or tipover. In order to prepare the transportation cask for transfer to the pool, the drain and vent port covers are removed to allow hoses to be attached to the quick disconnect fittings on the ports. This operation is performed to obtain a gas sample, to cool the cask cavity (if needed), and to vent the cask cavity and fill the

cavity with borated water. The drain and vent port covers are reinstalled following these tasks (prior to any cask movement), and a number of lid bolts are removed to facilitate pool operations.

The number of lid bolts remaining will vary depending on the type of transportation cask. This number is based on an analysis that determined the minimum number of bolts needed to ensure the lid is held in place in the event of a drop or tipover. This analysis assessed the impact of dropping seven types of casks during a transfer to the WHF pool. The scenario considered in this analysis involved an accidental drop of the cask from a height of one foot above the top edge of the WHF pool wall while positioned halfway over the edge of the wall and halfway over the pool. In this scenario, when the cask impacts the edge of the pool wall, the cask inverts as it falls. It is assumed that the cask is nearly vertical and upside-down when it strikes the crush pads on the pool staging shelf, 33 feet below the drop height.

The number of bolts needed to ensure that the stress in the bolt area is approximately half of the yield stress (to account for uncertainties) for the bolt was calculated for each cask type. It was determined that four bolts are needed for smaller truck-based transportation casks while larger rail-based transportation casks require as many as sixteen bolts. Further analyses will be completed during detailed design to consider other types of drop and tipover scenarios to ensure that the minimum number of bolts left in place is bounding for each type of event considered.

As described in SAR Section 1.9, procedural safety controls are defined as safety controls or administrative controls for the implementation of human activities that reduce the frequency of, or mitigate the consequences of, event sequences. A procedural safety control is a formally documented and controlled specific action or series of actions taken by the operating staff in preparation for, or during the execution of, a particular repository operation. The preclosure procedural safety controls are presented in SAR Table 1.9-10. PSC-6 in SAR Table 1.9-10 is a safety control developed to limit the probability that a drop or tipover of an STC or transportation cask during movement will result in a radiological release or criticality. This procedural safety control states that whenever a TAD canister or DPC is being moved in an STC or whenever uncanistered SNF is being moved in a transportation cask, the STC or transportation cask shall have a lid held in place with a required minimum number of installed fasteners such that the stress on the fasteners as a result of a drop will be less than the fastener yield stress. This control limits the probability that a drop or tipover of the STC or transportation cask during movement will result in a radiological release or criticality. It is a conservative criterion in that considered plastic strain can occur before failure. The probability of failure if the yield strength is attained is negligibly small.

1.2 Shielded Transfer Cask Containment

As discussed in Section 1.1, an analysis assessed the impact of dropping various types of casks that will be transferred to the WHF pool. This analysis also considered STCs, which are used to transfer loaded DPCs to the pool and transfer loaded TAD canisters out of the pool. Since the design of the STCs is not yet finalized, a cask with representative physical features of the STC was analyzed. It was determined that STCs require as many as sixteen bolts to be in place when the STC is placed in the WHF pool to ensure that the lid is held in place in the event of a drop or

tipover. Once the STC design is finalized, further analyses will be performed to consider potential drop and tipover scenarios to ensure that the minimum number of bolts left in place meets the requirement of not exceeding bolt yield strength.

PSC-6 in SAR Table 1.9-10 and SAR Section 1.2.5.1.4 also applies to the STC. This procedural safety control requires that the STC lid will have the required minimum number of fasteners in place when leaving the WHF pool such that the stress on the fasteners is less than the fastener yield stress.

1.3 Event Sequence and Consequence Calculations

Transportation casks and STCs are lifted in the WHF approximately one foot above the floor. STCs are represented in the preclosure safety analysis as representative transportation casks. A calculation that indicates that a cask drop outside of a pool will maintain cask containment is found in *Seismic and Structural Container Analyses for the PCSA* (BSC 2008, p. 53). The analysis for a 13.1-foot transportation cask drop (with 4 degrees off-vertical orientation) and subsequent slapdown does not result in exceedance of the yield stress for cask closure bolts. Bolts would, therefore, not be expected to fail in such out-of-pool drop event sequences. The previously described analysis involving a 33-foot cask drop within the pool calculated the number of bolts required such that the bolt yield stress is not exceeded. These calculations demonstrate that the number of bolts required to assure containment is less than or equal to the original complement of bolts.

Event sequences that include drops and breaches within or into the pool (such as event sequence ESD21-CSNF-SEQ2P-GRRU) have been shown to meet the Category 2, 5 rem per event sequence performance objective of 10 CFR 63.111, as shown in SAR Tables 1.8.-30 and 1.8-31.

In summary, for event sequences involving transportation casks and STCs (while holding uncanistered fuel, unsealed DPCs, and unsealed TAD canisters), bolt stresses will be maintained below yield stress. In addition, the probability of breach is beyond Category 2 for out-of-pool drops and the consequences for drops within, or into, the pool meet the performance objectives of 10 CFR 63.111.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008. *Seismic and Structural Container Analyses for the PCSA.* 000-PSA-MGR0-02100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080220.0003.

RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 5:

For direct exposure due to the splash of pool water (i.e., WHF-1803) for WHF-ESD30 shown in Figure F-30 of BSC, 2008bo, explain how DOE quantified event sequence frequency. Examples of areas needing clarification follow:

a) Explain how DOE considered the splash of pool water from the drop of both loaded and unloaded casks (i.e., shielded transfer cask containing a DPC and a transportation cask for CSNF); the drop of equipment such as a lifting yoke; and the drop of a shielded transfer cask containing a loaded TAD canister.

   DOE identifies in Table 10 of BSC, 2008bo on page 98 that it accounts for the, "Drop of a loaded STC/DPC or TC/CSNF resulting in splash of contaminated pool water." Table 6.1-2 of BSC, 2008bq on page 116 identifies initiating event trees WHF-ESD30-DPC and WHF-ESD30-FUEL. However, Table A4.30-2 of BSC, 2008bq on page A-109 associates the splash of pool water only with the transfer of an STC containing a loaded DPC to the pool (i.e., WHF-ESD30-DPC). DOE combines the probability for a drop with a throughput value of 346 DPCs identified in Table A4.30-1 of BSC, 2008bq on page A-108.

b) Explain how the Pool Handling Crane is involved in the splash of pool water and explain how DOE quantifies the drop probability involving the Pool Handling Crane shown in Figure B10.4-3 of BSC, 2008bq on page B10-26.

   i. Explain how the Pool Handling Crane differs from the Auxiliary Pool Crane described on page 1.2.5-21 of the SAR that is rated at 10 tons.

   ii. Explain if the drop probabilities and two-block drop probabilities included in Figure B10.4-3 of BSC, 2008bq are for very heavy load lifts only. As shown in Figure B10.4-3 of BSC, 2008bq, the Pool Handling Crane has the same drop probability and two block drop probability as the Cask Handling Crane.

1. RESPONSE

1.1 POOL WATER SPLASH EVENT SEQUENCE DEVELOPMENT

1.1.1 Splashes are Off-Normal Events, Not Event Sequences

Although the DOE had begun to evaluate direct exposure events involving a splash of pool water as event sequences, that work was suspended with the publication of Interim Staff Guidance HLWRS-ISG-03, *Preclosure Safety Analysis—Dose Performance Objectives and Radiation Protection Program* (NRC 2007). Footnote 1 of that guidance clarifies the treatment of such events: "1 Deviations from procedures, or equipment failures, that do not involve important to safety (ITS) structures, systems, and components (SSCs) failures, and that do not lead to

significantly elevated exposures to radiation workers, are considered off-normal and not Category 1 events…"

Consequently, the DOE initially evaluated event sequence frequencies for internal initiating event WHF-1803 (direct exposure events involving splash of pool water) for drops of loaded shielded transfer casks (STCs) containing dual-purpose canisters (DPCs) and transportation casks containing commercial spent nuclear fuel (SNF). However, with the publication of HLWRS-ISG-03 such splash events would be "off-normal" occurrences consistent with the definition in HLWRS-ISG-03 and not event sequences. Direct radiation doses to a Wet Handling Facility radiation worker from the low-level radioactivity in the pool are a part of the normal operation worker dose. The radioactivity in the pool represents a large volumetric direct radiation source, but a splash event would result in only a thin area source with the same low-level radioactivity and would not be a significant additional direct radiation dose contribution. Therefore, any splash event involving displacing pool water to the operating floor would not lead to significantly elevated exposures to radiation workers.

1.1.2 Explanation of Quantification of Splashes before Analysis Discontinued

The following discussion describes the approach to quantification of splash related event sequences accomplished before availability of the HLWRS-ISG-03 clarification. The discussions in *Wet Handling Facility Event Sequence Development Analysis* (BSC 2009a) and *Wet Handling Facility Reliability and Event Categorization Analysis* (BSC 2009b) are partial results of that work and do not represent event sequences germane to the safety analysis. The quantification of the loaded STC/DPC or transportation cask/commercial SNF splash event started with the identification of the potential internal initiating event, WHF-1803, "Drop of a loaded STC/DPC or TC/CSNF resulting in splash of contaminated pool water" (BSC 2009a, Table 10). That event was incorporated into the event sequence diagram WHF-ESD-30, "Direct Exposure Event Sequences for Activities Associated with Pool Operations" (BSC 2009a, Figure F-30). Two initiator event trees, WHF-ESD30-FUEL and WHF-ESD30-DPC (BSC 2009b, Figures A5-47 and A5-48) were developed for the event sequence diagram WHF-ESD-30. The event tree WHF-ESD30-FUEL was for an event resulting in direct exposure due to lifting a fuel assembly too high. The event tree WHF-ESD30-DPC included an end state of direct exposure to a pool splash initiating event. Although initiating event WHF-1803 was described in Table 10 of *Wet Handling Facility Event Sequence Development Analysis* (BSC 2009a) as applying to both an STC containing a loaded DPC and a transportation cask containing commercial SNF, only the STC/DPC combination in event tree WHF-ESD30-DPC had been quantified before publication of HLWRS-ISG-03 and completion of an evaluation that such splash events would be "off-normal" occurrences. Therefore, the transportation cask/commercial SNF combination was not developed or quantified.

