RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 7:

Explain how DOE developed the nuclear safety design basis for the cask cooling subsystem identified in Table 6.9-1 of BSC, 2008bq on page 234. Examples of areas needing clarification follow:

(a) Explain if the operator error, "Operator causes overpressurization" identified as basic event 050-OPDPC-OVP01-HFI-NOW shown in Figure B5.4-8 of BSC, 2008bq is included as part of the nuclear safety design basis. The operator error is connected by an "OR" gate to the components that are part of this system.

(b) Explain if all components that could result in an over pressurization have been accounted for in Figures B5.4-8 and B5.4-9. For example, DOE identifies failures such as pump failure and relief valve failure. DOE shows in Figure 1.2.5-69 of the SAR, the piping and instrument diagram for the Cask Cooling Subsystem. This figure also shows check valves and pressure transmitters. Explain if these other components can contribute to an over pressurization.

(c) DOE identifies, "Pipe BW-0003 plugs" in Figure B5.4-9 of BSC, 2008bq. Clarify where this pipe is and explain if this failure accounts for all of the areas where a pipe could plug and result in an over pressurization.

DOE identifies in Table 6.9-1 of BSC, 2008bq on page 234, "The mean probability of an overpressure of a cask or cooling system line during the cask cooling operation shall be less than or equal to 8 x 10^{-6} per cask." In this table, DOE identifies the source as, "OVERPRESSURIZATION." DOE describes cask over pressurization in Section B5.4.2 of BSC, 2008bq starting on page B5-11 and includes the fault tree in Figures B5.4-8 and B5.4-9.

1. RESPONSE

The cask cooling subsystem overpressurization event has been reevaluated since issuance of *Wet Handling Facility Reliability and Event Sequence Categorization Analysis* (BSC 2009), and the system fault tree model for overpressurization of the cask, canister, or sample line due to failures of the cask cooling subsystem has been revised. The revised system fault tree model is provided in Figure 1. The new model and accompanying text assess the relationship among the various components in the subsystem and their contributions to an overpressurization event. Overpressurization failure of the cask, canister, or sample line is modeled to occur only if both the pressure relief valve and the vent line to the gas/liquid separator fail to control the pressure.

The cooling water feed pump (also called "metering pump" in the preclosure safety analysis) is designed such that neither a mechanical failure nor an operator error can cause an overpressurization condition in the cask or canister. The cask or canister cooling subsystem is designed to pump water into the cask or canister via a positive displacement cooling water feed pump that has a maximum rated capacity of 20 gal per minute (SAR Figures 1.2.5-69 through

1.2.5-72). By design, when cooling water first contacts the fuel assemblies, it will flash into steam, which is removed through the vent line, and will reduce the temperature of the fuel assemblies. As water flow and cooling continue, steam production decreases. The vent line is designed to remove the maximum steam flow which is generated during this process by the maximum delivery rate of the cooling water feed pump. A mechanical failure or an operator error that causes the cooling water feed pump to go from normal operating to maximum capacity cannot lead to an overpressurization of the cask or canister. This event is therefore not modeled in the fault tree of Figure 1. Failure to remove steam is the cause for overpressurization. Because the pressure relief valve mitigates failure of the vent line, both the vent line and the pressure relief valve must fail to remove steam to cause the initiating event to occur.

In the fault tree model of the cask cooling subsystem (BSC 2009, Section B5.4.2), overpressurization was modeled as being caused by excess cooling water introduced into a heated cask or canister. Excess cooling water cannot overpressurize the system. As a result, the fault tree model of Figure 1 more accurately represents the cask/canister cooling subsystem design. The revised fault tree reflects the fact that both the vent line (shown as the vent line between the cask/canister and the gas/liquid separator vessel in SAR Figures 1.2.5-69 to 1.2.5-72) must fail to adequately pass fluid and the pressure relief valve (shown on the line from the cask/canister to the Wet Handling Facility pool in SAR Figures 1.2.5-69 to 1.2.5-72) must fail closed for the initiating event to occur. The manual valve on the vent lines will be locked open during operation; as a result, the probability of this valve failing to remain open will be dominated by random mechanical failure, which is an order of magnitude or two lower than the check valve failure probability. Operator error that results in inadvertent valve closure was not modeled for locked open manual valves.

The fault tree model in the categorization analysis document (BSC 2009) considered the failure to pump liquid water out of the gas/liquid separator vessel as a cause of overpressurization. However, the alternative path through the gas vent from the gas/liquid separator vessel prevents overpressurization even if water is not pumped out of the separator vessel. Therefore, the outlet line from the separator vessel, including the cooling water return pump (SAR Figures 1.2.5-69 to 1.2.5-72), is not included in Figure 1.