The fault tree ESD30-EXPOSURE-SPLASH (BSC 2009b, Table B10.4-1) was developed to describe the splash initiating event for event tree WHF-ESD30-DPC. That fault tree in Figure B10.4-3 of *Wet Handling Facility Reliability and Event Categorization Analysis* (BSC 2009b) illustrates the basic events resulting in direct exposure to a splash from drops of a cask or objects into the pool due to cask handling or pool handling crane load drops or two-block drops. The cask handling and pool handling crane drop probabilities per demand are based on very heavy

load lifts, and those probabilities are combined with an STC/DPC throughput value of 346 casks identified in Table A4.30-1 of *Wet Handling Facility Reliability and Event Categorization Analysis* (BSC 2009b) because only the drop of a loaded STC/DPC was quantified.

1.2 CRANE DROP PROBABILITIES

The terms "Pool Handling Crane" and "Auxiliary Pool Crane" are synonymous. The pool handling crane was involved in the pool water splash event sequence because of potential drops of objects such as a cask lid during activities associated with an STC/DPC transfer to the pool.

The crane drop probabilities and two-block drop probabilities included in Figure B10.4-3 of *Wet Handling Facility Reliability and Event Categorization Analysis* (BSC 2009b) for both the cask handling crane and pool handling crane are based on very heavy load lifts (defined as greater than 30 tons) with single-failure-proof cranes as developed in Section C1.3 of *Wet Handling Facility Reliability and Event Categorization Analysis* (BSC 2009b). Both the cask handling crane and pool handling crane are ASME NOG-1-2004, *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)* (ASME 2005), Type I cranes and are top running double-girder type bridge cranes with a top running trolley. The cask handling crane is rated at 200 tons with an auxiliary hoist rated at 20 tons, and the pool handling crane is rated at 10 tons.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

ASME (American Society of Mechanical Engineers) 2005. *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder).* ASME NOG-1-2004. New York, New York: American Society of Mechanical Engineers. TIC: 257672.

BSC (Bechtel SAIC Company) 2009a. *Wet Handling Facility Event Sequence Development Analysis*. 050-PSA-WH00-00100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0005.

BSC (Bechtel SAIC Company) 2009b. *Wet Handling Facility Reliability and Event Sequence Categorization Analysis.* 050-PSA-WH00-00200-000-00B, CACN 001 DOC.20090323.0006. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0006; DOC.20090323.0006.

NRC (U.S. Nuclear Regulatory Commission) 2007. *Preclosure Safety Analysis—Dose Performance Objectives and Radiation Protection Program*. HLWRS-ISG-03. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC. MOL.20070918.0096.

RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 9:

Explain what initiating events DOE identified for preparation activities involving a transportation cask containing CSNF (i.e., WHF-ESD16-CSNF). Examples of areas needing clarification follow:

a) Explain how the initiating events in Figure F-16 of BSC, 2008bo correspond to the results from the HAZOP analysis in Table E-22 of BSC, 2008bo on page E-32 and the MLD in Figure D-16 of BSC, 2008bo on page D-17. For example, Figure F-16 of BSC, 2008bo identifies over pressurization of the transportation cask as WHF-1602; however, the MLD in Figure D-16 associates over pressurization as WHF-1604 (i.e., error taking temperature sample resulting in cask over pressurization) and WHF-1606 (i.e., water added while cask inside temperature is too high). In addition, the MLD in Figure D-16 associates sample line failure with WHF-1603 and WHF-1605; whereas, the event sequence diagram in Figure F-16 associates WHF-1603, WHF-1604, WHF-1605, and WHF-1606 with sample line break.

b) Table 10 of BSC, 2008bo on page 98 does not identify the initiating event WHF-1607; however, the MLD in Figure D-16 of BSC, 2008bo does identify this initiating event as a direct exposure associated with the water line breaking.

1. RESPONSE

1.1 INITIATING EVENT DEVELOPMENT FOR CASK PREPARATION

A master logic diagram is the principal method used for the identification of internal initiating events associated with the geologic repository operations area waste handling operations, including preparation activities involving a transportation cask containing commercial spent nuclear fuel (SNF). The hazard and operability (HAZOP) evaluation technique, which is an accepted method for identifying and evaluating industrial hazards, is also used in the identification of internal initiating events at the geologic repository operations area as a secondary method to assure a comprehensive identification of risk-significant initiating events. The use of two different methods by two different preclosure safety analysis analyst teams provides a diversity of approach resulting in a potentially broader range of identified initiating events. However, all risk-significant HAZOP evaluation deviations are eventually associated with a master logic diagram initiating event identifier in a format such as “WHF-1603.” The completed master logic diagram captures all of the risk-significant initiating events identified within the master logic diagram and within the HAZOP evaluation.

An event sequence diagram is one of the ways the preclosure safety analysis diagrammed the structure, system, or component, and personnel responses to the initiating events captured in the master logic diagram. Each little bubble in an event sequence diagram is associated with one or more master logic diagram initiating event identifiers. The flow chart that displays the

relationships between these methods is shown in Figure 2 of *Wet Handling Facility Event Sequence Development Analysis* (BSC 2009).