Solving the Figure 1 fault tree results in a top event probability of 4×10^{-6}. This probability is less than the value stated as a nuclear safety design basis for the cask cooling subsystem, 8×10^{-6} (SAR Table 1.9-4). Therefore, the categorizations of cask overpressurization event sequences are not changed using this revised fault tree model.

1.1 OPERATOR ERROR

Operator error leading to overpressurization is included as a part of the nuclear safety design basis. However, the human error contribution to the overall failure probability is negligible relative to equipment failures and is not an important factor in the nuclear safety design basis (BSC 2009, Table B5.4-5). The revised fault tree model in Figure 1 recognizes that operator error does not contribute to an overpressurization event. Therefore, the event 050-OPDPC-OVP01-HFI-NOW shown in Figure B5.4-8 of the categorization analysis document (BSC 2009) is no longer used. In addition, the revised model conservatively does not rely on operator response to incipient overpressurization initiated by equipment failure. Therefore, human error does not contribute to the nuclear safety design basis for the overpressurization of the cask, canister, or sampling line.

1.2 EVALUATION OF ALL COMPONENTS THAT COULD CAUSE OVERPRESSURIZATION

1.2.1 Cooling System Components on the Inlet Side to the Cask/Canister

Components not included in the fault tree model in the categorization analysis document (BSC 2009) include valves (ball valves, butterfly valves, and check valves), pressure transmitter, pressure indicators, and flow meter/instrumentation.

Valves that are located in the flow path upstream of the cooling water feed pump (SAR Figures 1.2.5-69 to 1.2.5-72), and valves that branch off the line cannot contribute to overpressurization because, although their failure could restrict flow to the pump, that failure could not cause the pump to overpressurize the system. These components are not modeled because they cannot contribute to overpressurization of the cask, canister, or sample line.

The three components in the flow path between the cooling water feed pump and the inlet to the cask or canister are shown in SAR Figures 1.2.5-69 to 1.2.5-72 (moving downstream from the cooling water feed pump in sequence): a ball valve, a check valve, and a magnetic flow meter. Additional valves are located on branches from the inlet line. The failure of these components, whether in-line or on branches, cannot contribute to overpressurization. By failing, they may introduce a blockage or leakage out of the line, either of which would tend to prevent overpressurization. Likewise, the piping and flexible hose in the inlet line may become blocked, restricting flow to or from the cooling water feed pump, and thereby prevent overpressurization of the cask or canister.

Because the revised model does not rely on human actions to prevent overpressurization, no reliance is placed on the operation of the pump discharge pressure transmitter (shown on the line between the cooling water feed pumps and the cask/canister in SAR Figures 1.2.5-69 to 1.2.5-72) and pressure indicators to provide the operators with an indication of a potential overpressurization. Therefore, the revised model does not include this pressure instrumentation.

The following components on the inlet side of the cask or canister have been modeled in the categorization analysis document (BSC 2009): the cooling water feed pump, the digital control system (through a spurious signal demanding excessive flow from the pump), and the pressure relief valve. The model in Figure 1 does not include the spurious signal from the digital control system because, as noted in Section 1, overpressurization cannot be caused by excessive flow from the cooling water feed pump.

1.2.2 Cooling System Components on the Vent Side of the Cask/Canister

Some components on the vent side of the cooling subsystem were omitted from the model in the categorization analysis document (BSC 2009). These are the manual ball valve, butterfly valves, and check valves. The check valve could fail to admit flow through the vent line and thereby allow pressure to build up within the cask or canister. The revised model includes the check valve. Because the manual ball and butterfly valves are in the vent line, normal operating procedures would ensure that they are locked open during operation.

Locked open valves are not required to change position during operation. The most likely reason for an operator to change the position of these valves is during maintenance. After maintenance work is completed, the operator performs valve line-ups to ensure that valves are restored to the correct position prior to locking and restoring to service. An error in this maintenance operation would be similar to the operator error described in Table E6.0-2 of the categorization analysis document (BSC 2009), entry 050-#EEE-LDCNTRA-BUA-ROE, "Operator fails to restore load center post maintenance" with a human error probability of 1×10^{-5}. The human error probability value does not credit any independent check from a supervisor that would further reduce the cumulative human error probability to $<1 \times 10^{-5}$.

Because the probability that the normally locked open valves would be inadvertently left closed (conservatively, 1×10^{-5}), and the probability that manual valves (BSC 2009, Attachment H SAPHIRE model basic event DMP-FRO [8.4×10^{-8}]) would fail closed are lower than check valve failure probabilities (BSC 2009, Attachment H SAPHIRE model basic events CKV-FOD [6.6×10^{-4}] and CKV-FTX [2.2×10^{-3}]), they are not modeled in Figure 1.

1.3 PIPE PLUGGING

Pipe BW-0003 is the 1-in. vent pipe (BSC 2009, Figure B5.4-9) that connects the downstream end of the flexible hose piping section between the two quick disconnects on the cask vent side that lead to the gas/liquid separator vessel. Piping on the cask vent side is modeled due to its ability to contribute to overpressurization caused by flow restriction when water introduction is continued. The entire length of piping, including the flex-hose section, is effectively included in the model because the estimated pipe-plugging failure rate does not depend on the length of piping (BSC 2009, PPM-PLG in Table C4-1). This model is also applicable to the 1-in. vent piping shown on SAR Figures 1.2.5-70 to 1.2.5-72.

The 10-in. off-gas piping that vents gas from the gas/liquid separator vessel to the heating, ventilation, and air-conditioning system is much less restrictive than the 1-in. vent piping between the cask/canister and the gas/liquid separator vessel (10-in. as compared to 1-in.). Therefore, the 10-in. off-gas piping contribution to overpressurization is much less than the 1-in. vent piping and need not be modeled.

As noted in Section 1.2.1, plugging of piping on the inlet side of the cask or canister cannot contribute to overpressurization. Rather, plugging of inlet piping would have the opposite effect. Piping upstream of the cask or canister has not been modeled (BSC 2009, Figures B5.4-8 and B5.4-9).

The section of piping that connects the pressure relief valve to the cask or canister and the section that drains the outlet of the pressure relief valve to the pool have not been modeled. This piping is in series with the pressure relief valve. This means that either plugging of the pipe or failure of the pressure relief valve can contribute to overpressurization. Thus, the combined failure probability is given approximately by the sum of the individual probabilities. The piping failure probability is approximately 6×10^{-6} (based on an hourly failure rate of 7×10^{-7} (BSC 2009, PPM-PLG in Table C4-1) and a mission time of 8 hours) and the failure probability of the pressure relief valve is approximately 6×10^{-3} (BSC 2009, Figure B5.4-8). To a good approximation, the combined failure probability of the piping and the pressure relief valve is equal to the failure probability of the pressure relief valve alone. Therefore, the additional piping sections have not been modeled because the effect of including them would be negligible.

2. COMMITMENTS TO NRC

The license application will be updated to revise Figures 1.2.5-69 to 1.2.5-72 as described in Section 3.

3. DESCRIPTION OF PROPOSED LA CHANGE

SAR Figures 1.2.5-69 to 1.2.5-72 will be revised to show the manual ball and butterfly valves on the vent line are locked open during normal operation.

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.