Figure D-16 of the event sequence development analysis (BSC 2009) is a master logic diagram that identifies the initiating events that result in unplanned exposure of individuals to radioactive materials during preparation activities associated with a transportation cask containing commercial SNF. To ensure comprehensiveness of the initiating event identification process, in addition to the results of the master logic diagram, a HAZOP evaluation was also performed and documented in the event sequence development analysis (BSC 2009, Table E-22). The individual initiating events identified in the event sequence development analysis (BSC 2009, Figure D-16 and Table E-22) are grouped and indicated on the event sequence diagram in Figure F-16 of the event sequence development analysis (BSC 2009) by their initiating event (master logic diagram index) identifiers. The initiating events for these preparation activities are collected into three groups, shown below, which are represented as little bubbles in the event sequence development analysis (BSC 2009, Figure F-16). As clarified below, Figure F-16 of the event sequence development analysis (BSC 2009) contains two discrepancies: event WHF-1606 should be associated with Group 3, not Group 2, and event WHF-1602 should not be associated with Group 3. Figure and table references are from the event sequence development analysis (BSC 2009).

1) **Group 1**—Impact to cask valves

   - WHF-1602

     – From master logic diagram Figure D-16 (Cask handling crane malfunction/misoperation leads to impact to canister)

     – From HAZOP evaluation Table E-22 (Potential drop or collision leading to radioactive release (Node Items 21.17, 21.18, 21.20, 21.25, 21.26, 21.30 and 21.31))

2) **Group 2**—Sampling line break

   - WHF-1603

     – From master logic diagram Figure D-16 (Release of material from sample line failure)

     – From HAZOP evaluation Table E-22 (Potential loss of confinement boundary leading to radioactive release (Node Items 21.2 and 21.3))

   - WHF-1604

     – From master logic diagram Figure D-16 (Erroneous sample reading (false negative) causing a potential cask over-pressurization condition)

     – From HAZOP evaluation Table E-22 (Node Item 21.4)

- WHF-1605
  - From master logic diagram Figure D-16 (Exposure due to sample line failure caused by energetic hose whip)
  - From HAZOP evaluation Table E-22 (Potential loss of confinement boundary leading to radioactive release (Node Items 21.7 and 21.8))
- WHF-1606 (Should be moved to Group 3 as shown below)

3) **Group 3**—Over pressurization of transportation cask

- WHF-1602 (Should be deleted from Group 3)
- WHF-1606 (Should be moved from Group 2)
  - From master logic diagram Figure D-16 (Exposure due to water line break caused by an over-pressurization condition)
  - From HAZOP evaluation Table E-22 (Potential loss of confinement boundary leading to radioactive release (Node Items 21.5 and 21.11)).

As explained in the event sequence development analysis (BSC 2009, Section 4.3), initiating events identified in the HAZOP evaluation were matched to initiating events in the master logic diagram, and when no match was appropriate, a new master logic diagram event was defined. Initiating events were then grouped into small bubbles in the event sequence diagram based on similarity of pivotal events. The following illustrates an example association of HAZOP evaluation results to master logic diagram. In Table E-22 of the event sequence development analysis (BSC 2009), Node Item Numbers 21.4 and 21.5 have been identified with WHF-1604 and WHF-1606, respectively. WHF-1604, "Erroneous sample reading (false negative) causing potential cask over-pressurization condition" was grouped with "Sampling line break" because the pivotal events for the other initiating events are the same. WHF-1604 could instead have been grouped with "Over pressurization of TC" in the event sequence development analysis (BSC 2009, Figure F-16). In either case, all of the risk significant initiating events from the master logic diagram (BSC 2009, Figure D-16) and the HAZOP evaluation (BSC 2009, Table E-22) have been identified in the event sequence diagram (BSC 2009, Figure F-16), summarized in the event sequence development analysis (BSC 2009, Table 10), and included in the event sequence quantification of WHF-ESD-16 and its initiating event tree WHF-ESD16-CSNF.

1.2 DIRECT EXPOSURE EVENT EXCLUSION

The end states for WHF-ESD-16, which are shown in the event sequence development analysis (BSC 2009, Figure F-16), are associated only with radionuclide release. *Wet Handling Facility Event Sequence Development Analysis* (BSC 2008, Figure D-16) had identified initiating events WHF-1601 (Direct exposure from canister) and WHF-1607 (Direct exposure from water line failure). Direct exposure is associated only with shielding degradation or loss and not with

radionuclide release, and there are no shielding degradation events or loss of shielding events associated with the transportation cask/commercial SNF preparation activities. Further, WHF-1607 is associated with direct exposure from a low-level radioactivity water line break that would not lead to significantly elevated exposures to radiation workers. It is considered an off-normal event rather than an event sequence; therefore, the event sequence development analysis (BSC 2009, Figure D-16) has been revised to remove WHF-1601, WHF-1607 and WHF-1614. The direct exposure event WHF-1608 for STC/DPC preparation activities remains because it is associated with shielding degradation or loss.

In summary, the initiating events in the event sequence development analysis (BSC 2009, Figure D-16) are correctly summarized in the event sequence development analysis (BSC 2009, Table 10), which includes neither initiating events WHF-1601, WHF-1607 nor WHF-1614.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2008. *Wet Handling Facility Event Sequence Development Analysis*. 050-PSA-WH00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080225.0010.

BSC 2009. *Wet Handling Facility Event Sequence Development Analysis*. 050-PSA-WH00-00100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0005.

RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 10

> For the response tree, "RESPONSE-TCASK-CSNF" shown in Figure A5-3 of BSC, 2008bq on page A-125, DOE considers a filtered radionuclide release for both with and without importance to criticality and an unfiltered radionuclide release for both with and without importance to criticality. Explain why DOE separated the end states and resulting frequencies for filtered and unfiltered radionuclide releases based on importance to criticality. Address similar importance to criticality event sequences in other areas of the Preclosure Safety Analysis.

1. RESPONSE

The end-states of filtered and unfiltered event sequences are separated based on importance to criticality in order to utilize the initiating and pivotal events common to both dose consequence and criticality evaluations while using the same event tree structure. The preclosure safety analysis developed event sequences with end-states for both dose consequence and criticality evaluations. Event sequences associated with radionuclide release and moderator control used combined end-states for dose consequence and criticality evaluations. The common component for radionuclide containment and moderator control is the waste container (e.g., canister, cask, and waste package). A container breach allows for a pathway for radionuclide release as well as a pathway for moderator to enter a container. Therefore, the initiating events and pivotal events associated with containment are common to event sequences for dose consequence and criticality evaluations. In order to utilize the commonality between the two types of event sequences (i.e., containment), the same event tree structure is used for both types of analyses.

To ensure that event sequence frequencies appropriately account for the confinement function, the success branch of the moderator pivotal event is conservatively assigned a probability of one. This means that the entire event sequence frequency associated with filtered release (in the absence of an important to criticality condition) is captured, thereby preserving the event sequence frequency for the filtered dose consequence end-state. Similarly, the entire event sequence frequency associated with unfiltered release (in the absence of an important to criticality condition) is conservatively captured, thereby preserving the event sequence frequency for the unfiltered dose consequence end-state.

To ensure that event sequence frequencies appropriately account for the moderator control function, the success branch of the confinement pivotal event is conservatively assigned a probability of one. This means that the entire event sequence frequency associated with an important to criticality end-state is captured as a filtered release and the appropriate fraction of the important to criticality end-state with an unfiltered release is also captured. This treatment causes a small overestimate of the combined frequency of both filtered and unfiltered releases, as well as the combined frequency of filtered-important to criticality and unfiltered-important to criticality conditions. Because event sequences are categorized individually, this overestimate has no impact on the overall preclosure safety analysis or its conclusions.

As an example, to address the event tree described in the RAI (BSC 2009, Figure A5-3), a simplified event tree of "RESPONSE-TCASK-CSNF" with associated probability values is presented in Figure 1. Because the pivotal events for confinement and moderator are independent, their order within the event tree does not impact the end-state designations or associated probabilities as demonstrated in Figure 2. Note that the end-state probabilities shown in Figure 1 and Figure 2 are on a per unit basis and would be converted to an associated event sequence frequency (i.e., expected number of occurrences) by multiplication with the number of transportation casks processed over the preclosure period.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2009. *Wet Handling Facility Reliability and Event Sequence Categorization Analysis.* 050-PSA-WH00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0006.