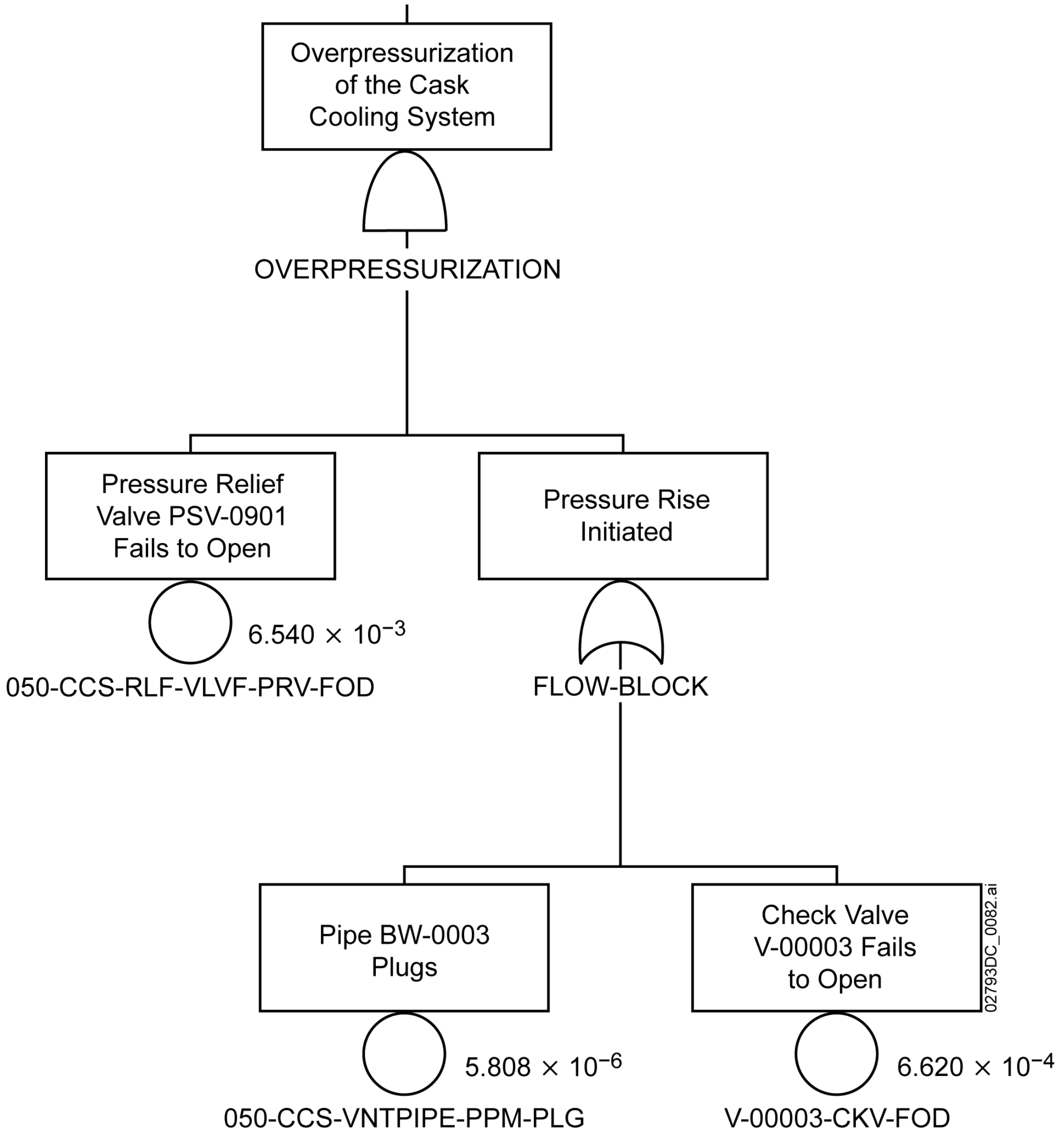

Figure 1. Revised Model of Overpressurization of the Cask Cooling System

RAI Volume 2, Chapter 2.1.1.4, Fifth Set, Number 8:

Explain how DOE quantified human error event 050-OPDPC-OVP01-HFI-NOW shown in Figure B5.4-8 of BSC, 2008bq on page B5-16 to account for a potential over pressurization involving a transportation cask containing CSNF (i.e., WHF-ESD16-CSNF). DOE indicates on page B5-11 of BSC, 2008bq that the cask over pressurization fault tree described in Section B5.4.2 of BSC, 2008bq is associated both with DPC preparation activities (i.e., WHF-ESD17-DPC) and transportation cask preparation activities (i.e., WHF-ESD16-CSNF); however, it is not clear that DOE accounted for the differences. Examples of areas needing clarification follow:

(a) DOE describes in Table E6.7-1 of BSC, 2008bq on page E-185 that, "The system is designed to accommodate the hot DPCs (temperature greater than 350 °C); therefore there is not a human-induced overpressurization event if the DPC is not at a low temperature before cooling begins (i.e., due to steam pressure)." However for transportation casks containing CSNF, DOE associates the temperature with cask over pressurization in the MLD diagram shown in Figure D-16 of BSC, 2008bo. In the detailed quantification for this human error event in Section E6.7.3.4.3 of BSC, 2008bq, DOE does not appear to account for an erroneous temperature reading leading to over pressurization (i.e., WHF-1604) as described in Figure D-16 of BSC, 2008bo on page D-17.

(b) DOE describes in Table E6.7-1 of BSC, 2008bq on page E-185 that, "This value was adjusted (x5) to account for the fact that this operation is performed by one crew member and is only performed weekly." Explain how the analysis would change given the throughput for transportation casks containing CSNF versus the throughput for DPCs.

(c) DOE indicates in Table E6.7-1 of BSC, 2008bq on page E-185 that this operation is performed by one crew member; however, page E-199 of BSC, 2008bq indicates that a second crew member is present.

(d) Explain how the dependencies were considered among the operator events, "A," "B," and "C" shown in Table E6.7-6 and Equation E-41 of BSC, 2008bq.

1. RESPONSE

In the response to RAI 2.2.1.1.4-5-007, a revised fault-tree model of the cask cooling subsystem is presented. The revised model (RAI 2.2.1.1.4-5-007, Figure 1) applies to the four cask/canister cooling systems depicted in SAR Figures 1.2.5-69 through 1.2.5-72. The revised fault tree model and discussion of the potential failure modes show that human initiation of overpressurization is not relevant to the initiating event. As such, the human failure event 050-OPDPC-OVP01-HFI-NOW is not required in the revised evaluation of the system.

Because parts (a), (b), (c), and (d) of this RAI are related to the human failure event 050-OPDPC-OVP01-HFI-NOW and this event is shown as not relevant in the response to RAI 2.2.1.1.4-5-007, the questions regarding WHF-1604 (part a), the adjustment factor (part b), the number of crew members (part c), and dependencies (part d) are not applicable, and therefore, not addressed in this response.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.