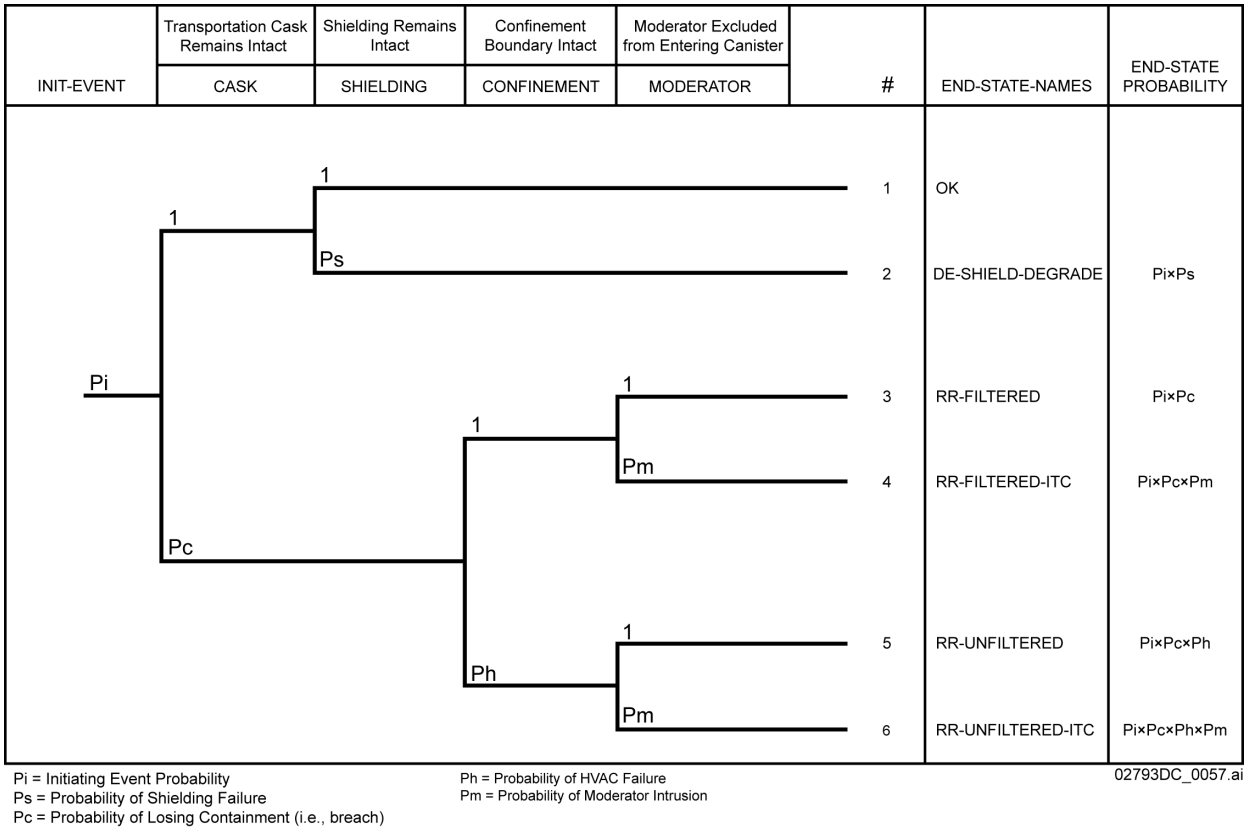

Figure 1. Simplified Response Tree, “RESPONSE-TCASK-CSNF”

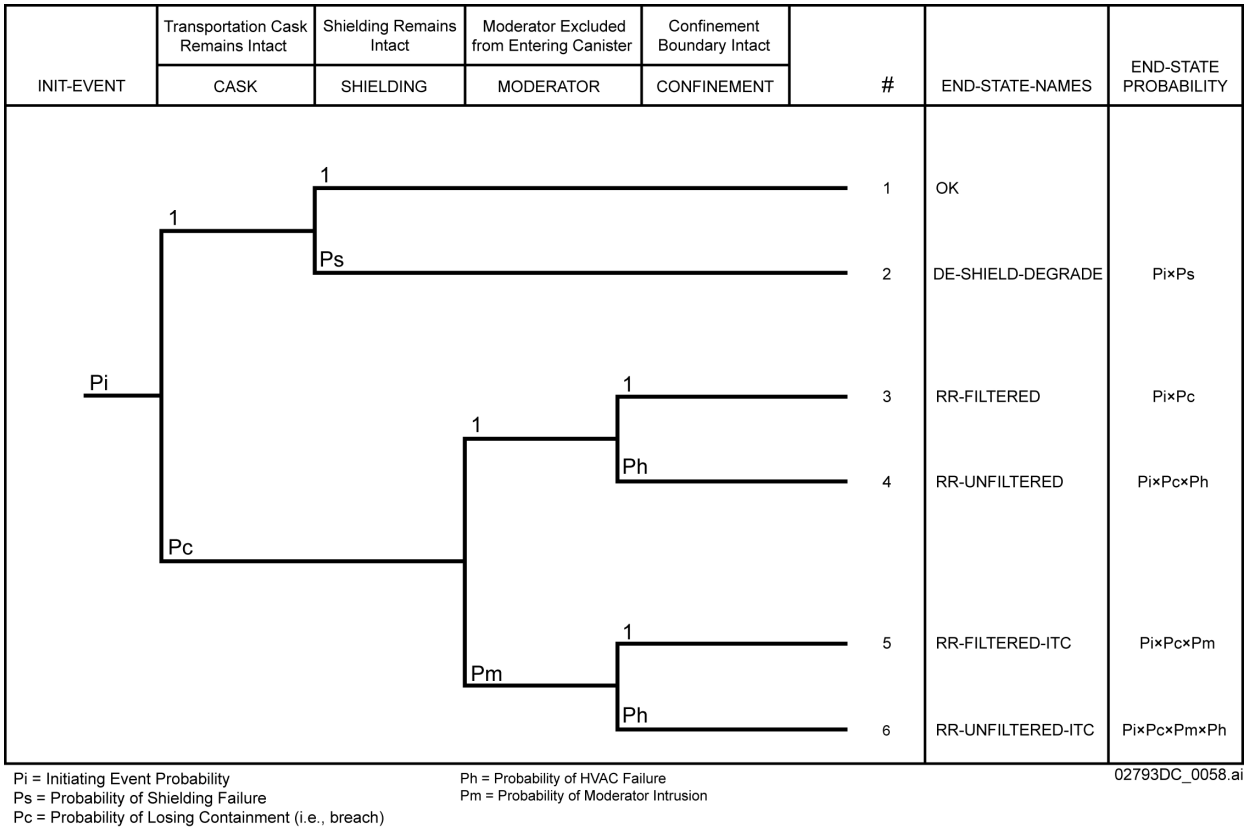

Figure 2. Simplified Response Tree, “RESPONSE-TCASK-CSNF” with a Different Order of Events

RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 11:

> This RAI is associated with Receipt Facility Fault Tree on Collision of Shield Door into ST (200-ST-COLLIDE-SDR)
>
> Justify the use of a mean probability value (2.843×10^{-2}) for failure of two motor No. 1 over torque sensors in fault tree 200-ST-COLLIDE-SDR in the SAPHIRE model that is different from that (1.44×10^{-2}) listed in Table 6.3-1 for active component reliability data summary (BSC, 2008be).

1. RESPONSE

The Table 6.3-1 mean probability value of 1.44×10^{-2} for the over torque sensors in the *Receipt Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008) was an error and does not reflect the updated probabilities used in the SAPHIRE model. Table 6.3-1 in *Receipt Facility Reliability and Event Sequence Categorization Analysis* (BSC 2009), updated to Revision B, reflects the correct mean probability of 2.84×10^{-2} for failure of two motor No. 1 over torque sensors used in fault tree 200-ST-COLLIDE-SDR.

The two basic events associated with the Receipt Facility fault tree "Collision of Shield Door into ST" (200-ST-COLLIDE-SDR) are 200-SD---TL001---TL--FOH and 200-SD---TL002---TL--FOH. The mean probability of these basic events is calculated by SAPHIRE using Calculation Type 7 for a standby component in a nondemand failure mode with consideration given to periodic testing. For Calculation Type 7, the basic event mean probability P is given by

$$P = 1 + [\exp(-L \times T) - 1] / (L \times T),$$

where L is the hourly failure rate and T is the testing interval in hours. The hourly failure rate of a torque limiter (L) is found in the event sequence analysis (BSC 2009, Table C4-1) under TL-FOH with a value of 8.05×10^{-5}. The periodic testing interval (T) is 720 hours. This yields a basic event mean probability of $P = 2.84 \times 10^{-2}$ for each of these two basic events. This value was used for the two basic events in the fault tree model 200-ST-COLLIDE-SDR as shown in the event sequence analysis (BSC 2009, Table 6.3-1, Table B3.4-5, Table B3.4-6, and Figure B3.4-9).

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

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

BSC 2009. *Receipt Facility Reliability and Event Sequence Categorization Analysis.* 200-PSA-RF00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0010.

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> Provide technical basis for considering a single type of waste form individually, instead of multiple types of waste forms that are likely to be present in a facility at one time, to categorize large fire event sequences in SAR Section 1.7-4 (Page 1.7-41).
>
> Many event sequences shown in the summary tables under SAR Chapter 1.7 (e.g., Tables 1.7-7, 1.7-9, 1.7-13, etc.) indicate that the "material at risk" given a particular fire-induced event sequence is "one transportation cask with…" Since this probability also includes the probability of exposure due to a large fire, explain how the potential presence of multiple canisters in a facility at the time of a large fire could affect the failure probability and subsequent dose calculations. This potential for multiple failures is also present in staging areas or other areas where a higher density of containers/waste forms may be present.

1. RESPONSE

Quantification of large fire event sequences need not consider the presence of multiple waste containers because failure of multiple waste forms in these fires and the resultant release of radionuclides are beyond Category 2 event sequences.

The preclosure safety analysis methodology is based on standard fire analysis practice as shown in NUREG/CR-6850 (EPRI and NRC 2005) that all fires start as small fires at an ignition source. Each small fire has an ignition frequency, and it may or may not grow to a large fire. The conditional probability of a small fire growing to a large fire is included in the analysis by multiplying the ignition frequency by the propagation probability developed in Appendix F.II of the facility reliability and event sequence categorization analyses. The propagation probability is always less than 1. The preclosure safety analysis conservatively overestimates the potential growth of a small fire to a large fire because it does not include the effects of suppression systems and fire fighting activities.

Large fire event sequences that result in a release of radioactive material include an ignition frequency, the conditional probability of growth to large fire (propagation probability), and the conditional probability that a fire will cause a breach of a waste container. As illustrated by the summary calculation of Canister Receipt and Closure Facility (CRCF) large fire event sequence frequencies resulting in canister failure shown in Table 1, all large fire event sequences that result in a release of radioactive material are beyond Category 2 event sequences. Further, releases from all canisters of the same type are also beyond Category 2 event sequences. The CRCF was chosen for this example because the waste forms and throughputs are bounding.

The only large fire event sequence resulting in a Category 2 event sequence release of radioactive material involves a single truck transportation cask containing uncanistered commercial spent nuclear fuel in the Wet Handling Facility (WHF). The resulting off-site radiation dose for this event sequence, as reported in SAR Chapter 1.8, is less than 0.01 rem total effective dose equivalent. The conditional probability of failure of other waste canisters in a large fire is a beyond Category 2 event sequence.

Because radioactive releases from all other large fire event sequences are beyond Category 2 event sequences and because, from the perspective of any given waste form, there is no fire until it reaches that waste form, the SAR Chapter 1.7 tables mentioned in the RAI identify the canister at the ignition source only, as there is no need to tally all of the potential canisters within a facility.

With the singular exception of the WHF Category 2 event sequence release of radioactive material involving a single truck transportation cask, large fire event sequences that have the potential to cause personnel exposure to radiation are either Category 2 event sequences resulting in a direct exposure, or beyond Category 2 event sequences resulting in a radionuclide release.

In the case of the Category 2 event sequences resulting in a direct exposure, the dose to an individual located on or beyond any point on the site boundary from direct radiation is reduced by more than 13 orders of magnitude to insignificant levels because of the large distances to locations of offsite receptors (SAR Section 1.8.3.2.2). Consequence analyses are not performed on beyond Category 2 event sequences.

In summary, radionuclide releases for each waste form from large fires are beyond Category 2 event sequences in the CRCF, Receipt Facility, and Initial Handling Facility. In the WHF, all releases from large fires are beyond Category 2 event sequences except for a fire involving a single truck cask containing commercial spent nuclear fuel. In this case, only one waste form in one container in the entire WHF would be exposed. Therefore, event sequences for each relevant type of waste form were evaluated.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Waste Form Throughputs for Preclosure Safety Analysis*. 000-PSA-MGR0-01800-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071106.0001.

BSC 2009. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0004.

EPRI and NRC 2005. *Summary & Overview.* Volume 1 of *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities.* EPRI-1011989 and NUREG/CR-6850. Palo Alto, California: Electric Power Research Institute. ACC: MOL.20070323.0061.

Table 1. CRCF Large Fire Event Sequence Frequencies

Event Sequence Description	Number of Targets[a] (N)	Ignition Frequency[b] (F)	Fire Propagation Probability[b] (Pp)	Target Residence Fraction[b] (RF)	Mean Canister Failure Probability[c] (Pcf)	Point Estimate Event Sequence Probability[d] (P)
Large Fire Threatens Transportation Cask/TAD Canister (Diesel Present)	6,978	3.13	0.169	2.1×10^{-6}	2.0×10^{-6}	1.55×10^{-8}
Large Fire Threatens Transportation Cask/TAD Canister (No Diesel)	6,978	3.13	0.169	3.3×10^{-5}	2.0×10^{-6}	2.44×10^{-7}
Large Fire Threatens TAD Canister in Aging Overpack (Diesel Present)	8,143	3.13	0.169	1.1×10^{-5}	1.0×10^{-6}	4.74×10^{-8}
Large Fire Threatens TAD Canister in Canister Transfer Machine	15,121	3.13	0.169	1.5×10^{-6}	1.4×10^{-4}	1.68×10^{-6}
Large Fire Threatens TAD Canister in Waste Package in Waste Package Transfer Trolley	8,143	3.13	0.169	1.0×10^{-4}	2.0×10^{-6}	8.61×10^{-7}
Large Fire Threatens TAD Canister in Waste Package in Transport and Emplacement Vehicle	8,143	3.13	0.169	1.8×10^{-6}	3.2×10^{-4}	2.48×10^{-6}
Large Fire Threatens Transportation Cask/HLW (Diesel Present)	1,960	3.13	0.169	2.1×10^{-6}	2.0×10^{-6}	4.35×10^{-9}
Large Fire Threatens Transportation Cask/HLW (No Diesel)	1,960	3.13	0.169	3.4×10^{-5}	2.0×10^{-6}	7.05×10^{-8}
Large Fire Threatens HLW in Canister Transfer Machine (per individual canister)	11,760	3.13	0.169	1.5×10^{-6}	1.4×10^{-4}	1.31×10^{-6}
Large Fire Threatens HLW in Waste Package	3,300	3.13	0.169	1.3×10^{-5}	3.2×10^{-4}	7.26×10^{-6}
Large Fire Threatens HLW and DOE-SNF in Waste Package	3,300	3.13	0.169	1.1×10^{-4}	3.2×10^{-4}	6.14×10^{-5}
Large Fire Threatens Transportation Cask/DOE-SNF (Diesel Present)	385	3.13	0.169	2.1×10^{-6}	2.0×10^{-6}	8.55×10^{-10}
Large Fire Threatens Transportation Cask/DOE-SNF (No Diesel)	385	3.13	0.169	3.2×10^{-5}	2.0×10^{-6}	1.30×10^{-8}
Large Fire Threatens DOE-SNF in Canister Transfer Machine (per canister)	6,215	3.13	0.169	1.1×10^{-6}	1.4×10^{-4}	5.06×10^{-7}
Large Fire Threatens DOE-SNF in Staging Area	10	3.13	0.169	1.0	2.0×10^{-6}	1.06×10^{-5}
Large Fire Threatens Transportation Cask/DPC (VTC) (Diesel)	346	3.13	0.169	2.1×10^{-6}	2.0×10^{-6}	7.69×10^{-10}

Large Fire Threatens Transportation Cask/DPC (VTC) (No Diesel)	346	3.13	0.169	3.0×10^{-5}	2.0×10^{-6}	1.10×10^{-8}
Large Fire Threatens DPC (VTC) in Canister Transfer Machine	692	3.13	0.169	1.2×10^{-6}	1.4×10^{-4}	6.15×10^{-8}
Large Fire Threatens DPC (VTC) in Aging Overpack (Diesel)	346	3.13	0.169	1.5×10^{-5}	1.0×10^{-6}	2.75×10^{-9}

NOTE: TAD = transportation, aging, and disposal; HLW = high-level radioactive waste; SNF = spent nuclear fuel; VTC = transportation cask upended on a railcar.

Conditional probability of canister failure given a large fire in the CRCF (P) = N × F × P_p × RF × P_{cf}, where N equals the numbers of each individual waste form potentially exposed to a large fire in the CRCF; F equals the fire ignition frequency for the CRCF; P_p equals the fire propagation probability; RF equals the residence fraction for each configuration of the individual waste form over the preclosure period; and P_{cf} equals the mean failure probability of the canistered waste form when exposed to a fire.

Source: [a]BSC 2007, Table 4.
[b]BSC 2009, Table F5.7-6.
[c]BSC 2009, Table 6.3-5.
[d]Point estimate event sequence probabilities are presented for the entire preclosure period.